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Assessment of Factors Influencing Maintenance Management in Workshop Machinery that Enhance Overall Equipment Effectiveness (OEE): A Review

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Abstract
Maintenance management significantly influences the efficiency, reliability, and lifespan of workshop machinery particularly in academic institutions where machinery availability supports hands-on training. This review paper critically assesses the key factors that influence maintenance management and their role in enhancing Overall Equipment Effectiveness (OEE), a comprehensive metric composed of availability, performance, and quality. The review further identifies and discusses ten major influencing factors: financial planning, human resource competency, maintenance strategy, availability rate, environmental conditions, equipment design complexity, maintenance timing, technology integration, management commitment, and user behavior. These factors are interrelated and impact maintenance outcomes in ways that directly affect OEE. The study emphasizes the shift from reactive to proactive maintenance approaches, supported by technologies such as CMMS, skilled personnel, sufficient funding, and strategic institutional planning. The findings offer valuable insights for academic and industrial stakeholders aiming to optimize maintenance systems, reduce equipment downtime, and improve productivity and training effectiveness through better management practices.

Key words: Overall equipment effectiveness, maintenance strategies, human factor, fund resource, technology

1 Introduction

Workshop machinery serves as a backbone for practical training in engineering and technical education institutions. Maintaining its functionality, safety, and efficiency is vital for ensuring quality training outcomes and operational continuity. In this context, the concept of Overall Equipment Effectiveness (OEE) has gained prominence as a key performance indicator that integrates equipment availability, performance efficiency, and output quality. Achieving optimal OEE requires a well-structured maintenance management system that minimizes downtime, prevents unexpected failures, and ensures consistent machine performance. An advanced system known as Computerised Maintenance Management System (CMMS) has the capability to plan predictive maintenance, manage spare parts more effectively, and make it easier to monitor the equipment operation (Wienker et al., 2016).

However, many academic workshops particularly in developing regions face challenges such as inadequate funding, unskilled maintenance personnel, poorly defined strategies, and limited technological adoption. These limitations contribute to inefficient maintenance practices, negatively affecting OEE. The effective maintenance management system is to prioritize preventive maintenance above reactive repair (Oluwatobi et al., 2019). Therefore, understanding the factors that influence maintenance management is critical to improving machinery performance and extending equipment lifespan.

This review paper aims to synthesize current literature to identify and evaluate these key influencing factors. By doing so, it seeks to provide a foundation for institutions to adopt best practices in maintenance management that are aligned with OEE enhancement goals.

2 Definition of Key Terms

2.1 Maintenance practices, according to (De Jonge & Scarf, 2020), are a systematic method to maintaining assets or systems that employ optimization techniques to improve decision-making, minimize costs, and improve overall system performance. The emphasis is on implementing these tactics in a way that minimizes downtime, prolongs the life cycle of the assets being maintained, and strikes a balance between operational requirements and available resources. According to (Reason & Hobbs, 2017), maintenance practice entails the careful management of both technical and human aspects, with the aim being not only to complete maintenance tasks accurately but also to prevent errors thorough training, proactive safety measures, and efficient maintenance management activity.

2.2 Maintenance Management. It is an essential component of modern industrial operations, as it directly affects asset reliability, efficiency, and profitability. The growth of maintenance methods, the function of technology, and the difficulties in putting efficient maintenance solutions into practice are all highlighted in the literature on maintenance management systems (MMS) (Palis & Misnan, 2018). In order to decrease downtime and improve reliability, (Wienker et al., 2016) suggest that businesses need to switch from reactive to proactive and predictive procedures, such as condition-based and preventative maintenance. (Laurila, 2017) backs up this argument by pointing out that condition-based maintenance, despite its complexity, are more cost-effective because it plans maintenance according to the real state of the equipment rather than predetermined intervals. Computerized Maintenance Management Systems (CMMS) facilitate proactive maintenance by automating work orders, documenting equipment history, maintaining spare parts inventory, and integrating with business processes such as project planning and accounting (Laurila, 2017). (Wienker et al., 2016) Point out that CMMS is a technology that supports current strategies rather than a maintenance strategy, assisting companies in making the transition from reactive to planned maintenance. Organizational a lack of preparation, poor IT infrastructure, a lack of senior management support, change fear, and a lack of resources are some of the obstacles that CMMS implementation must overcome (Wienker et al., 2016). Poor acceptance and underutilization result from many organizations' incorrect perception of CMMS as a solution rather than a tool that supports maintenance processes.

2.3 Inventory management system, according to (Hwang & Samat, 2019), is a vital component that involves the strategic management and control of spare parts inventory, particularly in the context of maintenance activities. Without overstocking or understocking, which can result in needless expenses or equipment downtime, the system is in charge of making sure the appropriate spare parts are accessible when needed to support maintenance activities. From (Madamidola et al., 2024), inventory management systems are positioned as essential instruments for preserving operational effectiveness and cutting expenses through precise inventory level tracking and control, the integration of multiple business operations, and the use of technology for more responsive and flexible inventory procedures.

2.4 Overall Equipment Effectiveness, As to (Binti Aminuddin et al., 2016), OEE is a metric that evaluates the efficiency of a manufacturing process by taking into account three essential elements: quality, performance, and availability. It is a tool for finding and fixing inefficiencies in the production, maintenance, and use of equipment, which eventually helps businesses become more productive and cut expenses. From (Chong et al., 2015), OEE is described as a critical performance metric that assesses the efficacy of equipment by combining quality, performance, and availability.

3 Key factors influencing maintenance management in workshop machinery

3.1 Fund Allocation and Financial Planning

According to (Dzulkifli et al., 2021), sufficient and reliable financial resources are necessary for effective maintenance management. Research continuously shows that inadequate financial allocation results in equipment failure, dependency on corrective maintenance, and postponed maintenance jobs, all of which have a detrimental effect on availability and performance. According to (Palis & Misnan, 2018), maintenance is frequently viewed as a low-priority expense in university settings, which leads to insufficient funding for repairs and improvements. (Breesam & Jawad, 2021) discovered that the top-ranked problems influencing maintenance schedules and efficacy were inadequate funding and poor budget control. In the same way**,** (Dzulkifli et al., 2021) highlighted inadequate financial planning as the most important planning and management problem impacting building maintenance. This may be applied to workshop settings where financial constraints restrict the availability of replacement parts, technicians, and timely interventions.

3.2 Human Resource Competency and Technician Skills

One important element influencing the success of maintenance operations and subsequently affecting OEE is the competency of the maintenance staff. Extended downtime, inadequate repairs, and inaccurate diagnostics might arise from a shortage of qualified personnel or professionals (Dzulkifli et al., 2021). (Breesam & Jawad, 2021) found that the availability of competent workers and technician expertise were the most important factors affecting maintenance performance. Accordingly**,** (Suresh & Dharunanand, 2023) discovered that education and training had a major influence on sustainable maintenance in manufacturing environments. Additionally, (Dzulkifli et al., 2021) identified personnel competency as one of the three crucial factors influencing the results of building maintenance. To guarantee dependable maintenance procedures and OEE optimization, planned training is even more crucial in academic workshop settings where trainees or less experienced employees frequently operate and repair machines.

3.3 Planning and Maintenance Strategy

Proactive and effective maintenance management is based on careful planning and a well-defined maintenance strategy. Equipment uptime and performance are adversely affected by reactive maintenance, missed service intervals, and delayed repairs, all of which are frequently caused by poor planning (Breesam & Jawad, 2021). According to (Dzulkifli et al., 2021), two major flaws in maintenance systems are a lack of a planned strategy and poor policy implementation. Similarly, in order to increase long-term maintainability and cost effectiveness, (Palis & Misnan, 2018) stressed the importance of early coordination between design and maintenance teams. This was further corroborated by (Breesam & Jawad, 2021), who pointed out that poor reaction times and delayed fault reporting are two significant effects of inadequate maintenance planning. Improving machine availability and coordinating operations with OEE objectives require the establishment of organized, preventive maintenance programs.

3.4 Availability Rate

One of OEE's three basic components, availability rate is a direct reflection of how well equipment is maintained and run. High availability denotes efficient maintenance planning and little downtime. Given its significance in performance evaluation, availability rate was found to be one of the most important factors in sustainable maintenance modeling by (Suresh & Dharunanand, 2023). According to (De Jonge & Scarf, 2020), availability is a crucial factor in maintenance optimization schemes, especially for systems that need production planning and repair to be coordinated. Maintaining continuous operations and productive hands-on learning settings in workshop machinery requires optimizing availability through prompt interventions and reduced breakdowns.

3.5 Environmental Conditions

(Palis & Misnan, 2018) noted that external environmental conditions should be taken into consideration in maintenance planning to prolong equipment life and reduce costs. (Breesam & Jawad, 2021) noted environmental factors like humidity and rain as moderately to highly significant elements impacting maintenance needs. These effects are particularly relevant in regions like Tanzania, where weather patterns can directly affect the degradation rate of workshop machinery, necessitating context-specific preventive measures. Environmental influences like dust, humidity, and temperature fluctuations can accelerate equipment wear and reduce reliability, especially in tropical or semi-controlled workshop environments.

3.6 Equipment Design Complexity and Component Quality

The complexities of the machine's design and the quality of its parts have a big influence on cost, repair time, and maintainability. Systems that are not built with maintainability in mind may be more difficult to service and more prone to malfunctions (Palis & Misnan, 2018). (Palis & Misnan, 2018) emphasized that because of inaccessible or inappropriate components, design complexity frequently leads to increased maintenance costs and decreased reliability. Design problems and construction-related defects were also noted by (Breesam & Jawad, 2021) as technical issues that increase the frequency and duration of maintenance. For consistent machine performance and hands-on maintenance training, training workshops must use standardized, maintainable equipment with easily accessible parts.

3.7 Maintenance Timing and Responsiveness

Prolonged downtime and expensive secondary failures can be avoided with timely maintenance actions. Delays in addressing reported problems can make damage worse and lower OEE by causing prolonged outages (Driessen et al., 2015). Slow reaction times and delayed fault reporting were identified by (Breesam & Jawad, 2021) as major issues in building maintenance, pointing out their effects on total maintenance effectiveness. Optimized inspection and maintenance intervals are also essential for reducing interruptions and preserving good system performance, according to (De Jonge & Scarf, 2020). Rapid defect detection and reaction are particularly crucial for workshop equipment since unscheduled downtime can seriously interfere with student training plans and academic output (Driessen et al., 2015).

3.8 Technology and Data Integration

By providing real-time insights and data-driven decision-making, the use of contemporary technologies like CMMS, Internet of Things (IoT)-based monitoring, and predictive analytics improves maintenance planning and execution. However, a shortage of these resources in many educational institutions results in reactive, ineffective maintenance methods (Kolinska et al., 2018). (De Jonge & Scarf, 2020) facilitate the integration of data availability and decision-support systems in maintenance optimization. The underutilization of digital tools was also identified by (Dzulkifli et al., 2021) as a significant barrier to attaining excellent maintenance practices. By putting such systems in place, workshops can increase long-term equipment reliability, expedite repair scheduling, and improve response tracking.

3.9 Organizational Support and Management Commitment

A maintenance system's effectiveness frequently hinges on cross-functional cooperation, leadership involvement, and alignment with institutional objectives (Kolinska et al., 2018). (Palis & Misnan, 2018) emphasized that in order to guarantee long-term operating efficiency, technical and maintenance staff must work together early on. This was supported by (Dzulkifli et al., 2021), who emphasized the value of strategic planning frameworks that support organized, performance-oriented maintenance methods, such as ISO 41001 and the PDCA cycle. Maintenance is prioritized, financed, and in line with productivity and OEE goals when there is strong management support.

3.10 User Behavior and Improper Use

Misuse, overuse, or carelessness is examples of improper equipment use that can accelerate machine wear and increase the need for more frequent repairs. User-related malfunctions are typical in training workshops where students regularly utilize machinery (Suresh & Dharunanand, 2023). (Palis & Misnan, 2018) found that two important factors affecting the longevity of equipment are user behavior and ignorance. This was confirmed by (Breesam & Jawad, 2021), who identified human behavior and inappropriate use as moderately to very significant social and cultural factors influencing maintenance requirements. Reducing user-related equipment failures and preserving high-quality outputs require awareness campaigns and operator training.

3.11 Spare Parts Availability

Availability of spare parts is one of the most significant aspects of good maintenance management, especially in environments where machine uptime directly determines the operations of institutions, such as training workshops of higher learning institutions. The lack of required parts when required tends to result in repair delays, prolonged downtime, and reduced Overall Equipment Effectiveness (OEE) (Kolinska et al., 2018). (Driessen et al., 2015) suggested hierarchical planning and control of spare parts with the focus on highlighting the fact that unavailability of spare parts is one of the key causes of maintenance delay. Their framework emphasizes coordination of logistics of spare parts with system maintenance schedules and defines Maintenance Logistics Organization (MLO) as core to reduce downtime by supporting dependable provisioning of spare parts. They contend that effective spare part planning enhances system availability and eliminates unnecessary waiting times, thus optimizing equipment performance and maintenance responsiveness. In training workshop environments, where the procurement cycle and budget could be fixed, classification and prioritization of the spare parts become more vital. (Kolinska et al., 2018) provided a systematic approach of spare parts categorization by consumption frequency and criticality. This approach allows maintenance managers to make solid stocking and procurement decisions for ensuring production continuity and mitigating machine stoppage risk. Their method also involves using the Analytic Hierarchy Process (AHP) to objectively determine spare parts criticality and providing a more structured alternative for judgment subjectivity. Both of these studies point out that spare parts availability is not merely concerned with inventory levels but the result of coordinated efforts in forecasting, supply chain integration, and strategic stocking.

3.12 Use of Poor Spare Parts Quality on Maintenance Management

Spare parts quality directly affects machine reliability, maintenance effectiveness, and Overall Equipment Effectiveness (OEE). Low quality spare parts in workshops will lead to a decrease in machine uptime, an increase in maintenance requirements, and impairment of learning and research (Driessen et al., 2015). (Driessen et al., 2015) note that poorly specified or non-conformant parts may prematurely fail, cause further equipment damage, and incur higher costs. They emphasize the need for technical specifications such as form, fit, and function in maintaining compatibility and performance. Components beyond normal shelf life or installed without inspection can cause additional wear and decreased system reliability. These problems, often caused by budget limitations or time-critical replacements, then lower OEE and raise unforeseen downtime. (Kolinska et al., 2018) highlight taking lead times, stocks, and supplier reliability into account when purchasing. Tools such as the Analytic Hierarchy Process (AHP) are utilized to prioritize high-usage and high-criticality components to minimize the risk of using low-quality parts.

4. Conclusion and Recommendations

4.1 Conclusion

The review highlights that the performance of workshop machinery and the achievement of high Overall Equipment Effectiveness (OEE) are deeply rooted in the effectiveness of maintenance management practices. Ten interconnected factors ranging from financial and human resource considerations to environmental and technical influences have been identified as central to this dynamic. Among the most critical are sufficient fund allocation, skilled maintenance personnel, proactive planning, and timely intervention. The findings emphasize the need for a systematic shift toward preventive and data-driven maintenance strategies supported by modern tools such as CMMS. Additionally, leadership involvement, organizational alignment, and user accountability are necessary for sustaining long-term maintenance efficiency. By addressing these factors, institutions can reduce downtime, enhance operational reliability, and ultimately improve the learning experience within workshop environments.

4.2 Recommendations

To strengthen maintenance management and enhance OEE in academic workshop machinery, the following recommendations are proposed:

1. **Adopt Preventive and Predictive Maintenance**: Shift from reactive approaches to scheduled and condition-based maintenance to reduce breakdowns and extend equipment life.
2. **Allocate Adequate Financial Resources**: Prioritize consistent budget planning for maintenance activities, including spare parts, training, and upgrades.
3. **Train and Upskill Maintenance Personnel**: Conduct regular training for technicians and users to ensure maintenance effectiveness and minimize human error.
4. **Implement CMMS and Digital Tools**: Use Computerized Maintenance Management Systems to track, plan, and analyze maintenance activities for improved decision-making.
5. **Strengthen Maintenance Policies and Planning**: Establish clear maintenance protocols, inspection schedules, and strategic frameworks that support reliability and performance goals.
6. **Consider Environmental and Equipment Design Factors**: Address local environmental impacts and invest in maintainable, user-friendly machinery.
7. **Foster Strong Management Commitment**: Encourage leadership engagement in maintenance planning, budgeting, and performance monitoring.
8. **Promote Responsible Equipment Usage**: Implement user training programs and enforce guidelines to prevent misuse and reduce unnecessary wear.

By adopting these recommendations, institutions can develop more sustainable maintenance systems that not only enhance OEE but also contribute to better academic outcomes and operational efficiency.

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