Asian Journal of Social Science and Management Technology
ISSN: 2313-7410
Volume 5, Issue 3, May-June, 2023
Available at www.ajssmt.com

Predictive Maintenance Policies of Tita B's Refilling Station and Its Impact to Manufacturing System

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ABSTRACT: Maintenance is a key to corporate success. This study studied three machines at Tita B's Water Refilling Station in P.J. Almendras St., Danao City's failure mode and manufacturing system effects. It also lists the business's equipment, useful life and age, each machine's FMEA, preventative maintenance procedures, run-to-failure, and which units can be configured for rule-based maintenance. FMEA qualitative research collected these variables: Tita B's Water Refilling Station Failure Mode and Effect, the machines it uses, their age, useable life, preventive maintenance plan, run-to-failure, and rule-based predictive maintenance machine. Tita B's Water Refilling Station, a family business that offers pure water, is managed by Mr. Lucio Bentecil. The investigation found age three machines at Tita B's Water Refilling Station to be good. The Failure Mode and Effect Analysis of these three machines gave Reverse Osmosis Membrane the highest Risk Priority Number. Tita B's Water Refilling Station had quarterly preventive maintenance. Every three months, backwash filters are cleaned, repaired, or replaced. Failure Mode and Effect Analysis data shows that RO membranes and storage tanks can be designed with rule-based (corrective) maintenance. The reverse osmosis membrane is the most prone to fail, resulting in higher maintenance expenses and reduced productivity.

Keywords: machine FMEA, maintenance practices, preventive maintenance, productivity

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1. INTRODUCTION

Maintenance should be implemented appropriately as one of the best ways to achieve a company's best performance and is one of the significant factors that help the company's goal preservation. Moreover, maintenance provides a proper flow of progress in the workplace and ensures a stable working process. A predictive maintenance policy develops efficient and effective control in manufacturing process systems. It ensures regular monitoring of the mechanical conditions of machine equipment and process system operating efficiency. A predictive maintenance policy is a program that takes as the control system in the field of machine-equipment failures and reduces the cost of maintenance. In addition, it can help to prevent costly machine-equipment failures and improve the availability of operating plants. Moreover, predictive maintenance policies can lessen the number and cost of unscheduled outages caused by machine failures and develop a more reliable scheduling tool for routine preventive maintenance tasks.

From an international perspective, maintenance divisions have historically been seen as an expense by many industry centers that do not add to a company's profitability. Nowadays, we can see maintenance as a crucial step in the production process that develops the final product's quality, the plant's availability, and the capacity to meet delivery deadlines. Singh (et al., 2020) defined "maintenance" as a comprehensive set of technical, administrative, and supervisory procedures to keep an object in proper order or restore it to that condition. Preventive follows regular and thorough maintenance practices to stop issues or failures before they arise; predictive ensures the capability to predict when a piece of equipment will break and to replace it before it does, while breakdown maintenance occurs when a component has failed. Policies applied within the industrial systems may contribute both beneficial and detrimental impacts. Thus, the decision to either apply maintenance policies must be rooted in the detailed analysis of potential benefits and the cost associated with such policies.

The effects of maintenance rules will differ from the companies' manufacturing system and country. The Philippine maintenance law is less severe than in other countries, which has an undesirable effect on productivity and enlarges expenses. According to Xing (2022), one of the most significant issues the industrial sector in the Philippines has to deal with is the need for regular maintenance. It has brought on several issues, the most important of which are the lack of skilled laborers and the scarcity of replacement parts. As a result, manufacturers in the Philippines need help to deal with faulty equipment, which can cause delays in production and higher expenses.

From a local standpoint, maintenance policy has tremendously impacted the company's proficiency in optimizing its production system and ensuring production equipment's maximum efficiency and availability. Thus, some communities need immediate access to a safe water supply. In order to address this problem, water refilling station facilities developed by entrepreneurs and company that seeks to render a more accessible and affordable option for satisfying people's water demand. Tita B's Water Refilling Station, located at PG Almendras, Poblacion, Danao City, Philippines, is a family-run business that has been offering quality and safe water in every home for almost fourteen years. Furthermore, maintenance policy guarantees that equipment is well-maintained to provide good quality products and competitive advantages. There are many reasons why maintaining all machinery in good condition would lead to higher productivity levels. If machinery is well-maintained, this ensures that there are no sudden and frequent breakdowns and is likely to be more efficient, contributing to higher productivity levels. Thus, well-maintained machinery will produce products of higher quality since it reduces the production of products with defects and is more precise, which will lead to products being more consistent in quality.

Conversely, maintenance is one of the main cornerstones for corporate or business growth. If maintenance costs remain in check, it can save much money, but if they are not, it can impact the company's bottom line. Thus, the study aimed to determine and provide an appropriate predictive maintenance policy program to increase the company's productivity. However, there are specific problems regarding maintenance policies and management problems, such as unexpected breakdowns, system downtime, maintenance expenses, and not formalized maintenance. With this study being approved and done, it will significantly impact the company's productivity, performance, and processes of manufacturing products, specifically achieving daily sales of P3400 and P45,000 per month and providing a documented predictive maintenance program that will serve as a guide for the company to boost sales and prevent machine breakdowns.

Statement of the Problem

THE PROBLEM

This study aimed to determine the Failure Mode and Effect of three machines used by Tita B's Water Refilling Station and the impact to its manufacturing system. Specifically, this study sought answers to the following questions:

1. What is/are the equipment used by Tita B's Water Refilling Station and its age, useful life and condition/remarks?
2. What is the FMEA (Failure Modes and Effects Analysis) of the different machine?

3. What is the preventive maintenance schedule of the company?
4. What is the run-to-failure of each machine?
5. What machine that can be designed with rule-based maintenance?

1.2. RESEARCH METHODOLOGY

This section presents the Qualitative research using FMEA approach. It contains research process flow; environment; respondents; instruments; procedure of gathering data; and treatment of data and definition of terms.

Research Process Flow

The phenomenological approach to data interpretation was used in this research study, which adhered to the qualitative research methodology using the FMEA approach. Qualitative information on the following variables will be gathered: Tita B's Water Refilling Station's failure mode and effect; the machines that the company uses and their corresponding age; the machine's Failure Mode and Effects Analysis (FMEA); the business's preventive maintenance schedule; the machine's run-to-failure; and the machine that can be designed with rule-based predictive maintenance.

As for methodological aspects, this study employed phenomenological inquiry in gathering vital data through the given responses among the necessary informants following the structured interview guide followed by unstructured interviews. The phenomenological inquiry studies the practices of Tita B's Water Refilling Station and its impact on its manufacturing system, showcasing the aspects of maintenance policies applied inside the business operation.

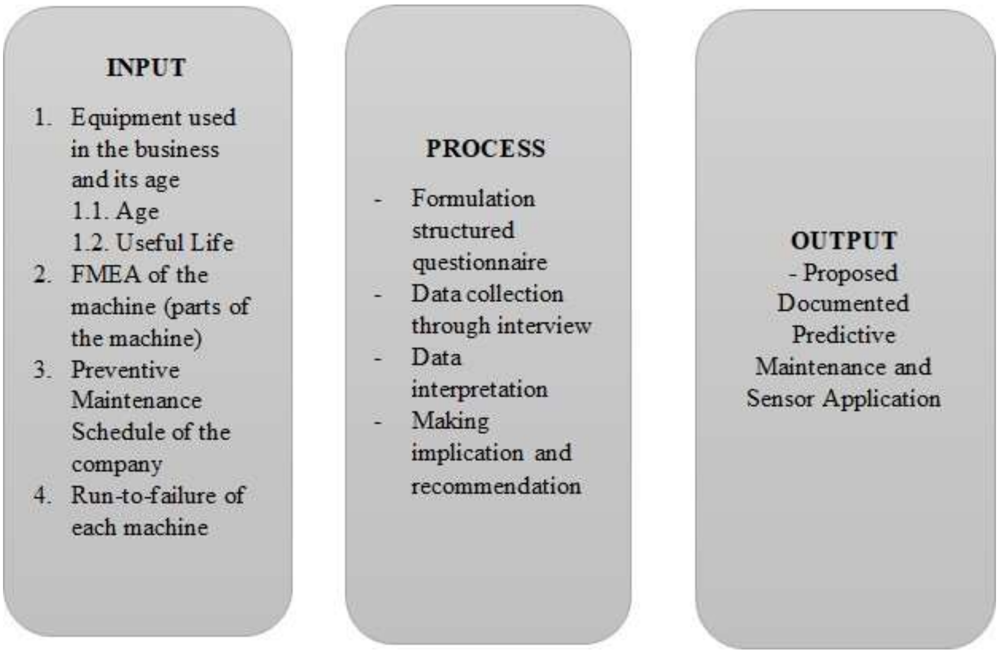

Figure 2: Process Flow of the Study

Research Environment

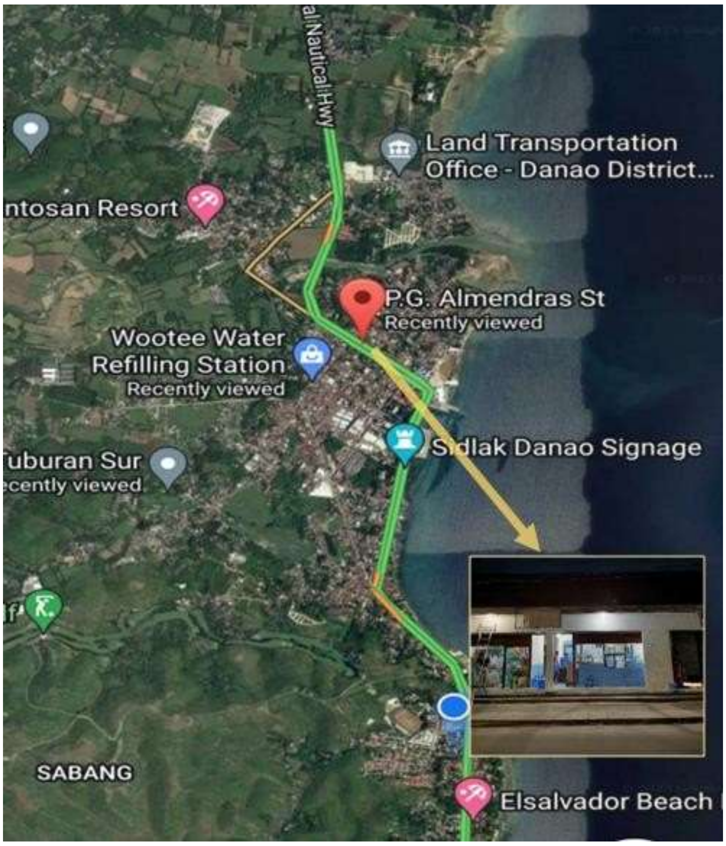

Figure 3: Research Environment of the Study

Research Instruments

This study followed a structured and semi-structured interview guide which is a researcher-made set of interview questions. A cellular phone with an audio recording application was used as an initial tool in recording the interview as permitted by the informants.

The researchers provided a series of questions corresponding to the study and determined the maintenance practices according to their business operation. Thus, the questions that were answered by the informants have identified the background characteristics of the business regarding its practices in terms of maintenance; their techniques and strategies used to address or give solution to their maintenance operation; and the effects of their specified maintenance practices applied to the business

Procedures of Data Gathering

Before collecting the necessary data through personal interviews with the informants from Tita B's staff, a letter of request was secured for approval from the owner and as part of the standard operating procedure for conducting a research study. The letter of correspondence bore information regarding the purpose and essence of the study.

The interview happened during the most convenient time for the informants, such as vacant times and breaks, to avoid conflict with their work. The interview had approximately taken 5-20 minutes. However, the informants could end the interview at their convenience. The researchers followed a structured questionnaire, unstructured questions, and an audio recorder for easy documentation and recording during the interview. The informants were informed that the conversation was documented and recorded and that their responses would be treated with the utmost confidentiality.

Furthermore, the results generated from the study would be exclusively used for educational purposes only. In order to establish spontaneous discussion, the interview was done using the informant's native language, the "Bisaya" language. The interview transcription was translated into English, which the researchers did during the coding process.

Data Analysis Tools

After the collection of the structured questionnaire and unstructured questions, the data was studied and consolidated using the Failure Mode and Effects Analysis (FMEA). The Failure Mode and Effects Analysis was used to analyze potential points of failure in a process and mitigate losses through proactive process adjustments.

Scoring Procedure

To gratify the gathered data through the structured interview guide followed by unstructured queries, the mode of scoring the Severity (S), Occurrence (O), and Detection(D) to get the Risk Priority Number (RPN) was based on the responses where 1 is the lowest and 10 is the highest. The classification of the responses will be presented using the following category:

Table 1: Table of Severity of FMEA

Code	Classification	Definition
10	Hazardous without warning	Very high ranking that affects operation safety
9	Hazardous with warning	Regulatory non compliance
8	Very High	Machine become inoperable with loss of function
7	High	Equipment remains operable but loss of performance
6	Moderate	Machine remain operable but it's not as convenient touse
5	Low	Machine remain operable but it's not as convenient to use
4	Very Low	Non-conformance noticed
3	Minor	Non-conformance by certain-Noticed
2	Very Minor	Non-conformance were unnoticed
1	None	No effect

Table 1 displays the severity criteria for a machine's potential failure mode concerning Failure Mode Analysis and Effect, along with the severity of an effect associated with a given failure mode. The severity of an issue is typically ranked on a scale varying from 1 to 10, where a rating of 1 signifies that the potential failure mode's effect on the severity of the issue is either insignificant or nonexistent. On the other hand, a scale rating of 10 indicates the severity of the effect that a potential failure mode has on the hazardous nature of the operation.

Table 2: Table of Occurrence of FMEA

Code	Classification	Definition
1	Remote	Failure Unlikely
2-4	Low	Few Failures
5-6	Moderate	Occasional Failures
7-8	High	Repeated Failures
9-10	Very High	Inevitable Failure

This section showed the table for occurrence of potential failure modes of a machine based on the Failure Mode Analysis and Effect. In addition to this, occurrence is a ranking that indicates how probable it is that the failure mode and the linked cause will be found. The rating begins at 1, which showed that it has a remote failure occurrence, which implies that failure has a smaller potential of occurring. This suggests that the likelihood of failure is lower. On the other hand, it concludes with a ranking of 10, which indicates that there is a greater likelihood of the occurrence of failure that cannot be prevented or avoided.

Table 3: Table of Detection of FMEA

Rank	Detection	Criteria
1	Extremely Likely	Can be corrected prior to prototype/ Controls will almost certainly detect
2	Very High Likelihood	Can be corrected prior to design release/very high probability of detection
3	High Likelihood	Likely to be corrected/high probability of detection
4	Moderately	Design controls are moderately effective
5-6	Medium Likelihood	Design controls may miss the problem
7	Low Likelihood	Design controls are likely to miss the problem
8	Very low likelihood	Design chance of detection
9	Very low likelihood	Unproven, Unreliable design/poor chance ofdetection
10	Extremely Unlikely	No design techniques available/control

The projected Table 3 above provides information about the criteria for the Detection of the Failure Mode and the Effects Analysis which considers the likelihood of detection of the failure mode/causes in terms of the machine failure mode or downtime. Based on the detection criteria of Machine FMEA, a rating of 1 indicates that the detection of the mentioned machine failure is classified as "Extremely likely" which indicates that the failure mode can be controlled before the prototype/controls will almost certainly be detected. Henceforth, a rating scale of 10 as the highest rating indicates an "Extremely unlikely" which points out that no design techniques are available/controlled.

2. PRESENTATION, ANALYSIS AND INTERPRETATION OF DATA

This chapter of the qualitative research study following the phenomenological method denotes the presentation, analysis and interpretation of the collected data from the structured and unstructured interview of the maintenance staff in Tita B's Water Refilling Station regarding of their machines, ages of each machine and their maintenance practices.

Ages and Useful Life of Machines

This section presents the corresponding machines used by Tita B’s Water Refilling Station which includes the ages and useful life of each machine.

The table shows the ages and useful life of each machines used.

Table 4: Ages and Useful Life of the Equipment

Equipment	Age of the Equipment	Useful Life	Remarks/Condition
Membrane/Romembrane	8 months	3-5 years	Good
Backwash Filter	1 month	3-6 months	Good/Functional
Storage Tank	13 years	10-15 years	Good

Table 4 shows the months and years that each machine had been in operation, along with its age and duration of usefulness. The findings showed that all three machines were in satisfactory working condition. The current membrane has an age of 8 months, which places it within the valuable life range of between 3 and 5 years. In addition, it is noted that the changed reverse osmosis membranes were in satisfactory condition.

An implication was then extracted from the data revealed above. According to Pype et al. (2016), Water quality is diminished due to membrane aging. In order to ensure public health, it is of the utmost necessity to monitor membrane function. In the context of public health protection, comprehending these potential changes in membrane performance is of utmost relevance over time. It is also essential to validate that the

membrane integrity test employed measures the virus elimination efficacy of the RO process.
The backwash filter utilized by the business has current age of 1 month, which signifies it falls within the range of its usable life, and it was implied that the machine was in good condition.

The information presented above was then used to find relevant information. According to Cutolo (2022), altering the backwash filter once every three to six months is the recommended procedure for optimal performance. According to Kroll (2022), it is imperative to check the condition of the backwash filter frequently to ensure it is functioning accurately. A noticeable decrease in water pressure throughout the home is one of the tell-tale indications that it is time to change the backwash filter. Additionally, if the water's appearance, flavor, or smell has changed, it is probably time to replace the filter. This is certainly relevant if the change occurred recently.
The age of the storage tank has remained appropriate with its useful life, which indicates that it has been functioning satisfactorily.

A water tank is a long-term investment. According to Tait (2022), the longevity of a water tank is subject to several variables. Consider the tank's intended function, location, and construction material. Moreover, Firstank (2022) states that acquiring a water storage tank for residential or commercial property is a long-term investment. The water tank's life expectancy is determined by the geophysical characteristics of the location where you will install the unit. The useful life of a tank is also dictated by how it is used. A unit that comprises clean and fresh water for human consumption will generally have a much more extended lifespan than a unit with harsh chemicals or salt.

Consequently, according to Gobena (2016), the tank storage structure is the only water source to store drinking water and help people to use it for domestic, institutional, agricultural, public, and industrial purposes. The storage tank is filled to its freeboard level and used when there is a supply shortage, and electricity is off. With the construction of water storage tanks, even minimal quantities of water can be used, which was impossible by direct pumping to the field due to more advanced time & higher losses.
By the year 2024, Tita B's Water Refilling Station could purchase another storage tank for a replacement since the age of the old storage tank could depreciate in the next two years.

Failure Mode and Effects Analysis of the Machines
The following tables presented each machine's Failure Mode and Effect Analysis with its recommended action.
Table 5 shows the RO membrane's Failure Mode and Effects Analysis. According to the findings, RO membranes can fail when the purifier is not working correctly, causing water channels and films to become choked. Thus, the failure mode's severity was 8, which is "Very High," rendering machines inoperable. Based on informant responses, this result was reached. The researchers observed wiring and power supply issues as possible explanations. These problems have an occurrence level of six, which is "Moderate," meaning failures may occur. The researchers found no controls in the RO membrane. Control was found. There was also a degree of detection of 10, indicating "Extremely Unlikely" and no design or control methods. The risk priority number (RPN) that would be determined would be 480.
Based on the calculations, the researchers came up with some recommendations for what should be done next: (1) call the RO administration master so that the problem can be diagnosed; (2) contact the maintenance technician so that the RO membrane can be cleaned or replaced; (3) recommend changing the clean water more frequently; and (4) apply a microsensor precisely flow meter that can detect the status of water in a tank or pipe.

Table 5: FMEA of the Romembrane/Membrane

Failure Mode and Effect Analysis											
										ACTION PLAN	
Subsystem	Subsystem Function	Potential Failure Mode	Effects of Failure	SC	Causes	O	Controls	D	RPN	Recommended Action	Responsible and Completion Date
Membrane/ Romembrane	Reverse Osmosis removes contaminants from unfiltered water when pressure forces it through a semipermeable membrane	Purifier doesn't work	Water Channels and films are gagged	8	Issues with the wiring or power supply connection	6	No Control	10	480	- Call RO administration master for diagnosing the issue - Contact maintenance technician for the Romembrane to be cleaned/supplanted - Advise changing of clean water more often - Application of microsensor flow meter which can detect level of water in a tank or pipe	

Table 6: FMEA of the Backwash Filter

Failure Mode and Effect Analysis											
										ACTION PLAN	
Subsystem	Subsystem Function	Potential Failure Mode	Effects of Failure	SC	Causes	O	Controls	D	RPN	Recommended Action	Responsible and Completion Date
Backwash Filter	Backwash Filters are used to flush filters which become clogged by dirt and other debris	Unable to produce quality drinking water	- As filters wear out, bacteria will infiltrate drinking water. - can cause a motor to overheat and break-down	10	- Overdue for a filter replacement -Dirt buildup	4	It has control but defective	9	360	- Immediate repair of their backwash filter control system - Regular cleaning of the backwash filter - Application of 5600 Fleck Control Valves	

Table 6 presented the Failure Mode and Effect Analysis of the Backwash Filter. Based on the findings, one of the potential failure modes of the Backwash Filter is when the filter cannot generate water suitable for drinking. Bacteria can enter drinking water when filters become less effective over time. In addition, one of the impacts of failure is that it might bring about overheating and subsequent failure of a motor. Therefore, the researchers concluded that the failure mode's severity level was 10, which is classified as "Hazardous without warning," indicating that it has a very high ranking that affects operation safety. This decision was reached based on the responses provided by the informant. In this regard, the researchers have identified probable causes, such as an overdue need for a filter replacement and dirt build-up inside the filter. Both of these potential causes have an occurrence level of 4, which is classified as "Low," which indicates few failures. Concerning the control, the researchers observed that a control was applied, but it is defective or needs to be fixed.

Furthermore, the level of detection was 9, which depicted that it was "Very Low Likelihood" This suggests that the design is unproven and unreliable, which in turn means that there is a poor possibility of detection. The risk priority number (RPN) that would be determined would be 360. Consequently, a backwash filter is essential to any water refilling station's ability to supply clean, safe water to its customers. To that end, businesses should take into consideration the deteriorating performance of their backwash filters as a sign that they need to be replaced if their water has a cloudy appearance, a lower flow rate or water pressure due to sediment build-up, or has a sour taste specifically metallic or salty taste. Furthermore, the backwash filter at Tita B's Water Refilling Station was changed every month. Based on the calculation, the researchers came up with the following set of recommended actions: (1) immediate repair of their backwash filter control system; (2) regular cleaning of the backwash filter; and (3) application of 5600 Fleck Control Valves, which can automatically control backwash and regeneration cycles for filters and water softeners.

Table 7 provides The Failure Mode and Effect Analysis of the Storage Tank. The results revealed that the probable failure of the Storage Tank is the failure of the auto-shutoff, which leads to the impacts of failure, which makes the filling of water run continuously and brings about the water coming out of the RO services, which will flood in the capacity tank. Therefore, the researchers concluded that the failure mode's severity level was 6, which is considered to be "moderate." This indicates that the machine can still function but is less convenient. The responses provided by the informant were taken into consideration for making this judgment. In this regard, the researchers have pinpointed a likely cause, such as the possibility that debris became trapped in the drain tube leading from the RO unit. This possible cause has an occurrence level of 5, which is classified as "Moderate" and implies that it has an occasional failure. Concerning the control, the researchers observed that there is no control applied. In addition, there was a degree of detection of 10, which represented that it was "Extremely Unlikely," which indicates that there are no design techniques/controls that can be used to regulate or prevent it. It was determined that the risk priority number, abbreviated as RPN, would be 300. Based on those calculations, the researchers came up with a set of recommendations that are as follows: (1) The problem was fixed by removing the tube from the drain clamp and cleaning it; (2) a valve that automatically shuts off the flow of water was attached so that the continuous flow of water could be stopped and additional water damage could be avoided. (3) An additional option is to attach a sensor from a different manufacturer, the OZEAN Auto Shut-off Float Sensor. (4) Contact a RO professional to have the faulty component fixed or replaced.

Table 7: FMEA of the Storage Tank

Failure Mode and Effect Analysis											
										ACTION PLAN	
Subsystem	Subsystem Function	Potential Failure Mode	Effects of Failure	SC	Causes	O	Controls	D	RPN	Recommended Action	Responsible and Completion Date
Storage Tank	holds clean water from your reverse osmosis system or other filter systems until ready to use.	Failure of the Auto shut-off	The filling of water will run continually. This would bring about water out of the RO services and spaces and will flood the capacity tank.	6	Dirt may have lodged in the drain tube coming from your RO unit	5	An auto shut-off valve (not observed/not applied)	10	300	- Fixed by removing the tube from the drain clamp and cleaning it. - Attach an auto shut-off valve that automatically closes to stop the continuous water flow and prevent more water damage. - Another alternative is to attach another brand which is OZEAN Auto Shut-off Float Sensor. - call a RO expert who will fix or supplant the flawed part.	

Preventive Maintenance

Preventive Maintenance of Tita B's Water Refilling Station operationally delves into the method or policy of regularly scheduled maintenance on a machine to prevent unscheduled failure or breakdown. The maintenance practices of Tita B's Water Refilling Station are presumed to be a great help in carrying out a business operation in preventive maintenance. During the interview, the informant was asked if they employed preventive scheduling maintenance. He stated, "Oo, kada 3 months mi mag schedule ug maintenance nya apil napud didto ang paglimpyo sa mga machine ug uban parts niini". (Yes, we follow the 3-month rule of schedule maintenance upon checking and cleaning each machine and other parts of it). Based on the informant's statement, an implication was made from such. According to Eslami et al. (2018), preventive maintenance is one of the essential factors for eliminating equipment defects, enhancing quality, and boosting productivity. Although several factors influence the line's productivity and efficiency, various variables associated with a system's competitive factors can be included in multi-criteria decision-making approaches and handled.

Run-to-failure of Each Machine

According to Jimenez et al. (2020), keeping machinery on a run-to-failure basis is not a desirable technique since it requires organizations to respond to problems as they occur rather than preventing problems from occurring in the first place. Nevertheless, there are situations in which this method of equipment upkeep is acceptable, such as when the piece of machinery needs to be mission-critical in the organization's operation or when it is not integral to the primary system's mechanism for generating value. Based on the findings detailed in Table 4, the reverse osmosis membrane has a service life ranging from 3 to 5 years. As of right now, the machine has an age of 8 months, which suggests that it is still functioning correctly and is in good condition. Before that, if the RO membrane reaches a defective stage, the run-to-failure maintenance that might be conducted after it fails comprises cleaning the unit and quick repair. Another option is to replace the membrane entirely. In addition, run-to-failure maintenance will be implemented based on the severity of the problem that may be caused to the business operation.

On the other hand, the usable life of the backwash filter is between 3 and 6 months, and based on the response received from the informant, the filter has an age of 1 month. This suggests that the filter utilized in the operation of the business is still in good condition and has two months of estimated available time before it is required to be repaired or replaced. As a result, the run-to-failure of a backwash filter after three months includes general cleaning of the filter and its parts, repair of damaged parts if they are observed, and replacement of the backwash filter with a new one. The informant provided this information during the interview.

Lastly, regarding the run-to-failure of the storage tank, table 4 revealed that the usable life of a storage tank lasts approximately 10-15 years, which can be used in the operation of a business. Therefore, according to the informant, the storage tank utilized in the company has already been in operation for 13 years, which indicates that there are around two years left until it will most likely be replaced with a new one after it reaches the stage where it is defective.

Rule-Based Maintenance

Machines are designed with rule-based (corrective) maintenance based on monitoring the equipment's performance and controlling the corrective measures that are done as a result. This technique, when implemented throughout a more extended period, enables a significant reduction in the expenses associated with maintenance. As a result, significant faults are reduced, and the management of the available economic resources is improved.

Based on the gathered data presented in the Failure Mode and Effect Analysis table, the machines that can be designed with rule-based (corrective) maintenance are RO membrane and Storage Tank. Thus, these two machines can be applied with sensors for condition monitoring.

Reverse osmosis can use microsensors to control water pressure or level to produce clean drinking water. On the other hand, a storage tank can use an OZEAN Auto Shut-off sensor, which will automatically shut off the run of the storage tank when the water reaches its maximum level.

In connection with this, either of these machines may be fitted with sensors to do condition monitoring. In order to attain a heightened level of water purification by reverse osmosis, it is possible to use microsensors to regulate the water pressure or level. On the other hand, the OZEAN Auto Shut-off sensor can be installed in a storage tank so that when the water level reaches its maximum capacity, the sensor will automatically turn off the tank.

3. SUMMARY, FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the summary of findings based from the qualitative data analysis; the conclusion is based on the significant findings of the research study, and recommendations are offered based on the summary of findings and conclusion.

Summary

This section presents the summary of the research study.

As an essential component of life, the quantity and quality of water is also an essential factor. The quality of the water supply has a considerable impact on human health. Therefore, a review of failure mode and effect analysis is necessary to improve or eliminate failures before the deterioration in system performance and to attain a maintenance policy that would help the operation of the business. Moreover, the sources of data and information came from the staff/technician as the primary informants of the study. On the one hand, the method used to gather the necessary data was the Failure Mode and Effects Analysis with input severity rating (S), occurrence (O), detection (D), and the output value of Risk Priority Number (RPN). Furthermore, results revealed that the RO membrane has the highest risk priority number, which is 480 when the purifier does not work, followed by the backwash filter with 360 RPN when it is unable to produce quality drinking water, and the storage tank with 300 RPN when auto shut-off fails to function.

Indeed, the need to address this potential failure mode and effects analysis would greatly help the business operation and productivity, especially the impacts on its manufacturing system.

Findings

The following presents the empirical results of the study:

The results revealed that the machine with the highest Risk Priority Number (RPN) is the Reverse Osmosis Membrane which has 480 RPN when the water purifier does not work. When this occurs, the effect of failure will occur mainly because water channels and films are gagged with a severity of 8, which is classified as "Very High," indicating that the machines become inoperable due to a loss of function. Moreover, an occurrence of 6 is classified as "Moderate," indicating that failures will occasionally occur. Moreover, a level of detection of 10 portrayed that it was "Extremely Unlikely," which indicates that no design techniques are available or controlled. Furthermore, the potential causes of this failure were issues with the wiring or power supply connection.

The results revealed that the backwash filter has a Risk Priority Number (RPN) of 360. It was revealed that the potential failure of a backwash filter is when unable to produce quality drinking water. In this regard, the failure effect would be bacteria will infiltrate drinking water with a severity of 10, classified as "Hazardous without warning," indicating that it has a very high ranking that affects operation safety. It was found that the occurrence level was 4, which is classified as "Low," indicating few failures. Moreover, the detection level was 9, which depicted it as a "Very Low Likelihood." This suggests that the design could be more proven and reliable, which means there is a better possibility of detection. Moreover, the causes of this failure are Overdue for a filter replacement and dirt buildup.

Consequently, a backwash filter is essential to any water refilling station's ability to supply clean, safe water to its customers. To that end, businesses should take into consideration the deteriorating performance of their backwash filters as a sign that they need to be replaced if their water has a cloudy appearance, a lower flow rate or water pressure due to sediment buildup, or has a sour taste specifically metallic or salty taste. Furthermore, the backwash filter at Tita B's Water Refilling Station was changed every month.

The Storage Tank's Risk Priority Number (RPN) was found to be 300. The potential failure was identified to be the failure of the Auto shut-off. Therefore, the failure mode's severity level was 6, regarded as "moderate." This shows that while the device is still functional, it is more challenging to operate. Additionally, the possible cause has an occurrence level of 5, which is classified as "Moderate" and implies an occasional failure. Lastly, the degree of detection is 10, representing that it was "Extremely Unlikely," which indicates that no design techniques/controls can be used to regulate or prevent it.

Conclusion

This section presents the conclusion based on the results and empirical data drawn from this study.

Peripherally, based on the results, it was observed that the most significant point of potential failure is the reverse osmosis membrane, which has the highest Risk Priority Number (RPN) that signifies the purifier does not work (480). Thus, the calculated Risk Priority Number (RPN) was based on severity, occurrence, and detection. In addition, the findings of this study indicate that the potential failure mode of a reverse osmosis membrane can affect the manufacturing system in such a way that it will have a higher risk factor in the business operation, which typically results in increased costs for maintenance and decreased levels of productivity.

Recommendation

This section is based on the summary, findings, and conclusion, which presents the study's recommendation.

Based on the summary, findings, and conclusion, the researchers came to the following recommendation for Tita B's Water Refilling Station, which will be operating their business specifically in Danao City, in light of the conclusion that in order to predict the potential failure mode of the machines.

Microsensor Flow Meter

As for the recommendation, the researchers recommended that Tita B's Water Refilling Station install microsensors, more precisely a flow meter, on the Reverse Osmosis Membrane to monitor the volume of water passing through the system over time. Moreover, the flow meter's life expectancy lasts over 30 years and can be recalibrated every two years. Tita B's Water Refilling Station can purchase Microsensor Flow Meter amounting to ₱17,150.00.

Figure 4: Design of the Microsensor

Guide Installation of Flow Meter Microsensor:

1. The sensor must always be completely full of liquid
2. Therefore, avoid the following:
   2.1 Installation at the highest point in the pipe system
   2.2 Installation in vertical pipes with free outlet
3. The flow meter should be located in a U-tube for partially filled pipes with a downward flow and free outlet.
4. Recommended flow direction is upward, which minimizes the effect of measuring any gas/air bubbles in the liquid.
5. The sensor must be mounted as shown in the 5th figure. Do not mount the sensor as shown in the lower figure. This will position the electrodes at the top, where there is a possibility for air bubbles and at the bottom where there is a possibility for mud, sludge, sand etc. if using empty pipe detection. The sensor can be tilted 45o, as shown in the 5th figure.

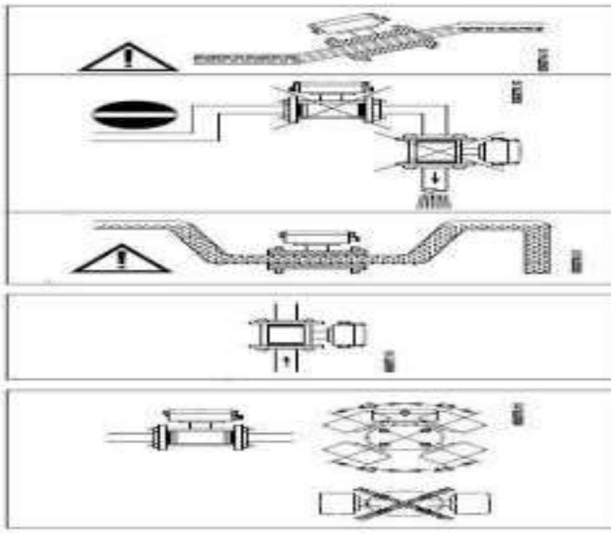

Figure 5: Guide Installation of Flow Meter Microsensor

5600 Fleck Control Valve

Fleck Control Valve can be installed in the Backwash Filter which can automatically regulate the backwash and regeneration processes for media filters and water softeners. Moreover, the fleck control valve has an average useful life of over 10-12 years and can be regenerated in 3-15 days. Thus, as for the recommendation, the researchers provide an installation guide for the 5600 Fleck Control Valve. The cost of the 5600 Fleck Control Valve is ₱5,200.00

Figure 6: Design of 5600 Fleck Control Valve

Installation Guide for 5600 Fleck Control Valve

1. There are two O-rings on a 5600 filter. One is located within the valve's central hole on its underside. When the riser tube is pushed past it, a seal is created. The second O-ring is installed in a lip above the tank's threaded mounting holes. To ensure smooth operation of the valve, silicone lubricant should be applied to both O-rings.
2. Screw the filter valve onto the tank. (Remember to remove the temporary plug from the end of the riser tube.) The tube slips into the center hole at the bottom of the valve. No tools are needed, just hand tighten the valve until it's snug.
3. When the valve is installed, set the filter and install it to the home's plumbing according to the local plumbing code. "In" and "Out" are indicated on the valve body. Be sure to get it right. Looking from

behind, water enters the 5600 valves from the left.

4. Attach a drain hose to the barbed drain fitting that comes out of the back of the control valve. Secure it with a hose clamp. Attach to a drain according to the local plumbing code, or if convenient, place the end of the drain line so that it can drain onto the ground. Remember that the filter will run several gallons of water out of the drain line during the backwash cycle.

OZEAN Auto Shut-off Float Sensor

Before applying OZEAN Auto Shut-off Float Sensor, Tita B's Water Refilling Station could purchase another storage tank for a replacement since the useful life of the old storage tank will expire in the next two years. Researchers recommended installing an OZEAN Auto Shut-Off Float sensor in the Storage Tank because it sets the storage tank levels whenever the water reaches the maximum level where the machine automatically shuts off. When the water reaches its level, the machine will automatically start. Furthermore, OZEAN Auto Shut-Off Float Sensor has a life expectancy of over 10-15 years and can be adjusted for at least a year. Tita B's Water Refilling Station can purchase an OZEAN Auto Shut-Off Float Sensor, which has a cost of
₱299.00 – ₱350.00

Figure 7: Design of OZEAN Auto Shut-Off Float Sensor

Guide Installation of OZEAN Auto Shut-Off (Float Sensor)

To connect a float switch to a submersible pump, it needs to uses a piggyback float switch to affix it. This float switch has two wires connecting to the pump's power source and a third wire connecting to the pump's control panel. The float switch must be wired to the control panel to activate the pump whenever the water level reaches a certain point.

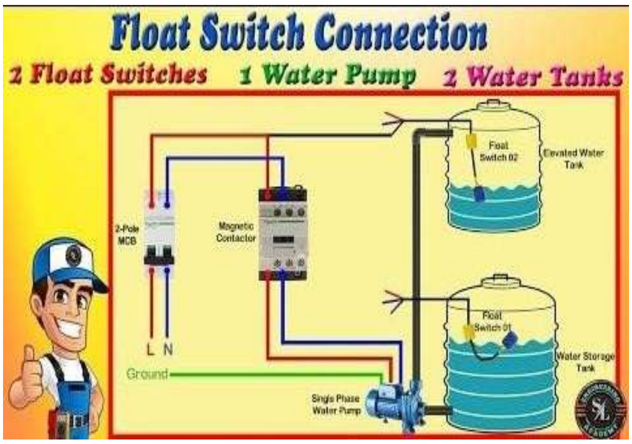

Figure 8: Guide Installation of OZEAN Auto Shut-Off (Float Sensor)

Table 8: Failure Mode and Effect Analysis andPredictive Maintenance Schedule

Subsystem	Subsystem Function	Useful Life	Recommended Action	Useful Life	Maintenance Schedule
RO membrane	Reverse Osmosis removes contaminants from unfiltered water when pressure forces it through a semipermeable membrane	3-5 years	Application of Microsensor (Flow Meter)	30 years	Every two years
Backwash Filter	Backwash Filters are used to flush filters which become clogged by dirt and other debris	3-6 years	Application of Fleck Control Valve	10-12 years	Regenerated in 3-15 days
Storage Tank	holds clean water from your reverse osmosis system or other filter systems until ready to use	10-15 years	Application of OZEAN Auto Shut-Off Sensor	10-15 years	Adjusted for at least a year

4. ACKNOWLEDGEMENTS

Success is peace of mind, which is a direct result of self-satisfaction in knowing you made the effort to become the best of which you are capable." —John Wooden

First thing first, we thank the Great Man up above who believed in us and showered us endless strength to grasp each opportunities the world has opened us.

Believing in ourselves to make this whole research output possible is another bunch of labour, thanks to those people who surround us and give their full support to extract the best in us push us to make a step.

To our beloved parents who have seen struggling to send us in school, we owe you a lot. Never would this whole thing happen if not because of your sacrifices. This little step we have taken will serves as a living proof of your hardships and this may guide us to move forward in improving the best version of ourselves.

Our sincerest thank you to the informant and to Tita B's Water Refilling Station who welcomed us wholeheartedly and shared us the fragment of their experiences that aids us to finish our study.

Our greatest luck to our research teacher Mrs. Delfa G. Castilla who helped us throughout this research, thank you for extracting your full potential and knowledge that serves as our motivation to finish our study.

- **The Researchers**

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How to cite this article: Fel Ellen Grace B. Almagro, Delfa G. Castilla, M.A.Ed, Patrianne Kaye Casas3, Rupert James Casas, Carmel Kaye Lao, "Predictive Maintenance Policies of Tita B's Refilling Station and Its Impact to Manufacturing System", Asian. Jour. Social. Scie. Mgmt. Tech.2023; 5(3): 43-58.