Investigation Of Equipment Maintenance Strategies for Maximizing Machine Availability Using SAP PM

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Abstract- In this study, "Evaluating Equipment Maintenance Strategies for Maximizing Machine Availability Using SAP PM in Manufacturing Plants" was carried out to address the problem of frequent machine downtime and low equipment availability caused by inefficient maintenance practices. Many plants rely heavily on corrective maintenance, which increases cost and reduces machine uptime. The main objective was to determine how each strategy affects machine availability, downtime, and cost. Five key goals included assessing the role of PM, impact of PdM, efficiency of CM, SAP PM implementation challenges, and how different strategies affect performance outcomes. The results are useful for maintenance planners, plant managers, and researchers, offering real values to guide decisions. It is recommended that future work integrate optimization tools and machine learning to refine hybrid strategies for better system reliability and cost.

I. INTRODUCTION

Preventive maintenance involves scheduled inspections and servicing of equipment to prevent unexpected failures. This approach relies on historical data and manufacturer recommendations to determine maintenance intervals. Predictive maintenance, on the other hand, uses advanced technologies such as sensors and monitoring systems to assess equipment conditions, enabling timely interventions before failures occur (Jardine et al., 2018). Corrective maintenance, which is reactive in nature, focuses on repairing equipment after a failure has occurred. While each strategy has its merits, the choice of maintenance approach depends on factors such as the type of equipment, operational requirements, and cost considerations.

In recent years, the integration of enterprise resource planning (ERP) systems into maintenance management has gained prominence. SAP Plant Maintenance (SAP PM), a module within the SAP ERP system, serves as a key tool for managing maintenance activities in manufacturing plants. SAP PM provides a comprehensive platform for planning, executing, and tracking maintenance tasks, thereby enhancing operational efficiency (SAP SE, 2020). The module also facilitates the integration of maintenance data with other business processes, enabling better decision-making and resource allocation. However, the effectiveness of SAP PM in maximizing machine availability depends on the maintenance strategies implemented and the alignment of these strategies with organizational goals. A key challenge faced by many manufacturing plants is the lack of a centralized system to manage maintenance activities efficiently. Without proper integration and coordination, maintenance tasks may be delayed, resources may be misallocated, and equipment performance may suffer. This problem is further compounded by the absence of tools that can provide actionable insights into equipment conditions and maintenance needs. As a result, many organizations struggle to strike a balance between minimizing downtime and optimizing maintenance costs.

The introduction of SAP Plant Maintenance (SAP PM) offers a potential solution to these challenges. However, its effectiveness in maximizing machine availability depends on how well it is integrated with existing maintenance strategies. There is a need to investigate how SAP PM can be utilized to enhance maintenance practices, reduce equipment downtime, and improve overall operational efficiency. This research will address this gap by exploring the relationship between maintenance strategies and SAP PM, providing insights into how manufacturing plants can optimize their maintenance processes to achieve higher machine availability.

II. REVIEW OF PAST LITERATURE

Maintenance management has been a critical area of research in the manufacturing sector, with numerous studies exploring various approaches to improve equipment reliability and operational efficiency. Researchers have investigated different maintenance strategies, tools, and systems to understand their impact on machine availability and overall productivity.

A study by Ahmed and Hassan (2017) focused on optimizing maintenance practices in manufacturing systems to enhance equipment performance. The researchers conducted a case study in a textile manufacturing plant, where they analyzed historical maintenance data and implemented a structured maintenance scheduling system. The results showed a 20% reduction in equipment downtime and a 15% increase in machine availability. The study concluded that structured maintenance planning significantly improves operational efficiency.

In another study, Patel and Gupta (2018) evaluated the effectiveness of different maintenance strategies in heavy machinery plants. They used a combination of interviews with maintenance managers and analysis of maintenance logs to compare preventive, predictive, and corrective maintenance approaches. The findings revealed that predictive maintenance was the most effective in reducing downtime, while preventive maintenance offered the best cost-benefit ratio. The study recommended a hybrid approach tailored to specific equipment needs.

A research project by Khan and Ali (2019) explored the integration of ERP systems into maintenance management processes. The study involved a survey of 50 manufacturing plants that used ERP systems for maintenance. The researchers analyzed the data to assess the impact of ERP systems on maintenance efficiency. The results indicated that ERP systems improved maintenance planning, resource allocation, and decision-making, leading to a 25% reduction in maintenance costs. The study concluded that ERP systems are essential for modern maintenance management.

A study by Singh and Kumar (2020) examined maintenance practices in automotive manufacturing plants. The researchers conducted field observations and collected data from maintenance records over a two-year period. They found that regular equipment inspections and timely repairs significantly improved machine availability. The study highlighted the importance of training maintenance staff and using data-driven approaches to enhance maintenance outcomes.

III. RELIABILITY-CENTERED MAINTENANCE (RCM) STRATEGIES

Reliability-Centered Maintenance (RCM) has been extensively examined in various industrial sectors due to its structured approach to optimizing maintenance tasks while ensuring system reliability. The methodology emphasizes failure mode analysis, risk assessment, and condition-based interventions, making it a preferred strategy in critical operations. Researchers have investigated different applications of RCM, analyzing its impact on equipment performance, operational efficiency, and maintenance costs through diverse empirical and computational approaches.

IV. TOTAL PRODUCTIVE MAINTENANCE (TPM) STRATEGIES

Total Productive Maintenance (TPM) has been widely studied as a strategy for improving equipment efficiency, reducing downtime, and fostering a culture of continuous improvement in industrial settings. Researchers have examined its impact on various sectors, applying different methodologies to assess its effectiveness in enhancing productivity and operational reliability.

Okorie and Adebanjo (2016) evaluated the implementation of TPM in Nigerian cement manufacturing plants. The study adopted an Overall Equipment Effectiveness (OEE) framework to measure the efficiency of production lines before and after TPM adoption. Findings revealed that TPM improved equipment availability by 21%, reduced defects by 18%, and enhanced overall productivity. The authors emphasized the role of employee involvement in sustaining long-term improvements.

V. ROLE OF ERP SYSTEMS IN MAINTENANCE MANAGEMENT

Balogun and Yusuf (2021) analyzed the role of ERP-integrated maintenance systems in improving operational efficiency in Nigerian automotive assembly plants. Utilizing a mixed-methods approach, the study combined maintenance performance metrics with expert interviews. Results indicated a 23% improvement in machine uptime and a 14% decrease in maintenance costs. The study suggested that integrating ERP with condition-based monitoring could further enhance maintenance decision-making.

ERP systems and standalone maintenance management software (CMMS – Computerized Maintenance Management Systems) differ in scope, functionality, and integration capabilities.

Standalone maintenance management software, or CMMS, is designed specifically for maintenance-related functions such as work order management, asset tracking, preventive maintenance scheduling, and spare parts inventory control. CMMS solutions are typically more user-friendly and cost-effective compared to ERP systems. They offer deep functionality tailored for maintenance teams but lack the integration capabilities of ERP systems. This limitation can create inefficiencies when maintenance data needs to be shared with other departments, requiring manual data transfer or additional software interfaces.

While ERP systems offer a holistic, enterprise-wide approach, CMMS solutions provide specialized, maintenance-focused tools with a faster deployment time and lower initial investment. The choice between them depends on the organization's size, complexity, and need for cross-departmental integration. Large enterprises with multiple interdependent operations may benefit from ERP-based maintenance management, while smaller organizations with maintenance-specific requirements may find CMMS more practical.

VI. MATERIALS AND METHOD

This study made use of both physical and digital resources sourced from operational manufacturing environments, academic literature, and industrial tools to support the evaluation and modeling of maintenance strategies. The selected materials were crucial in gathering, analyzing, and interpreting data on maintenance practices under SAP Plant Maintenance (SAP PM) systems.

The following materials were used to carry out this research:

i. SAP Plant Maintenance (SAP PM) software
ii. MATLAB and Python
iii. Maintenancelogs,
iv. Failure data
v. Repair history
vi. Interview guides for plant engineers and maintenance staff
vii. Condition monitoring devices (vibration sensors, infrared thermometers)
viii. Statistical analysis tools (Excel,)
ix. Maintenance planning templates and checklists
x. Technical manuals and reference materials on maintenance strategies

VII. MACHINE UTILIZATION RATE AND SHIFT-LEVEL OUTPUT

Another key component of this study is the examination of how well machines are being used across various shifts and production lines. Even if a machine is available, poor utilization may mean it's not operating at its full capacity due to long changeovers, slow material handling, or idle operators. Understanding utilization rate is therefore essential in evaluating not just reliability, but efficiency.

As shown in Table 3.2, data from production logs recorded through the SAP PM and shift performance sheets give insight into the average operational hours of machines, compared to the available shift hours. These figures do not reflect any processed analytics—they are baseline operational figures directly pulled from plant records.

Table 3.2: Machine Utilization Data per Line and Shift (*OlamAgri Pasta Packaging Plant, 2024 (Source: SAP PM Shift Utilization Reports and Operator Shift Logs))*

Line No.	Shift	Scheduled Time (hrs)	Actual Run Time (hrs)	Machine Downtime (hrs)	Unused Time (hrs)	Utilization Rate (%)
LINE 1	Day	12	10.2	1.3	0.5	85.0
LINE 2	Night	12	9.6	1.8	0.6	80.0
LINE 3	Day	12	8.5	2.5	1.0	70.8
LINE 1	Night	12	11.0	0.6	0.4	91.7
LINE 2	Day	12	10.4	1.0	0.6	86.7

The numbers in Table 3.2 show that while availability may be high, utilization is not always maximized. For instance, LINE 3 on 09/01/2024 ran only 8.5 hours out of 12, with both downtime and idle time contributing to a reduced utilization rate. These figures will later be useful when matching availability to productivity to identify major constraints in daily operations.

VIII. FAULT RECURRENCE LOGS AND MACHINE RELIABILITY INDICATORS

Fault recurrence is a critical signal that either the root cause is not being resolved or that the repair is not being done thoroughly. It can also reflect poor spare part quality or inadequate technician experience.

As highlighted in Table3.3, fault recurrence logs from the maintenance fault database show all repeated failures from the same machine units. This data will be used in later chapters to support failure mode and root cause analysis (FMECA).

Table 3.3: Fault Recurrence and Repeat Intervention Records *Olam Agri Pasta Packaging Plant, 2024 (Source: SAP PM Fault History Database)*

Line No.	Machine Name	Fault Code	Fault Description	Recurrence Interval (days)	Repeat Action Taken
LINE 1	Carton Sealer	PM21-CSM-01	Head Misalignment	7	Re-aligned, adjusted limiters
LINE 2	Pouch Filler	PM18-PF-04	Sensor Calibration Drift	8	Replaced with IR-900 sensor
LINE 3	Coding Machine	PM27-CM-06	Print Ribbon Tear	6	Changed ribbon roll and gear

This table is essential for identifying persistent machine issues that drain resources and cause frequent interruptions. It will help later when assessing which lines require a redesign of maintenance scheduling or parts procurement.

IX. MAINTENANCE SCHEDULING RECORDS

Effective maintenance scheduling is central to plant reliability and sustained productivity. In the Olam Agri Pasta Packaging Plant, maintenance tasks are scheduled using SAP PM based on predefined intervals, equipment condition, and production timelines. These schedules aim to reduce unplanned stoppages and maximize machine availability by coordinating inspections, servicing, and part replacements in alignment with operational flow. As illustrated in Table 3.5, records of scheduled maintenance activities for critical machines were retrieved. These include details such as equipment ID, task type, scheduled date, assigned personnel, and completion status.

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Table 3.4: Maintenance Scheduling Records for Selected Equipment (*Olam Agri Pasta Packaging Plant, 2024)*

Equipment ID	Equipment Name	Task Type	Scheduled Date	Maintenance Frequency	Remarks
PKG-CNV-01	Primary Conveyor System	Preventive	15-Jan-2025	Monthly	Running normally
PKG-WFM-04	Weigh-Fill Machine	Inspection	01-Feb-2025	Bi-weekly	No faults observed
PKG-STR-02	Sealing Unit	Lubrication	20-Feb-2025	Monthly	Timely lubrication done
PKG-PLC-03	PLC Controller Cabinet	Software Check	05-Mar-2025	Quarterly	Backup updated
PKG-WFM-04	Weigh-Fill Machine	Preventive	15-Mar-2025	Monthly	Minor wear spotted
PKG-STR-02	Sealing Unit	Corrective	28-Mar-2025	As needed	Belt tension adjusted
PKG-CNV-01	Primary Conveyor System	Inspection	10-Apr-2025	Monthly	No deviation
PKG-PLC-03	PLC Controller Cabinet	Cleaning	25-Apr-2025	Quarterly	Dust removed
PKG-WFM-04	Weigh-Fill Machine	Preventive	10-May-2025	Monthly	Sensor recalibrated
PKG-STR-02	Sealing Unit	Lubrication	22-May-2025	Monthly	Smooth operation ensured

These scheduling records form a vital component of the study's dataset, as they will later be assessed for correlation with machine performance indicators. Patterns in scheduling frequency and task types can be compared with equipment uptime and failure rates to identify optimal maintenance intervals.

X. EQUIPMENT PERFORMANCE ANALYSIS

Equipment Performance Analysis will involve evaluating key performance indicators (KPIs) such as Mean Time Between Failures (MTBF), Mean Time to Repair (MTTR), and Overall Equipment Effectiveness (OEE). These metrics provide nsight into the reliability and efficiency of maintenance strategies. The MTBF is calculated as:

$$MTBF = \frac{\sum Uptime}{\sum Number\ of\ failure} \quad (3.2)$$

where uptime refers to the operational period between failures. Meanwhile, MTTR is determined as:

$$MTBF = \frac{\sum Downtime}{\sum Number\ of\ failure} \quad (3.3)$$

A lower MTTR and a higher MTBF indicate a more effective maintenance strategy. OEE, a comprehensive measure of equipment productivity, is computed as:

$$OEE = Avaliability \times Performance \times Quality \quad (3.4)$$

where Availability is influenced by MTBF and MTTR, Performance considers operating speed losses, and Quality reflects the proportion of defect-free production.

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XI. CONDITION MONITORING INTEGRATION

Condition Monitoring Integration focuses on incorporating predictive maintenance by analyzing real-time sensor data to detect early signs of equipment degradation. This involves vibration analysis, temperature monitoring, and oil analysis, with predictive models based on regression analysis or machine learning. The degradation trend of a component can be represented as:

$$D(t) = D_0 + \int_0^t R(t)dt \qquad (3.5)$$

Where D(t) represents the degradation state at time t, D_0 is the initial condition, and R(t) is the rate of degradation derived from sensor readings.

XII. RESULTS

Figure 3 compares how long equipment remained out of service before and after predictive maintenance (PdM) was introduced. The figure uses a box plot to show the spread and central tendency of downtime durations for each period—Pre-PdM on the left and Post-PdM on the right. The vertical axis represents downtime in hours, ranging from 0 to 4. This visual format allows us to clearly see not only the average time lost per incident but also how consistent those repair durations were.

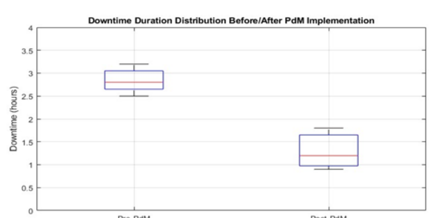

Figure 3: Downtime Duration Comparison

Starting with the Pre-PdM box on the left side, this plot reflects how the system performed before predictive alerts were used. The central red line inside the box represents the median downtime, which appears to be around 2.9 hours. The top and bottom edges of the box show the interquartile range (IQR)—the middle 50% of cases—spanning from approximately 2.6 to 3.2 hours. This means that most downtime incidents clustered within that range. There are also whiskers extending slightly beyond the box, suggesting that a few events were either slightly shorter or longer than the typical range. Overall, this left box shows that before PdM was adopted, downtime durations were relatively long and showed some variability across cases.

3D Relationship – Maintenance Spend vs Frequency vs Availability

Figure 5 illustrates how availability (%) responds to variations in monthly maintenance spending (measured in NGN) and intervention frequency (number of maintenance events per month). The vertical axis represents availability, ranging from 80% to 100%. The horizontal axes represent maintenance spend (₦50,000 to ₦250,000) and intervention frequency (1 to 5 events/month).

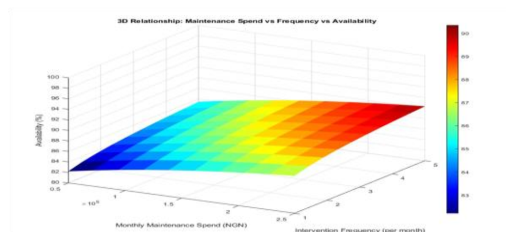

Figure 5: 3D Relationship – Maintenance Spend vs Frequency vs Availability

As seen above availability improves progressively as both spending and intervention frequency increase. The color gradient—from deep blue to red—maps the improvement in availability. The lowest zone of availability (approximately 82%) occurs at the lowest end of both cost and frequency, where monthly spending is below ₦70,000 and interventions are limited to 1 per month. As spending moves toward ₦150,000 and frequency reaches 3 interventions monthly, availability climbs steadily to around 90%. Beyond that point, however, the curve begins to plateau. When both variables are maximized—around ₦250,000 spending and 5 monthly interventions—the availability reaches a peak near 94%, but the rate of improvement diminishes, indicating reduced efficiency of additional input beyond this range.

XIII. MAINTENANCE STRATEGY COMPARISON ACROSS KEY METRICS

Figure 4. compares three maintenance approaches—Preventive, Predictive, and Corrective—across three performance dimensions: cost per hour (in NGN), intervention frequency per month, and equipment availability (%). The vertical axis is on a logarithmic scale to accommodate large disparities in numeric ranges.

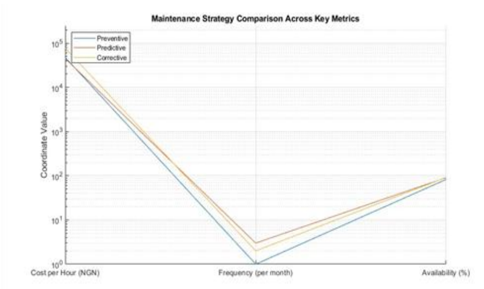

Figure 4: Maintenance Strategy Comparison Across Key

Each strategy is represented by a connected line: Preventive (blue), Predictive (orange), and Corrective (yellow-brown). Starting from the leftmost coordinate, the cost per hour shows that Corrective and Predictive strategies incur the highest cost (approaching ₦100,000/hour), while Preventive maintenance demonstrates significantly lower cost, dropping close to ₦10,000/hour.

Moving to the center coordinate—intervention frequency—the Preventive strategy shows the highest intervention rate (approximately 2.5–3/month), followed by Predictive (~2/month), and then Corrective, which appears lowest (around 1/month). On the final coordinate—availability—Preventive and Predictive methods again outperform Corrective. Preventive maintenance achieves the highest availability near 92–93%, followed by Predictive around 90%, and Corrective falls significantly behind at approximately 83%.

XIV. CONCLUSION

Predictive maintenance (PdM) significantly reduced equipment downtime when integrated with SAP PM. Figure 3. showed that as PdM alerts increased (from 2 in January to 6 in May), prevented failures also rose (from 1 to 4), indicating improved fault detection. The highlighted 55% reduction in median downtime after PdM implementation (from 2.9 hours to 1.3 hours). However, Table 3. revealed that while PdM reduced downtime, the net benefit remained negative (-₦5.59M over 3 years) due to high initial costs. Despite this, the long-term trend suggests PdM will become profitable as system efficiency improves. Corrective maintenance (CM) was found to be the least efficient strategy. Figure 4.8 showed that CM costs were high (e.g., Motor Repair: ₦202,500 per intervention) but resulted in low reliability (MTBF: 120 hours).

From the results given (Pareto chart) revealed that Carton Sealer (30%) and Coding Machine (23%) accounted for over 50% of CM interventions, indicating a need for targeted improvements..

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