HEURISTIC
Vol. 23, No. 1, April 2026
ISSN(p) 1693-8232
ISSN(e) 2723-1585

MTTR, MTBF, and OEE Analysis of a Blown Film Extrusion Machine for Preventive Maintenance Optimization

Elisabet Priska Arkadewi Kononis[1], Desrina Yusi Irawati[2*], David Andrian[3]
[1,2,3]Industrial Engineering Department, Faculty of Engineering, Universitas Katolik Darma Cendika

***Corresponding Author**: desrina.yusi@gmail.com

Article history:
Received: 14 February 2026
Accepted: 2 April 2026
Published: 30 April 2026

Keywords:
MTBF;
MTTR;
OEE;
Preventive Maintenance;
Blown Film Extrusion Machines

ABSTRACT

Blown Film Extrusion Machines are critical equipment in the plastic manufacturing industry, where machine reliability and maintenance effectiveness significantly affect productivity and product quality. This condition was observed in a plastic manufacturing plant in Sidoarjo Regency, where maintenance activities are still predominantly reactive and lack a structured preventive maintenance system. This study aims to analyze the performance and reliability of Blown Film Extrusion Machines and to determine critical components as a basis for optimizing preventive maintenance through the integration of Overall Equipment Effectiveness (OEE), Mean Time Between Failure (MTBF), and Mean Time to Repair (MTTR). The research methodology employs a quantitative descriptive approach with an applied case study design. Data collection was conducted through direct observation of 11 Blown Film Extrusion Machines, including data on downtime, failure frequency, repair duration, operating time, and production output consisting of good and defective products. Data processing involved calculating OEE to evaluate machine effectiveness, MTBF to measure reliability, and MTTR to assess repair efficiency. Downtime analysis was also performed to identify components contributing most significantly to production stoppages. The results indicate an overall OEE value of 73%, an MTTR of 229.89 minutes, and an MTBF of 1,421.67 minutes. The PLC, chiller, and bearing were identified as the main contributors to downtime. This study concludes that low machine effectiveness is caused by frequent failures and prolonged repair times, highlighting the need to prioritize preventive maintenance on critical components to improve machine reliability and effectiveness.

INTRODUCTION

At the global level, industrial maintenance has emerged as a primary strategic concern, driven by the escalating demand for high-efficiency and zero-defect production systems. Critical component failures, specifically within heater bands, chillers, programmable logic controllers (PLCs), extruder screws, winders, and gearboxes, frequently precipitate production defects and systemic interruptions. Empirical evidence suggests that 20-30% of manufacturing defects are directly attributable to degraded

machine performance resulting from suboptimal maintenance of critical assets [1]. Conversely, the implementation of preventive maintenance has proven effective in mitigating such defects by identifying potential failures preemptively. Recent longitudinal studies in the automotive sector indicate that a robust PM strategy can reduce machine-related defects by 25% and enhance availability by over 15% within a two-year period [2]. Furthermore, research in chemical manufacturing demonstrates that PM can extend component lifespans by up to 20% while reducing unplanned downtime costs by 35%. Consequently, preventive maintenance serves as a vital framework for sustaining industrial productivity.

The blown film extrusion machine serves as pivotal equipment in the plastics industry for the production of polyethylene films, including low-density polyethylene (LDPE), linear low-density polyethylene (LLDPE), and high-density polyethylene (HDPE). The process initiates with the melting of polymer granules within the extruder, facilitated by a primary mechanical assembly comprising heater bands, chillers, PLCs, extruder screws, winders, and gearboxes. The screw mechanism homogenizes and propels the molten polymer toward the die, while the heater bands maintain precise zonal temperatures to ensure uniform melting. Furthermore, the gearbox stabilizes torque transmission from the motor to the screw, maintaining constant melt pressure throughout the cycle [3]. As the polymer exits the annular die, it forms a tube that is inflated into a bubble, subsequently cooled, flattened by nip rollers, and wound into film rolls. Screw efficiency and thermal stability are critical determinants of melt homogeneity, while the mechanical reliability of the gearbox and drive motor ensures consistent film thickness. Malfunctions in these components frequently induce defects such as gels and gauge variations. Consequently, rigorous preventive maintenance, including systematic inspections of thermal zones and mechanical drive stability, is essential to mitigate downtime and preserve film quality [4].

The plastics industry, particularly operations employing blown film extrusion technology, encounters substantial reliability challenges. Critical subsystems, including heater bands, chillers, PLCs, extruder screws, and gearboxes, are frequently subjected to premature failure due to abrasive wear, extreme thermal loading, and the absence of structured maintenance frameworks. Such failures inevitably lead to prolonged downtime and diminished Overall Equipment Effectiveness (OEE). This study investigates these phenomena within a plastic manufacturing facility in Sidoarjo Regency, East Java, Indonesia. Despite the relatively short operational age of the machinery (ten months), the facility lacks a systematic maintenance scheduling protocol, with maintenance activities being predominantly reactive rather than proactive. Currently, the plant adheres to a run-to-failure policy, where components are only addressed upon functional breakdown. This lack of preventive intervention accelerates component degradation and prevents the machinery from achieving its design-life performance stability. Consequently, the implementation of a robust preventive maintenance strategy is imperative to mitigate unscheduled interruptions and ensure that machine productivity remains consistent with technical specifications.

Preventive maintenance (PM) is defined as a systematic, pre-emptive intervention designed to uphold optimal component integrity, mitigate production disruptions, and avert escalating repair expenditures [5]. The strategic implementation of PM is paramount for extending asset longevity, enhancing machinery reliability, and ensuring consistent productivity throughout the manufacturing cycle. Conventional PM protocols typically involve rigorous maintenance scheduling, the replacement of wear-prone components, and standardized inspections to minimize the risk of stochastic downtime [6]. While PM

is fundamentally a strategic necessity, its efficacy depends on precise, data-driven execution. This necessitates a robust computational framework that moves beyond qualitative assessment. Therefore, this study proposes a holistic yet streamlined approach by integrating Overall Equipment Effectiveness (OEE), Mean Time Between Failures (MTBF), and Mean Time to Repair (MTTR) as synergistic metrics to optimize maintenance decision-making.

In maintenance management, there are three main indicators that are often used, namely OEE, MTBF, and MTTR. These calculations are performed to assess the effectiveness of equipment. OEE is an indicator that measures machine effectiveness across three dimensions: availability, performance, and quality. The advantage of OEE lies in its comprehensive representation of machine productivity, facilitating management's ability to identify any decline in effectiveness. However, OEE has limitations in specifically indicating the root cause of damage or the frequency of component failures [7]. MTBF is defined as the average time between machine or component failures, making it a primary indicator of machine reliability. A high MTBF value indicates good reliability levels and can be utilized to design more appropriate maintenance intervals. Its advantage is the ability to predict component durability, while its disadvantage is that it does not describe the specific recovery duration when a component is damaged [8]. Meanwhile, MTTR represents the average time required to repair damage until the machine returns to normal operation. This indicator is important as it assesses the efficiency of the maintenance team in responding to failures. The advantage of MTTR is that it helps companies measure and accelerate the repair process, while its weakness is that it does not provide information on failure frequency [9]. These three indicators complement each other when applied in an integrated manner. OEE provides a macro perspective on production effectiveness, MTBF emphasizes long-term reliability aspects, while MTTR highlights the speed of recovery after failure.

Despite the importance of these indicators, many manufacturing facilities still experience difficulties in systematically evaluating machine performance and determining appropriate maintenance strategies. In the observed plastic manufacturing facility, maintenance activities are predominantly reactive, and the company has not yet implemented an integrated evaluation of machine effectiveness, reliability, and repair performance. As a result, machine failures occur frequently and contribute to significant downtime, which ultimately affects production efficiency. Therefore, it is necessary to conduct a comprehensive analysis of machine performance using integrated indicators such as OEE, MTBF, and MTTR in order to identify critical maintenance problems and support the development of more effective preventive maintenance strategies.

Based on the identified problems, this study aims to analyze the performance of a blown film extrusion machine through the integration of OEE, MTBF, and MTTR calculations at a plastic manufacturing facility in Sidoarjo, Indonesia. Furthermore, this study seeks to identify machine components that significantly contribute to downtime and provide recommendations for improving preventive maintenance strategies. These efforts are expected to improve the efficiency, effectiveness, and sustainability of the production process through a more systematic evaluation of machine performance using OEE, MTBF, and MTTR indicators.

This study contributes to the existing literature by providing an integrated analysis of machine performance using OEE, MTBF, and MTTR in a blown film extrusion production system. While previous studies often evaluate these indicators separately, this research combines the three metrics to obtain a more comprehensive assessment of machine effectiveness, reliability, and repair performance. Therefore, this study not only

offers practical recommendations for improving preventive maintenance strategies in plastic manufacturing industries but also enriches the academic understanding of integrated maintenance performance evaluation.

MATERIALS AND METHODS

The overall research procedure conducted in this study is illustrated in Figure 1. The methodology begins with field observations and problem identification, followed by data collection related to production performance, downtime, and maintenance activities. The collected data are then analyzed using OEE, MTBF, and MTTR calculations to evaluate machine performance. Finally, the results of the analysis are used to identify critical machine.

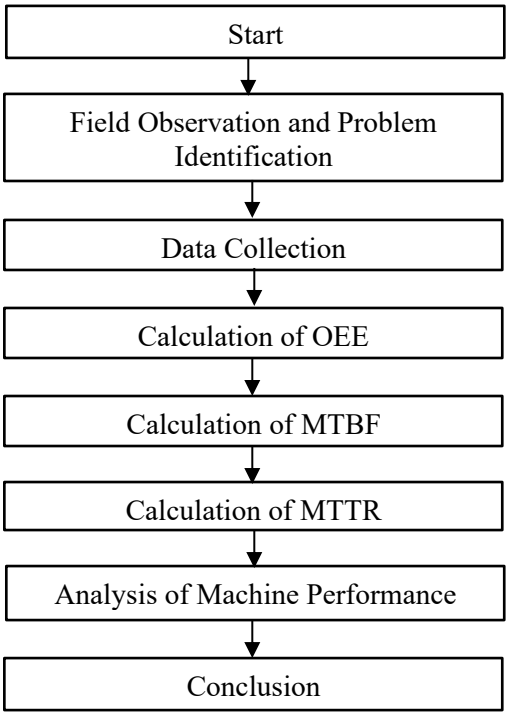


Figure 1. Research methodology for evaluating machine performance using OEE, MTBF, and MTTR

This study employed a quantitative descriptive approach because the analyzed data consisted of numerical information related to machine operational time, production output, downtime duration, and defect quantity. The research was conducted at a plastic manufacturing company located in Wonoayu District, Sidoarjo Regency, Indonesia. The object of the study consisted of eleven blown film extrusion machines operating in the production line, which were selected as the research sample because they represent the primary equipment contributing to production activities.

The research design used in this study is an applied case study focusing on evaluating machine performance and identifying maintenance problems based on actual operational data. Data collection was carried out through direct observation and documentation of machine operational activities, including machine identification, downtime date and duration, frequency of machine failures, damaged machine components, types of failures, causes of machine damage, production output, and the number of defective products.

The collected data were analyzed using the OEE method, which consists of three

main components: availability, performance, and quality. In addition, reliability indicators such as MTBF and MTTR were calculated to evaluate machine reliability and repair performance. The integration of these indicators provides a comprehensive evaluation of machine effectiveness and supports the identification of critical maintenance problems for determining appropriate preventive maintenance strategies.

Data analysis in this study was conducted using three main calculations: OEE, MTBF, and MTTR. The OEE calculation is used to determine the level of machine effectiveness through the components of availability, performance, and quality. The availability calculation formula uses Equation (1), performance uses Equation (2), and quality uses Equation (3). The overall OEE value is calculated using Equation (4).

(1) Availability = (Loading Time - Downtime) / Loading Time

(2) Performance = (Ideal Cycle Time × Total Output) / Operating Time

(3) Quality = Good Product / Total Product

(4) OEE = Availability × Performance × Quality

The analytical parameters for calculating each OEE component that can be identified as ideal or not are as follows:

1. Availability > 90%
2. Performance Efficiency > 95%
3. Quality Rate > 99%

Therefore, the ideal condition for achieving OEE is > 85%.

MTBF calculations are used to assess machine reliability based on the average time between failures. The MTBF formula is shown in Equation (5):

(5) MTBF = Total Operating Time / Number of Failures

The MTTR calculation is used to calculate the average machine repair time as shown in Equation (6):

(6) MTTR = Total Repair Time / Number of Failures.

These three indicators complement each other to determine the ideal maintenance interval, identify critical components, and determine preventive maintenance strategies. The analysis results of OEE, MTBF, and MTTR form the basis for developing more structured maintenance recommendations for heater bands, chillers, PLCs, extruder screws, winders, pumps, bearings, dies, motors, air rings, and gearboxes. The use of these formulas aims to identify the level of productivity and efficiency in the production line. To provide a comprehensive understanding of the parameters measured, the following is a summary of the formulas along with the unit nomenclature used in the calculations:

Table 1. List of unit nomenclature

Category	Variable / Parameter	Description	Measurement Unit
Time	Loading time	Time available for production	Minutes
	Downtime	Machine stoppage time due to failures or disturbances	Minutes
	Operating time	Effective machine operating time (Loading Time - Downtime)	Minutes
	Repair time	Total duration of machine repair activities	Minutes
Production	Total output / product	Total products produced (Good + Defective)	Units
	Good product	Products that meet quality standards	Units

	Ideal cycle time	Standard time required to produce one unit	Minutes/Unit
Reliability	Number of failures	Frequency of machine breakdowns	Occurrences
	MTBF	Average operating time between failures	Minutes/Failure
	MTTR	Average time required to repair the machine	Minutes/Failure
OEE Results	Availability	Percentage of machine readiness for operation	Percentage (%)
	Performance	Percentage of actual machine speed compared to standard speed	Percentage (%)
	Quality	Percentage of good products from total output	Percentage (%)
	OEE score	Overall equipment effectiveness (A × P × Q)	Percentage (%)

RESULTS AND DISCUSSIONS

This study evaluates system-wide performance through a data aggregation approach involving eleven machines integrated within a single production line. Given their interdependent functions and homogeneous operational characteristics, data from individual units were synthesized to derive a representative performance metric for the entire system. This aggregation was executed by consolidating key parameters, specifically total downtime, cumulative operating hours, frequency of breakdowns, and aggregate throughput, to serve as the computational basis for MTBF, MTTR, and OEE. Consequently, the findings do not characterize the performance of isolated units but rather provide a holistic reflection of the production system's operational efficacy.

Overall Equipment Effectiveness (OEE) Analysis

Based on the calculation results, the OEE value of the machine system was 73%. This value indicates that the machine performance is still below the commonly accepted world-class OEE benchmark of 85%. Similar conditions have also been reported in several manufacturing studies, where production systems frequently experience OEE values below the ideal benchmark due to machine downtime, operational inefficiencies, and limitations in maintenance practices. These findings suggest that the blown film extrusion production system still faces operational constraints that affect machine availability and overall performance. Therefore, integrating OEE with reliability indicators such as MTBF and MTTR provides a more comprehensive evaluation of machine performance and supports the identification of maintenance improvement priorities.

The obtained OEE value is derived from the multiplication of three main components, namely availability, performance, and quality. The availability value of 86% was obtained from the comparison between the total operating time of 299,973 minutes and the total loading time of 348,480 minutes, indicating that production time losses due to downtime remain relatively significant. The performance value of 86% suggests that the actual production speed has not consistently reached the machine's ideal operating speed. Meanwhile, the quality rate of 96% indicates that the proportion of acceptable products remains relatively high, although 4,170.65 defective products were still recorded

during the observation period.

Table 2. Recapitulation of OEE components

OEE Component	Value	Ideal Standard	Remarks
Availability	86%	> 90%	Needs improvement
Performance	86%	> 95%	Needs improvement
Quality	96%	> 99%	Needs improvement
OEE	73%	> 85%	Far below target

The OEE value of 73% indicates that the machine system performance is still below world-class standards. Low availability and performance values are the main factors causing the low overall OEE value. Based on the OEE approach, components that contribute the most downtime can be categorized as critical components because they directly affect machine availability. Thus, the results of the downtime analysis based on components in this study are in line with the OEE concept, where efforts to increase machine effectiveness must be focused on reducing downtime through improving the maintenance system on components with the highest downtime contribution.

MTTR and MTBF Calculation Results

Based on the recapitulation of downtime data and failure frequency for 11 machines, the MTTR value was 229.89 minutes. This value indicates that the average time required to repair a single machine system failure is nearly four hours. The MTTR value was calculated by comparing the total machine system downtime of 48,507 minutes with the total number of failures, 211. This figure represents the aggregate performance of the maintenance function, as all machines are handled by the same maintenance system.

A relatively high MTTR value indicates that the engine repair process still requires a considerable amount of time. This is due to the complexity of the damage, limited availability of critical spare parts, and the need for in-depth troubleshooting, especially for key control and mechanical components. A relatively high MTTR value reflects the length of the engine repair process and indicates potential opportunities for improving maintenance performance, particularly in terms of repair speed, spare part availability, and troubleshooting effectiveness, as also found in research.

Table 3. Downtime and MTTR recapitulation

Parameter	Value
Total Downtime	48,507
Total Failures	211
MTTR	229.89

The MTBF value obtained from data processing was 1,421.67 minutes. This value indicates that the engine system can only operate for an average of 23-24 hours before experiencing further damage. MTBF is calculated by comparing the total engine system operating time of 299,973 minutes with the number of failure events, 211. This calculation provides an overview of the overall reliability of the engine system.

The relatively low MTBF value indicates that the frequency of failures is still quite high. This indicates that the engine system is not yet able to operate stably for a long period of time without interruption, especially due to repeated damage to critical components. Based on the obtained MTBF value, it can be concluded that the level of reliability of the engine system is still relatively low, indicated by the high frequency of failures and short intervals of trouble-free operation. This finding is in line with reliability engineering literature which states that a low MTBF indicates the need for evaluation and improvement of maintenance strategies to increase the reliability and continuity of engine operations.

Table 4. Recapitulation of operating time and MTBF

Parameter	Value
Total operating time	299,973
Total failures	211
MTBF	1,421.67

Downtime Analysis Based on Machine Components

A component-based downtime analysis was conducted to identify machine components that contributed most to production downtime. Data were obtained from a recapitulation of component downtime on 11 machines during the observation period. Based on the data processing results, it was found that the largest downtime occurred in the PLC, extruder screw, winder, bearing, heater band, and chiller components. These components consistently emerged as the dominant contributors to downtime across almost all machines.

Table 5. Summary of the types of downtime that occur in critical components of the machine

Component	Failure Characteristics	Impact on Production	Downtime Duration (Minutes)
PLC	Control and electrical system failures	Complete system shutdown	5,179
Chiller	Inadequate cooling performance	Process temperature instability	5,088
Bearing	Wear and high mechanical load	Increased vibration and further damage	4,539
Extruder Screw	Wear and lubrication issues	Reduced production continuity	4,125
Winder	Mechanical instability	Disruption of production flow	4,070
Heater Band	Heating malfunction	Decreased product quality	3,972

The dominance of downtime in these components indicates that the main problems in the machine system are not only mechanical, but also related to the control and thermal systems. Based on these six machines, three machines were selected with the highest downtime: the PLC, chiller, and bearing. Based on the Pareto analysis, the selection of the PLC, chiller, and bearing as the focus of preventive maintenance is considered accurate and data-driven, because these three components contribute more than 50% of the total system downtime. This strategy is in line with the Pareto principle and supports increased machine reliability, repair time efficiency, and production continuity.

The Relationship Between MTTR, MTBF, OEE, and Component Downtime

The analysis results show a strong relationship between MTTR, MTBF, and OEE with machine component downtime. High downtime on critical components leads to longer repair times, thereby increasing MTTR values. In addition, repeated failures in the same components contribute to lower MTBF values. This condition directly reduces system availability, which ultimately decreases the overall equipment effectiveness (OEE). Therefore, poor machine performance is not caused by a single factor but rather by the combined effect of frequent failures and prolonged repair times on critical components.

These findings are consistent with recent studies highlighting that MTTR and MTBF are key indicators of system reliability and maintenance performance. A study by Aji and Uchendu (2025) emphasizes that MTTR and MTBF are critical metrics for evaluating operational efficiency and reliability in maintenance systems [10]. Similarly, Moemenishahraki (2025) found that improvements in MTBF combined with reductions in MTTR significantly reduce total downtime and enhance system performance [11]. This confirms that effective maintenance strategies should focus on minimizing repair time and increasing the interval between failures.

Furthermore, the results of this study align with recent research showing that downtime is a dominant factor affecting OEE performance, particularly through the availability component. Previous studies indicate that OEE is widely used as a key performance indicator to measure equipment productivity and is highly sensitive to breakdown losses and maintenance inefficiencies [12]. In addition, modern maintenance approaches such as predictive and prescriptive maintenance have been shown to reduce unexpected downtime and improve equipment effectiveness by addressing root causes of failure.

this study highlights the importance of identifying critical components that contribute most to downtime. This finding aligns with recent literature emphasizing component-level analysis as a key strategy in modern maintenance systems. Systematic reviews in smart manufacturing indicate that integrating reliability analysis with critical component identification can significantly enhance maintenance decision-making and system performance [13].

CONCLUSION

This study analyzed the performance of a blown film extrusion machine by integrating OEE, MTBF, and MTTR indicators. The results show that the OEE value of the machine system is 73%, which is still below the world-class standard of 85%, indicating that machine performance has not yet reached the optimal level. The analysis of OEE components shows that the availability and performance rates are both 86%, while the quality rate reaches 96%, indicating that production quality is relatively high but production efficiency is still affected by machine downtime and operational inefficiencies. The integration of OEE with MTBF and MTTR provides a more comprehensive understanding of machine reliability and maintenance performance, enabling the identification of critical factors that influence production effectiveness. Therefore, the findings of this study can serve as a basis for improving preventive maintenance strategies in order to reduce downtime, increase machine reliability, and enhance overall production performance in plastic manufacturing industries.

REFERENCES

[1] P. Moemenishahraki, “Reliability and maintenance performance analysis of a 1600-ton press machine using MTBF, MTTR, KPI, and downtime indicators,” *Industrial Engineering*, vol. 9, no. 2, pp. 36-41, 2025, doi: 10.11648/j.ie.20250902.11

[2] B. Habeahan, H. V. Gea, and R. R. Margana, “Analisis efektifitas penerapan preventive maintenancemenggunakan mean time between failures dan mean time to repair terhadap kinerja operasional forklift di PT XYZ,” *Journal Logic: Logistics & Supply Chain Center*, vol. 4, no. 2, pp. 61-66, 2025, doi:

10.33197/jlscc.v4i2.3401

[3] S. Badgujar, S. Asthana, R. Kanawade, K. Suthar, A. Solanki, K. Nagaraj, M. S. Bilkhu, H. Sutar, and S. R. Panda, "Blown film extrusion process for polybags: Technical overview and applications," *Advances in Chemical Engineering and Science*, vol. 14, pp. 188–201, 2024, doi: 10.4236/aces.2024.144012

[4] J. Zhang, X. Chen, Y. An, L. Zhang, H. Shi, W. Xu, "Joint optimization of preventive maintenance and product quality improvement policies for deteriorating manufacturing systems with quality-reliability dependency," *Reliability Engineering & System Safety*, vol. 255, pp. 1-15, 2025, doi: 10.1016/j.ress.2024.110661

[5] E. I. Basri, I. H. A. Razak, H. A. Samat, and S. Kamaruddin, "Preventive maintenance (PM) planning: A review," *Journal of Quality in Maintenance Engineering*, vol. 23, no. 2, pp. 114–143, 2017. doi: 10.1108/JQME-04-2016-0014

[6] F. S. Al-Duais, A. B. A. Mohamed, T. M. Jawa, and N. Sayed-Ahmed, "Optimal periods of conducting preventive maintenance to reduce expected downtime and its impact on improving reliability," *Computational Intelligence and Neuroscience*, vol. 1, pp. 1–11, 2022, doi: 10.1155/2022/7105526

[7] L. M. A. Pintelon, P. N. Muchiri, "Performance measurement using overall equipment effectiveness (OEE): Literature review and practical application discussion," *International Journal of Production Research*, vol. 46, no. 13, pp. 3517-3535, 2008.

[8] N. F. Fatma, H. Ponda, and R. A. Kuswara, "Analisis preventive maintenance dengan metode menghitung mean time between failure (MTBF) dan mean time to repair (MTTR) (Studi kasus PT. Gajah Tunggal Tbk). *Heuristic*, vol. 17, no. 2, pp. 87-94, 2020, doi: 10.30996/heuristic.v17i2.4648

[9] A. I. Aguilar, "Lowering mean time to recovery (MTTR) in responding to system downtime or outages: An application of Lean Six Sigma methodology," *Proceedings of the International Conference on Industrial Engineering and Operations Management Manila,* Philippines, March 7-9, 2023

[10] J. O. Aji and I. Uchendu, "Improving facility operations: A quantitative evaluation of MTBF, MTTR, and SLA targets," *European Journal of Innovative Studies and Sustainability*, vol. 1, no. 3, pp. 247-261, 2025, doi: 10.59324/ejiss.2025.1(3).20

[11] P. Moemenishahraki, "Reliability and maintenance performance analysis of a 1600-ton press machine using MTBF, MTTR, KPI, and downtime indicators," *Industrial Engineering*, vol. 9, no. 2, pp. 36-41, 2025, doi: 10.11648/j.ie.20250902.11

[12] L. C. N. Corrales, M. P. Lamban, M. E. H. Korner, and J. Royo, "Overall equipment effectiveness: Systematic literature review and overview of different approaches," *Applied Sciences*, vol. 10, 2025, doi:10.3390/app10186469

[13] M. R. Karim, "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*, vol. 4, no. 2, pp 176-206, 2025, doi: 10.63125/np7nnf78