

Optimizing Preventive Maintenance to Improve Operational Efficiency and Reduce Maintenance Costs - Review Article

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ABSTRACT

The Total Productive Maintenance (TPM) approach is one of the main operational strategies to improve production efficiency and reduce maintenance costs. This article reviews the important role of TPM components, especially the Planned Maintenance System (PMS) and Computerized Maintenance Management System (CMMS), in supporting operational performance. The implementation of these systems involves structured data collection and systematic analysis to improve predictive and preventive maintenance. This article also highlights the success factors and obstacles to implementing TPM, PMS, and CMMS, including management commitment, employee training, technology integration, and challenges such as resistance to change and system complexity. The review results show that cross-functional collaboration, a continuous improvement mindset, and the use of advanced technology are the keys to success in optimizing equipment maintenance, reducing downtime, and increasing operational efficiency and cost effectiveness. Across reviewed studies, operational efficiency increased by 12–35% and maintenance costs decreased by 10–30% after adopting TPM, PMS, or CMMS. These findings emphasize the critical role of digital integration and proactive culture in maintenance optimization.

KEYWORDS: *Total productive maintenance (TPM), Planned Maintenance system (PMS), Computerized Maintenance Management System (CMMS).*

1. INTRODUCTION

Total Productive Maintenance is a system used to maintain and improve production quality through maintenance of work equipment such as machines, tools, and work tools. The main focus of TPM is to ensure that all equipment and supplies are in the best condition so as to avoid damage or delays in the

production process. This is a company strategy so that the machines and equipment used are always in efficient and effective conditions so that it will reduce the impact of failure in the production process so that it can reduce operational costs in the Company [1]. Total Productive Maintenance approach is one of the effective operational strategies to reduce production losses caused by equipment failure and various other types of downtime [2].

TPM fundamental activities are also referred to as TPM pillars or components. TPM is formed based on eight pillars. TPM provides a way to improve planning, coordination, monitoring, and control of activities with a unique eight-pillar approach. The core TPM approach is classified into eight pillars or TPM actions to achieve improved production performance, which include: autonomous maintenance, focused maintenance, planned maintenance, quality maintenance, education and training, office TPM, development management, and safety, health, and environment [3].

Planned maintenance, which is one of the main pillars of Total Productive Maintenance (TPM), plays a vital role in supporting an integrated approach to improving production performance. Planned maintenance is a pre-designed maintenance process, including control and recording carried out according to a predetermined schedule. The historical data required for machines or equipment includes various documents such as maintenance request reports, inspection reports, repair reports, and other related documents [4].

CMMS, or Computerized Maintenance Management System, is a software solution designed to streamline the maintenance process while improving the management of an organization's assets. It enables maintenance managers to efficiently schedule, track, and analyze the entire workflow, from work order management, inventory, maintenance tasks, to budget management. By utilizing CMMS, organizations can reduce downtime, extend the life of systems, machinery, and equipment, optimize the use of labor resources, and overall improve the effectiveness of maintenance operations [5].

OEE (Overall Equipment Effectiveness) is a comprehensive indicator used to measure the level of productivity and performance of machines or equipment theoretically. This measurement plays an important role in identifying areas that require increased productivity or efficiency, while also helping to reveal obstacles or bottlenecks in the production line. In addition, OEE serves as an evaluation

tool to determine effective strategies in ensuring increased use of machines or equipment [6].

While many studies have explored TPM or CMMS separately, limited reviews integrate their comparative effectiveness in enhancing efficiency and reducing costs across different industries. This paper aims to synthesize empirical findings to compare the effectiveness of TPM, PMS, and CMMS in improving operational performance and reducing maintenance costs.

2. METHOD

2.1 Research Flowchart

This research was implemented in several steps as shown in the research flowchart in Figure 1. This flow chart presents a systematic approach to analyzing Total Productive Maintenance (TPM) and its integration with Computerized Maintenance Management System (CMMS).

2.2 Research steps

The research began by searching for articles related to the method of using Total Productive Maintenance (TPM) and its derivatives from the TPM pillars, namely Planned maintenance which is collaborated using the Computerized Maintenance Management System (CMMS). Furthermore, a review of the article was conducted, so that conclusions can be drawn about the method used.

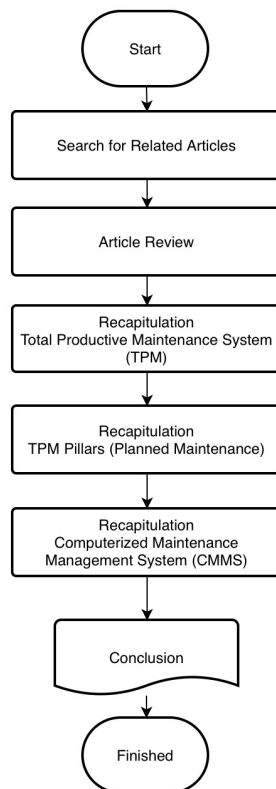


Figure 1: Research flow diagram

2.3 Review Reference Articles

Reference articles reviewed from 41 national and

international journal articles regarding the application of Total Productive Maintenance (TPM) in an industrial context. The literature selection covered journal articles and conference papers indexed in Scopus and Google Scholar between 2010 and 2024. Keywords included 'TPM,' 'CMMS,' 'preventive maintenance,' and 'OEE.' A total of 30 studies were screened, and 10 with quantitative performance results were included in the final synthesis

3. DISCUSSION

3.1 Total Productive Maintenance

3.1.1 TPM Approach

Total Productive Maintenance (TPM) has been widely adopted across industries to improve productivity and operational efficiency, demonstrating significant benefits in performance metrics such as Overall Equipment Effectiveness (OEE) and reduced downtime [1], [7]. TPM implementation involves systematic data recording and analysis, with a focus on key performance indicators such as failures, setup time, and run time, which are critical for benchmarking and continuous improvement [1], [7]. TPM contributes to lower operational costs, improved product quality, and smoother product delivery, ultimately leading to increased productivity [1].

Systematic analysis of various industries reveals that the application of TPM principles can effectively address the root causes of equipment failures, leading to increased equipment availability and reliability [1], [8]. Integration of training programs for operators is critical to the TPM approach, as it fosters a culture of continuous improvement and empowers employees to take ownership of equipment maintenance [1], [8]. TPM implementation requires measurable activities, with Overall Equipment Effectiveness (OEE) being a critical metric for assessing machine performance and identifying areas for improvement [1], [7].

3.1.2 Success Factors for TPM Implementation

Some factors that determine the success of TPM implementation include:

1. Management Commitment

Strong support and commitment from top management is critical to the success of TPM implementation, as it sets the tone for the entire organization and ensures that resources are allocated effectively [9].

2. Employee Engagement

Involving employees at all levels in the TPM process fosters a sense of ownership and responsibility, which is essential to sustaining improvements and achieving long-term success [10].

3. Training and Education

Providing comprehensive training programs for employees on TPM principles and practices enhances their skills and knowledge, enabling them to contribute effectively to maintenance activities [11].

4. Clear Communication

Establishing clear communication channels helps spread information about TPM goals, progress, and expectations, which is critical to aligning efforts across the organization [12].

5. Data-Driven Decision Making

Leveraging metrics such as Overall Equipment

Effectiveness (OEE) allows organizations to accurately assess the performance of their equipment. This data-driven approach helps in identifying areas for improvement and implementing targeted strategies to increase productivity [13], [14].

6. Advanced Technology Integration

The integration of digital technologies, such as IoT and big data analytics, enriches the application of TPM. These technologies provide real-time insights into equipment performance, facilitate proactive maintenance and further improve operational efficiency [13].

7. Continuous Improvement Mindset

Fostering a culture of continuous improvement is critical to sustaining the benefits of TPM. Organizations that regularly assess and improve their maintenance processes are more likely to achieve long-term success and increased productivity [13], [14].

8. Cross Functional Collaboration

Encouraging collaboration between different departments ensures that maintenance efforts are aligned with production goals. This integrated approach improves overall operational effectiveness and supports the success of TPM implementation [13], [14].

3.1.3 Factors of Failure in Implementing of TPM

Factors that cause failure in implementing TPM are:

1. Lack of Management Support

Inadequate commitment and involvement from top management can lead to inadequate resource allocation and lack of strategic direction, hampering the successful implementation of TPM initiatives [12].

2. Inadequate Training

Failure to provide comprehensive training for employees can result in a lack of understanding of TPM principles and practices, limiting their ability to engage effectively in maintenance activities [10].

3. Resistance to Change

Employees may resist adopting new maintenance practices due to fear of change or lack of understanding of the benefits of TPM, which can hinder implementation efforts [11].

4. Bad Communication

Ineffective communication regarding TPM goals and processes can lead to confusion and misalignment among employees, undermining the collaborative efforts necessary for successful implementation [15].

5. Insufficient Data Usage

Not utilizing data analytics to monitor equipment performance and maintenance activities can prevent organizations from identifying problems and making informed decisions, ultimately impacting the effectiveness of TPM [10].

6. Ignoring Continuous Improvement

Lack of focus on continuous improvement can result in stagnation, where organizations fail to adapt and improve their maintenance processes over time, leading to diminishing returns on TPM efforts [16].

7. Fragmented Approach

Implementing TPM in isolation without integrating it into the broader organizational strategy can result in disjointed efforts that are not aligned with overall business objectives, reducing the effectiveness of the program [17].

3.2 Planned Maintenance System (PMS)

3.2.1 Planned Maintenance System (PMS) Approach

Planned Maintenance System (PMS) is a structured approach designed to ensure the reliability and efficiency of machinery and equipment, thus playing a vital role in minimizing downtime and optimizing operational performance across a range of industries. However, despite its significance, PMS implementations are often not executed effectively, leaving many organizations struggling to fully realize its benefits and ending up with suboptimal maintenance practices. One of the most important aspects of PMS is understanding the implementation procedures, including identifying key issues associated with the system and utilizing the instruction manual to improve maintenance practices and adherence to established protocols [18].

PMS typically includes planned maintenance and corrective maintenance, enabling organizations to develop effective strategies that align with their operational goals and improve overall productivity [16], [19]. Successful implementation of PMS not only leads to increased equipment reliability but also results in reduced operational costs, demonstrating its importance in achieving organizational success [19], [20].

3.2.2 Success Factors for Implementing of PMS

Several factors that determine the success of implementing a planned maintenance system [18]:

1. Setting Clear Goals

Defining specific objectives for the Planned Maintenance System (PMS) is critical to guiding maintenance efforts and ensuring they align with the overall organizational strategy. This clarity helps in evaluating success and identifying areas for improvement.

2. Training and Development

Providing adequate training to maintenance personnel improves their skills and understanding of PMS procedures. This investment in human resources is critical to effective implementation and operational efficiency.

3. Ensuring Spare Parts Availability

Timely availability of spare parts is critical to minimizing downtime during maintenance activities. Lack of required components can significantly hamper the effectiveness of the PMS.

4. Routine Monitoring and Evaluation

Continuous assessment of the PMS through metrics such as Overall Equipment Effectiveness (OEE) helps organizations identify weaknesses and make necessary adjustments to improve performance.

5. Management Support

Strong commitment and support from management is critical to the success of a PMS implementation. This includes providing resources and cultivating a culture that prioritizes maintenance as a key operational component.

6. Integration with Other Systems

Integrating a Production Management System (PMS) with other operational systems, like production planning and inventory management, significantly enhances overall efficiency. This integration ensures that all necessary maintenance activities are precisely synchronized with current production schedules, minimizing costly downtime. Consequently, this interconnected approach leads to optimized resource utilization and a more reliable

manufacturing flow.

3.2.3 Benefits of implementing of a PMS

The benefits of implementing a planned maintenance system include:

1. Reduction of Downtime

Implementing a planned maintenance system significantly reduces equipment downtime, leading to increased operational efficiency. Studies show that organizations can achieve up to a 50% reduction in downtime through effective maintenance practices [13], [21].

2. Enhanced Equipment Reliability

A structured maintenance approach improves machine reliability, ensuring that equipment operates smoothly and consistently. This reliability is critical to maintaining production schedules and meeting customer demand [21].

3. Cost Savings

By preventing unexpected breakdowns and extending the life of equipment, planned maintenance systems contribute to substantial cost savings. Organizations can minimize repair costs and reduce the financial impact of production downtime due to equipment failure [13].

4. Increased Productivity

With reduced downtime and increased equipment reliability, overall productivity in the manufacturing process increases. This increased productivity can lead to higher output and better resource utilization [21].

5. Employee Engagement and Training

Implementing a planned maintenance system often involves employee training, which not only improves their skills but also fosters a sense of ownership and responsibility for equipment maintenance [13], [21].

6. Supportive Organizational Culture

A successful planned maintenance system promotes a culture that values proactive maintenance and continuous improvement. This cultural shift encourages employees to communicate openly about maintenance issues, leading to faster resolution and more efficient operations [21].

3.3 Computerized Maintenance Management System (CMMS)

3.3.1 CMMS Implementation Approach

Implementing a Computerized Maintenance Management System (CMMS) is essential to improving operational efficiency across a variety of industries, including manufacturing, healthcare, and transportation. These systems help manage maintenance schedules and reduce equipment failure rates, ultimately leading to cost savings and increased productivity [22]. A significant factor influencing CMMS success is data quality and availability. Research shows that organizations that prioritize data management experience better outcomes in their CMMS applications, highlighting the need for continuous improvement in data quality [23], [24]. The adaptability of a CMMS to align with the company's work culture is critical to a successful implementation. Many organizations modify CMMS features to better suit their operational needs, which can lead to increased user engagement and system effectiveness [22], [25].

Reports generated by CMMS play a vital role in the decision-making process. The ability to generate reliable and customizable reports enables maintenance teams to track performance indicators, failure history, and material

consumption, which are critical to optimizing maintenance strategies [26]. Integrating CMMS into a Total Productive Maintenance (TPM) framework fosters a culture of continuous improvement. This approach not only improves maintenance practices but also supports overall organizational goals by promoting proactive maintenance strategies [24], [25]. Challenges in CMMS implementation often arise from the complexity of the software and the need for user training. Organizations that invest in training and support for their employees tend to see greater success in effectively utilizing a CMMS [22], [27].

3.3.2 Benefits of CMMS

CMMS improves operational efficiency across industries, from small businesses to large enterprises, by streamlining maintenance management processes and increasing overall productivity [28]. This software automates various logistics functions related to maintenance, which helps reduce manual errors and saves time for maintenance teams, allowing them to focus on critical tasks [22]. By facilitating better management of maintenance operations, CMMS contributes to cost savings by minimizing equipment downtime and extending asset life [26].

CMMS applications often include features for user grouping and access management, which enhances security and ensures that users can only access information relevant to their roles [29]. CMMS implementation supports condition-based monitoring (CBM) of machines, providing insight into wear and potential failures, which aids in proactive maintenance strategies [25]. CMMS can be customized to fit the specific needs and culture of an organization, which increases user engagement and the likelihood of a successful implementation [23]. The implementation of CMMS in healthcare settings, such as hospitals, ensures the availability of critical medical equipment, thereby improving patient safety and operational reliability [26].

3.3.3 CMMS implementation constraints

In the implementation of a CMMS, various interrelated constraints may arise that collectively affect the success of the system's deployment, including:

1. Software Complexity

Many CMMS applications are complex and may not be aligned with an organization's specific operational needs, leading to challenges during implementation and user adaptation [23], [30].

2. User Training Requirements

Effective use of a CMMS often requires comprehensive training for users. Without proper training, employees may struggle to utilize the system effectively, which can hinder the overall benefits of the software [23], [30].

3. Customization Challenge

While customization is essential to aligning a CMMS with a company's culture, it can also lead to implementation difficulties. Organizations may face challenges in modifying the software to meet their specific requirements without incurring high costs [22], [30].

4. Resistance to Change

Employees may resist adopting new technologies, including CMMS, due to comfort with existing processes. This resistance can hinder the successful integration of the system into day-to-day operations [22], [28].

5. Integration with Existing Systems

Integrating a CMMS with other existing systems (such as ERP) can be complicated, leading to potential data silos and inefficiencies if not managed properly [23], [30].

6. Implementation Costs

The initial investment and ongoing costs associated with a CMMS can be significant, especially for smaller organizations, which may deter them from adopting the

system [22], [30].

3.3.4 CMMS Implementation Approach to Operational Efficiency and Maintenance Costs

The CMMS implementation approach is detailed in Table 1, focusing on a phased rollout that includes system configuration, data migration, and comprehensive user training.

Table 1: CMMS implementation approach for operational efficiency and maintenance costs

No	Writer	Research Object	Maintenance costs	Operational Efficiency
1	Chairiyah W. et al (2019) [31]	Agroindustry	CMMS supports preventive maintenance to avoid corrective maintenance costs, streamline parts procurement, and reduce delays. With detailed analytics, CMMS improves inventory control and minimizes waste.	CMMS facilitates preventive maintenance scheduling, reduces downtime, and improves machine performance. It also improves spare parts management and provides a centralized database for maintenance records, facilitating tracking and decision making.
2	Witonohadi A, Timothy I (2011) [28]	Manufacturing Industry	CMMS facilitates efficient maintenance scheduling, reducing downtime and costly breakdowns. By automating work orders, the system improves accuracy, lowers labor costs, and supports predictive maintenance to extend equipment life.	CMMS automates maintenance scheduling, reducing machine breakdowns and production disruptions. With equipment data integration, the system accelerates maintenance and supports Total Productive Maintenance (TPM) to optimize performance and improve Overall Equipment Effectiveness (OEE).
3	Abimbola O. et al (2013) [32]	Manufacturing Industry	CMMS organizes maintenance records, reducing the risk of lost work orders and delays. With efficient equipment tracking, the system enables timely maintenance, prevents equipment failures, and reduces repair costs and production downtime.	CMMS monitors work cycles to ensure timely maintenance and reduce downtime. The system streamlines work order management, reduces paperwork, and shifts from corrective to preventive maintenance, extending equipment life and improving safety and quality.
4	Meira D. et al (2020) [24]	Technology Industry	CMMS implementations reduce costs across industries, increasing maintenance productivity from 35% to 70-80%, and reducing inventory costs by 5-12%. A textile company reported reduced spare part costs and increased equipment availability in seven months, with an ROI of 0.46 years. CMMS supports efficient and cost-effective maintenance management.	CMMS enables real-time monitoring of maintenance activities, improving planning and scheduling, and productivity. Studies show that industries using CMMS experience a 35 to 80% increase in maintenance productivity and a 5 to 12% reduction in inventory costs.
5	H Mohd Noor. et al (2009) [33]	Technology Industry	CMMS leverages real-time data and predictive maintenance to minimize equipment failures, reducing downtime and costs. It improves decision-making, resource allocation efficiency, and inventory control, reducing spending on unnecessary parts.	The system supports preventive and predictive maintenance, allowing organizations to anticipate problems before they develop, thereby minimizing failures. With real-time data and analytics, CMMS facilitates informed decision-making, optimizes resource allocation, and reduces operational costs.
6	Mobin M. et al [34]	Manufacturing Industry	CMMS improves decision making and reduces maintenance costs. Historical data helps select efficient policies, minimizes production losses and damages, and increases equipment life and reduces failures.	CMMS implementation improves operational efficiency with real-time access to maintenance data, supporting decision-making. CMMS enables Condition Based Maintenance (CBM) for timely intervention, minimizing machine breakdowns and downtime, and accelerating communication between operations and maintenance teams.
7	Bjorling S. et al (2013) [35]	Maintenance management	CMMS enables automatic work order creation and historical data analysis, helping to optimize maintenance schedules and reduce unnecessary repairs. This increases efficiency, lowers costs, and increases equipment uptime. Its effectiveness depends on the knowledge and experience of the maintenance staff.	CMMS facilitates automatic creation of preventive maintenance work orders and provides historical data to reduce unnecessary repairs. It optimizes equipment uptime, lowers maintenance costs, and improves plant efficiency by integrating inventory tracking and labor management.
8	Rodrigues R. et al (2023) [36]	Maintenance management	CMMS reduces the cost of unexpected interventions through better planning. Preventive maintenance software minimizes the cost of hiring specialists, while improved maintenance actions result in substantial cost reductions.	CMMS improves maintenance planning and decision-making by integrating technology. KPIs monitor maintenance performance, and software can be customized to meet institutional needs. Technologies such as IoT also improve operational efficiency.

No	Writer	Research Object	Maintenance costs	Operational Efficiency
9	Stazić L. et al (2023) [27]	Shipping industry	CMMS improves data quality and maintenance efficiency, leading to cost savings. Improved database evaluation provides significant financial benefits, over 60% of databases being upgraded.	CMMS improves the organization of maintenance tasks and planning. It improves data quality, positively impacting operational efficiency.
10	Shankar L. et al.(2024) [37]	Manufacturing Industry	CMMS optimizes maintenance, reduces costs and downtime, and lowers operating expenses. Asset management extends equipment life, and predictive analytics prevents failures, while streamlined workflows increase efficiency and reduce expenses.	CMMS streamlines work order management and efficiency, improves preventive maintenance scheduling, and reduces downtime. It provides real-time asset monitoring and reporting for continuous improvement, and optimizes inventory management to prevent stockouts.
11	Shagluf A,etal (2014) [38]	Maintenance management	CMMS optimizes maintenance management and reduces operational costs. It improves asset lifecycle, prevents data duplication, and saves time and resources. Efficient work order management also reduces delays and costs.	CMMS improves maintenance management efficiency with real-time data access. Integration of technologies such as Augmented Reality and Expert Systems reduces intervention time and errors, and facilitates communication between maintenance systems.
12	Sukmana F, Rozi F(2024) [23]	Manufacturing Industry	CMMS manages maintenance costs by reducing downtime and lowering maintenance costs. Efficient asset management generates savings, and cost prediction prevents overspending. Implementation failures can increase costs, requiring careful planning.	CMMS improves asset monitoring and identifies stages that need improvement. Inefficiencies occur when design time is less than twice the workload. Focus on data analysis and module implementation is important, while future research can explore inefficiency factors.
13	Almomani Het all (2021) [39]	Construction Industry	CMMS significantly minimizes repair costs. Reduces downtime and number of failures. Increases resource availability for efficient operations. Reduces costs associated with equipment failures.	CMMS reduces MTTR and increases MTBF, minimizing downtime and failures. It improves resource availability, efficiency, and accountability with real-time information, and simplifies work priorities for effective scheduling.
14	ES Amorim. et all (2024) [40]	Construction Industry	CMMS enables efficient access to service costs and material records, as well as real-time maintenance monitoring. This improves planning and control, resulting in productivity and cost reduction.	CMMS simplifies building maintenance, improves asset management, reduces downtime, and extends equipment life. It also improves scheduling and tracking, and integrates with IoT and smart sensors for better management.
15	Wienker M. et all (2016) [41]	Industry	A properly implemented CMMS reduces direct maintenance costs by 5-10%. Significant improvements in inventory planning and control drive cost reductions. The ROI for a CMMS is often less than one year.	CMMS improves workforce planning, inventory control, and reduces direct maintenance costs by 5-10% in three years. It also provides a cross-department communication platform and turns data into insights for performance analysis.
16	Luca F. et all (2009) [33]	Industry	CMMS reduces resource consumption and maintenance time, increases efficiency, and indirectly lowers operational and maintenance costs.	CMMS improves maintenance efficiency by transforming data into actionable information and prioritizing actions for better decisions, especially in complex maintenance systems.

This systematic process is designed to streamline maintenance workflows and improve asset reliability, directly contributing to enhanced operational efficiency and a significant reduction in overall maintenance costs. The success hinges on accurate data input and high user adoption achieved through the dedicated training phase.

3.4 Trends in Efficiency Improvement and Cost Reduction

To enhance the validity of the literature review and visualize the performance trends, quantitative data from ten reviewed studies were compiled and analyzed. These data reflect the impact of implementing Total Productive Maintenance (TPM), Planned Maintenance System (PMS), and Computerized Maintenance Management System (CMMS) on both operational efficiency and maintenance cost reduction. The summarized findings show consistent improvements in equipment reliability and measurable reductions in maintenance expenses across manufacturing, energy, and

service sectors. Table 2 presents the compiled results.

The CMMS yields the highest improvement trends, primarily due to its integration of real-time monitoring and predictive analytics. Summary of efficiency improvement and maintenance cost reduction trends from reviewed articles (2010–2024) depicted in Table 3. The PMS, which emphasizes-

Table 3: Summary of efficiency improvement and maintenance cost reduction trends from reviewed articles (2010–2024)

System	Average Efficiency Improvement (%)	Average Cost Reduction (%)	Year Range
TPM	12–25%	10–18%	2010–2022
PMS	15–28%	12–20%	2012–2023
CMMS	20–35%	15–30%	2014–2024

structured planning and preventive scheduling, demonstrates steady benefits in reducing downtime and optimizing labor utilization. TPM continues to play a foundational role in cultivating proactive maintenance culture and operator ownership, which are critical for sustainable system improvement.

The comparative trends shown in Figure 2 demonstrate a clear relationship between the adoption of modern maintenance frameworks such as Total Productive Maintenance (TPM), Preventive Maintenance Scheduling (PMS), and Computerized Maintenance Management Systems (CMMS), and improvements in operational efficiency and cost management. Across all three frameworks, the data consistently illustrates an upward trend in average efficiency improvement, suggesting that by moving away from reactive maintenance, organizations achieve better asset reliability, reduced downtime, and higher overall equipment effectiveness. This efficiency gain is a primary driver of operational success.

Conversely, the Figure 2 also highlights a compelling and desired downward trend in average maintenance costs following the implementation of these frameworks. This cost reduction is achieved through several factors: minimizing unexpected, high-cost emergency repairs; optimizing labor deployment through planned scheduling; extending the useful life of assets; and better inventory management of spare parts enabled by systems like CMMS. The combined effect of these two trends can rise efficiency and falling costs, underscores the significant return on investment (ROI) associated with adopting structured and proactive maintenance strategies like TPM, PMS, and CMMS.

Comparative Trend of Average Efficiency Improvement and Cost Reduction (TPM, PMS, CMMS)

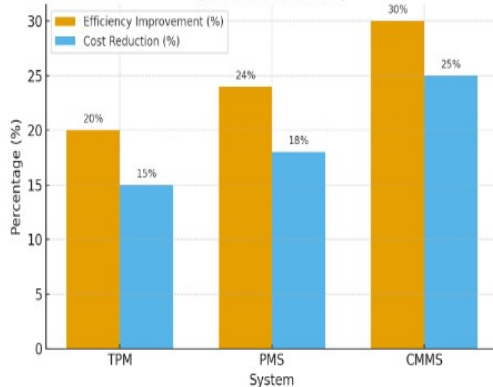


Figure 4: Comparative trend of average efficiency improvement and cost reduction (TPM, PMS, CMMS)

4.0 CONCLUSION

The implementation of Total Productive Maintenance (TPM) through Planned Maintenance System (PMS) and Computerized Maintenance Management System (CMMS) has proven effective in improving operational efficiency and reducing maintenance costs. Based on the compiled data from the reviewed studies, TPM, PMS, and CMMS have shown consistent trends of increasing operational efficiency and

reducing maintenance costs, with CMMS delivering the highest measurable impact due to its digital integration and predictive capability. The success of the implementation depends on several key factors, such as management support, employee training, clear communication, and data-driven decision making. The use of advanced technologies, such as IoT and data analytics, also enriches the maintenance strategy by providing real-time insights that support a proactive approach. However, obstacles such as resistance to change, inadequate training, and implementation costs are challenges that must be overcome. By integrating these systems into the broader organizational strategy and adopting a culture of continuous improvement, companies can achieve higher efficiency, increase productivity, and reduce the risk of equipment failure. Based on the result above, managers should prioritize integrating PMS and CMMS to achieve predictive maintenance maturity. Future research could examine how AI-based monitoring enhances TPM frameworks in Industry 4.0 environments.

REFERENCES

- [1] Setiawan, L. (2021). Literature review of the implementation of total productive maintenance (TPM) in various industries in Indonesia. *IJIEM: Indonesian Journal of Industrial Engineering & Management*, 2, 16–34.
- [2] San, S. (2021). A systematic literature review of total productive maintenance on industries. *Performance: Industrial Engineering Scientific Media*, 20(2), 97. <https://doi.org/10.20961/performa.20.2.50087>
- [3] Ngoy, K. R., & Israel, K. (2021). The strategy of successful total productive maintenance (TPM): Implementation and benefits of TPM (literature review). *International Journal of Innovation Research in Engineering, Multidisciplinary, and Physical Sciences*, 9, 43-52.
- [4] Duffuaa, S. O., & Al-Shayea, M. M. (2020, July). Systematic and effective maintenance capacity planning. In *2020 Industrial & Systems Engineering Conference (ISEC)* (pp. 1-4). IEEE.
- [5] Amorim, E., Silva, E., & Lordsleem, A., Jr. (2024). Current overview of CMMS operability: Brazilian scenario. *International Journal of Business Administration*, 14(4), 66. <https://doi.org/10.5430/ijba.v14n4p66>.
- [6] Sianturi, G., & Alatas, H. (2019). Analisis Efektivitas Mesin Injection Molding Di Bagian Produksi Pt. Dian Megah Indo Perkasa Menggunakan Metode Overall Equipment Effectiveness Dan Fault Tree Analysis. *Inaque: Journal of Industrial and Quality Engineering*, 7(2), 127-136.
- [7] Mutaqiem, A., & Soediantono, D. (2022). Literature review of total productive maintenance (TPM) and recommendations for application in the defense industry. *Journal of Industrial Engineering & Management Research*, 3(2), 48-60.
- [8] Muhaemin, G., & Nugraha, A. E. (2022). Implementation of total productive maintenance (TPM) in cutter machine maintenance at PT. XYZ. *Scientific Journal of Educational Vehicle*, 8(9), 205–219.

- <https://doi.org/10.5281/zenodo.6645451>.
- [9] Krisnaningsih, E. (2015). Proposal for implementing TPM to improve machine effectiveness with OEE as a measurement tool at PT XYZ. *PROSISKO Journal*, 2(2).
- [10] Gianfranco, J., Taufik, M. I., Hariadi, F., & Fauzi, M. (2022). Measurement of total productive maintenance (TPM) using overall equipment effectiveness (OEE) on production reactor machines. *Lingkar Biru*, 3(1). <https://doi.org/10.46306/lb.v3i1>.
- [11] Hidayat, D. F., Hardono, J., & Wijaya, W. A. (2020). Total productive maintenance (TPM) analysis using overall equipment effectiveness (OEE) on a CNC milling machine. <http://jurnal.umt.ac.id/index.php/jt/index>.
- [12] Diniaty, D., & Susanto, R. (2017). Analisis Total Produktive Maintenance (Tpm) Pada Stasiun Kernel Dengan Menggunakan Metode Overall Equipment Effectiveness (Oee) Di Pt. Surya Agrolika Reksa. *Jurnal Teknik Industri*, 3(2), 60-64.
- [13] Karim, M. R. (2025). Optimizing Maintenance Strategies in Smart Manufacturing: A Systematic Review Of Lean Practices, Total Productive Maintenance (TPM), And Digital Reliability. *Review of Applied Science and Technology*, 4(02), 176-206.
- [14] Nurdin, F. F. (2023). Peningkatan Produktivitas Peralatan dan Perawatan Mesin Total Productive Maintenance (TPM) menggunakan metode Overall Equipment Effectiveness (OEE). *Prosiding Sains dan Teknologi*, 2(1), 388-399.
- [15] Zaenal Arifin, S. T. (2020). Implementasi Overall Equipment Effectiveness (OEE) Dalam Penerapan Metode Total Productive Maintenance (TPM) di PT. FJT. *PROFISIENSI: Jurnal Program Studi Teknik Industri*, 8(1), 55-63.
- [16] Idrus Taba, M., & Hakim, H. (2022). The effect of total productive maintenance (TPM) and lean manufacturing (LM) maintenance systems on overall equipment effectiveness (OEE) (Case study at PT. Semen Tonasa). *SEIKO: Journal of Management & Business*, 5(1), 2022-393. <https://doi.org/10.37531/sejaman.v5i2.2039>.
- [17] Prabowo, R. F., Hariyono, H., & Rimawan, E. (2020). Total Productive Maintenance (TPM) pada perawatan mesin grinding menggunakan metode overall equipment effectiveness (OEE). *Journal Industrial Servics*, 5(2), 207-212.
- [18] Heri Londong Allo, H. L. A. (2022). *Efektifitas Planned Maintenance System (PMS) Mesin Induk Mv. Ace Oscar* (Final Project, Politeknik Ilmu Pelayaran Makassar).
- [19] Prabowo, R., & Sulistyowati, E. (2020, July). Analysis of Total Productive Maintenance (TPM) and Failure Mode and Effect Analysis (FMEA) to improve machine effectiveness: A study on Indonesia's sugar mills. In *IOP Conference Series: Materials Science and Engineering* (Vol. 885, No. 1, p. 012063). IOP Publishing.
- [20] Majid, A. M., Moengin, P., & Witonohadi, A. (2014). Usulan penerapan total productive maintenance (tpm) dengan pengukuran overall equipment effectiveness (oeo) untuk perencanaan perawatan pabrik bar mill pada PT. Krakatau Wajatama. *Jurnal Teknik Industri*, 4(3).
- [21] Nursubiyantoro, E., & Rozaq, M. I. (2016). Implementation of total productive maintenance (TPM) in the application of overall equipment effectiveness (OEE). *Jurnal OPSI*, 9(1).
- [22] Gunathilaka, N. V., Tennakoon, W., & Lasanthika, W. (2021). Factors affecting the success of computerized maintenance management system in multinational beer companies. <https://www.sab.ac.lk/sujcs/>.
- [23] Sukmana, F., & Rozi, F. (2024). Efficiency of CMMS project stages with K-means. *JIPi: Scientific Journal of Informatics Research and Learning*, 9(1), 424-437. <https://doi.org/10.29100/jipi.v9i1.5453>.
- [24] Meira, D., Lopes, I., & Pires, C. (2020). Selection of computerized maintenance management systems using AHP. *Procedia Manufacturing*, 1573-1580. <https://doi.org/10.1016/j.promfg.2020.10.219>.
- [25] Labib, A. W. (2004). A decision analysis model for maintenance policy selection using a CMMS. *Journal of Quality in Maintenance Engineering*, 10(3), 191-202. <https://doi.org/10.1108/13552510410553244>.
- [26] Febrihartina, S. S., Sholihah, W., & Irawan, B. (2019). Pembuatan Modul User Dan Master Data Pada Aplikasi CMMS Berbasis Web di PT Bit Maker Automation. *Jurnal Sains Terapan: Wahana Informasi dan Alih Teknologi Pertanian*, 9(1), 1-16.
- [27] Stazić, L., Račić, N., Stanivuk, T., & Dobrota, Đ. (2023). Determination of benefits of the application of CMMS database improvement proposals. *Applied Sciences*, 13(4). <https://doi.org/10.3390/app13042731>.
- [28] Witonohadi, A., & Timothy, I. (2011). Usulan Perbaikan Sistem Perawatan Mesin dengan Pendekatan Computerized Maintenance Management System (CMMS) di PT. NTP. *Teknik dan Manajemen Industri*, 6(2), 80-86.
- [29] Azahar, N. F. (2017). *Study of Technology Acceptance of Computerized Maintenance Management Systems (CMMS) as a Tool for Measuring Contractor's Performance: A Case Study of Public Work Department, Putrajaya* (Master's thesis, University of Malaya (Malaysia)).
- [30] Mansouri, Z., Sarir, H., & Mahboub, O. (2019, October). MCDM-Review of Decision Making Modules Integration in CMMS. In *Proceedings of the 4th International Conference on Big Data and Internet of Things* (pp. 1-4).
- [31] Chairiyah, W., Syakhroni, A. S., Sukendar, I. S., & Raya Kaligawe, J. K. (2019). *Design of machine maintenance information system with CMMS approach (Case study of PT. PMKS-BPJ)*. Proceedings of UNISSULA Students' Scientific Conference (KIMU) 2.
- [32] Aniki, A.O., Akinlabi, E.T. (2013). Implementation of CMMS Software for a Maintenance Plan in a Manufacturing Industry. *International Journal of Mechanical, Industrial Science and Engineering*, 7, 85-88.
- [33] Fumagalli, L., Macchi, M., & Rapaccini, M. (2009). Computerized maintenance management systems in SMEs: A survey in Italy and remarks for the implementation of condition-based maintenance. *IFAC-PapersOnline*, 1615-1619. <https://doi.org/10.3182/20090603-3-RU-2001.0416>.
- [34] Mobin, M. Maintenance Decision Making, Supported By Computerized Maintenance Management System. *Organization*, 6, 193.
- [35] Björling, S.-E., Galar, D., Baglee, D., Singh, S., & Kumar, U. (2013). *Maintenance knowledge management with fusion of CMMS and CM*.

- [36] Rodrigues, R. C., Sousa, H., & Gondim, I. A. (2023). SMARTS-based decision support model for CMMS selection in integrated building maintenance management. *Buildings*, 13(10). <https://doi.org/10.3390/buildings13102521>.
- [37] Shankar, L., Singh, C. D., & Singh, R. (2024). AI and CMMS: A powerful duo for enhanced maintenance in manufacturing. *Educational Administration: Theory and Practice*, 30(5), 8647–8654. <https://doi.org/10.53555/kuey.v30i5.4434>.
- [38] Shagluf, A., & Longstaff, A. P. (2014). Maintenance strategies to reduce downtime due to machine positional errors. In *Proceedings of Maintenance Performance Measurement and Management (MPMM) Conference* (pp. 111–118). https://doi.org/10.14195/978-972-8954-42-0_16.
- [39] Almomani, H., & Aldaihani, A. H. (2021). Using Computerized Maintenance Management System (CMMS) in Roads Maintenance Operations. *International Journal of Environmental Science*, 6.
- [40] Amorim, E., Silva, E., & Lordsleem, A., Jr. (2024). Current overview of CMMS operability: Brazilian scenario. *International Journal of Business Administration*, 14(4), 66. <https://doi.org/10.5430/ijba.v14n4p66>.
- [41] Wienker, M., Henderson, K., & Volkerts, J. (2016). The computerized maintenance management system: An essential tool for world-class maintenance. *Procedia Engineering*, 413–420. <https://doi.org/10.1016/j.proeng.2016.02.100>.