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Analysis of Medical Equipment Utilization and Management in Hospital

Sally Marion K[1], Lekshmi R. Kumar[2], Dr. Priestly Shan Boaz[3], Dr. Rekhar Nair[4]

[1,2]*Asian School of Business, Trivandrum – 695316, Kerala, India*

[3,4]*Alliance University, Bengaluru – 562 106, Karnataka, India*

***Abstract*:**

Purpose: Assessing X-ray and Endoscopy machine efficiency at Jubilee Memorial Hospital, proposing a tailored monitoring system, aligning with charitable mission and optimizing investments.

Theoretical framework: Utilizing Total Productive Maintenance concepts, the study assesses X-ray and Endoscopy machine efficiency, aligning with Industry 4.0 trends and hospital mission.

Design/methodology/approach: The study employed secondary data analysis from operators and biomedical records, evaluating X-ray and Endoscopy machine efficiency from April 20 to May 19, 2022.

Findings: Identified areas for enhancement in X-ray and Endoscopy machine efficiency, emphasizing the need for effective investment decisions in a hospital setting.

Research, Practical & Social implications: Research: Enhances Total Productive Maintenance understanding. Practical: Guides hospital investment. Social: Improves patient care aligning with charitable mission

Originality/value: Originality lies in integrating TPM concepts for medical equipment efficiency, offering valuable insights for hospital management and patient care.

Keywords: *Overall Equipment Efficiency (OEE), Total Eff , Business Management , Industry , Innovation and Infrastructure*

1. Introduction

The healthcare industry provides a wide range of services to address the health- care needs of a community or an individualJaworski et al. (2023). The healthcare industry's products are divided into several categoriesShakeel et al. (2023). Hos- pitals and healthcare systems are continually changing their service offerings and responding to several internal and external factors, such as reimbursement is- sues, technological improvements, and changing demographicsDixit et al. (2022) Rudd et al. (2023). The healthcare market functions through the following seg- ments. The inception of Overall Equipment Efficiency (OEE) as a fundamental concept in Total Productive Maintenance (TPM) in 1982 marked a pivotal mo- ment for industrial efficiency assessment AHMED et al. (2023) Rao (2023). The Japan Institute of Plant Maintenance introduced OEE, and its significance was elucidated in the 1989 book "TPM Development Program: Implementing To- tal Productive Maintenance," edited by Seiichi NakajimaPekih and Sutawijaya (2023). This study focuses on applying OEE, a cornerstone in Industry 4.0, to assess the efficiency of critical medical equipment—specifically, the X-ray and Endoscopy machines—at Jubilee Memorial Hospital in Thiruvananthapuram. As a charitable institution committed to delivering quality healthcare at a minimal feasible fee, the hospital's investment decisions bear substantial weight in fulfill- ing both managerial obligations and the vision of the organizationOrganization et al. (2023). The work aims to analyze the efficiency parameters of the selected equipment and proposes an integrated system for their continuous monitoring. Utilizing secondary data obtained from registers maintained by operators and the biomedical department, the study spans from April 20, 2022, to May 19, 2022. Preliminary findings reveal that the OEE of the X-ray machine aligns with world-class standards, while the Endoscopy machine falls short. The ensu- ing sections explore the reasons behind this variance and offer recommendations for improvement.

The study for determining OEE, utilization, and TEEP is limited by the secondary data that is already available in the registers maintained by the operators and the biomedical department. It also explores ways to implement OEE monitoring in a hospital environment.

The research objectives of the study include the following:

– To determine the OEE of X-ray and endoscopy machines

– To determine the utilization of X-ray and endoscopy machines

– To determine the TEEP of X-ray and endoscopy machines

– To suggest an integrated system to monitor OEE in the hospital

The remaining part of the paper is arranged as follows. Methodology in Section 2, Data Analysis and Interpretation in Section 3 and Conclusion and future scope of the work in Section 4.

2. Methodology

The framework of the proposed work is illustrated in Figure 1.

Overall Equipment Effectiveness

The concept of Overall Equipment Effectiveness (OEE) was introduced to monitor efficiencyDobra and Jósvai (2023). Before OEE, people monitored equipment performance through Availability or Downtime. This was fine until it was realized that it is possible to have the same downtime for the same piece of equipment over different timeframes yet get a different output.

$$OEE = Availability * Performance * Quality \quad (1)$$

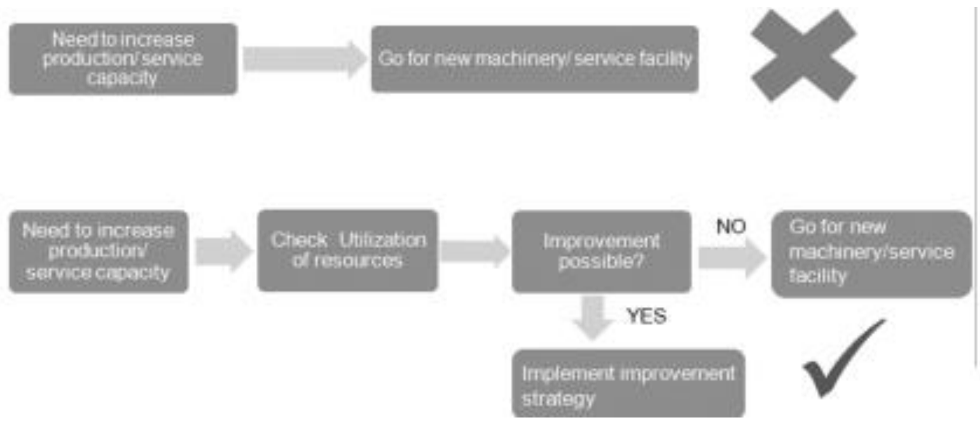


Fig. 1. Framework of the work

Availability is the percentage of the actual amount of Production time the machine is running to the production time the machine is available.

$$Availability = Operatingtime/LoadingTime \quad (2)$$

Performance is the percentage of total parts produced on the machine to the production rate of the machine.

$$Performance = Totaloutput/potentialoutput \quad (3)$$

Quality is the percentage of good parts out of the total parts produced on the machine.

$$Quality = Goodoutput/totaloutput \quad (4)$$

Traditional thinking has often identified best practice OEE in a discrete manufacturing plant as 85% based on the notion of 90% Availability × 95% Rate × 99% Quality. The 90% Availability recognizes that there will be losses from Setup or Changeover downtime and, as a consequence of this, also have some speed loss associated with starting up again. In continuous process industries that don't have setup or changeover downtime, the best practice OEE is often stated as 95% based on 98% Availability × 98% Rate × 99% Quality.

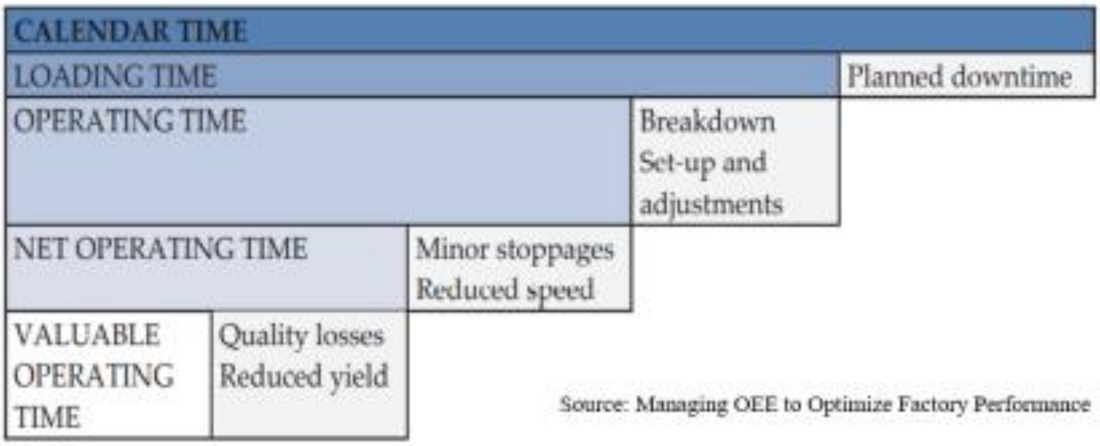


Fig. 2. Breakdown of the calendar time

Loss Analysis

Losses are actions that consume resources but do not produce valueSowmya and Chetan (2016). Losses are classified according to the frequency with which they occur, the cause of the loss, and the many forms of loss as shown in Figure 2. The Six Big Losses paradigm was created by Nakajima is shown in Table 1. To increase the equipment's performance, external losses must be eliminated, while losses generated by machine malfunctions and processes that may be changed daily can be classified as shown in Figure 2.

Downtime Losses: when the machine should run, but it stands still. Time losses happen when a malfunction arises, an unplanned maintenance task must be done in addition to the big revisions, or a set-up/start-up time occurs.

Speed losses: when equipment is not running at its maximum designed speed. It could be due to a malfunction, minor technical flaws, such as stuck packaging, or the start-up of equipment for a maintenance operation, a setup, or an organizational stoppage.

Quality losses: when the equipment is producing products that do not fully meet the specified quality requirements.

Table 5.1: Six Big Losses model proposed by Nakajima.

Category	Big Losses
Downtime	- Breakdown - Set-up and adjustments
Speed	- Idling, minor stoppages - Reduced speed
Quality	- Quality losses - Reduced yield

Table 5.2: World class standard for OEE factors

Factors	World class Standard
Availability	> 90%
Performance	>95%
Quality	> 99%
OEE	>85%

Utilization

Equipment utilization is the amount of time a piece of equipment, machinery, or asset is used. Based on the calculated utilization rate, businesses can better understand how to best use their equipment and make more informed decisions on project timelines, inventory, or equipment rentals.

$$\text{Utilization} = \frac{N}{M} \text{ X } 100$$

- N, Average number of hours the equipment is used
- M, Maximum number of hours the equipment can be used

TEEP Total Effective Equipment Performance

TEEP (Total Effective Equipment Performance) is a performance statistic that can reveal manufacturing operation's true capacity. This considers both equipment losses (as determined by OEE) and schedules losses (as measured by Utilization). OEE is useful in demonstrating how productive a manufacturing operation is while it's running during scheduled working hours TEEP takes things a step further and highlights the impact of scheduled downtime-primarily the hours the factory is closed it demonstrates the untapped potential in a manufacturing plant, or the hidden factory showing how much more capacity a manufacturer has available to increase production without spending a single dollar on new equipment or property.

$$TEEP = Availability \times Performance \times Quality \times Utilization$$

$$= OEE \times Utilization$$

Integrated system to monitor OEE

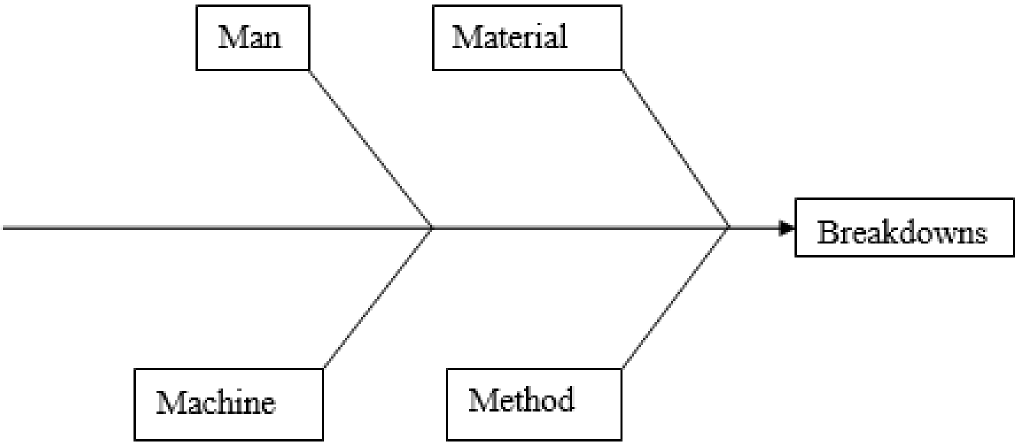
To establish a well-organized OEE system to monitor and precisely evaluate the OEE, an integrated system should be put in place. OEE provides simple and unified formulas for determining the equipment or production system's efficacy.OEE can also be used to compare performance across the plant, emphasizing poor line performance or quantifying improvements achieved, since it is directly tied to losses. The benefits of implementing OEE in the healthcare sector are as follows:

- Directly tie efficiency to fiscal reporting.
- Reduce investigation time for root cause analysis when equipment breakdown.
- Keeping track of ROI.
- Decrease cost through effective monitoring of preventive and predictive maintenance.

- Increase in customer satisfaction through quality improvement.

Fish Bone Diagram

A fishbone diagram is a cause-and-effect diagram that assists managers in determining the causes of flaws, variations, defects, and failures. The diagram resembles the skeleton of a fish, with the problem at the top and the causes feeding down the spine. Managers can begin looking for remedies to ensure that the problem does not return once all of the underlying reasons have been discovered.



Data Requirements and Data Source

For calculation of OEE, Utilization, and TEEP, the following data points are required.

Table 5.3: Data requirements and data sources

Data Points	Source
Calendar Time	The time frame of the study
Planned downtime	The worktime schedule
Breakdown/Setup time	Biomedical department registers
Process Amount	Registers maintained at the service facility
Ideal Cycle Time	Registers maintained at the service facility
Defective Output	Registers maintained at the service facility

Data Analysis and Interpretation

X-ray machine Data Collection

The span of study was from 20 April 2022 to 19 May 2022. The data required for the calculation of OEE was obtained as secondary data from the registers maintained by the X-ray room operators and those maintained by the biomedical engineering department. Based on the results shown in Table 4, the average OEE value for the Xray machine from 20 April 2022 to 19 May 2022 is 88.82%. This value is very much in line with the value of the ideal standard of OEE, which is 85%. In the OEE category, the OEE value below 65% is not acceptable, because it causes significant economic losses and very low competitiveness for the organization. The utilization of the machine is found to be 79.166% and TEEP was found to be 70.316%. Even though the X-ray facility is said to be running 24 hrs in three shifts, from primary interaction with the staff it was found that usually, they switch off the machine for 5h from 12:00 a.m. to 5:00 a.m.

Table 4: Performance of X-ray machine

Availability	Performance	Quality	OEE	Utilization	TEEP
97.31%	91.7%	99.54%	88.8227%	79.166%	70.316%

Table 5: Data points for X-ray machine

Data Points	Values
Calendar Time	720 h
Planned Downtime	150 h
Loading Time	570 h
Breakdown/setup Time	15.33 h
Operating Time	554.67 h
Process amount	1526 nos.
Ideal cycle time	0.333 h
Defective Outputs	7 nos.

Table 6: Data points for Endoscopy machine

Data Points	Values
Calendar Time	624 h
Planned Downtime	416 h
Loading Time	208 h
Breakdown/setup Time	4 h
Operating Time	204 h
Process amount	781nos.
Ideal cycle time	0.166 h
Defective Outputs	0 nos.

Endoscopy Machine Data Collection

The span of study was from 20 April 2022 to 19 May 2022. The data required for the calculation of OEE was obtained as secondary data from the registers maintained by the endoscopy operators and those maintained by the biomedical engineering department as shown in Table 6.

Table 7: Performance of Endoscopy machine

Availability	Performance	Quality	OEE	Utilization	TEEP
98.01%	64.1215%	100%	62.889%	33.334%	20.86%

Based on the results of calculations that have been made, the average OEE value for the endoscopy machine from 20 April 2022 to 19 May 2022 is 62.88%. This value is still far from the value of the ideal standard of OEE, which is 85%. The utilization of the machine is found to be 33.33% and the TEEP was found to be 20.86%. In the OEE category, the OEE value below 65% is not acceptable, because it causes significant economic losses and very low competitiveness for the organization. The value that greatly affects the low OEE is the value of the efficiency of the performance ratio because the value does not meet the standards of the Japan Institute of Plant Maintenance (JIPM). Judging from the performance efficiency, the OEE value does not meet the standard because the usage target is not achieved. The low use of the Endoscopy machine is due to less number of patients being treated. The low number of patient visits is caused because of the fact that only diagnostic service is provided and no procedural endoscopy is provided in the system. . This makes the patients rely on another hospital facility that provides both diagnostic and procedural endoscopy. The common reasons for losses in the medical equipments are depicted in the fishbone diagram Figure 4. These include non-availability of inventory, and delay in procurement of spare parts required. The non-availability of space to keep the materials is the core cause of this issue. Less number of staff in the biomedical department causes workload and delays in attending to breakdown problems. For major breakdowns, it generally takes weeks for the servicemen from the OEM to reach the facility. This delay urges the engineers to bypass various interlocks for the machines. The endoscopy machine is prone to clogging issues frequently. Proper cleaning of the scope after each examination should be done judiciously. No proper digital data is maintained in the equipment consoles only physical registers in writing are available. Operational inertia of writing unique cycle times for every patient attended to be changed.

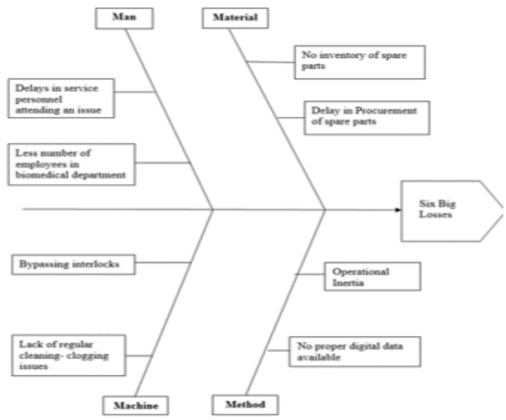


Fig. 4: Fishbone Diagram for losses

Findings of the study

1. The OEE of the X-ray machine is 88.882
2. Performance rate measurement is a challenge in the hospital environment. The time required to manage each patient differs significantly and enhancing the same is against the morale of a hospital setup.
3. Availability of equipment could be improved in the background of providing service which is available to patients when required. Availability can be further improved by reducing unscheduled breakdowns through effective preventive and predictive maintenance. Preventive maintenance is being monitored by the biomedical engineering department through various AMCs (Annual Maintenance Contract).
4. The OEE of the endoscopy machine is found to be 62.88
5. The OEE of endoscopy is very much affected by the low-performance rate. The reason for the same is identified that only diagnostic endoscopy service is provided by the facility and no procedural service is provided by the facility.
6. The cycle time for each patient will not be the same. But in the registers, it is found to be the same. This operational inertia or procedural inertia has affected the calculations.

Suggestions of the study

1. OEE could be implemented as an integrated specialized module in HIS (Hospital Information System), EIS – Equipment Information System with stake holders being the technicians, radiologists, and biomedical department.
2. Measurement of OEE could be executed in two ways. One, with static data which could be obtained at end of a certain period, and the other by using the dynamic data, which calculated OEE parameters in real-time. For a hospital environment, the static data method could be preferred.
3. OEE could be implemented by following three steps, which are: acquisition, analysis, and visualization.

3. Conclusion And Future Scope Of The Work

The assessment of Overall Equipment Efficiency (OEE) within the medical equipment landscape, specifically the X-ray and Endoscopy machines at Jubilee Memorial Hospital, has yielded valuable insights. The project, conducted between April and May 2022, revealed that the X-ray machine operates at worldclass standards, while the Endoscopy machine falls below these benchmarks. This discrepancy underscores the need for targeted improvements and highlights the importance of continuous monitoring in a hospital setting. The study emphasizes the significance of effective investment decisions, particularly in a charitable healthcare institution, where balancing financial prudence with quality patient care is paramount. As the healthcare industry evolves, integrating OEE as a key performance indicator becomes increasingly crucial, aligning with the broader paradigm of Industry 4.0. The proposed recommendations aim to enhance the efficiency of the Endoscopy machine, contributing to the overall goal of providing quality healthcare in a cost-effective manner.

Future studies on OEE could define OEE specifically for each industry and also link the OEE with financials and as a factor to determine investment decisions.

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