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Total Productive Maintenance Strategy to Increase Overall Equipment Effectiveness of Integrated Filling Machine N2 Vaccine Production Pt. Xyz

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ABSTRACT: In the midst of production process to fulfilling the needs of n2 vaccine, several problems occur and cause the production process to be hampered. The high frequency of breakdowns that occurred became problems that results in longer production process and some products become rejected and cannot be absorbed as a whole to meet the production needs. Preventive maintenance that have been conducted so far are considered not optimal because there are more breakdown maintenance than preventive maintenance. History of the breakdown shows that 35% of the total number of production batches experiences failure of the machine in the production process experiences failure of the production process. The results of the study using quantitative analysis show that the OEE of the integrated Filling Machine is only 55%, far below the ideal OEE standard of 95%. A qualitative analysis also conducted to further explores the cause of the bottlenecks in the production process which involves the production and maintenance unit.

Study and analyses are conducted to find the root cause of high disturbances that results in losses and obstacle to production process. By using current reality tree, found that the main cause of the bottleneck in the production process on the high number of the breakdown in the Integrated Filling Machine is lack in maintenance activity which the preventive maintenance that conducted doesn't have clear procedure then coupled with the maintenance team's habit that prefer to work in breakdown maintenance than preventive maintenance.

To solve the problem three alternative solutions are prepared to be choose. The alternative solutions are Autonomous Maintenance, Planned Maintenance, and Principal's service agreement. All of the alternative solution is selected with consideration of production needs with their respected advantages and disadvantages. Of the three alternative solutions provided, Analytical Hierarchy process will be conducted to determine which alternative is more likely to be implemented. Planned maintenance was chosen as the best solution that meet the needs of each stakeholder with the most mitigable risks and has advantages that can solve the problems that occur.

KEYWORDS: Analytical Hierarchy Process, Integrated Filling Machine, n2 Vaccine Production, Overall Equipment Effectiveness, Planned Maintenance.

INTRODUCTION

The world's effort to confront Polio Outbreak since the last 30 years have been very great and close to eradication of the virus. But in fact, the same virus reappeared with a different strain which was immediately analyzed by the World Health Organization and declared an outbreak. PT XYZ is a State-Owned Company that has been established since 1980 and once successfully made the polio vaccine that brought this outbreak to an end, entrusted with conducting research and production of Vaccines in Emergency Situation (EUL) so that they can deal with this outbreak immediately. Finally, PT XYZ successfully to develop the vaccine of this type with the name n2 Vaccine which a new vaccine that modified from the first Oral Polio Vaccine in the world.

PT XYZ was trusted by WHO to produce 6.000.000 doses of this n2 vaccine and targeted to be fulfilled in one year. This production number is quite large for a vaccine that has just been established and produced. In addition to large of quantities and limited deadline, WHO has regulation related to quality in accepting each product that has produced. There are still possibilities that the product will not be absorbed perfectly if there are regulation that are not complied by PT XYZ. Currently, at the end of 2022, the production need for the n-2 vaccine has still not been fulfilled maximally. This deficiency is due to the long production time required in each production process, and rejects that occur which not all of the vaccines that have been produced can be proceed to the next process so that some production process must be repeated to cover the production shortages that occur. The deficiency in the production process that occurred results potential loss of company revenue of $4,740,975 due to a lack of production results that should have

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been distributed to sales. Furthermore, PT XYZ potentially loss the opportunity to continue to be an n2 vaccine producer due to a lack of customer's trust for the capability to produce n2 vaccines according to the quality and quantity needs.

BUSINESS ISSUE

Production process of the n2 vaccine is the process that processing the bulk of vaccine until final products which will continued in visual inspection and labelling process. The entire process is carried out in a series of some machine that integrated and functioning in continuity and automatically to minimize intervention from outside of the production machine. This integrated process consists of several machine that each of the machine has different function but works in continuity so if there are a machine that interrupted, it will be causing another machine to be stopped.

The most determines successful of production process from the entire production process in Filling machine which this process is the process injection of the products from the pooling tank into the vial. This integrated filling machine is also become a bottleneck of the production which one machine fails; it will make the entire production process to stop. The series of Integrated Filling Machine has a production capacity of 125 vials/minute or according 7500 vial/hour. This means the production process of 37.000 vials will take time about 5 hours. But what happening now is so much time that the production process takes every batch production is carried out.

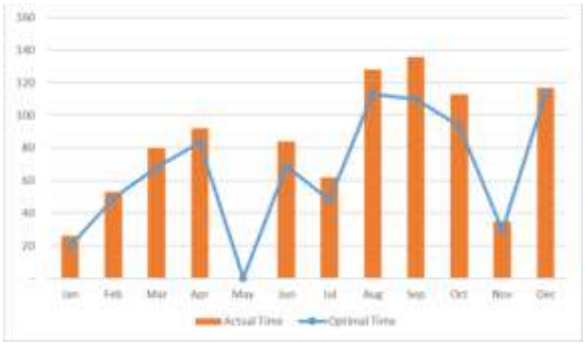

Figure 1. Comparison between optimal time production and actual time of production

In figure it can be seen that every production process takes time more than the optimal time obtainer by calculating the production capacity of the machine. This is caused by frequent errors that appear in the production process so the production process will be stopped for a while. In handling the errors that appears, the operator often does a visual check to the warning that occurs. Because the limitations of the knowledge, skill, and equipment the operator doesn't checks the overall of the machine and then choosing the acknowledge the warning at the machine so the machine continue the production process. Unfortunately, because of the warning at the machine was not solved, the warning will appear again with higher intensity and further disrupting the production process. Errors that occur intensively are actually the initial symptom of a bigger damage that will cause a breakdown of the machine. Generally, the error will be ignored and then it will become the breakdown so the machine cannot be able to continue the production process. And if the machine stopped because there was a broken down, the production unit will report to maintenance team so they can fix the problem that occur due to the machine so the production process be able to continue the production process. The maintenance team function more as a repairman that responsible to fixing the machine until it can be operated normally.

Based on breakdown data and observation to production unit, machine breakdown reaches 35% of available time that used on production process. This shows that almost half of production process experienced the obstacle and delays from overall of the production process.

The maintenance process that has been implemented so far are maintenance activity that known by corrective maintenance which the maintenance activity that meant is carried out when the machine has breakdowns. Breakdown maintenance is the activity of maintenance that consume more expensive cost because the troubleshooting process must be conducted in very minimum time and procurements of the parts that prepare suddenly. This activity is also very risky because there is no guarantee that the maintenance team can be solve the problem immediately so the machine cannot continue the production process and the product must be destroyed. Furthermore, this corrective maintenance activity will be increasing the contamination possibility that caused by attendance the maintenance personnel that come from sterile area and bring the equipment and parts that enter the sterile area.

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LITERATURE REVIEW

Maintenance management is the management of maintenance work through a process of planning, organizing, controlling maintenance operations, and producing good performance for facilities or machines in the industry so as to maximize the company's operational efficiency. Maintenance plays an important role in production activities because machine performance will be related to the smooth production process, volume and quality. In addition, maintenance activities are very influential with the production schedule and utilization of production personnel because if there is damage, losses will occur in the form of operators who cannot carry out their work plus the production process is late. In addition, good maintenance will improve the performance of machines and facilities, so that the company's performance will also be good because the quality of the products produced will be better and reduce waste (Corder, 1996)

According to Patrick (2001) Preventive maintenance is maintenance and care activities carried out to prevent unexpected damage and find conditions or circumstances that can cause product facilities to be damaged in the production process. Corrective Maintenance is a maintenance activity carried out after a machine or facility is damaged or disturbed so that it cannot function properly (Patrick, 2001). Corrective maintenance activities are synonymous with repair actions for breakdown machines.

Knowledge Management can be interpreted as a step in doing something with maximum results from knowledge resources. Knowledge Management. Knowledge management is important because its implementation provides benefits in the fields of operations and services, can increase personal competence, maintains the availability of knowledge and innovation and product development (Prayogo, 2017). The implementation of Knowledge management is very broad and can be implemented in various types of activities, one of which is Maintenance.

Total Production Maintenance as known as TPM is a maintenance activity that includes all elements of the company, which aims to create a critical mass in the industrial environment in order to achieve zero defects and zero accidents (Kurniawan, 2013). TPM involves all employees, from floor level workers to top management. TPM was developed by Seiichi Nakajima in Japan between 1950 and 1970 which was also part of the application of lean manufacturing with the aim of eliminating waste.

Overall Equipment Effectiveness is a method that is able to evaluate all indicators used in measuring the performance of the production process up to the level of product quality produced. By using the OEE method, organizations can monitor, evaluate, and improve processes that are inappropriate or deemed ineffective. OEE is Calculated as the product of three contributing factors (Nakajima, 1988).

Total Productive maintenance aims to maximize the effectiveness of facilities or equipment so as to expedite the production process. All facilities and equipment have the potential to experience losses caused by errors and operational problems. Six Big Losses are activities that absorb resources but do not create any value (Jonsson, 1999)

CONCEPTUAL FRAMEWORK

The conceptual framework will be used as a reference for designing solutions that will be proposed based on the root of the problem obtained from the business issues that occur to be implemented in the company. As explained in the business issue chapter, most production failures are caused by damage to production machines and production facilities. Machine breakdown occurs when there is a malfunction in terms of control, electrical, and mechanical which causes the production machine to stop during the production process.

When the machine is broken down, the downtime will depend on the damage that experienced by the machine and usually the troubleshooting process takes a long time in the maintenance process. The troubleshooting process until the machine operates normally varies depending on the severity of the damage, the skills of the technician staff who handle it, and the availability of replacement parts needed for the machine. Therefore, good troubleshooting and inventory planning skills are needed in this maintenance activity. By reducing non-productive time in maintenance activity, this will increase the effectiveness of maintenance activity time and reduce downtime.

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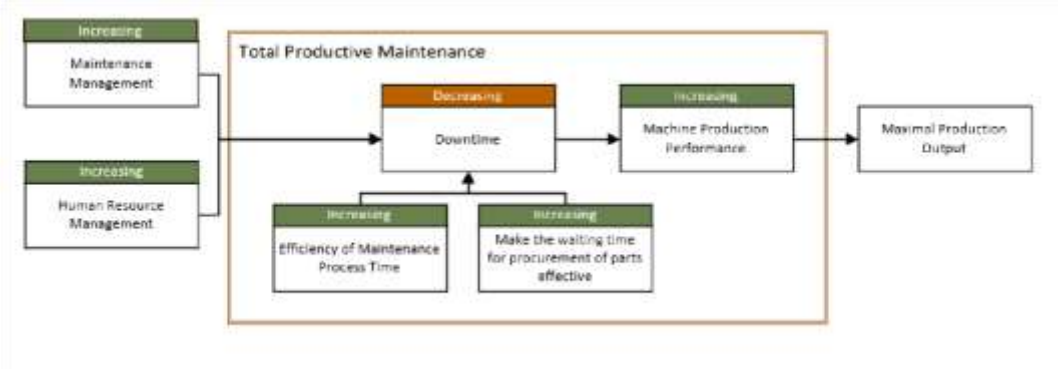

Figure 2. Conceptual Framework

The main objective of this research is to obtain maximum production output so that the company can meet the vaccine needs according to the contract. Even better if the fulfillment of these needs not only fulfills the contract, but also fulfills the needs of the global market so that the company's revenue potential can increase.

METHODOLOGY

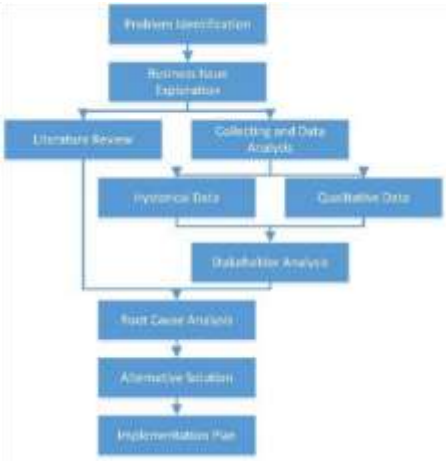

Figure 3. Research design.

The business issue that has been explained in chapter 1 is the company can't fulfil the production target as the contract. This condition potentially makes the company gets a loss of revenue by $4,582,945 because the n-2 vaccine that has been ordered cannot be produced so there is a gap in quantity. This is caused by machine breakdowns that repeatedly occurs in the production process and causes the production process not going smoothly and take a longer time than it should be. In addition, losses are also experienced because when there is damage, the product being processed will be threatened with production failure if repairs are not immediately carried out, and if repairs are successful and the production process continues, further investigation is needed regarding the batch production whether it can be released or not considering the potential contamination that occurs during the repair process.
The losses are not only the revenue of the company that decreased, but also the company's credibility that can be threatened so can open the chance for the other company to take the same project to be done.
The research will conduct using mix of Qualitative and Quantitative Data Research. Qualitative Research is research that addresses business objective through techniques that allow researchers to provide detailed interpretations of market phenomena without depending on numerical measurements (Zikmund, 2013). The focus of qualitative research is to obtain the information contained in the situation in the field.

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There are two method that conducted in collecting the data. First is data collection for qualitative research that conducts the structured and semi-structured interview. Second is data collection for quantitative data that conducts calculation for the machine performance based on the production records that contain the operation time, machine output, and the number of released products.

In analysing qualitative data, the data analysis technique used in this research is narrative analysis. Narrative inquiry is a form of qualitative research in which the stories themselves become the raw data (Bleakley, 2005). Therefore, data analysis will be taken from the results of interviews and observations that have been carried out to explore information and find possible causes of business issues that occur and get the perspectives of stakeholders involved in this process.

From the results of the interviews, which were followed by observations to explore information that there were several causes of losses that occurred in the production of this n-2 vaccine. From the production unit, information was obtained that losses where there was a shift in the schedule which resulted in the insufficiency of fulfilling the needs for the production of the n-2 vaccine were mainly caused by the high level of breakdown to the production facility unit. Apart from the production team's point of view, the author also explores the maintenance team's point of view regarding the production process which is mostly carried out automatically and using machines and finds that it is true that there are lots of breakdown that occur and stop the production process then causing losses.

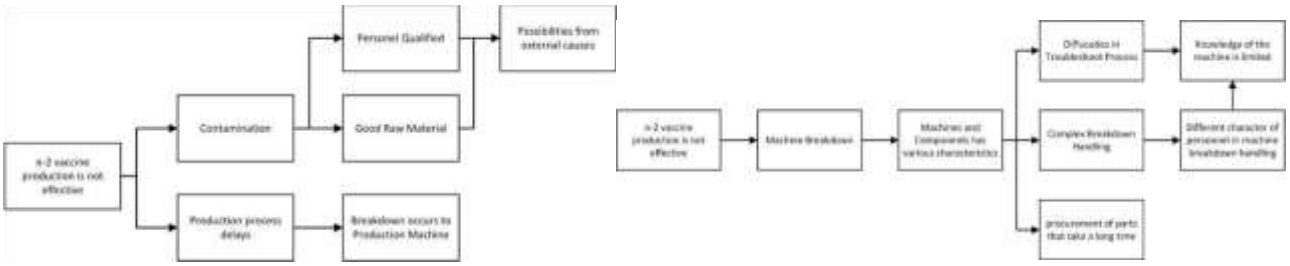

Figure 4. Observation Results of Qualitative data.

To conduct Qualitative data analysis, data processing is carried out by calculating Overall Equipment Effectiveness (OEE), Mean Time Between Failure and Mean Time To Repair.

Overall Equipment Effectiveness (OEE) is used for calculating the effectiveness of the machine. In OEE calculation, the data that needed are Availability Rate, Performance Rate, and Quality Rate.

Availability rate is a ratio that describe the utilization of available time to machine operation activity. Performance rate is the ratio that indicates the ability of the machine or equipment in producing the product or item (Hedge, 2009). Quality Rate is the machine ratio in producing the product or item that appropriated with the standard that have been set (Hedge, 2009). To calculate the OEE, a multiplication between Availability Rate, Performance Rate, and Quality rate is performed. Mean Time To Repair or MTTR calculated when the machine breakdown until it can start to operates again.

MTBF and MTTR calculation is conduct to analysis the average time for a component to broken and average time that utilize in repair process. Mean Time Between Failure or MTBF is the average of the time of machine to operates until get a breakdown.

Table 1 shows the results of each calculation in calculates the OEE and MTTR, and table 2 shows the results of MTBF of each parts calculation

Table I. OEE and MTTR Calculation

Month	Availability	Performance	Quality	OEE	MTTR (H)
January	76%	71%	89%	48%	1
February	93%	84%	89%	69%	4
March	85%	72%	83%	51%	1
April	91%	81%	88%	65%	1
May	-				

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June	82%	75%	88%	54%	1
July	77%	66%	80%	41%	1
August	88%	78%	84%	58%	1
September	81%	68%	80%	44%	1
October	83%	70%	79%	46%	1
November	84%	77%	88%	57%	1
December	97%	85%	88%	73%	2
Average	**85%**	**75%**	**85%**	**55%**	**1.25**

Table 2. MTBF Calculation

Failure	**Mean Time Between Failure (H)**
Bearing Motor Turning Table Jammed	133
Electric Heater	398
Error Dozing Pump Servo Motor	47
HMI Error	796
Input not detected	159
Interface Card Error	47
Leakage System	133
Lost Power DC	398
Low Airflow	36
Low Temperature Tunnel	159
Motor Conveyor Short Circuit	398
Motor Shutter displacement	796
Over Current Dozing Pump Servo Driver	80
Over Current Variable Speed Drive Motor Turning Table	24
SIP not Completed	133
Temperature error	796
Valve Sensor	38
Pre-Filter Blocked	265
Blower Short Circuit	265
Bearing Motor Turning Table Jammed	133

ANALYSIS AND FINDINGS

Throughout 2022 there were breakdowns that occurs to Integrated Filling Machine that results the amount of production was not achieved as target that has planned. Based on observation and interview that has conducted to maintenance team, there were some breakdowns that occurs in variative ways from minor failure which can be done quickly by acknowledge the error on the machine, until major breakdowns that stops the production process. Figure 5 shows the number of breakdown that occurs to several machine in 2022.

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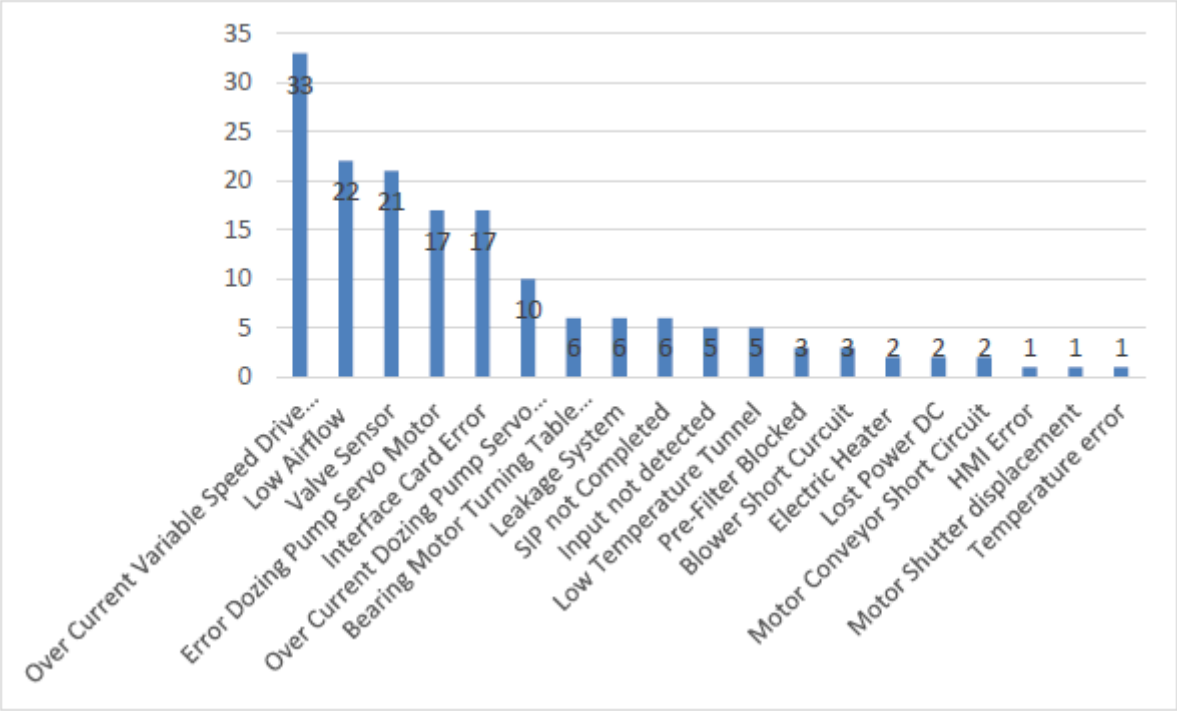

Figure 5. Number of failures for breakdown occur

There are several errors that occurs repeatedly during the production process in 2022. In addition, sometimes the error that occurs repeatedly will turn into bigger problem causing the production process to stop and require handling from the maintenance team to repair the machine so the production process can continue.

The Engineering and Maintenance Division is the division which is responsible for handling any problems that occur in the production process and production facilities. The work unit that has the most contact with the production process is the Control and Instrumentation section. The Control and Instrumentation Section is responsible for handling problems with all production machines, one of which is the n2 production machines which often experience trouble so that the process of fulfilling the needs for the n-2 vaccine production is disrupted.

The different capabilities and troubleshooting styles of each control and instrumentation section personnel, too many machine variations and spare parts that are not available and sometimes identical parts that are limited on the market make this section work extra in the process of handling failure in all production facilities, especially in an n2 vaccine production facility. Failure that occurs in the n2 vaccine production work unit generally occurs during the production process where breakdown occurs to the machine that is operating. This really needs immediate treatment because the vaccine that has been processed cannot last long if it has entered the production phase. this has the potential to cause losses because raw materials that have been processed will be wasted due to production process failures. Therefore, the control and instrumentation work unit really need speed in the process of analysis, troubleshooting, and supply of parts in handling machine failure to minimize potential losses that will occur. On the other hand, if the process can be continued, further inspection must also be carried out because of the potential for contamination that occurs during the maintenance process, both from control personnel and instruments entering the sterile room or from goods carried, including replacement parts or work tools, as well as from the process of stopping the machine resulting in contact from outside the machine allows it to enter and contaminate the product.

OEE Analysis is carried out by calculating the availability of the production process, the performance of the machine, and the quality of the product that has produced.

Through secondary data, six big losses can be classified. Table 3 shows the six big losses that occurs to the integrated filling machine in 2022.

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Table 3. Six big losses of integrated filling machine's failure

OEE Parameter	Six Big Losses Category	Machine Failures
Availability	Breakdowns	Bearing Motor Turning Table Jammed
		Electric Heater Short Circuit
		HMI Error
		Interface Card Error
		Blower Short Circuit
		Valve sensor Breakdown
Availability	Setup and Adjustment	Dozing Pump Servo Motor
		Motor Shutter Displacement
		Warming Up tunnel
Performance	Idling and Minor Stoppage	Low Temperature Tunnel
		Over Current Dozing Pup Servo Driver
		Over Current VSD Motor Turning Table
		Lost Power DC
		Input not Detected
Performance	Reduce Speed	Pre-Filter Blocked
		Errors Repeated
Quality	Process Defect	SIP not Complete
		Low Airflow
Quality	Production Reject	Cracked Vials
		Vials Broken
		Contamination

Throughout 2022, there were a total 163 breakdowns occurs during n2 vaccine production process. By doing observation by secondary data, some breakdown was obtained and results the disruption of the production process which the breakdown was repeated several times. By MTBF calculation that conducted in table 2, it is found that the average of the time that the component will be broken down. By MTTR calculation which also conducted in table 1, it is found that the MTTR in this integrated filling machine is 1.2 hours. This means that the averages of downtime that occurs to Filling Machine used for repairs is 1.25 hours per breakdown. Table 4 shows the breakdown duration that occurred during the production process in 2022.

Table 4. Breakdown duration

Failure	Number of Failure	Total Breakdown Duration	Percentages
Over Current Variable Speed Drive Motor Turning Table	33	39,5	20%
Low Airflow	22	26,3	13%
Valve Sensor	21	25,1	13%
Error Dozing Pump Servo Motor	17	20,4	10%
Interface Card Error	17	20,4	10%
Over Current Dozing Pump Servo Driver	10	12,0	6%
Bearing Motor Turning Table Jammed	6	7,2	4%
Leakage System	6	7,2	4%
SIP not Completed	6	7,2	4%
Input not detected	5	6,0	3%
Low Temperature Tunnel	5	6,0	3%
Pre-Filter Blocked	3	3,6	2%

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Blower Short Circuit	3	3,6	2%
Electric Heater	2	2,4	1%
Lost Power DC	2	2,4	1%
Motor Conveyor Short Circuit	2	2,4	1%
HMI Error	1	1,2	1%
Motor Shutter displacement	1	1,2	1%
Temperature error	1	1,2	1%
Total	163	195,2064204	100%

Next, an analysis using pareto chart that shows in figure 6 to show that in many events, about 80% of the effect is caused the 20% of the cause

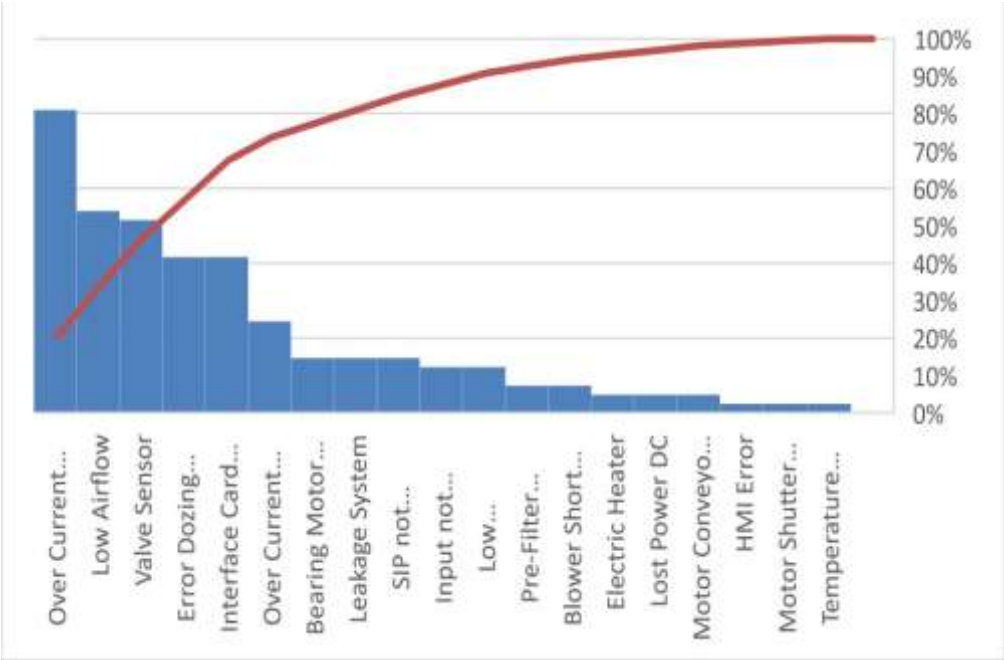

Figure 6. Pareto for breakdown occur

Figure 4.9 shows that about 80% from the breakdown duration is caused by overcurrent case from the variable speed drive from turning table, which from further observation, stated that there are 15 motors that integrated into a conveyor. As the time the machine usage was increased, the performance of the motor will be decreased and if proper maintenance activity is not carried out, the driver motor which formed a VSD will no longer strong enough to provide the power to the motor and then will causing a breakdown.
Stakeholder analysis is carried out by mapping the power-interest grid which will classify stakeholders based on their level of authority in this production process. There are quite a number of stakeholders involved and have been written quite clearly in the business process in the previous sub-chapter. By doing this stakeholder mapping, it will be obtained which stakeholders are more involved in resolving the business issues that occur. Figure 7 shows stakeholder mapping that have analysed.

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Figure 7. Stakeholder Mapping

Current Reality Tree is used to identify the main problem and root cause of the production realization that not meet the production target that has to planned so reducing the company's profit by $4,582,945. The root cause can be known by using Current Reality Tree that using data from observation and interviews conducted to stakeholders who are most responsible work unit to vaccine production activity, that is the n2 Vaccine Production department and Engineering and Maintenance Department. Figure 8 shows the current reality tree that observed and analysed.

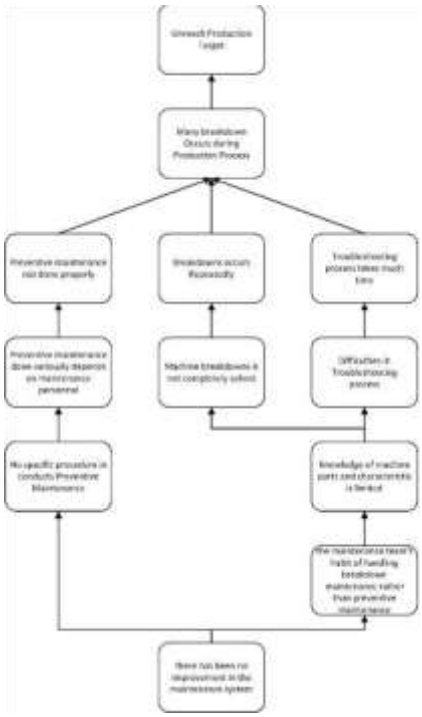

Figure 8. Current Reality Tree

The task list on the preventive maintenance that are currently being carried out routinely only provide the general overview of checking the entire system. This results in a lack in information to what kind of maintenance activity that should be done by technician during maintenance process. The different character and experiences of technician and the unclear the procedure that

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should be carried out make each activity in preventive maintenance process different. This will result in unorganized and more uncontrollable checks. This is exacerbated by the habit that has been implemented by the maintenance team which prefer to waiting to breakdown occur and then repairing the broken-down machine. Almost all maintenance activities that conducted are corrective maintenance which is waiting to breakdown on the machine.

Inappropriate task list and correction maintenance habit also makes maintenance and troubleshooting activities take longer time because there is lack of documentation so that all personnel on duty have difficulties in handling the breakdown because they don't know what maintenance activities that have been carried out and breakdown history this machine has experienced. Therefore, a detailed description of the task list is very important procedure and maintenance activities should be continuously documented so that each personnel can find out what problem have occurred with this machine and how to handling it and also the use of parts and equipment in the maintenance process.

BUSINESS SOLUTION

After identifying the problems using the current reality tree, conducts interview with stakeholders and direct observation of the condition of the production machine, the root cause of the failure to meet the number of production can be identified. The first root cause is the procedure of Preventive maintenance that not listed properly so the maintenance personnel only doing checks according their wants. The second is related to maintenance habits that prefer to doing corrective maintenance instead of preventive maintenance which results in high downtime and repeated breakdowns resulting in continuous repair without any systemic improvements. After identifying the root cause, the author formulate several business solution that considering the interest of stakeholders that can implemented in handling the breakdowns of the machine that occur continuously and causing many losses. All of the alternatives will be assessed based on needs and will choose which one is more effective and more appropriate to implements to reducing the number of machine breakdown and downtime so the target of production amount can be achieved. Part of the alternative solutions prepared are several pillar of total productive maintenance and other alternative solution is to involve the principal as part of the maintenance activities to be carried out. The three alternative solutions are given to be assess further.

1. Autonomous Maintenance
2. Planned Maintenance
3. Principal's Services Agreements

The purpose of the overall alternative solution provided is to increase the OEE of the integrated filling machine which in line with high OEE, the output of the products will be better. A high OEE also indicates production process that runs smoothly so the time required for production is on schedule (High Availability). This is caused by the machine that operate according to it capacity (High Performance) and produce good product without defects (High Quality). There are some differences compared between the three alternative solutions proposed.

All of three alternative solutions have different methods of reducing machine breakdowns that occur. Table 5 shows the methods of the three-alternative solution.

Table 5. Methods of each alternative solution

Alternative Solution	Methods
Autonomous Maintenance	Maintenance activity involves the operators from production unit
	Maintenance activity includes cleaning, lubricating, and tightening that done by operator in a schedule that planned
	Inspection is conducted by operator and will be reported to maintenance team who will take an action due the report from operator
Planned Maintenance	Maintenance Activity conducted by maintenance team from engineering and maintenance division
	The maintenance task and the schedule are based on OMM, Historical of breakdown and MTBF to replacement activity on Planned Maintenance
	Maintenance activity includes cleaning, lubricating, and tightening that done by maintenance team in a schedule that planned

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Principal's services agreements	Maintenance activity involves principals who experts in that type of machine
	Maintenance activity includes cleaning, lubricating, and tightening that done by experts' team in a schedule that planned
	Troubleshooting activity when breakdown occur will be handled by expert

Each of the alternative solution also have strength and weaknesses that must be considered. Table 6 shows the strength and weaknesses of each alternative solution.

Table 6. Strength and Weaknesses of each alternative solution

Alternative Solution	Strength	Weaknesses
Autonomous maintenance	• Increase operator's sense of belonging • Quick awareness when there is an anomaly occur to the machine • Machine cleanliness maintained • lubrication maintained	• Takes more operator's time to maintenance activity • Increase the operator's workload • Need to be trained first do doing maintenance activity • Major breakdown will still require a maintenance team
Planned Maintenance	• Decreasing the number of breakdowns to machine • Maintenance task will list properly • Decrease the downtime because there is documentation in maintenance • Increasing technician's skill • Maintenance team were familiar with the system	• Higher maintenance cost because of parts changes periodically even when it's not broken • Need technician to increase their skill in maintenance activity and troubleshoot • Not all of documentation already yet so the technician will have difficulties in troubleshooting activities
Principal's Services Agreement	• Guaranteed production process • Guaranteed availability of spare parts • Machine handling by professionals	• very high cost for experts and guaranteed spare parts • there is still the possibility of involvement of the maintenance team in the maintenance process or troubleshoots • Outsource personnel must carry out initial qualifications in advance to be able to enter the production room

Each alternative solution will have different results because the methods that used is also different. In this comparison, OEE calculation will be carried out by simulating each alternative solution. Table 7 shows the comparison of OEE between each alternative solution provided that made by using simulation

Table 7. Comparison between OEE 2022 and OEE simulation of each alternative solution provided

	Availability	**Performance**	**Quality**	**OEE**
2022	85%	75%	85%	55%
Simulation				
Autonomous Maintenance	92%	75%	93%	64%
Planned Maintenance	85%	88%	93%	69%
Principal's Services Agreement	92%	88%	93%	75%

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By conducting comparison in OEE simulation that can be seen in table 4.15, from overall alternative solution, the principal's services agreement is the alternative that increases highest OEE which will increasing OEE to 75% while the second one is Planned Maintenance that can increasing OEE to 69%, and the last is Autonomous Maintenance with 64% OEE.

The observation must be conducted again to determine which solution is the most appropriate to be implemented from the three alternative solution that provided. The observation that conducted mostly explain about the description, system, output estimates, and advantages and disadvantages of each alternative solution. In observation process, a questionnaire was given which provides the priorities choice to be taken from all criteria and the alternative solution that provided and the result of those choice will be processed using Analytical Hierarchy Process (AHP).

In conducts observation, to determine the solution that will be choose, author formulates and explains the criteria selected in determining the choice of solution. Selected criteria for analytic hierarchy process shown in table 8.

Table 8. Criteria for AHP

Criteria	Description
Cost	This criterion represented how the effect of cost that will be charged to company on the selected alternative solution. Each alternative solution imposes a different cost, so it can be analysed whether the selection of this criteria is a top priority or can be ruled out
Benefit	This criterion represents the benefits that will be obtained from each alternative solution. The benefits that will be obtained can be seen in the OEE comparison in table 4.14 which each alternative solution provides different benefits, so it can be analysed whether this criterion is a top priority or can be ruled out.
Suitability	This criterion represents the suitability and ease of implementation of each alternative solution offered. Because there will be different views from stakeholders regarding the possibilities of implementation of all alternative solution whether it is very possible to be implemented or not.

With the criteria that contained in table 8, the AHP based on all provided alternative solution can be calculated. The calculation conducted by using software Spicelogic. Results of the calculation and comparison of weighted attributes shown in figure 9.

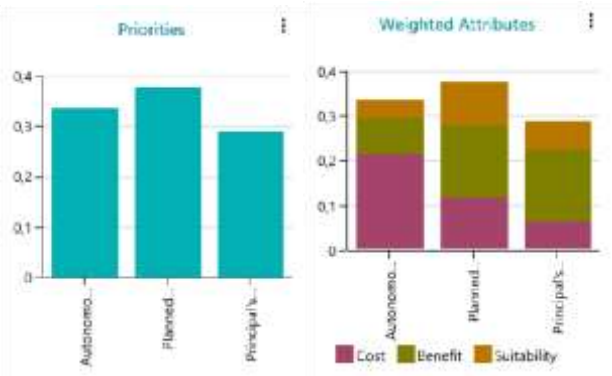

Figure 8.· AHP Results

The result of AHP from 4 stakeholders shows that Planned Maintenance is the most feasible solution to be implemented among the 3 alternative solutions provided. The second possible solution to be implemented is the principal service agreement and autonomous maintenance, which is solution that are deemed impracticable.

Planned maintenance is expected to make performance of the machine better so that it can carried out production optimally and produce good products with minimum reject ratio. Planned maintenance is applied by involved maintenance team in carrying out all maintenance activity and will be conducts from mid of 2023 to start the planning then applied in the same year and will be implemented to the integrated filling machine in n-2 vaccine production unit. The timeline created using Gantt Chart for implementation that proposed and shown is figure 9.

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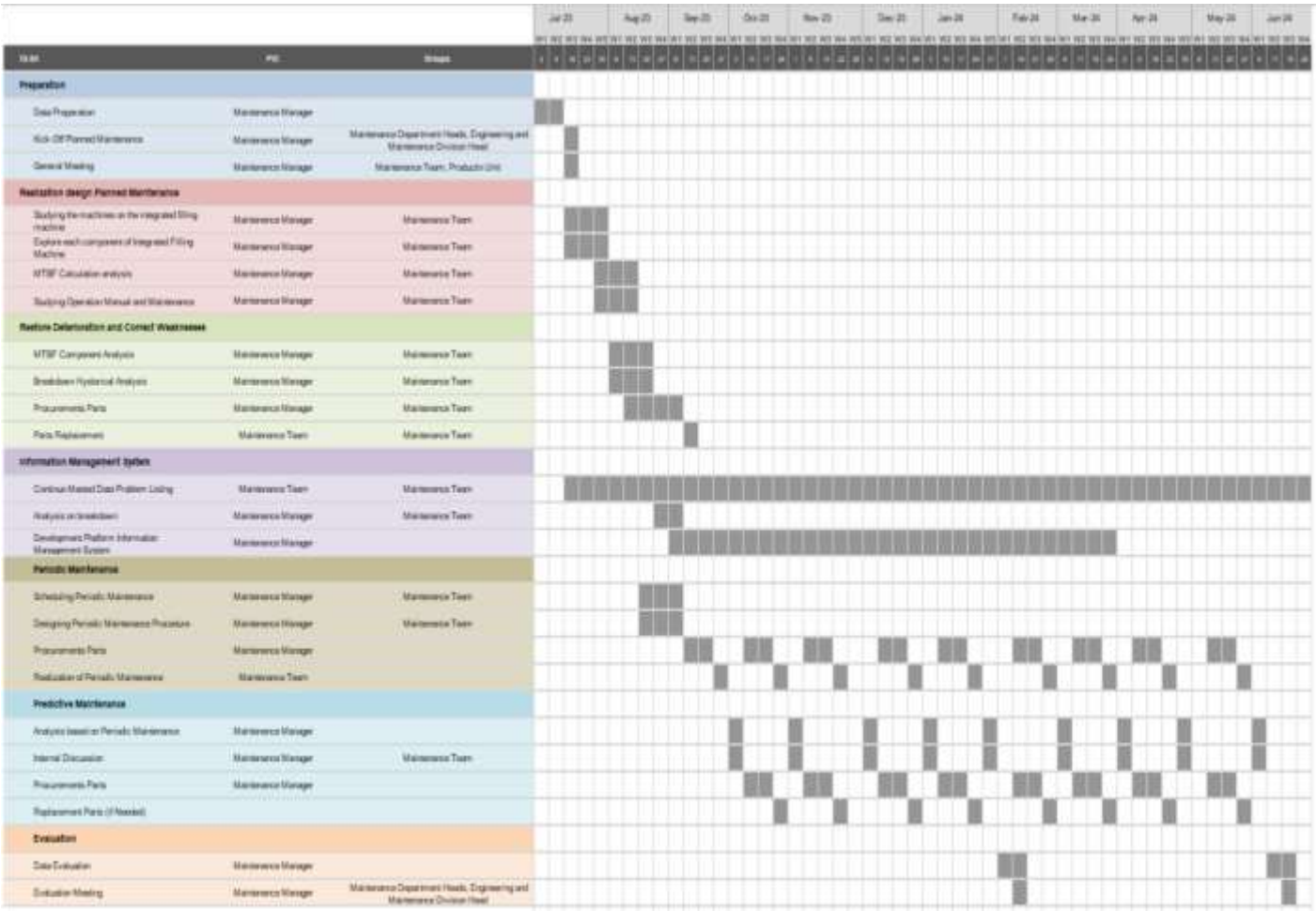

Figure 9. Gantt Chart for implementation

Figure 9 shows the implementation plan for the planned Maintenance. However, preventive maintenance and corrective maintenance have been conducted periodically at PT XYZ. Planned maintenance that will be implemented is required to have complete procedures for carrying out maintenance and planning for spare parts replacement in accordance to predetermined schedule so that in the application will provides significant result and in accordance with the calculation.

CONCLUSIONS

Through this finding and research, it was found the most problem comes from the Integrated Machine Filling that work not properly which caused by damage that occurs repeatedly during production process because of the maintenance process that is not implemented optimally. So far, preventive maintenance has been implemented but the Integrated Filling Machine still run into breakdown, even several times the machine breakdowns with the same problem. This also results the breakdown maintenance is more frequent than preventive maintenance. This is reinforced by the results of OEE calculations which show that the OEE of the Integrated Filling Machine is 55%. All of these deficiencies causing problems that occur when the production process is running due to poor machine performance, thereby increasing production processing time and product quality with many defects.

To solve the problem that occurs, an analysis and observation of the conditions of work units and stakeholders is conducted so that three alternative solutions are obtained. The alternative solutions are Autonomous Maintenance, Planned Maintenance, and Principal Service Agreements which each of the alternative solutions have their respective advantages and disadvantages both in terms of cost and results that obtained. The best solution which selected using the Analytical Hierarchy Process is Planned Maintenance that expected to solve the problems that occur.

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By implementing Planned Maintenance, it is assumed that the performance of the machine will increase by 13% and be able to produce in output by 8%. The improvement of machine's performance and Quality of the product will increase OEE by 14% and has potential to cut losses by up to $885,628 if simulated with the same data as production data in 2022.

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