

## **A study and development of Total Productive Maintenance (TPM) techniques for X-ray machine in Healthcare Sectors**

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### **KEYWORDS**

Total Productive Maintenance (TPM), Healthcare equipment maintenance, Overall Equipment Effectiveness (OEE), Medical equipment reliability, TPM implementation in healthcare, Maintenance strategies and techniques.

### **ABSTRACT**

This research examines the application of Total Productive Maintenance (TPM) techniques to enhance the efficiency and reliability of medical equipment in hospitals across South Karnataka, India. Recognizing the critical role of medical devices in healthcare delivery, the study addresses challenges such as frequent breakdowns, improper handling, and inadequate maintenance, which contribute to significant operational disruptions. By implementing TPM, a strategic maintenance methodology emphasizing collaboration, proactive care, and efficiency, the study achieved notable improvements: an 8% increase in Overall Equipment Effectiveness (OEE), a 6% rise in equipment availability, a 5% improvement in quality rates, and reductions in cycle time and defect rates. These outcomes highlight TPM's potential to optimize equipment performance, reduce downtime, and improve healthcare service delivery, offering a sustainable framework for addressing maintenance challenges in the healthcare sector.

### **INTRODUCTION**

This research investigates the implementation of Total Productive Maintenance (TPM) techniques in healthcare facilities across South Karnataka, India, focusing on improving the efficiency and reliability of medical equipment. The study highlights the critical role of medical devices in healthcare delivery, emphasizing that poor maintenance practices, inadequate training, and preventable failures contribute significantly to equipment downtime. While India's healthcare industry is rapidly growing, challenges in maintaining and repairing medical devices persist, impacting service quality and efficiency.

TPM, a proactive maintenance methodology originating in Japan, integrates preventive maintenance with collaborative involvement from all organizational levels. The approach aims to optimize equipment performance, enhance availability, reliability, and quality, and minimize disruptions. By addressing common failure causes such as improper handling and wear, TPM fosters shared responsibility among management and technical staff, leading to improved overall performance. The study underscores TPM's effectiveness in achieving goals like "zero error, zero work-related accident, and zero loss," with its outcomes measured using Overall Equipment Effectiveness (OEE).

### **OBJECTIVES**

- To increase the overall equipment efficiency of equipments in the healthcare centers.
- To Achieve Zero Defects, Zero Accidents and Zero Breakdown across all operational fields of the organization.
- To help hospital lengthen asset life, improve labor productivity, monitor maintenance costs, reduce costly downtimes, prevent and predict mechanical failures, reduce the total maintenance costs and minimize investments in inventory.

- To respond quickly to the service requests and to effectively schedule total productive maintenance schedules and to develop interpersonal relation among the departments in the hospitals.

### **DATA COLLECTION –METHODS AND ANALYSIS**

To meet the objectives of research, the data can be collected by adopting the effective research strategy regarding the experience of hospital equipments operators and involvement towards the maintenance of equipments and work performance.

Data was obtained from logbooks; questionnaires had been administered and interviews were undertaken. It is sought to determine the following:

- Patterns of hospital procurement surveyed
- Post-installation testing implementation
- Application of quality control assessments and preventive maintenance measures.

In addition, the following have been ascertained:

- Period of equipment downtime
- Availability of existing equipment breakdown inventories
- Adequacy of measures taken to repair such equipment

Medical accidents occurring during and after equipment downtime.

### **TOTAL PRODUCTIVE MAINTENANCE OVERVIEW & INDIAN HOSPITALS SCENARIO**

In today's competitive global market, cost-effective manufacturing requires a focus on quality, productivity, and maintenance processes. Total Productive Maintenance (TPM), originating in Japan, is a proactive approach aimed at maximizing equipment efficiency, minimizing downtime, and reducing defects. TPM emphasizes shared responsibility among employees for routine maintenance tasks, enhancing production and fostering job satisfaction. It integrates Lean Manufacturing and Six Sigma principles, using Overall Equipment Effectiveness (OEE) as a measure of success. TPM's comprehensive approach ensures optimal equipment use, extending machinery life and improving organizational performance.

#### **Importance of TPM**

TPM has been developed to attain the following aims. The important points have been mentioned below.

- a) To achieve zero breakdown and accident
- b) High profit by reducing ideal cycle time.
- c) Cost saving by reducing wastage of films in radiology departments.
- d) Systematic maintenance and utilization of equipment and manpower.
- e) Producing reliable examinations.
- f) Patients Satisfaction.
- g) Involve equipment operators in the basic everyday essentials of hardware tidiness and checks to upgrade employee possession in keeping up and recognizing equipment issues quickly.

#### **TPM Implementation Methodology**

The 12-step program is designed to implement TPM, establish TPM assistance from management, union members and staff, achieve TPM recognition, generate excitement and optimistic expectations for TPM, develop a practical custom installation schedule and produce timely outcomes to the world class.

1. **Announce TPM Decision:** Gain top management support and communicate TPM objectives and goals through company-wide channels.
2. **Training and Information Collection:** Educate employees on TPM concepts, benefits, and implementation steps while gathering relevant data.

3. **Organize Teams:** Form a cross-functional team, including members from all organizational levels, to drive and sustain TPM activities.
4. **Set Policies and Objectives:** Establish clear, measurable, and achievable TPM policies and goals based on current conditions.
5. **Develop a Master Plan:** Create and present a detailed TPM implementation plan to management, highlighting costs, benefits, and strategies.
6. **Conduct Feasibility Study:** Evaluate equipment conditions, plant culture, and maintenance needs to establish a baseline for improvement and set realistic targets.
7. **Pilot Installation:** Implement TPM on a selected area (10-25% of equipment), train employees, and monitor progress with clear objectives and deadlines.
8. **Plant-Wide Installation:** Expand TPM to the entire plant using a structured plan and phased implementation every 3-6 months.
9. **Implementation Audit:** Perform audits to verify adherence to TPM practices and progress toward implementation goals.
10. **Progress Audit:** Evaluate TPM's impact, including improvements in OEE, skill development, and project execution, after 18-30 months.
11. **Certification:** Achieve certification by meeting stringent criteria to ensure enhanced equipment reliability and operational excellence.
12. **TPM Award:** Strive for the prestigious TPM Award, signifying world-class productivity, quality, and teamwork.

#### **CURRENT MEDICAL DEVICES MAINTENANCE WORK**

Operational failures in healthcare can hamper delay patient care, decrease care quality, risk patients, employees, waste hospital resources and decrease productivity. Many operational failures were the result of material and information supply breakdowns. Therefore, before moving ahead to the breakdowns and their causes, it really is worth identifying the entire system of maintaining any equipment from the breakdown call till the equipment is returned to its working condition. And the work procedure of process flow chart is shown in Figure 4.2. The hospital maintenance department uses the term: Percent of Maintenance Calls Attained as a measure of repair and work performance as part of the hospital's implementation of TQM. For future improvement decisions, the above indicator is usually measured for each month to follow its success pattern.

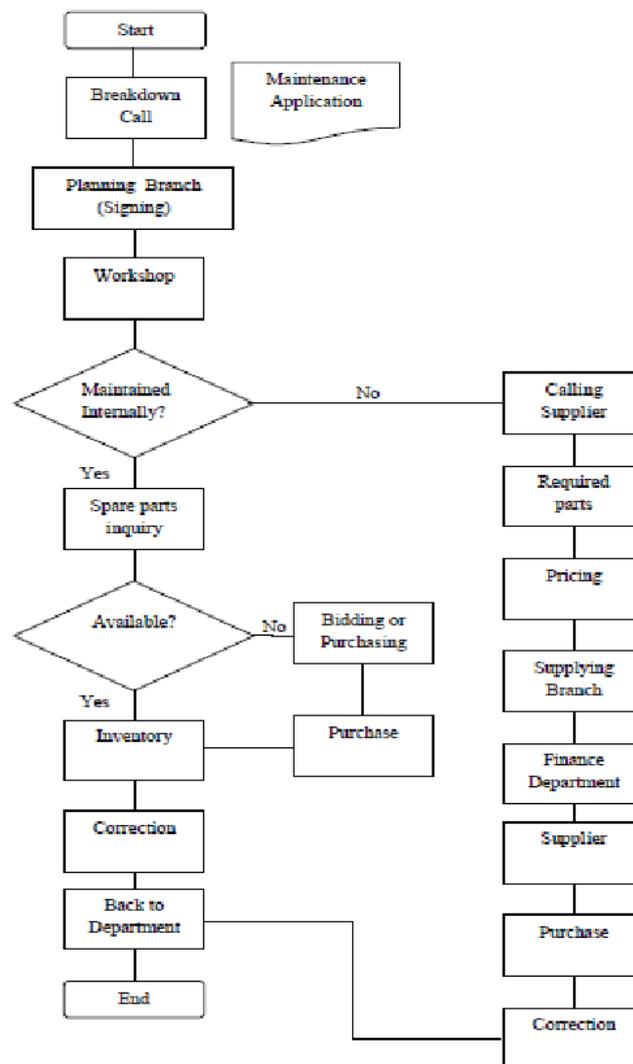


Fig 4.2 – Flow chart of Current medical devices maintenance procedure

**Difficulties Faced in TPM Implementation on Medical Equipment in healthcare:**

It is difficult to achieve TPM implementation although it is easy on paper. This is mainly due to the organization's reluctance to understand and implement TPM concepts and inability to recognize the benefits of implementing TPM [69] [70] [71]. Fig.4.3 demonstrates the TPM difficulties.

Here are important barriers in the use of TPM.

- Generally, individuals demonstrate solid protection against change.
- Many Employees consider it to be one more "Program of the Month" without agreeing to pay any concentration and in addition, inquire about the effectiveness. Not sufficient resources and assistance provided.
- Insufficient understanding of procedure and theory by the centre administration.
- TPM is not really a "Swift Solution" technique, it requires a social change in the way we do things.
- Departmental obstruction active in the business unit Few workers find TPM exercises to be extra work / danger.

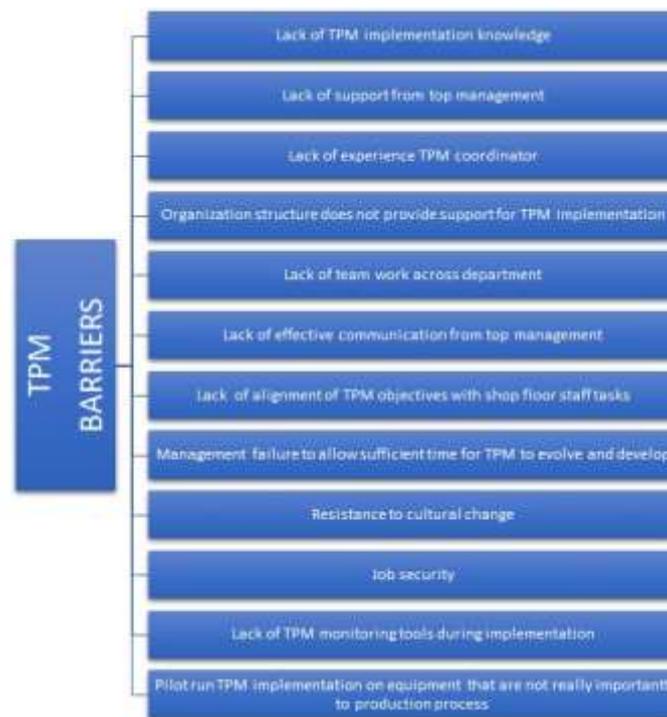


Fig.4.3: The TPM barriers

### **OEE (OVERALL EQUIPMENT EFFICIENCY)**

OEE measures how effectively an asset operates compared to its full potential. A perfect OEE score of 100% represents flawless production: only good parts made, at maximum speed, with zero downtime.

#### **Uses of OEE**

1. **Benchmarking:** Compare asset performance against industry standards or in-house shifts.
2. **Baseline:** Track and improve waste elimination over time.

#### **OEE Benchmarks**

- **100%:** Perfect production.
- **85%:** World-class performance.
- **60%:** Typical for many manufacturers, with room for improvement.
- **40%:** Common starting point; simple actions can improve this.

#### **OEE Formula**

$OEE = \frac{\text{Good Count} \times \text{Ideal Cycle Time}}{\text{Planned Production Time}}$   
 Alternatively,  $OEE = \text{Availability} \times \text{Performance} \times \text{Quality}$

#### **Loss Categories in OEE**

1. **Availability:** Time lost due to unplanned (e.g., breakdowns) and planned stops (e.g., changeovers).
  - $\text{Availability} = \frac{\text{Run Time}}{\text{Planned Production Time}}$
2. **Performance:** Losses from slow cycles or minor stops.
  - $\text{Performance} = \frac{\text{Ideal Cycle Time} \times \text{Total Count}}{\text{Run Time}}$
3. **Quality:** Loss from defective or reworked parts.
  - $\text{Quality} = \frac{\text{Good Count}}{\text{Total Count}}$

#### **Perfect Production**

Achieved when:

- **Quality = 100%:** Only good parts produced.
- **Performance = 100%:** Maximum speed achieved.
- **Availability = 100%:** Zero downtime.

OEE highlights waste sources and drives improvements toward operational excellence.

## **IMPLEMENTATION OF TOTAL PRODUCTIVE MAINTENANCE FOR THE SELECTED HOSPITALS – CASE STUDY**

The study was conducted at the Karnataka Public Hospital through in-depth interviews, observations and record collections. A methodology for implementing the TPM was developed to increase the overall equipment efficiency of the x-ray equipment and to reduce its failures. The defined staff working process and new responsibilities have been clarified by TPM techniques with a recommendation for additional performance measures.

The hospital considered for study is 650-750 bedded hospitals with 21 medical departments. The hospital consists of four operation theatres- minor OT, major OT, OBG OT, Ophtho OT. It has a separate mechanical maintenance department with five bio medical engineers to take care of the medical equipment maintenances.

The case study was conducted in radiology department of public hospital to understand current OEE of x ray equipment unit based on historical data. The four months details of the total number of scanning performed in the X ray equipment and the details regarding the failure and downtime were collected from the radiology department of the public hospital during the year 2017.

### **Before Implementation of TPM:**

Table 5.9: The details of number of x ray before the implementation of TPM

| Month    | Number of scans |
|----------|-----------------|
| January  | 5930            |
| February | 5185            |
| March    | 5700            |
| April    | 5818            |
|          | Total= 22633    |

The reduction in equipment utilization comprises of three components referring to the availability (A) of the medical equipment, the rate at which the medical equipment is performing (PE) and the Therapeutic Accuracy of the Quality Performance of the Medical Equipment (Q).

The overall equipment efficiency (OEE) = A X PE X Q

The calculation of components of OEE is given below.

Availability (A) calculation:

- (a) Total running time: 2880 Hours
  - (b) Number of failures: 4
  - (c) Downtime of equipment: 480 Hours
- Mean time between failure (MTBF): ( a/b ) = 720
- Mean time to repair (MTTR) : ( c/b ) = 120

Availability (A) = (MTBF – MTTR) / MTBF = 0.8333

### **After implementation of TPM**

After the implementation of Total Productive Maintenance techniques, next four months details of the total number of scanning performed in the X ray equipment and the details regarding the failure and downtime were collected from the radiology department of the public hospital during the year 2017.

Table 5.10: The details of number of X Ray scans after the implementation of TPM

| Month  | Number of scans |
|--------|-----------------|
| May    | 6020            |
| June   | 5754            |
| July   | 5874            |
| August | 5559            |
|        | Total= 23,207   |

Availability (A) calculation:

- (a) Total running time : 2952 Hours
  - (b) Number of failures : 3
  - (c) Downtime of equipment : 296 Hours
- Mean time between failure (MTBF): ( a/b ) = 984  
 Mean time to repair ( MTTR ) : ( c/b ) = 98.66

Availability (A) = (MTBF – MTTR) / MTBF = 0.8997

Performance Rate calculation:

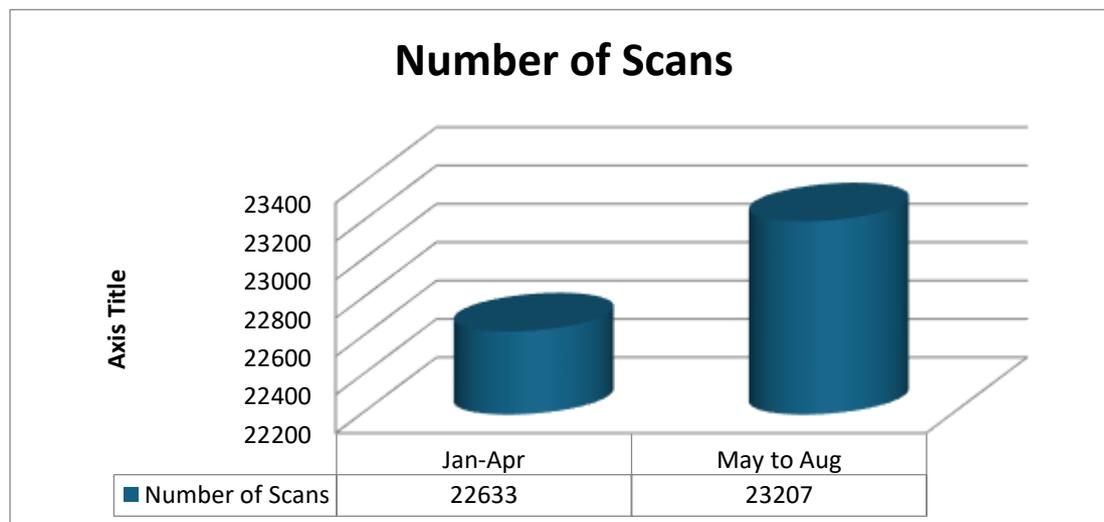
- ( p ) Ideal cycle time per patient: 0.1 Hours.
- ( q ) Number of patients scanned : 23207
- ( r ) Operation Time : 2952 Hours

Performance Rate (PE) = p X q / r = 0.7861

Quality Rate has major constituent’s i.e. patient cooperation during scanning, calibrated machine with no image artifacts & proper parameter selection by technician.

- ( x ) Number of good patient images taken from X Ray scanner unit = 23207
- ( y ) Number of patient images taken from X Ray scanner unit = 21350

Quality rate (Q) = x / y = 0.9199



OEE = A X PE X Q = 0.6506

Figure 5.13: Bar chart showing the increase in number of scans using X- Ray equipment

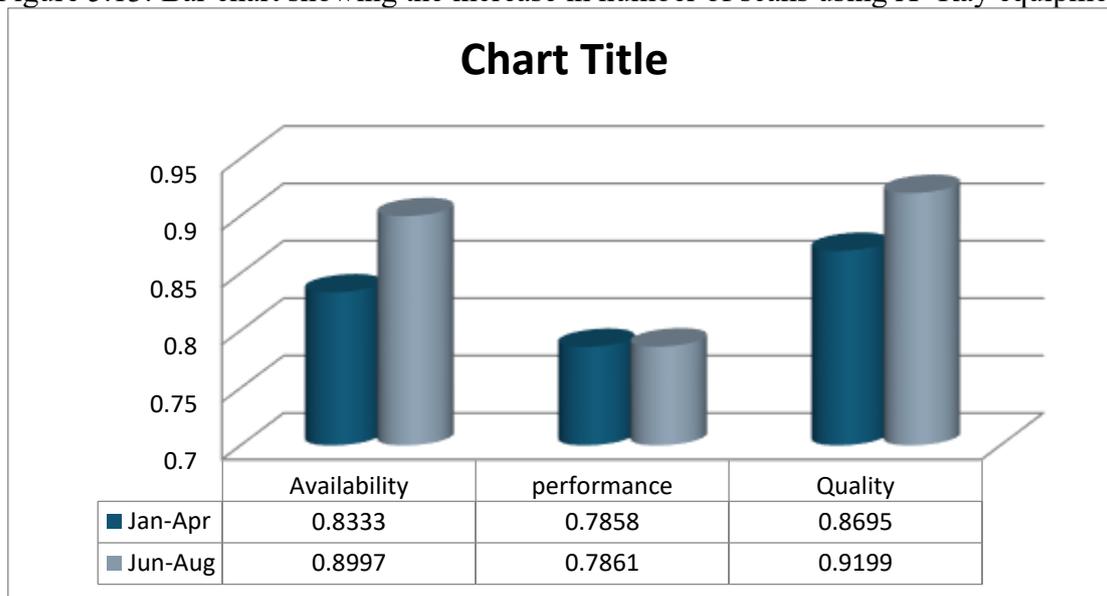


Figure 5.14: Bar chart shows the increase in availability, performance rate and quality rate of X Ray equipment.

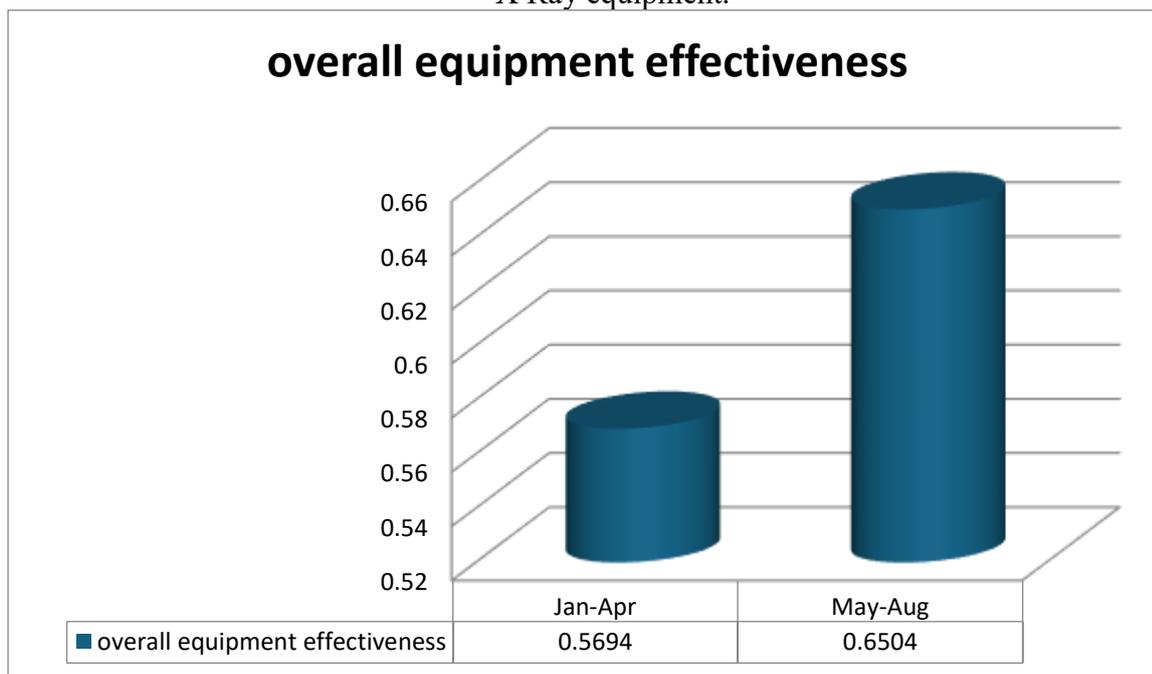


Figure 5.15: Bar chart shows the increase in overall equipment effectiveness of X Ray equipment

**Cost analysis before implementation of TPM**

Average Cost of each X Ray = Rs 110

Before implementation

Table 5.11: The average monthly income from the X Ray before the implementation of TPM

| Month    | Number of scans | Average Income from the scans |
|----------|-----------------|-------------------------------|
| January  | 5930            | Rs 6,52,300                   |
| February | 5185            | Rs 5,70,350                   |
| March    | 5700            | Rs 6,27,000                   |
| April    | 5818            | Rs 6,39,980                   |
|          | Total= 22633    | Total income=<br>Rs 24,89,630 |

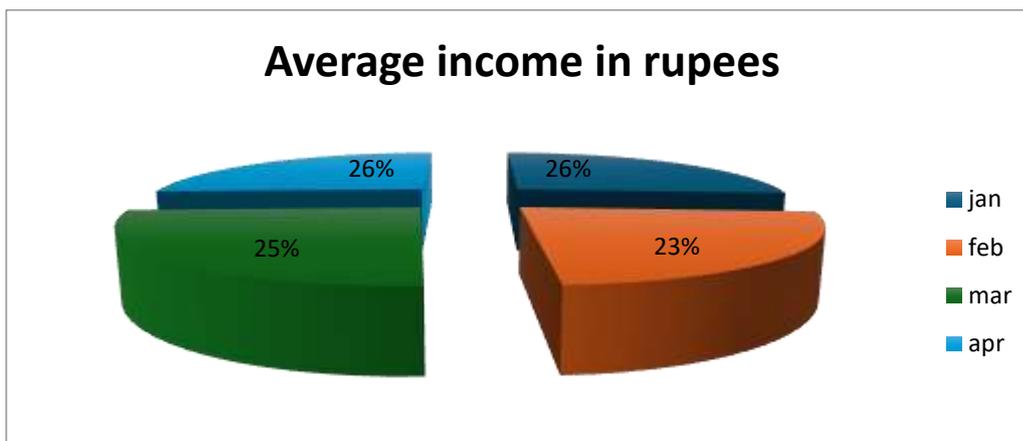


Figure 5.16: The average monthly income from the X ray equipment before the implementation of TPM.

**cost analysis After implementation of TPM**

Table 5.12: The average monthly income from the x ray equipment after the implementation of TPM.

| Month  | Number of scans | Average Income from the scans |
|--------|-----------------|-------------------------------|
| May    | 6020            | Rs 6,62,200                   |
| June   | 5754            | Rs 6,32,940                   |
| July   | 5874            | Rs 6,46,140                   |
| August | 5559            | Rs 6,11,490                   |
|        | Total= 23,207   | Total income=<br>Rs 25,52,770 |

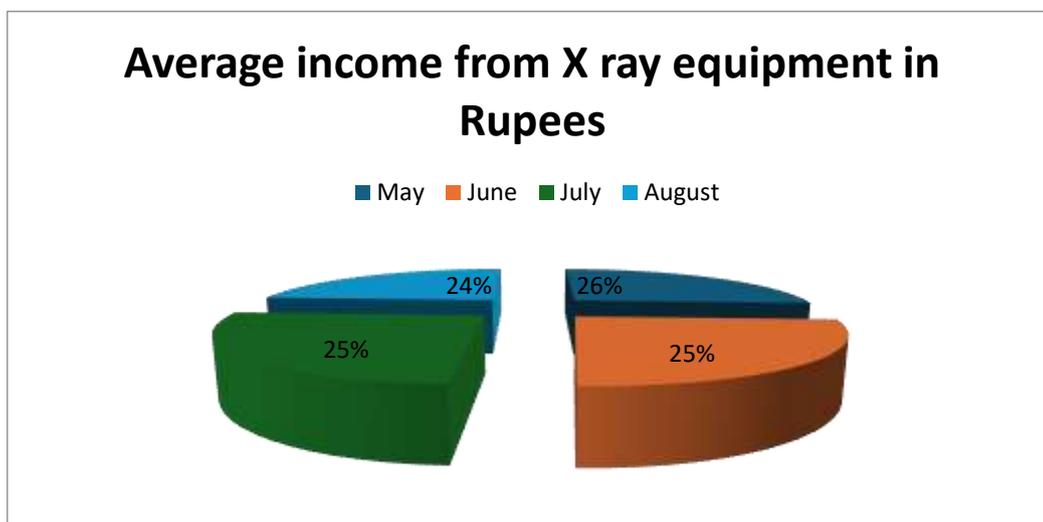


Figure 5.17: The average monthly income from the X Ray Equipment after the implementation of TPM.

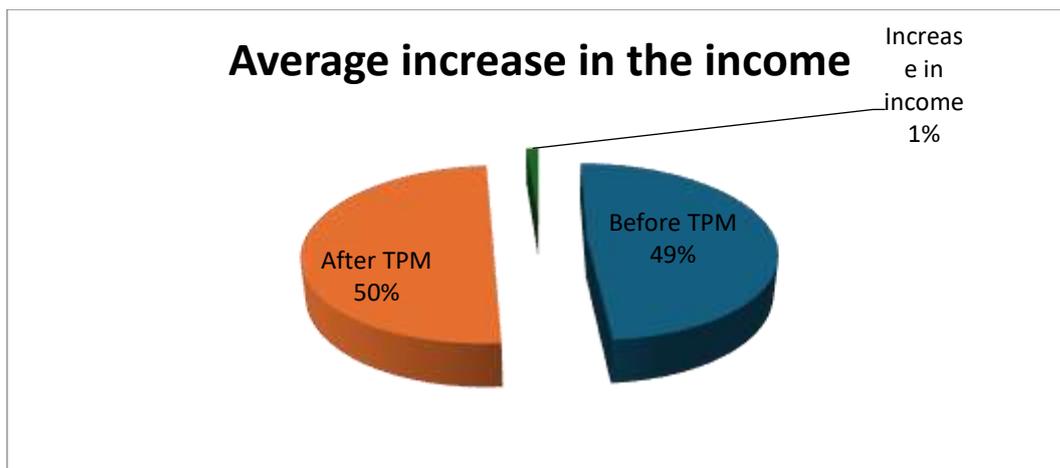


Figure 5.18: The average increase in from the X Ray equipment

### Conclusions

- From the above work we observed that over all equipment efficiency of the X Ray equipment was increased by 8%.
- Availability of the equipment was found to have increased by 6% by increasing the number of scans due to the reduction of failures.
- Performance of the equipment was found to have increased by 0.3% by decreasing the ideal cycle time per patient.
- Quality rate of the equipment is found to have increased by 5%.
- Increase in the average income after the implementation of TPM was found to be 1%.
- Ideal cycle time / patient were decreased due to an increase in operator productivity and a decrease in set time, thus increasing the performance rate of the equipment.
- Number of defect images taken due to overheating of equipment and improper knowledge regarding usage of films was reduced through proper maintenance techniques, training and education. This increased the quality rate of the equipment.
- The continuous implementation of TPM in the healthcare sector therefore helps to reduce losses and improve the rate of performance, availability, quality to increase the OEE and thus ultimately increase the productivity and profitability of the sector.

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