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Case Study

Authorship Correction: Application of the Total Productive Maintenance to Increase the Overall Value of Equipment Effectiveness on Ventilator

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A ventilator machine is a medical device that plays an important role in handling Covid-19 cases during a pandemic. Covid 19 patients are arriving at a referral hospital in Jakarta, meaning that the hospital must prepare its medical equipment, including a ventilator machine. The ventilator machine experienced problems because the efficiency of the machine decreased so many patients waited in the ICU room. Machine effectiveness has an average value of 62.26% so it has an impact on disrupting patient services at home. The purpose of this research is to look for factors that cause the lack of effective value of ventilator machines and find effective solutions to increase the effectiveness of ventilator machines so that they can serve Covid-19 patients during a pandemic. This research method combines Focus Group Discussion in determining 5W+1H and implementing the pillars of Total Productive Maintenance to improve the Overall Effectiveness of Equipment on Ventilator machines. This study found a breakdown factor of 54.10%, idle and minor loss of 41.20%, and others of 4.70%. The effect of overall improvement has been able to increase the average effectiveness value by 85.00% from Sep 2021-Feb 2022, so this is supported by the hospital's program in terms of increasing the effectiveness of machines in patient care.

INTRODUCTION

At the end of 2019, the world was faced with the emergence of a new virus called Corona Viruses disease 2019 (Covid-19). The Covid-19 pandemic is an event that spreads disease throughout the world caused by a new type of coronavirus named SARS-CoV-2 [1]. In Indonesia, this virus was first detected on March 2 2020 with two people confirmed positive for Covid-19, then on April 9 2020 the pandemic spread to 34 provinces throughout Indonesia, including DKI Jakarta, West Java, and Central Java as the provinces most much exposure. to viruses.

This virus attacks parts of the human respiratory system, common symptoms felt due to being exposed to this virus include fever, cough, and shortness of breath, complications can include pneumonia and severe acute respiratory disease [2]. To handle the Covid-19 virus pandemic, the healthcare facility industry or hospital is expected to be able to prepare special treatment rooms for infected patients, including also to prepare Incentive Care Unit (ICU) rooms. Therefore, this research is important to do so that Covid-19 patients get good health services because ventilator machine facilities can support these obstacles with standard OEE values.

The ICU room has medical equipment including a patient monitor, ventilator, infusion/syringe pump, defibrillator, electric bed, and catheter [3]. Hospital data shows that of the human population infected with the Covid-19 virus, 25% to 50% of them are hospitalized, and of all patients who are hospitalized 7%-26% of them are treated in the ICU and require medical devices that play an important role in handling Covid-19 cases. In this case, this device is called a breathing apparatus or ventilator [4]. A ventilator is a machine that is used to help with breathing that is used in the intensive care unit (ICU) service room in a hospital. The output of this machine is a flow of positive pressure air which is arranged in such a way that the patient can start the process of inspiration and expiration, then another treatment is given in the hope that the patient will recover.

The success rate of using ventilators in patients with Covid-19 is around 43%-63%. According to other studies, it is necessary to improve the system in organizing health equipment, especially ventilators which are quite important in helping to handle Covid-19 cases in hospital healthcare facilities [5]. Management of medical devices including maintenance, calibration, and repair management [6]. The management can also apply a Lean Six Sigma (LSS) approach in identifying

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patient needs and eliminating waste of work processes for hospital employees [7]. The success rate of repairs with the Overall Effectiveness Equipment (OEE) method on health machines, the increase in the OEE value can reach 14.6% so that it can assist in the treatment of cancer patients in hospitals using the Linear accelerator (LINAC) Synergy Platform (SP) machine [8]. Other studies also use OEE in the analysis of pre-turning engine performance so that engine efficiency can increase by 90% [9].

The new approach of this research is in solving the problem of the low OEE value in handling Covid-19 patients using a combination of the Total Productive Maintenance (TPM) approach with root cause analysis carried out in Focus Group Discussion (FGD) as outlined in the why-why analysis and What-Why-Who-When-Where-How (5W+1H) methods. The purpose of this research is to look for factors that cause the lack of effective value of ventilator machines and find effective solutions to increase the effectiveness of ventilator machines so that they can serve Covid-19 patients during a pandemic. Thus, it is necessary to improve the system in organizing health equipment, especially ventilators which are quite important in helping to handle Covid-19 cases in hospital healthcare facilities.

Ventilator Machine

The ventilator machine functions to improve oxygenation, reduce carbon dioxide and help the respiratory muscles work without damaging lung function [10]. In the treatment, 80% of the therapy given is ventilation modes such as air pressure, volume control, and oxygenation, the most needed medical device technology to support this therapy is a ventilator machine [11]. In this study, the ventilator machine is very important in handling Covid-19 case patients who experience shortness of breath as further assistance in the ICU room before entering the isolation room for Covid-19 patients. Paying attention to the interests of hospitals and patients, providing satisfaction, and meeting patient needs is one of the main goals of scheduling nurses in their activities in the hospital [12]. Ventilators are machines with quite complex systems, so in managing these machines good planning of maintenance activities is required. One of the factors that affect the quality of the ventilator machine is the accuracy of the damage analysis. Ventilators have historical status or history of errors, which if there is damage or system failure, can be known sometime later.

Overall Effectiveness Equipment (OEE)

Increasing the value of OEE can be applied in various manufacturing industries, for example, the garment industry [13] and sugar factories [14]. Improvement of machine performance to increase productivity is the TPM approach with 8 pillars, one of which is increasing the OEE value by using a questionnaire-based survey method in the food industry [15]. Another study combines the TPM approach and the Plan-Do-Check-Act (PDCA) cycle in which there are improvement tools such as Pareto diagrams and Fishbone diagrams. This has increased the OEE value from 60.7% to 65.3% in the automotive component industry [16]. The OEE method can also be included in the improvement phase of the PDCA approach combined with seven quality improvement tools [13]. In this study, the quality of health services is a ratio that describes the ability of health equipment with a high OEE value to produce services following quality standards so that this ventilator machine helps Covid-19 patients in the context of handling patients.

Total Productive Maintenance (TPM)

In general, maintenance can be defined as preventive measures taken to keep the performance conditions of a machine/equipment optimum/prime but with the lowest possible maintenance costs (Seiichi Nakajima) in the quote [17]. The Ventilator machine is a fairly complex system, so in the management of the machine, it is necessary to plan good maintenance activities. System failure in the ICU, 41.3% of which came from medical equipment and ventilators, was the highest contributor to failure or the level of damage compared to other medical equipment [18]. TPM is a tool to improve or improve engine performance with a maximum output of increasing OEE value [19], and can also be applied to gas turbine engines [20]. TPM provides an optimal solution for increasing effectiveness by involving all human resources who are responsible for production facilities [21]. In this study, the application of TPM is expected to be a solution to the low OEE value of the Ventilator engine because this machine is very important to use during the Covid-19 Pandemic.

METHOD

This research is descriptive exploratory research with mixed-method research, conducted by collecting data and information on a problem. Primary data can be obtained from informant sources, namely individuals or individuals as expert judgments such as the results of interviews conducted by researchers. This is in line with the other research in determining the value of Failure Mode Effect Analysis (FMEA) methods [22]. Secondary data is obtained from literature review, previous research, books, specification brochures, and so on. The population collection technique in this study used a probability sampling technique with a simple random type, namely by collecting data on six big losses for six months, January-June 2021 (before improvement) and September 2021-February 2022 (after improvement). The population of this study was ventilator machines used as breathing aids in patients who experienced respiratory system failure, while the sample for this study was 3 ventilator machines in the ICU. The study framework can be seen in Figure 1. Figure 1 has shown the stages of OEE calculation using the formula Lead Time (LT), Available Ratio (AR), Performance Efficiency, Quality Rate (QR), and Overall Effectiveness Equipment (OEE).

$$\text{LT} = \text{Number of machines x Number of working days x } \frac{\text{Working hours}}{\text{Days}} \text{ x } \frac{\text{Minutes}}{\text{Hours}} \quad (1)$$

$$\text{AR} = \frac{(\text{Loading Time} - \text{Downtime})}{\text{Loading Time}} \text{ x } 100\% \quad (2)$$

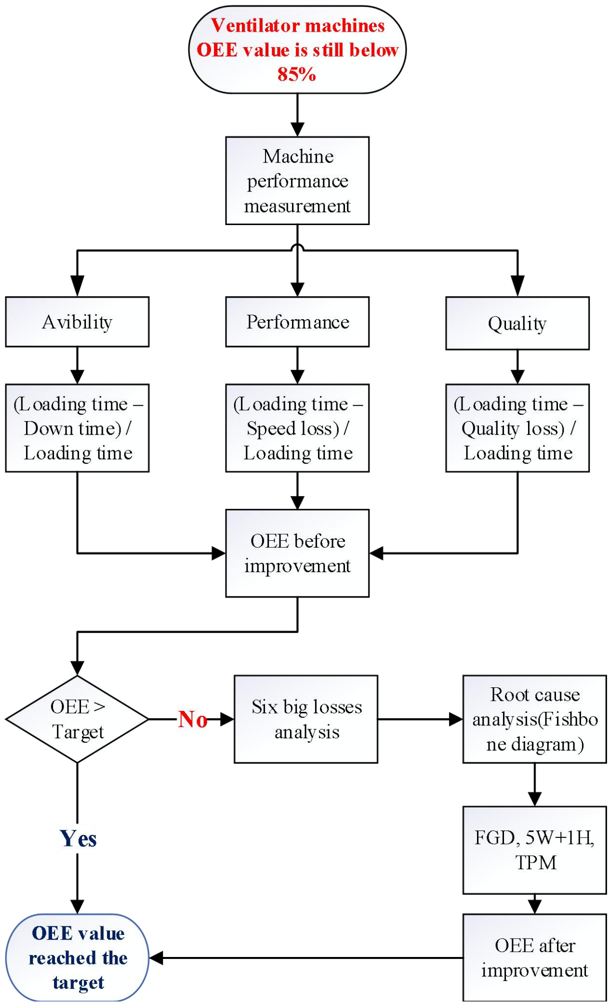
$$\text{PE} = \frac{(\text{Loading Time} - \text{Speed Loss Time})}{\text{Loading Time}} \text{ x } 100\% \quad (3)$$

$$\text{QR} = \frac{(\text{Loading Time} - \text{Quality Loss Time})}{\text{Loading Time}} \text{ x } 100\% \quad (4)$$

$$\text{OEE} = \text{AR x E x QR} \quad (5)$$

Based on Figure 1, there has been a problem with the OEE value of the ventilator machine below the target of 85%. The initial step in the research stage is to measure engine performance which consists of Lead time, availability, performance, and quality. The formulation of the engine performance measurement can be seen in formulas (1), (2), (3), and (4). After the data processing and calculations have been carried out, the results of the OEE value before the repair will be known using the formula (5). The results of the OEE value before the repair will be compared with the target of 85%, if the OEE value is in the standard then no further improvement steps are needed, all that remains is to maintain it.

Meanwhile, if the OEE value is below standard, corrective steps are needed, including analyzing six big losses, then making a root cause analysis using the fishbone diagram method. The next step is to find solutions to the dominant problems shown in the fishbone diagram. The steps for improvement start from forming FGDs, discussing the 5W+1H method, and making improvements with the TPM approach. After everything is obtained, the final step is to calculate the OEE value after repair using the formula (5). If the results of the OEE value enter the target of 85% then all corrective actions are declared successful and if they are still below the target then data analysis needs to be repeated until corrective actions are taken.



RESULT AND DISCUSSION

In this section, we will discuss the results of the research along with a discussion of how much influence the OEE value after repairs will have when compared to the target to be achieved.

Determination of Six Big Losses

Six big losses can already be known and analyzed from the observations of the maintenance party on 3 Ventilator machines in the ICU. Six big losses data is designed by the maintenance party as long as the machine is used in patient care. The results of the measurement of loading time before improvement (Jan-Jun 2021) can be seen in Table 1. Table 1 shows the measurement results of loading time before improvement from Jan-Jun 2021 (6 months) with a total loading time average value of 29,282 minutes. These loading time data will be included in the calculation of the availability rate every month.

The results of the report from the maintenance party that for 6 months, the data shows that downtime, speed loss, and quality loss have been obtained according to the use of ventilator machines in serving patients. The six big losses parameter consists of 6 losses including small idling and stopping losses, failure losses, adjustment and adjustment losses, and rework losses [23]. More detail can be seen in Table 2. In Table 2 it can be seen that the most dominant six big losses are those caused by downtime loss with an average of 6.828 minutes (Figure 2).

Based on Figure 2 the most dominant cause of the six big losses on the Ventilator engine is the downtime problem on the breakdown loss machine condition of 6.666 minutes per month or 54.1%, the speed loss problem on the idling machine condition and minor loss of 5.084 minutes per month or by 41.2%, and other problems by 4.7%. Meanwhile, for the problem of quality loss, there is no problem with the engine stopping because the ventilator output is problematic. All Ventilator engine products run normally when the machine is operational. Other research on the results of the Pareto chart is taken 1st and 2nd with a total percentage of 80% for corrective action to be taken [24].

Table 1. Data Loading Time Before Improvement

Month	Machines	Number of working days	Working hours/ days	Minute/ hour	Loading Time (minute)
Jan 21	3	23	8	60	33,120
Feb 21	3	16	8	60	22,665
Mar 21	3	22	8	60	30,990
Apr 21	3	21	8	60	30,190
Mei 21	3	21	8	60	30,240
Jun 21	3	19	8	60	27,950
Average	3	20	8	60	29,282

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Table 2. Six Big Losses Before Improvement

Month	Downtime Loss (minute)			Speed Loss (minute)			Quality Loss (minute)		
	Breakdown loss	Setup loss	Sum	Idling and minor loss	Reduce speed loss	Sum	Reject loss	Rework loss	Sum
Jan 21	8,948	45	8,993	3,967	430	4,397	0	0	0
Feb 21	6,772	160	6,932	3,820	355	4,175	0	0	0
Mar 21	5,860	165	6,025	3,899	430	4,329	0	0	0
Apr 21	6,769	150	6,919	5,788	555	6,343	0	0	0
Mei 21	7,678	270	7,948	6,895	205	7,100	0	0	0
Jun 21	3,971	180	4,151	6,135	550	6,685	0	0	0
Average	6,666	162	6,828	5,084	421	5,505	0	0	0

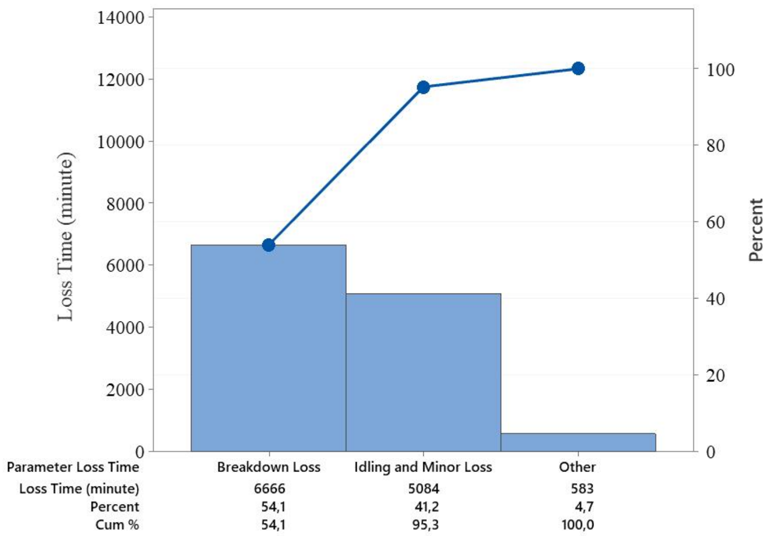

Figure 2. Pareto Diagram of Six Big Losses

Measuring OEE Value Before Improvement

In this section, we will discuss the results of the OEE calculation using formulas (2), (3), and (4) for example in January 2021.

$$AR = \frac{(33{,}120-8{,}993)}{33{,}120} \text{ x } 100\% = 72.85\%$$

$$PE = \frac{(33{,}120-4{,}397)}{33{,}120} \text{ x } 100\% = 86.72\%$$

$$QR = \frac{(33{,}120-0)}{33{,}120} \text{ x } 100\% = 100.00\%$$

$$OEE\ (\%) = 72.85\% \text{ x } 86.72\% \text{ x } 100.00\% = 63.17\%$$

The calculation data for the OEE value before improvement is based on the recapitulation from January-June 2021 on the ventilator machine (Table 3). Table 3 shows the results of the OEE value before the average improvement from Jan-Jun 2021 of 62.26%. This result is still far from what was expected by the hospital management, which was 85.00%. Success in improving the effectiveness value of production machines or other machines must have an OEE value greater than 85% [25].

Table 3. Recapitulation of OEE Result Before Improvement

Month	AR (%)	PE (%)	QR (%)	OEE (%)
Jan 21	72.85	86.72	100.00	63.17
Feb 21	69.41	81.58	100.00	56.62
Mar 21	80.55	86.03	100.00	69.30
Apr 21	77.08	78.99	100.00	60.88
Mei 21	74.17	76.93	100.00	57.00
Jun 21	85.15	76.08	100.00	64.78
Average	76.68	81.20	100.00	62.26

Problem Cause Analysis

This section has produced a report in the form of a Fishbone diagram obtained from brainstorming between machine operators, electromedical, and sterilizers. The Fishbone chart organizes and displays the relationships between different causes for the effect that is being examined [26]. Figure 5 is the result of the Fishbone diagram. After knowing the factors causing the low OEE value of the ventilator machine, then make an analysis using why-why analysis. The why-why analysis of the four factors can be seen in Table 4.

Focus Group Discussion (FGD) Result

In this section, we will discuss the corrective actions of several factors causing the breakdown loss problem generated by the Ventilator engine. To determine corrective actions that are right on target, an FGD meeting was held which was attended by seven expert judges in their respective fields. The purpose of this FGD is to discuss all forms of corrective action through the 5W+1H method [27].

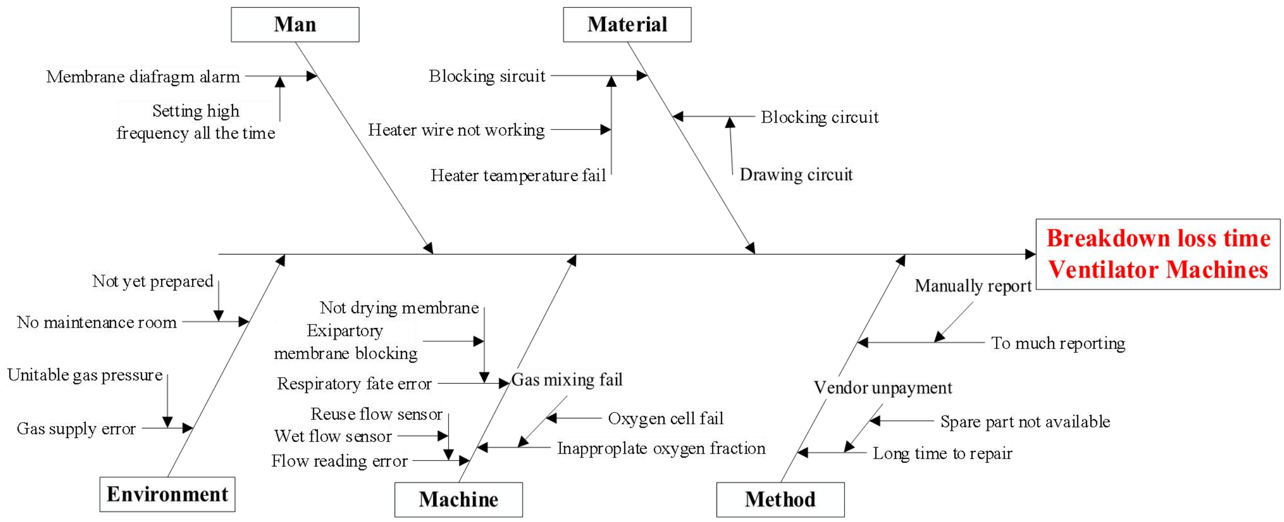

Table 4. Why-why Analysis Breakdown Problem

Causes of problem	Why 1	Why 2	Why 3
Man	Usage error	Technical alarm fault diagnosis	HFO setting time is too long
Material	Breathing circuit blocking	Heater not working	Broken heater cable
		Foggy circuit pipe	Use more than 1 time
Machine	Respiratory rate error	Expiratory cassette blocking	Wet membrane, not yet dry when sterilizing
	Inappropriate oxygen dosage	Oxygen cells do not detect	Mixing gas fail
	Reading flow error	Wet flow sensor	Use must be 1 time/patient
Method	The part replacement process is too long	Spare parts not available	Indent spare parts
	Gas supply error	Central gas pressure is often unstable	

Member of the FGD meeting consists of 1 Specialist Doctor, 2 Electromedics, 1 Medical Physicist, 2 ICU responsibilities, and 1 technical machine. The 7 expert judgments discussed the main causes and corrective actions comprehensively in handling Ventilator engine breakdowns. The results of the FGD are stated in an improvement plan called 5W+1H.

Improvement Plan 5W+1H

The corrective action plan taken from the FGD meeting leads to the handling of the Ventilator machines breakdown in the ICU room. The 5W+1H agenda can be seen in Table 5.

TPM Implementation

The implementation of TPM is a continuous action after the implementation of 5W+1H, which serves to maintain the condition of continuous improvement with the consistent pillars of TPM. The application of TPM in the health service industry, especially in increasing the value of OEE on health machines, for example, Ventilator machines, is expected to be able to maintain good system effectiveness in terms of managing medical devices, especially ventilators. The implementation of the TPM pillar in this research is based on the priority of the problem. Therefore, based on the decision of the FGD results, the implementation of the TPM pillars chosen for improvement in this study was Autonomic Maintenance (AM), Focused Improvement (FM), and Planned Maintenance (PM).

Autonomous Maintenance

Autonomous Maintenance is part of the implementation of TPM which aims to improve engine performance so that productivity is maintained [28]. This AM activity involves all parties by providing knowledge to operators regarding the understanding of Ventilator machines who are trained by experts in their fields. The training contains knowledge of machine safety systems, basic machine maintenance, and repairs, to advanced machine stages. Some of the knowledge and training delivered are aimed at enabling operators and electromedical personnel to be able to run or operate machines properly according to SOPs, schedule regular machine cleanings, check parts that are prone to abnormalities, and to be able to take early preventive actions.

Planned Maintenance

The concept of planned maintenance is intended to be able to avoid and even overcome problems that may occur. Planned maintenance is carried out at 2 main points, namely preventive maintenance and predictive maintenance. The phenomenon problem that occurs in this Ventilator machine is the problem of lost time in engine breakdown. Therefore, it is necessary to make preventive maintenance scheduling for the Ventilator machine (Table 6).

When the predictive maintenance action is carried out on a date that has been made on a predetermined schedule. At a certain

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Table 5. Improvement Plan 5W+1H

Causes of problem	What	Why	Who	Where	When	How
HFO mode setting time is too long	SOP related to how to use HFO mode settings	The machine does not shut down suddenly	Operator and electromedical	Ventilator interface	First Jul 21	Perform SOP improvement and operation training
Blocking the airway to the patient is delayed	The heater wire on the Breathing circuit is adjusted to the type of plastic	The ventilator is not working efficiently	Operator and electromedical	Breathing circuit	Middle Jul 21	The heater wire is assigned the same code/mark as the breathing circuit code
Expiratory cassette replacement technique	The membrane must be removed when changing the cassette	The visual monitor of the ventilator is missing	Operator and electromedical	Expiratory cassette	End Jul 21	Performing SOP improvement and operator training
SOP for sterilization flow sensor and usage needs to be improved	SOPs related to use and sterilization	The flow sensor is often broken	Operator, electromedical, and sterilizers	Mouthpiece breathing circuit	First Aug 21	Change reading flow sensor sterilization every 2 months
Compress moist water and contains water	Gas input	The machine is quickly damaged due to the replacement of the mixing gas supply component	Electromedical	Central gas supply	Middle Aug 21	Adding an air dryer to the central compressor and adding a water filter to the gas inlet of the ventilator

Table 6. Preventive Maintenance Schedule

Activity	Before Improvement	After Improvement
Checking machines	4 months	1 month
Respiratory rate error	6 months	3 months
Inappropriate oxygen dosage	2 months	1 month
Reading flow error	4 months	2 months
Consumable spare part	Base on report	The consignment system

frequency, predictive maintenance activities are carried out by replacing several consumable parts which are routinely replaced based on the hour meter on the ventilator. These consumable parts were previously provided based on reports of damage/failure, so currently, the repair solution is carried out by changing the procurement system for the parts affected by the consignment system. This system is a form of collaboration where the vendor as a ventilator agent entrusts parts to be sold by the logistics department at the hospital. Some consumable parts for the ventilator are; oxygen cells, flow sensors, membrane cassettes, breathing circuits, batteries, and bacterial filters.

Focused Improvement

The main focus in carrying out this focused improvement is on the accessories used in the ventilator, especially the breathing circuit. In recent years the breathing circuit used on the ventilator has changed and needs to be adapted to the heater wire in it. Repairs are carried out by using a power heater according to the shape and type of the breathing circuit. This improvement is stated in the work instructions which are derivatives of the Standard Operational Procedure (SOP) on how to use a ventilator. With the implementation of this focused improvement, it is hoped that blocking circuit problems will not occur frequently so that ventilator services for patients can be maximized and efficient.

The Standard Operational Procedure (SOP) on how to use a ventilator that has been made by the repair team has been disseminated to all hospital workers so that it is hoped that health workers can operate the ventilator machine safely and properly according to the SOP. All of this is so that the handling of Covid-19 patients can be addressed immediately and there is not much time waiting in the queue for the ventilator machine

Measuring OEE Value After Improvement

After taking corrective and preventive actions with the application of TPM on the Ventilator engine, the next step is to measure the OEE value. However, before the OEE calculation, load time checks were carried out on the 3 Ventilator machines (Table 7).

The loading time data has been obtained, then analyze the loss time through the six major losses whose data has been obtained and filled in by the Ventilator engine technician. The calculation of the six major losses can be seen in Table 8. If all the OEE parameters have data, then the OEE value can then be calculated, the calculation of the OEE value after the repair from September 2021-February 2022 (Table 9).

Table 7. Loading Time Results After Improvement

Month	Machines	Number of working days	Working hours/ days	Minute/ hour	Loading Time (minute)
Sep 21	3	23	8	60	33,120
Oct 21	3	22	8	60	31,680
Nov 21	3	22	8	60	31,680
Dec 21	3	21	8	60	30,240
Jan 22	3	23	8	60	33,120
Feb 22	3	16	8	60	23,040
Average	3	21	8	60	30,240

Table 8. Data Six Big Losses After Improvement

Month	Downtime Loss (minute)			Speed Loss (minute)			Quality Loss (minute)		
	Breakdown loss	Setup loss	Sum	Idling & minor loss	Reduce speed loss	Sum	Reject loss	Rework loss	Sum
Sep 21	4,089	42	4,131	1,422	115	1,537	0	0	0
Oct 21	4,021	65	4,086	1,487	106	1,593	0	0	0
Nov 21	3,473	60	3,533	1,465	111	1,576	0	0	0
Dec 21	3,077	63	3,140	1,379	133	1,512	0	0	0
Jan 21	3,295	70	3,365	1,122	108	1,230	0	0	0
Feb 21	1,795	48	1,843	964	87	1,051	0	0	0
Average	**3,292**	**58**	**3,350**	**1,306**	**110**	**1,416**	**0**	**0**	**0**

Table 9. Recapitulation OEE Result After Improvement

Month	AR (%)	PE (%)	QR (%)	OEE (%)
Sep 21	87.52	95.36	100.00	83.46
Oct 21	87.10	94.97	100.00	82.72
Nov 21	88.85	95.02	100.00	84.42
Dec 21	89.61	95.00	100.00	85.13
Jan 21	89.84	96.28	100.00	86.50
Feb 21	92.00	95.43	100.00	87.80
Average	89.15	95.34	100.00	85.00

In this section, we will discuss the results of the OEE calculation using formulas (2), (3), and (4) for example in September 2021.

$$AR = \frac{(33{,}120-4{,}131)}{33{,}120} x\ 100\% = 87.52\%$$

$$PE = \frac{(33{,}120-1{,}537)}{33{,}120} x\ 100\% = 95.36\%$$

$$QR = \frac{(33{,}120-0)}{33{,}120} x\ 100\% = 100.00\%$$

$$OEE = 87.52\%\ x\ 95.36\%\ x\ 100.00\% = 83.46\%$$

Data for calculating OEE values after repairs based on recapitulation from September 2021–February 2022 (6 months) on the Ventilator machine (Table 9). Table 9 has shown the results of the OEE value after the average improvement from Sep 2021-Feb 2022 of 85.00%. This result has met the target of hospital management, which is 85.00%. This proves that the evaluation of the ventilator machine that has been carried out is running as expected and all forms of corrective action are following the predetermined plan. This condition must be consistently maintained by all hospital parties.

Impact After Improvement

After the improvement was implemented, there was an increase in the OEE value which had an impact on patient care. Starting in September 2021 still in the conditions of the Covid-19 pandemic, the needs of patients who require services with ventilators at 90% can be accommodated and management at the service can anticipate if services spike up because the condition of health equipment including ventilators well-conditioned.

The improvement time on ventilator damage can be minimized so that the number of ventilator operations increases. Before repairing the system, damaged ventilators need an average of 14 days to repair, after an increase in the OEE value the repair time decreases by an average of 9 days. The establishment of a common perception and goal between management and operators to routinely carry out continuous maintenance to maintain the reliability of the ventilator.

Discussion with Previous Research

Implementation of TPM with the OEE method on health machines whose corrective actions are combined with other methods FMEA, Pareto diagrams, and Fishbone diagrams [7]. The OEE method can also be applied to the PDCA approach in line with the other research of Jaqin et al [16]. The management can invest in machine parts components or medical equipment infrastructure to support the implementation of TPM is necessary to increase machine effectiveness. Therefore the need for attention from maintenance management related to the availability of consumable parts is in line with the other research of Sutoni et al [29]. According to Patil et al, replacement of spare parts must be prepared earlier in scheduling the inventory of engine spare parts components, so there is a need for a purchase schedule to the supplier [30].

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In addition, to spare parts that must be scheduled, management must be committed to carrying out regularly scheduled training, and socialization related to AM becomes a work culture for all medical personnel. According to Bekar et al [31] If applying PM with a method based on input maintenance schedules will facilitate planning for the procurement of parts needed in the future. Corrective action with the concept of FM will provide the right target in terms of engine repair. The implementation of TPM with 3 pillars of Autonomic Maintenance (AM), Focused Improvement (FM), and Planned Maintenance (PM) that have been carried out has succeeded in increasing the OEE value so that patients waiting in the ICU room can immediately be served by their health and provide fast and non-queuing treatment.

CONCLUSION

This research found that there are factors that affect the low effectiveness of the Ventilator machine based on the analysis of the six big losses, namely the breakdown factor of 54.10%, idling and minor loss of 41.20%, and others of 4.70%. So that the average OEE result measured before improvement for 6 months from Jan-Jun 2021 is 62.26%. Based on FGDs with experts, the corrective action in this study is to implement the pillars of sustainable TPM. The SOP needs to be revised regarding how to use HFO mode settings and conduct training for operators. The heater wire is assigned the same code/mark as the breathing circuit code. It is necessary to improve the SOP and conduct training for operators related to expiratory cassette replacement techniques. Replacement of spare parts from reading flow sensor sterilization from 4 months to every 2 months, adding an air dryer to the central compressor, and adding a water filter to the gas inlet of the ventilator. The effect of comprehensive improvements has been able to increase the OEE value by an average of 85.00% from Sep 2021-Feb 2022 (6 months), which means an increase in OEE value by 22.74%. So, this has supported the hospital program in terms of increasing the effectiveness of the machine in patient care. The implication of this research in analyzing machines is only in the ICU with a sample of 3 machines. Due to limited access to other rooms, the ventilator machine in that room is not allowed for research. The continuous and consistent implementation of TPM with AM, PM, and FM pillars has increased the OEE value of Ventilator machines in the hospital service industry. This result has given satisfaction to the hospital management because it has been able to provide effective machine maintenance, save on machine repair costs and increase the effectiveness of the machine in treating Covid-19 patients. With the success of increasing the OEE value for 6 months, to maintain the consistency of the effectiveness, the authors suggest further research to include the monthly OEE target value into the Hospital's Key Performance Indicators (KPI). The hope is that all hospital employees, especially the ICU section can consistently implement TPM because there is a bonus from the hospital management every year.

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