



Implementation of Total Productive Maintenance to Improve Overall Equipment Effectiveness of Linear Accelerator Synergy Platform Cancer Therapy

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ABSTRACT

The Jakarta Government Hospital provides cancer services with several available types of equipment, one of which is the Linear accelerator (LINAC) Synergy Platform (SP) machine. The phenomenon of this machine experiencing a low effectiveness value because it is not able to handle the patient queue so it is not able to reduce the severity of cancer. The purpose of this study was to determine the factors causing the low value of Overall Equipment Effectiveness (OEE) and provide suggestions for improvement to increase the OEE value. The new approach of this research is using the Total Productive Maintenance (TPM) approach with OEE analysis as a success parameter because TPM is more identical in the manufacturing industry. Another update is using Failure Mode and Effect Analysis (FMEA) through Focus Group Discussions (FGD) with experts. The results of the study found that the factors that influenced the low OEE value on the LINAC SP machine were caused by breakdown loss of 76.29%, setup loss of 9.59%, idling and minor stop of 8.80%, and a decrease in speed of 5.29%. The continuous and consistent implementation of the TPM Pillar has increased the OEE value of the LINAC SP machine.

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NOMENCLATURE

LT Loading Time
AR Availability Ratio

PE Performance Efficiency
QR Quality Rate

1. INTRODUCTION

The medical equipment is the most important part of health service activities both in hospitals and other health facilities. A medical device is an instrument, equipment, or machine that has a function to assist nurses, doctors in diagnosing, detecting, measuring, curing, preventing, and repairing parts of the human body for health purposes. Medical equipment is a very vital medical device so this tool must require training in its use, calibration and maintenance must be carried out periodically. Medical equipment is usually managed by technical personnel. Medical equipment does not include implants and disposable [1]. Medical equipment also has an important role in handling various types of diseases that exist in hospitals in addition to the role of medical personnel,

doctors, and nurses. Therefore, it becomes very important for hospitals to maintain the availability and reliability of equipment. Health services, especially in hospitals, are carried out by scheduling nurse performance which consists of scheduling patient services, providing satisfaction, and fulfilling nurse needs [2].

The Jakarta government hospital is one of the hospitals that provides cancer services with several available types of equipment, one of which is the LINAC SP. Based on initial observations, this machine experienced a low effectiveness value because it was unable to handle the patient queue so it was unable to reduce the severity of cancer. The inability to service the LINAC SP machine is due to the overall effectiveness of the LINAC SP machine being below the standard set by the ministry of health of 85%. LINAC SP machine as a

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radiotherapy machine for the treatment of cancer is often found experiencing damage that varies from year to year.

The LINAC SP machine breakdown data for 2021 was 76% exceeding the target set by management; which is 35% of the time loss parameter and the OEE value of under 80%. Based on these problems, it is necessary to make improvements to get reliable equipment to be able to improve cancer patient services [3]. Applying the TPM concept is one of the best ways to overcome OEE values below 80%, so the implementation of TPM is a new thing in the hospital service industry because the TPM concept is more attached to the manufacturing industry. The implementation of TPM depends on the sincerity of all employees involved in TPM activities, from employees to management. Discipline in carrying out procedures and maintenance guidelines that have been made will greatly help the achievement of each TPM pillar [4].

The implementation of the TPM stage can bring other non-economic benefits such as increased safety and facilitation of repairs; thanks to work standardization based on 3 main pillars of TPM, namely focussed maintenance, autonomous maintenance, and planned maintenance [5]. Performance improvement is not only pursued by the industrial sector but also in the health care sector to reduce maintenance costs and increase operational efficiency [6].

TPM has characteristics that are measured by three parameters, namely improving overall equipment, maintenance by all human resources and activities carried out by small groups. The involvement of Human Resources (HR) is a key factor in TPM performance [7]. The effectiveness of the traditional overall tool is by considering the performance of human resources and the performance of equipment [8]. Another study used the Kaizen approach to improve maintenance elements, performance, and equipment availability [9, 10]. Modern medical machines and equipment have complex characteristics and different parts [11].

Therefore, TPM is a priority maintenance action by hospitals to analyze problems so that it can be seen how to improve OEE on equipment/machines. Increasing the effectiveness of the tool can be done by looking for six big losses, implementing TPM pillars and 5S foundation to increase the OEE value. Implementation of FMEA is used to analyze problems and determine improvement priorities. This study refers to research by Sharma et al. [12] where the TPM approach is used to increase the effectiveness of machines in the industry so that companies can survive, compete and dominate the global market. The research conducted by Xiang and Feng [13], Pacaiova and Izarikova [14], Thorat and Mahesha [15] applied the pillars of TPM in the manufacturing industry to increase machine effectiveness.

Reducing total network costs and maximizing responsiveness to customer requests in advance and reverse case, based on performance metrics and statistical

hypotheses [16]. The TPM method can be combined with the Plan Do Check Action (PDCA) cycle in the manufacturing industry [17]. But in this study, the TPM method is combined with FMEA in the health services industry. The strength of this research will implement the pillar of TPM on one of the machines in the health service so that it becomes a new approach in this research.

This study aims to find the causal factors that affect the low OEE value and provide suggestions for improvements that must be made to increase the OEE value on the LINAC SP machine by using the TPM approach. The next sub-section contains a literature review as an understanding of the method used, methodology as a flow of problem-solving in this study, results, and discussion as a section for analysis, improvement, and discussion of this research, and conclusion as a section that collects research findings and results.

2. LITERATURE REVIEW

In this section, we will discuss the literature review that is still related to the materials and methods taken in this study. This grouping of literature studies should be focused and conceptualized between the research methods taken and the literature review used.

2. 1. LINAC SP Machine The LINAC SP machine is an ionizing radiotherapy medical machine that is used as a cancer therapy. Cancer treatment with this device uses radiation from radioactive particles to treat and control cancer growth. According to Ahmed Ali Omer [18] this machine requires high energy radiation so that it can be used to treat cancer with electricity utilizing fast-moving subatomic particles. LINAC machine produces beams of X-rays and radiate them to the patient's cancerous region [19]. Complex beam delivery techniques for patient care using clinical LINAC can result in variations in the photon spectrum, which can lead to dosimetric differences in patients that cannot be explained by current Treatment Planning Systems (TPS) [20]. Dosymmetrical Characterization of the Elekta LINAC SP that can be used for cancer therapy [21]. The simulation includes all components of the LINAC head and a homogeneous water ghost that yields in terms of depth dose and lateral dose profiles are presented for the 6 Megavolts [22].

2. 2. TPM According to Nakajima [23] TPM is defined as a popular approach used on equipment/machines for maintenance, preventing machine trouble, improving performance, and promoting maintenance by machine operators through daily maintenance activities involving all personnel from operators to top management.

The TPM implementation has many benefits for the workforce including sharpening knowledge and skills related to maintenance, improving internal communication, increasing teamwork, preparing equipment diagnosis so that they can prepare for inspection audits. TPM extends equipment life, zero defects, and zero accidents by involving operators [14]. The TPM implementation is based on the 5S foundation and 8 pillars [4, 24]. The eight pillars of TPM namely autonomous maintenance, planned maintenance, focussed maintenance, quality maintenance, training and education, office maintenance, occupation health and safety maintenance, and early equipment maintenance [25]. TPM method in various manufacturing industries as an approach to machine consistency in productivity and machine efficiency improvement [7, 26].

The implementation of the triple bottom line concept in production scheduling can result in the continuous solution of the Distributed Permutation Flow Store Scheduling Problem (DPFSP) [27]. a mixed-integer mathematical programming model was proposed to minimize cycle time and environmental costs, while a metaheuristic approach based on fruit fly optimization (FOA) algorithm was developed to find a fuzzy unloading scheduling scheme [28]. Other research has applied the design of experiment (DOE) method and a mathematical modeling approach based on the fuzzy possibility regression integrated (FPRI) model [29].

2. 3. OEE OEE is a method of measuring the effectiveness of an equipment/machine consisting of availability, performance, and quality factors [23, 28]. OEE is generally measured from the three losses, namely the availability function, machine performance level, and production line. The operating conditions of production machines/equipment will not be displayed accurately if it is only based on the calculation of one factor, such as performance efficiency [17]. However, the other six factors in the six losses should be included in the OEE analysis. The actual condition of the machine/equipment can be seen accurately. Through the Japan Institute of Planned Maintenance (JIPM), the OEE value that has met international standards is 85% [29]. An increase in OEE value can also be applied to the DMAIC approach at the analysis stage before and after improvement [6].

2. 4. FMEA According to Stamatis [30] FMEA is an analytical method that is intended to analyze, determine, and identify failure factors and problems of a process, product, and service in a manufacturing or service industry. FMEA is an analysis that an organization can decide that any Risk Priority Number (RPN) above 200 creates an unacceptable risk [31, 32]. RPN calculation is based on three elements, namely severity (S), occurrence (O), and detection (D). The FMEA method can be included in the DMAIC approach,

namely at the Analyst stage, which was previously carried out by FGD in determining the RPN value [33, 34]. Improvements in service quality can also use the FMEA method in the service industry [35]. The use of the FMEA analysis method is one of the most practical techniques with high reliability in HSE risk assessment integrated with fuzzy system [32].

The gap between this study and other studies is the use of the kaizen concept consisting of Pareto diagrams, fishbone diagrams, and FMEA combined with the implementation of the TPM concept in taking corrective actions to increase the OEE value of LINAC SP machines in the health care industry. In contrast to other research related to industrial health services, it is more directed to TPS [20]. The contribution of this research can provide alternative inputs in increasing the value of OEE on machines in hospitals, especially those related to patient care. Other studies also use the PDCA approach so that it is more conceptual and focused which is combined with the TPM concept to increase the OEE value in the manufacturing industry [17]

3. METHODOLOGY

This research was conducted in the health care industry in the cancer service unit. The focus of this research is on the LSP machine of the ionizing radiation beam. This type of research is mixed methods. The design of this research is descriptive exploratory which aims to determine the causes of the emergence of losses/loss of machine operating time and how to make repairs. The types of data needed in this study are primary data and secondary data. Primary data was obtained from FGD with 5 experts consisting of 2 electromedical informants, 1 field Quality Control (QC) of medical physics, and 2 radiotherapists. Primary data is also obtained online from the electronic implementation of medical devices. While secondary data were obtained from literature, previous research, books, and company reports such as the number of defects, downtime, and total maintenance time.

This study uses systematic steps so that this research is focused and directed. This research step is divided into 4 stages, namely as follows:

Stage 1: Explain the phenomenon of problems that occur on LSP machines. Set research objectives to fix problems. Conduct a literature review on the TPM approach, FMEA, and OEE methods. The literature study is intended to deepen the theory used as a method of problem-solving.

Stage 2: Analyzing six big losses for OEE calculations by measuring the loading time used during the study, while the loading time formula is as follows:

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

The next step is to calculate the baseline OEE before the repair, using the following formula:

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

$$PE = \frac{(\text{Idle Run Time} \times \text{Total Production Part})}{\text{Operating Time}} \times 100\% \quad (3)$$

$$QR = \frac{(\text{Total Produced Parts} - \text{Total Defect Parts})}{\text{Total Produced Parts}} \times 100\% \quad (4)$$

$$OEE = AR \times PE \times QR \quad (5)$$

The next step is to make a Pareto diagram from the results of the Six Big Losses analysis with the help of Minitab 19 software. Based on the Pareto diagram then create a Fishbone diagram to determine the causes of the main problems through FGD.

Stage 3: FMEA analysis is carried out through FGD with 5 experts. The purpose of FMEA is to determine the priority failure mode based on the Risk Priority Number (RPN), which is calculated based on the risk factors for occurrence (O), severity (S), and detection (D). Give each score with an integer from 1 to 10 through the assessment of the expert. Next, the RPN calculation is carried out with the formula (6):

$$RPN = S \times O \times D \quad (6)$$

After the priority ranking is known, then make improvements by applying the TPM pillar.

Stage 4: Performing OEE calculations after improvement in Jul–Oct 2021 in the same way in the second stage and finally the conclusions of this research are obtained.

The new approach of this research is that the type of machine used in analyzing the OEE value is the LINAC SP machine, while the method used when determining the RPN value with FMEA analysis uses FGD with experts in their field [17]. But the kaizen method will also be systematic in the Pareto diagram, FMEA, and OEE

methods because it includes quantitative research and uses FGD and Fishbone diagrams which are qualitative research. The framework can be seen in Figure 1.

4. RESULT AND DISCUSSION

In this section, we will discuss data collection starting from measurement loading time data as the basis for calculating six big losses. Calculation of OEE value data starting from AR, PE, and QR. Then to determine the biggest six big losses, using the Pareto diagram. After the dominant problem is known, the Fishbone diagram is used to find the main cause of a problem with FGD meeting was held to determine the priority values of the RPN using the FMEA method. Finally, the TPM method is used to determine corrective actions and prevent problems from recurring.

4. 1. Six Big Losses Analysis In this study, the six big losses on the LINAC SP machine are explained according to the operating time loss conditions. Breakdown loss on a LINAC SP machine is a time and quantity failure/loss caused by a faulty machine that cannot be operated. While the setup is the loss of setting and adjustment time when the LINAC SP machine warms up before use. Idling and minor loss is a loss when the machine is operating due to a shortstop or the process is temporarily interrupted. Reduce speed loss is the loss of time in the patient's therapy process due to additional time due to late admission. Reject loss is the loss of time due to the patient's treatment results being failed/rejected or canceled. Rework loss is the machine working again due to electrical problems or data is not stored. This first section will discuss the results of the calculation of loading time carried out during this research. Calculation of loading using formula (1). The results are summarized in Table 1.

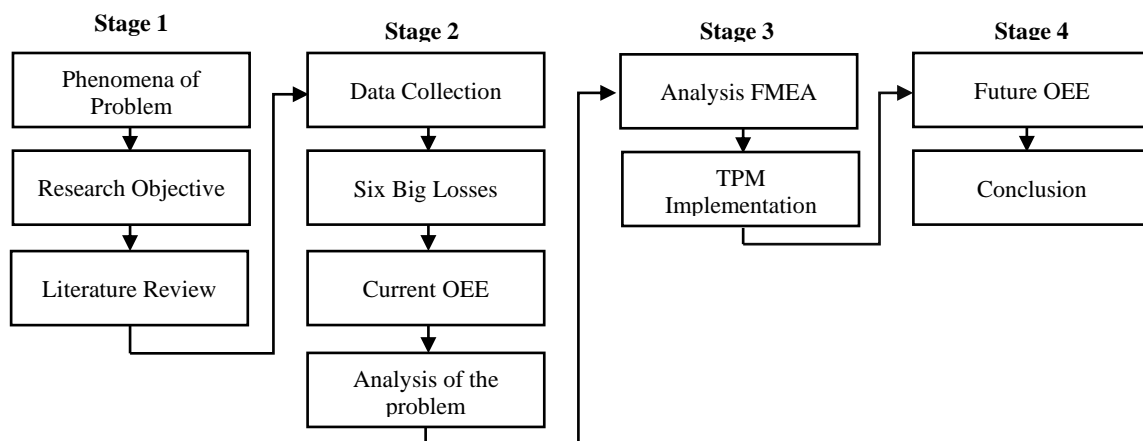


Figure 1. Research framework

TABLE 1. Measurement of data loading time before improvement

Month	Number of working days	Working hours/ days	Minute/ hour	Loading Time (minute)
Jan 21	20	8	60	9,600
Feb 21	19	8	60	9,120
Mar 21	22	8	60	10,560
Apr 21	20	8	60	9,600
Total	81	8	60	39,360

TABLE 2. Calculation of six big losses before 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
Jan 21	1,765	230	1,995	200	125	325	0	0	0
Feb 21	1,965	215	2,180	210	125	335	0	0	0
Mar 21	1,875	245	2,120	240	140	380	0	0	0
Apr 21	1,670	225	1,895	190	115	305	0	0	0
Total	7,275	915	8,190	840	505	1,345	0	0	0

Table 1 shows that the number of working days for LINAC SP machines are 81 days with 8 machine operating hours and 60 machine operating minutes/hour. The total loading time before the repair was 39,360 minutes. Next, analyze the six big losses generated from the checksheet done by the LINAC SP machine operator. The results of the report can be seen in Table 2.

Table 2 shows that the downtime loss includes breakdown and setup loss with a total of 8,190 minutes. Speed losses include idling & minor loss with a total of 1,345 minutes. Meanwhile, reject loss and rework loss do not lose time. Based on the data of six big losses, then data processing is carried out using the Pareto diagram. Based on the Pareto diagram in Figure 2, it can be seen that the highest loss/time loss occurred in the breakdown loss, which was 76.3%. So this breakdown loss will be evaluated for improvement.

Table 2 shows the results that the quality rate is 0, which means that there is no reject loss in the form of printouts from the LINAC SP machine and there is no rework in the process of working on cancer therapy at the hospital. This is because the output on the LINAC SP machine is a patient, not a product. While Figure 2 shows that the dominant problem is breakdown time which is very high at 76.3%.

4. 2. OEE Calculation In this section, the baseline OEE value is calculated using secondary data, namely health service annual report data. The data used is data from Jan-Apr 2021. The calculation of the OEE value before the improvement (January sample) using the formulas (2), (3), (4) and (5) is as follows:

$$AR = \frac{(9,600-1,995)}{9,600} \times 100\% = 79.22\%$$

$$PE = \frac{(15 \times 465)}{7605} \times 100\% = 91.78\%$$

$$QR = \frac{(640-0)}{640} \times 100\% = 100\%$$

$$OEE (\%) = 79.22\% \times 91.78\% \times 100\% = 72.71\%$$

Based on the calculation with formulas (2), (3), (4) and (5) the OEE value is 72.71%. The value of this calculation is carried out on the January sample. The recapitulation of OEE values from Jan-Apr 2021 (before improvement) can be seen in Table 3.

4. 3. Problem Cause Analysis In this section, the results of the Fishbone diagram obtained from brainstorming will be explained including machine operators, inspectors, and other medical personnel. The results of the Fishbone diagram can be seen in Figure 3.

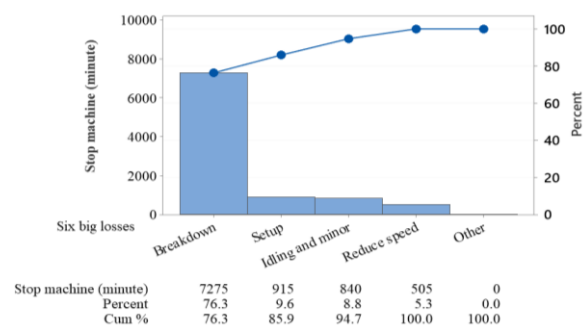


Figure 2. Pareto diagram of six big losses

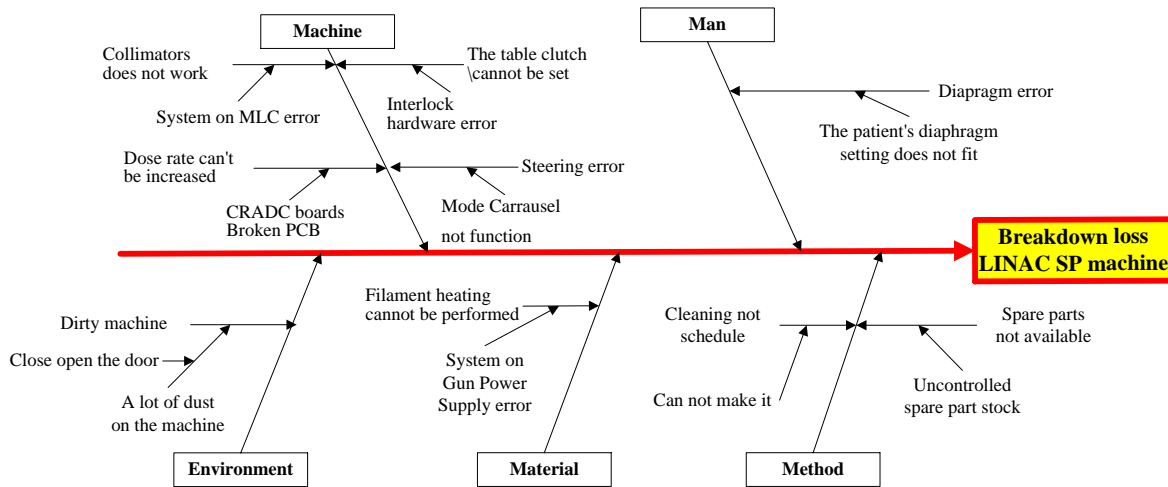


Figure 3. Fishbone diagram of breakdown losses

TABLE 4. FMEA analysis of breakdown losses

Potential Failure Mode	Sev	Potential Failure Effects	Occ	Potential Cause of Failure	Det	RPN	Rank
Multi-Leaf Collimators (MLC) not working	9	Machine off	8	System on MLC error	7	504	1
The table can't go up and down	8	The table cannot be set	9	Interlock hardware	7	504	2
Filament heating cannot be performed	8	Gun Filament not working	7	System on gun power supply error	9	504	3
Spare part not available	7	Permanent machine off	8	Uncontrolled spare part stock	9	504	4
Steering error	7	Carrousel mode not working	8	Carrousel locking pin doesn't fit the hole	6	343	5
Dirty machine	5	Machine restarted frequently	8	There is dust on the table, 5S is lacking	6	240	6
Control System	5	Dose rate can't be increased	6	Board CRADC PCB is broken	6	180	7
Diaphragm error	5	Machine often hangs	8	The patient's diaphragm setting is not up to standard	4	160	8
Unscheduled cleaning	4	Dirty machine	8	Bad scheduling	5	160	9

4. 4. Analysis of FMEA This FMEA analysis is carried out to determine the priority ranking of problems that will be repaired. FMEA analysis is based on the calculation of the RPN where the scorer is carried out by 5 experts. The FGD was conducted to determine the priority ranking and how to determine corrective action by applying the TPM pillar so that the expected improvements were obtained, namely increasing and maintaining the OEE value in controlling LINAC SP machines in health services. The results of the FMEA analysis can be seen in Table 4.

4. 5. Implementation of Pilar TPM After obtaining the priority value for the potential failure, further improvements, and implementation will be

carried out by applying the TPM pillar. Maintenance activities in the industry directly impact output, production quality, production costs, safety, and environmental performance [36]. Several improvement implementations must be critical points to implement TPM in the health care industry, especially in increasing the OEE value on LINAC SP machines. The improvements made by referring to the principles of the TPM pillar are as follows:

4. 5. 1. Autonomous Maintenance (AM) The concept of implementing autonomous maintenance must involve all personnel from the operator level to top management. AM activities by providing knowledge to operators regarding the understanding of LINAC SP

machines from technicians and experts. Operators will get material on basic understanding of machines, machine operations, machine safety systems, basic machine maintenance, to more advanced stages of machines. There are critical points in carrying out autonomous maintenance aimed at operators, including:

- Able to run the machine correctly
- Clean the machine regularly
- Knowing the inspection points to check on the machine
- Able to perform lubrication on machine parts
- Checking parts that are prone to abnormality and able to take early preventive action
- Perform machine startup and machine shutdown correctly.

4. 5. 2. Planned Maintenance (PM) Planned maintenance aims to control the damage of each machine component to avoid more severe damage. Based on the problem in the breakdown, it is necessary to schedule an earlier to prevent abnormality from occurring. The following schedule of preventive activities resulting from the FGD can be seen in Table 5.

TABLE 5. LINAC SP machine preventive schedule

Activity	Before Improvement	After Improvement
System control on MLC	6 month	1 month
Periodic control of gun power supply system	3 month	2 month
Hardware interlock check	3 month	2 month
Procurement of spare parts	6 month	2 month

TABLE 6. Measurement of data loading time after improvement

Month	Number of working day	Working hours/ days	Minute/ hour	Loading Time (minute)
May 21	18	8	60	8,640
Jun 21	21	8	60	10,080
Jul 21	21	8	60	10,080
Aug 21	20	8	60	9,600
Total	81	8	60	38,880

TABLE 7. Calculation of 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
May 21	980	205	1,185	185	95	280	0	0	0
Jun 21	975	210	1,185	210	120	330	0	0	0
Jul 21	925	215	1,140	210	125	335	0	0	0
Aug 21	920	220	1,140	195	105	300	0	0	0
Total	3,800	850	4,650	800	445	1,245	0	0	0

4. 5. 3. Kaizen/Focused Maintenance (FM)

This pillar section implements changes to the existing Standard Operation Procedure (SOP). The problem with the carousel mode during setup is that there is no standardization in the SOP so maintenance is not optimal.

Changes to the SOP were made by adding several standardizations, including setting the carousel mode during setup and making One Point Lessons.

4. 6. OEE Calculation After Improvement

In this section, the calculation of the OEE value after improvement is carried out. However, before going to this section, the results of the loading time inspection carried out in this study will be explained in Table 6. After the loading time results are obtained, then a loss/time loss analysis is carried out through the six big losses which have been filled in by the LINAC SP machine operator. The calculation of six big losses can be seen in Table 7. Based on the loading time data in Table 5 and the six big losses data in Table 7, the OEE value can then be calculated after the improvement. The calculation of OEE value after improvement (May 2021 sample) is as follows:

$$AR = \frac{(8,640-1,185)}{8,640} \times 100\% = 86.28\%$$

$$PE = \frac{(15 \times 471)}{7,445} \times 100\% = 94.90\%$$

$$QR = \frac{(471-0)}{471} \times 100\% = 100\%$$

$$OEE (\%) = 76.28\% \times 94.90\% \times 100\% = 81.88\%$$

Based on the calculation with formulas (2), (3), (4) and (5) the OEE value is 81.88%. The value of this calculation is carried out on the May sample. The recapitulation of OEE values from May to August (after improvement) can be seen in Table 3.

TABLE 3. Recapitulation data before and after improvement

	Month	Availability	Performance	Quality	OEE
Before	January 2021	79.21%	91.78%	100%	72.70%
	February 2021	76.09%	92.16%	100%	70.13%
	March 2021	79.92%	92.80%	100%	74.16%
	April 2021	80.26%	92.98%	100%	74.62%
	Average	78.94%	92.98%	100%	73.39%
After	May 2021	86.28%	94.90%	100%	81.88%
	June 2021	88.24%	96.86%	100%	85.47%
	July 2021	88.69%	97.00%	100%	86.02%
	August 2021	88.12%	97.85%	100%	86.23%
	Average	87.89%	97.85%	100%	86.00%

Table 3 shows that the OEE value before improvement is 73.39% and after improvement is 86.00%. This increased the OEE value of 14.6% and it can be discussed that this success rate has met the target of the Indonesian Ministry of Health of 86% of the 85% target.

4. 7. Discussion with Previous Research Based on the improvements made in the previous section, maintenance management must pay attention to the availability of equipment spare parts to minimize the risk of increased downtime due to the replacement of spare parts. Investments are needed for repairing medical equipment and machinery infrastructure to properly support the TPM program and increase productivity, however, the hospital's managerial insight must fully support and approve the improvement program that results in this comprehensive increase in OEE value. This is in line with the research of Sutoni et al. [37]. Investment in training and socialization is also needed so that AM becomes a work culture for all medical personnel. Scheduling of component replacement activities in the PM program requires the availability of the required components. The implementation of PM using the time-based maintenance method will facilitate the planning for the supply of the required components. This is in line with the research performed by Bekar et al. [38].

The purchase of components needs to be planned properly so that when the schedule for the replacement implementation arrives, the required components are already available. This is in line with the research of Patil et al. [39]. Management can maximize maintenance scheduling by combining the TPM method with advanced optimization algorithms such as heuristics or metaheuristics. This is in line with the research of Dulebenets [40, 41]. The implementation of two-hybrid

meta-heuristic algorithms can overcome the design problem of a two-channel closed-loop supply chain network in the tire industry [42].

The distribution of this research related to the implementation of TPM on the LINAC SP machine in the hospital service industry can provide a reference with the 3 pillars of TPM namely AM, PM, and FM which is carried out consistently by hospital service workers and fully supported by the management, it will create an increase OEE value so that cancer therapy services can run well.

4. 8. Research Gap Analysis This study used the direct improvement Kaizen method according to existing needs, while other studies use the PDCA approach so that it is more conceptual and focused [17]. But the Kaizen method also has a synergetic relation with Pareto diagram, FMEA, and OEE methods for quantitative method and with FGD and Fishbone diagrams for qualitative method.

The Synergy Platform machine through various thicknesses of graphite and lead is measured using an ion chamber so that there is an ion space response as a function of photon energy obtained by using the MC method in the Geant4 simulation code [20]. Simulate the radiotherapy process using LINAC machine to perform dosimetric analysis and this simulation uses the Monte Carlo (MC) method which has been proven to provide realistic results in terms of accuracy [19]. However, present the strategy to simulate a clinical linear accelerator based on the geometry provided by the manufacturer and summarize the corresponding experimental validation. Simulations were performed with the Geant4 MC code under a grid computing environment [43].

The other research gap is the implementation of the MC method in the treatment of cancer therapy patients in

the LINAC SP machine [20, 19, 43]. The difference with this study is more directed at improving the service of cancer therapy patients by increasing the OEE value of the LINAC SP machine. In this study, it has been successful in the implementation of the TPM Pillar that is continuous and consistent has increased the OEE value of the LINAC SP machine in the hospital service industry.

5. CONCLUSION

Based on the analysis in the previous section, several conclusions were obtained. The conclusions obtained in this study include finding that there are factors that affect the low OEE value on the LSP machine, namely the breakdown loss factor of 76.29% setup loss of 9.59%, idling and minor stops of 8.80%, and reduced speed of 5.29%. Based on the FGD with the experts, the improvement in this research is to apply the pillars of sustainable TPM. Controlling the system on the MLC periodically once a month, setting the carousel mode at the time of setup must be according to standards, controlling the gun power supply system periodically every 2 months, providing scheduled spare parts where spare parts that are difficult to procure must be stocked at least 5 pcs, checking interlocks hardware every 2 months so that the table setting can go up and down smoothly, cleaning the Printed Circuit Board (PCB) board is done every 2 months during machine maintenance. Setting the patient's diaphragm by making a One Point Lesson (OPL).

The limitation of this research is that it only uses 1 machine and the limited permission to analyze this machine is very limited because it is under strict supervision by the hospital. The continuous and consistent implementation of the TPM Pillar has increased the OEE value of LINAC SP machines in the hospital service industry. These results give satisfaction to the health management because it has been able to provide effective patient care and cost savings inefficient machine repairs. For further research, suggestions and recommendations that can be given are to apply TPM which refers to technology 4.0 on the same type of machine or other types of machines in the health industry. The installation of sensors on the machine is expected to can predict early damage such as abnormal temperatures and vibrations with the help of signals/sirens.

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Persian Abstract

چکیده

بیمارستان دولتی جاکارتا خدمات سرطان را با چندین نوع تجهیزات موجود ارائه می دهد که یکی از آنها دستگاه پلنفرم هم افزایی (SP) شتاب دهنده خطی (LINAC) است . پدیده ای که این دستگاه ارزش اثربخشی پایینی را تجربه می کند زیرا قادر به رسیدگی به صف بیماران نیست بنابراین قادر به کاهش شدت سرطان نیست .هدف از این مطالعه تعیین عوامل ایجاد کننده ارزش پایین اثربخشی کلی تجهیزات (OEE) و ارائه پیشنهادهایی برای بهبود برای افزایش مقدار OEE بود . رویکرد جدید این تحقیق استفاده از رویکرد نگهداری کل تولیدی (TPM) با تحلیل OEE به عنوان پارامتر موفقیت است زیرا TPM در صنعت تولید یکسان تر است .به روز رسانی دیگر استفاده از حالت شکست و تجزیه و تحلیل اثر (FMEA) از طریق گفتگوهای گروهی متمرکز (FGD) با کارشناسان است .نتایج این مطالعه نشان داد که عواملی که بر مقدار OEE پایین در ماشین LINAC SP تأثیر می گذارند، ناشی از افت خرابی 76.29 درصد، افت راه اندازی 9.59 درصد، در حالت آرام و توقف جزئی 8.80 درصد و کاهش سرعت 5.29 است .٪. کاربرد مداوم و مداوم ستون TPM باعث افزایش ارزش OEE دستگاه LINAC SP شده است.
