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Preventive Maintenance and Financial Performance: Serial Mediation of OEE and Productivity in the Paper Industry

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Abstract

Background: The pulp and paper industry is capital-intensive and operates continuously, making equipment availability a critical determinant of corporate performance. Preventive maintenance is often regarded merely as a cost center, despite its significant potential as a strategic value-creating activity.

Objective: This study aims to analyze the influence of preventive maintenance on the financial performance of PT Indah Kiat Pulp and Paper Serang Mill through the serial mediation of Overall Equipment Effectiveness (OEE) and paper machine productivity, offering a novel chain-mediation framework that connects maintenance activities to corporate financial outcomes.

Methods: A quantitative approach was employed using Structural Equation Modeling Partial Least Squares (SEM-PLS) with SmartPLS, based on data from 120 internal respondents collected through a five-point Likert-scale questionnaire and triangulated with company operational and financial data.

Results: All six hypotheses are statistically supported. Preventive maintenance positively affects OEE (β = 0.570); OEE affects productivity (β = 0.601); and productivity affects financial performance (β = 0.514). Serial mediation is confirmed: OEE mediates preventive maintenance → productivity, while productivity mediates OEE → financial performance. Full serial mediation yields an indirect effect of 0.176.

Conclusion: These findings confirm a complete value-creation chain through a novel serial mediation model (preventive maintenance → OEE → productivity → financial performance), extending maintenance management theory by repositioning preventive maintenance as a strategic mechanism for sustainable corporate value creation in capital-intensive manufacturing industries.

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INTRODUCTION

The pulp and paper industry is one of the manufacturing sectors that has the characteristics of being capital-intensive, technology-intensive, and operating continuously (Handayani & Suseno, 2026). In this industry, the availability and reliability of production machinery are important factors that determine the company's ability to meet production targets, maintain product quality, and maintain competitiveness. Operational disruptions caused by machine breakdowns can result in downtime, decreased productivity, increased operating costs, and reduced profitability of the company (Ringo & Kuriniawan, 2022; Nugroho et al., 2025).

Globally, unplanned equipment downtime is estimated to cost manufacturing industries approximately USD 50 billion annually, and maintenance activities account for 15–40 percent of

total production costs in capital-intensive sectors (Achouch et al., 2022). In the context of Industry 4.0, the integration of digital technologies into maintenance systems has increasingly positioned maintenance management as a strategic function that transcends its traditional cost-reduction role. The rapid development of smart manufacturing, predictive analytics, and connected production systems has reinforced the importance of proactive maintenance strategies in ensuring asset reliability and operational continuity (Guidotti et al., 2025; Zonta et al., 2020).

Preventive maintenance is a maintenance approach that is carried out in a planned manner to prevent equipment damage before failure occurs (Erbiyik, 2022; Tiddens et al., 2020). Various studies show that the implementation of preventive maintenance can improve machine reliability, reduce downtime, and improve the company's operational performance. In the context of modern manufacturing, the effectiveness of maintenance programs is generally measured using the concept of Overall Equipment Effectiveness (OEE) which reflects the level of availability, performance, and quality of production equipment. A high OEE value indicates that production assets are able to operate optimally, potentially increasing output and production efficiency (Calandreli et al., 2025; Tsarouhas, 2019; Ullah et al., 2023).

Several previous studies have examined the relationship between preventive maintenance and OEE, as well as the relationship between OEE and manufacturing productivity. Research by Chaurey et al. (2021), Jurewicz et al. (2024), and Singh et al. (2022) found that effective maintenance implementation contributes to increased OEE and company productivity. Other research also shows that increased operational productivity affects a company's financial performance through cost efficiency and increased production capacity (Istan et al., 2021; Liu et al., 2020; Suseno et al., 2023). However, most of these studies still place these variables separately and focus on operational aspects alone.

A critical review of the existing literature reveals that most prior studies examined isolated relationships, such as the preventive maintenance–OEE dyad (Khalili et al., 2023; Singh et al., 2022), without integrating these relationships into a unified value-creation pathway extending to financial performance (Kirana et al., 2024). Studies by Chaurey et al. (2021) and Jurewicz et al. (2024), while valuable in establishing the link between maintenance and OEE, did not examine how such operational improvements ultimately translate into corporate financial outcomes. This fragmented approach limits the theoretical explanatory power of maintenance management research and prevents practitioners from understanding the complete economic return on maintenance investment.

The research gap arises because there are still limited studies that explain how preventive maintenance can contribute to the creation of company value through integrated mechanisms. Most studies only test the direct effect of maintenance on OEE or productivity without explaining the chain of relationships that link maintenance activities to a company's financial results. In fact, from the perspective of technology management and value creation, investment in maintenance should be seen as a source of competitive advantage that can increase asset effectiveness, boost productivity, and ultimately improve the company's financial performance. Specifically, prior research has failed to: (1) establish an empirically validated chain from preventive maintenance through OEE and productivity to financial performance; (2) explain the precise mechanisms through which maintenance activities convert into financial value; and (3) position preventive maintenance within a comprehensive corporate value-creation framework. These gaps highlight the need for an integrated serial mediation model that explains the value-creation pathway from maintenance activities to organizational financial outcomes.

PT Indah Kiat Pulp and Paper Serang Mill is one of the largest pulp and paper manufacturing companies in Indonesia that operates production machinery in a sustainable manner. The characteristics of the complex production process and the high dependence on the reliability of the paper machine make maintenance activities a crucial factor in maintaining continuity of operations. Therefore, the company is a relevant context to examine how preventive maintenance can generate operational and financial benefits simultaneously.

The novelty of this research lies in the development and empirical validation of a serial mediation model connecting preventive maintenance → OEE → productivity → financial performance, a complete chain that has not been previously integrated and tested in a single study within the Indonesian pulp and paper manufacturing context. Unlike existing research that

examines these relationships in isolation, this study introduces a comprehensive value-creation framework explaining how maintenance activities generate financial returns through sequential operational improvements. This serial mediation approach constitutes a theoretical contribution to the maintenance management, operations management, and technology management literature.

Based on this description, this study aims to analyze the influence of preventive maintenance on company performance through the mediating role of OEE and productivity. In contrast to previous research, this study developed a chain mediation model that explains the mechanism of value creation ranging from preventive maintenance activities, increasing equipment effectiveness, increasing productivity, to its impact on the company's financial performance. The results of the research are expected to make a theoretical contribution to the development of the operations management and technology management literature and provide practical implications for manufacturing companies in managing maintenance strategies oriented towards enterprise value creation. Theoretically, this research is expected to contribute to the development of maintenance management and technology management literature by providing empirical evidence that preventive maintenance serves as a strategic mechanism in the value-creation chain, extending the Resource-Based View (RBV) framework to maintenance capabilities in capital-intensive industries (Barney, 2018; Mehrabi et al., 2025; Teece, 2018). Practically, the findings are expected to provide actionable guidance for manufacturing companies to redesign their maintenance strategies from cost-reduction-oriented approaches to value-creation-oriented investments, with OEE and productivity as measurable intermediate performance targets.

METHOD

This study used a quantitative approach with an explanatory research design to examine the causal relationship between preventive maintenance, Overall Equipment Effectiveness (OEE), productivity, and corporate financial performance. The research was carried out at PT Indah Kiat Pulp and Paper Serang Mill which is a pulp and paper manufacturing company with the characteristics of continuous production operations. The quantitative approach was chosen because it allows the objective testing of relationships between variables through structured statistical models.

SEM-PLS was selected as the primary analytical method for several methodological reasons. First, PLS-SEM is particularly appropriate for models with multiple latent variables and reflective indicators. Second, it makes no strict distributional assumptions and performs robustly with moderately sized samples. Third, PLS-SEM is suitable for exploratory research involving complex structural models with mediation chains (Demir & Uşak, 2025; Hair et al., 2019). SmartPLS software was selected because it provides bootstrapping procedures for mediation testing and comprehensive diagnostics for both outer and inner model evaluation.

The research population consists of employees who are directly involved in the operational activities and maintenance of paper machines, including personnel of the maintenance, production, engineering, and operational management departments. The research sample totaled 120 respondents who were selected using the purposive sampling technique with the criteria of having at least one year of work experience and understanding the maintenance process and operation of production machines. The number of samples has met the minimum requirements of the Structural Equation Modeling Partial Least Squares (SEM-PLS) analysis. All participants provide written consent prior to data collection, and their identities are protected under the principle of strict confidentiality.

Purposive sampling was preferred over probability sampling because the research questions require respondents with specific domain knowledge of maintenance and production operations. Random sampling from the broader employee population would have included personnel without direct operational involvement, potentially introducing measurement error. The purposive criteria, minimum one year of experience and direct operational involvement, ensured informed and accurate assessments of each research construct. The sample size of 120 respondents satisfies the minimum requirements for PLS-SEM, which recommends at least 10 times the maximum number of structural paths directed at any single construct in the model (Demir & Uşak, 2025; Hair et al., 2019).

PT Indah Kiat Pulp and Paper Serang Mill was selected based on several scientific criteria: (1) it is one of the largest integrated pulp and paper mills in Indonesia and Southeast Asia, representing a typical capital-intensive continuous manufacturing operation; (2) the company operates multiple paper machine lines requiring intensive preventive maintenance programs; (3) it maintains comprehensive records of maintenance activities, OEE measurements, and financial performance data, enabling triangulation between primary and secondary data; and (4) its operational scale and complexity provide a sufficiently rich context to test the proposed serial mediation model.

The research data consists of primary data and secondary data. Primary data was obtained through the distribution of questionnaires using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Secondary data is obtained from company documents which include maintenance reports, machine effectiveness data, productivity data, and financial performance reports. To strengthen the validity of the findings, the study also triangulated through documentation studies and semi-structured interviews with related parties. The secondary data served multiple functions: (1) triangulation to verify and validate perceptual data from questionnaires; (2) contextual support for interpreting SEM-PLS results by cross-checking coefficient patterns against actual operational metrics; and (3) supplementary evidence for the practical significance of findings. Semi-structured interviews provided interpretive depth and contextual richness to the quantitative findings, particularly in understanding the practical implementation of preventive maintenance programs and their perceived effects on equipment performance.

Instrument validity was established through a multi-stage process. Content validity was assessed through expert judgment involving three academics specializing in operations management and maintenance engineering, who evaluated the relevance and representativeness of each indicator for its respective construct. Following expert review, indicator refinements were incorporated based on expert consensus. A pilot test was subsequently conducted with 30 respondents from similar operational backgrounds to evaluate construct clarity and preliminary discriminant validity at the indicator level before main data collection commenced.

The research variables consisted of preventive maintenance as an exogenous variable, Overall Equipment Effectiveness (OEE) as the first mediating variable, paper machine productivity as the second mediating variable, and financial performance as an endogenous variable. Preventive maintenance is measured through maintenance planning indicators, compliance with maintenance schedules, routine inspections, and planned component replacements. OEE is measured based on availability, performance, and quality dimensions. Productivity is measured through the efficiency of production output compared to the resources used, while financial performance is measured through the perception of achieving profitability, cost efficiency, and increasing the value of the company.

The operationalization of each variable was grounded in established theoretical frameworks. Preventive maintenance dimensions (TBM, CBM, PdM, AM) were derived from Total Productive Maintenance literature and standard maintenance management theory (Erbiyik, 2022; Tiddens et al., 2020). OEE dimensions (availability, performance, quality) follow the formulation adapted for manufacturing contexts (Harfoush et al., 2024; Tsarouhas, 2019). Productivity indicators were drawn from operations management literature on manufacturing efficiency (Asogwa et al., 2023), while financial performance indicators follow the multi-dimensional conceptualization commonly applied in management accounting research (Albulescu & Turcu, 2022).

Data analysis was carried out using Structural Equation Modeling–Partial Least Squares (SEM-PLS) with the help of SmartPLS software. The analysis stages include the evaluation of the measurement model (outer model) and the evaluation of the structural model (inner model). The evaluation of the outer model was carried out through convergent validity testing using outer loading values and Average Variance Extracted (AVE), discriminant validity using Fornell-Larcker criteria, and construct reliability using Composite Reliability and Cronbach's Alpha. Furthermore, the internal model evaluation was carried out through testing the determination coefficient (R^2), predictive relevance (Q^2), effect size (f^2), and hypothesis testing using a bootstrapping procedure with a significance level of 5%.

Prior to hypothesis testing, several SEM-PLS assumption checks were conducted. Multicollinearity was assessed using Variance Inflation Factor (VIF) values for all inner and outer model relationships; all VIF values were below 3.3, confirming the absence of multicollinearity. Discriminant validity was further evaluated using the Heterotrait-Monotrait (HTMT) ratio criterion; all HTMT values were below 0.85, confirming adequate discriminant validity (Franke & Sarstedt, 2019; Hubley, 2024). To control for Common Method Bias (CMB), Harman's Single Factor Test was applied; no single factor explained more than 50% of total variance (highest factor = 31.4%), suggesting CMB is not a serious threat to validity (Bozionelos & Simmering, 2022; Tehseen et al., 2017).

The research model examined the direct influence of preventive maintenance on OEE, the effect of OEE on productivity, the effect of productivity on financial performance, and indirect influence through chain mediation mechanisms. Thus, this research can explain the company's value creation path starting from preventive maintenance practices to resulting in improved financial performance through increased equipment effectiveness and operational productivity.

RESULTS AND DISCUSSION

Results

Outer Model

Table 1. Demographic Characteristics of Respondents (n = 120)

Categories		Frequency	Percentage
Gender			
	Male	105	87,5%
	Women	15	12,5%
Age			
	< 25	14	11,7%
	25-35	27	22,5%
	36-45	41	34,2%
	46-55	30	25,0%
	> 55	8	6,7%
Education			
	High School/Vocational School	61	50,8%
	D3	22	18,3%
	S1	33	27,5%
	S2	4	3,3%
	S3	0	0,0%
Departments			
	Production	74	61,7%
	Maintenance	43	35,8%
	Others	3	2,5%
Departments			
	Operator	46	38,3%
	Foreman	30	25,0%
	Supervisor	28	23,3%
	Assistant Manager	5	4,2%
	Manager	7	5,8%
	Senior Manager	4	3,3%
Tenure			
	2-5	35	29,2%
	6-10	36	30,0%
	11-15	23	19,2%
	16-20	18	15,0%
	> 20	8	6,7%
Engine			

Categories		Frequency	Percentage
	PM Brown Paper	72	60,0%
	PM White Containerboard	43	35,8%
	Others	5	4,2%

Source: Reseach Data

Based on Table 1, most respondents were male (87.5%), reflecting the characteristics of the workforce in the operational and machinery maintenance environment. In terms of age, the largest group was in the range of 36–45 years (34.2%) and 46–55 years (25.0%), indicating that respondents were at a productive age with mature experience. The level of education is dominated by high school/vocational school graduates (50.8%), followed by S1 (27.5%) and D3 (18.3%), consistent with the composition of field technical personnel and supervisory staff in the capital-intensive manufacturing industry.

The departmental distribution showed that respondents came from the Production Department (61.7%) and the Maintenance Department (35.8%), as per the definition of the research population. In terms of positions, respondents were spread from operators (38.3%), foremen (25.0%), supervisors (23.3%), to managerial levels of 13.3%, thus providing a wealth of perspectives from operational to managerial levels. All respondents had a minimum working period of two years with concentrations in the range of 6–10 years (30.0%) and 2–5 years (29.2%), so that the criteria for understanding the research object were met. Of the machine groups, the majority handle PM Brown Paper (60.0%) and PM White Containerboard (35.8%), reflecting the two groups of paper machines operated by Serang Mill.

Table 2. Outer Loading Indicator

Code	Construct	Outer Loading	Remarks
TBM1	Preventive Maintenance	0,720	Meet (≥0.708)
TBM2	Preventive Maintenance	0,768	Meet (≥0.708)
TBM3	Preventive Maintenance	0,831	Meet (≥0.708)
CBM1	Preventive Maintenance	0,715	Meet (≥0.708)
CBM2	Preventive Maintenance	0,692	Retained (0.40–0.708)
CBM3	Preventive Maintenance	0,816	Meet (≥0.708)
PdM1	Preventive Maintenance	0,686	Retained (0.40–0.708)
PdM2	Preventive Maintenance	0,740	Meet (≥0.708)
PdM3	Preventive Maintenance	0,794	Meet (≥0.708)
AM1	Preventive Maintenance	0,824	Meet (≥0.708)
AM2	Preventive Maintenance	0,792	Meet (≥0.708)
AM3	Preventive Maintenance	0,731	Meet (≥0.708)
AV1	OEE	0,832	Meet (≥0.708)
AV2	OEE	0,793	Meet (≥0.708)
AV3	OEE	0,834	Meet (≥0.708)
PF1	OEE	0,742	Meet (≥0.708)
PF2	OEE	0,724	Meet (≥0.708)
QL1	OEE	0,685	Retained (0.40–0.708)
QL2	OEE	0,780	Meet (≥0.708)
VP1	Productivity Paper Machine	0,855	Meet (≥0.708)
VP2	Productivity Paper Machine	0,822	Meet (≥0.708)

Code	Construct	Outer Loading	Remarks
EO1	Productivity Paper Machine	0,823	Meet (≥0.708)
EO2	Productivity Paper Machine	0,835	Meet (≥0.708)
KN1	Productivity Paper Machine	0,840	Meet (≥0.708)
MP1	Financial Performance	0,799	Meet (≥0.708)
MP2	Financial Performance	0,832	Meet (≥0.708)
MP3	Financial Performance	0,819	Meet (≥0.708)
PN1	Financial Performance	0,798	Meet (≥0.708)
PN2	Financial Performance	0,784	Meet (≥0.708)

Source: Processed Data

Based on Table 2, most indicators have an outer loading above 0.708. There are four indicators with loading slightly below the ideal threshold, namely CBM1 (0.699), CBM2 (0.700), PdM1 (0.689), and QL1 (0.685). According to the rules of Hair et al. (2021), the four indicators are still maintained because their elimination is not necessary; The AVE value and composite reliability of the entire construct have been above the threshold (Hair et al., 2026). Thus, all indicators meet convergent validity at the indicator level. From a practical standpoint, the four indicators with loadings slightly below 0.708 (CBM2 = 0.692, PdM1 = 0.686, QL1 = 0.685) were retained based on two complementary criteria: first, their loadings remain substantially above the minimum acceptable threshold of 0.40; and second, their removal did not meaningfully improve the AVE or composite reliability of the respective constructs (Hair et al., 2019; 2026). Retaining these indicators also preserves the theoretical completeness of construct measurement, ensuring no relevant dimensions are omitted from analysis.

The second aspect is the Average Variance Extracted (AVE) with a minimum value of 0.50, which is presented together with the reliability indicator in Table 3.

Table 3. Composite Reliability, Cronbach's Alpha, and AVE

Construct	Cronbach's α	Comp. Rel. (CR)	AVE	Remarks
Preventive Maintenance (X)	0,933	0,943	0,579	Valid & Reliable
OEE (Z1)	0,886	0,911	0,595	Valid & Reliable
Productivity Paper Machine (Z2)	0,892	0,920	0,697	Valid & Reliable
Financial Performance (Y)	0,866	0,903	0,651	Valid & Reliable

Source: Processed Data

Table 3 shows that the AVE value of the entire construct is above 0.50, namely Preventive Maintenance (0.579), OEE (0.595), Paper Machine Productivity (0.697), and Financial Performance (0.651). Each construct can explain more than 50% of the variance of its indicators, so that the convergent validity at the construct level is me

Inner Model

Table 4. Coefficient of Determination (R^2)

Endogenous constructs	R^2	Categories
OEE (Z1)	0,324	Weak–Moderate
Productivity Paper Machine (Z2)	0,361	Moderate
Financial Performance (Y)	0,264	Weak–Moderate

Source: Processed Data

Table 4 shows Preventive Maintenance explains 32.4% of the OEE variance, OEE explains 36.1% of the Productivity variance, and Productivity explains 26.4% of the Financial Performance variance. All three values are in the moderate category. The relatively lower R^2 value of Financial Performance is understandable because financial performance is also influenced by external factors outside the model, such as global pulp and paper prices, exchange rates, and macroeconomic conditions. External variables not captured in the model (including global pulp and paper commodity prices, currency exchange rates, raw material costs, environmental compliance expenses, and competitive market dynamics) collectively explain the remaining unexplained variance, underscoring the importance of acknowledging model boundary conditions.

Table 5. Influence Size (f^2)

Pathway	f^2	Categories
Preventive Maintenance → OEE	0,480	Large
OEE → Productivity	0,564	Large
Productivity → Financial Performance	0,359	Large

Source: Processed Data

Based on Table 5, the three structural pathways have large influence measures, namely Preventive Maintenance → OEE (f^2 = 0.480), OEE → Productivity (f^2 = 0.564), and Productivity → Financial Performance (f^2 = 0.359). This confirms the substantial contribution of each predictor construct to its endogenous construct.

Hypothesis Test

Table 6. Direct Impact Test Results

H	Pathway	β	t-stat	p-value	Verdict
H1	Preventive Maintenance → OEE	0,570	9,722	<0.001	Supported
H2	OEE → Productivity Paper Machine	0,601	10,573	<0.001	Supported
H3	Productivity → Financial Performance	0,514	8,504	<0.001	Supported

Source: Processed Data

Table 6 shows that all three direct influence hypotheses are statistically supported. H1: Preventive Maintenance had a positive and significant effect on OEE (β = 0.570; t = 9.722; p <0.001). H2: OEE has a positive and significant effect on Paper Machine Productivity (β = 0.601; t = 10.573; p <0.001). H3: Paper Machine Productivity has a positive and significant effect on Financial Performance (β = 0.514; t = 8.504; p <0.001). Thus, each strand of the main causal chain is empirically proven.

In practical terms, the path coefficient β = 0.570 (H1) indicates that preventive maintenance is the dominant controllable predictor of equipment effectiveness: every unit improvement in maintenance quality corresponds to a 0.570 standard-deviation increase in OEE. The β = 0.601 (H2) confirms that OEE is the primary driver of operational output efficiency, explaining 36.1% of productivity variance (R^2 = 0.361). The β = 0.514 (H3) demonstrates that productivity meaningfully predicts financial performance, though the moderate R^2 = 0.264 appropriately reflects the multi-determined nature of corporate financial outcomes, where external market variables also contribute substantially.

Table 7. Indirect Influence Test Results (Mediation)

H	Indirect Pathway	β	t-stat	CI 95%	Verdict
H4	Pem. Preventive → OEE → Productivity	0,342	6,313	[0,244; 0,456]	Supported
H5	OEE → Productivity → Financial Performance	0,309	6,104	[0,217; 0,414]	Supported

H	Indirect Pathway	β	t-stat	CI 95%	Verdict
H6	Pem. Preventive → OEE → Productivity → Financial Performance	0,176	4,843	[0,115; 0,255]	Supported

Source: Processed Data

Table 7 shows that all three mediation hypotheses are supported. H4: OEE mediated the effect of Preventive Maintenance on Paper Machine Productivity (β = 0.342; t = 6.313; CI 95% [0.244; 0.456]). H5: Productivity mediates the influence of OEE on Financial Performance (β = 0.309; t = 6.104; CI 95% [0.217; 0.414]). In both, the confidence interval does not contain zero, so the mediation effect is significant.

H6 as the main hypothesis proves serial mediation: Preventive Maintenance affects Financial Performance indirectly through OEE then Paper Machine Productivity (β = 0.176; t = 4.843; CI 95% [0.115; 0.255]). Because the model is specified without a direct path from Preventive Maintenance to Financial Performance and its indirect chain influences are significant, the pattern that occurs is full mediation. These findings mean that preventive maintenance investments do not necessarily improve financial performance directly, but must first improve equipment effectiveness (OEE) and machine productivity before impacting a company's financial performance.

Discussion

The Effect of Preventive Maintenance on Overall Equipment Effectiveness (OEE)

The results of the study showed that preventive maintenance had a positive and significant effect on Overall Equipment Effectiveness (OEE). These findings indicate that the better the implementation of preventive maintenance, the higher the effectiveness of production equipment which is reflected in the increase in availability, performance, and quality. At PT Indah Kiat Pulp and Paper Serang Mill, the implementation of routine inspections, periodic lubrication, replacement of components before experiencing failures, and compliance with maintenance schedules can reduce unplanned downtime and maintain the stability of machine operations. These conditions allow the equipment to operate optimally, thereby increasing the OEE value.

These findings are in line with the concept of Total Productive Maintenance (TPM) which states that planned maintenance is an important factor in reducing the six big losses that lead to low equipment effectiveness (Singh et al., 2022; Vital & Lima, 2020). Through preventive maintenance, companies can reduce the frequency of machine breakdowns, reduce production downtime, and maintain the quality of the output produced. Thus, preventive maintenance not only serves to maintain the technical condition of the machine, but also becomes a mechanism that supports the efficiency and reliability of the overall production process.

The results of this study are also consistent with the research Khalili et al. (2023) and Alexander et al. (2024) who found that the implementation of preventive maintenance contributed to an increase in OEE in various manufacturing sectors. The similarity of these results shows that preventive maintenance is an effective operation management practice in increasing the utilization of production assets. Therefore, companies need to view preventive maintenance as a strategic investment that not only aims to reduce machine breakdowns, but also improve the effectiveness of equipment as the basis for achieving better productivity and company performance.

From the perspective of the Resource-Based View (RBV) framework, preventive maintenance capabilities can be conceptualized as organizational resources that, when systematically developed and deployed, generate sustained competitive advantages (Bahçelerli, 2026; Barney, 2018). In capital-intensive industries like pulp and paper, characterized by high asset specificity and dependence on continuous production, maintenance capabilities are difficult to imitate and create firm-specific value. The findings of this study support RBV by demonstrating that preventive maintenance investments generate measurable improvements in equipment effectiveness, consistent with the proposition that rare and inimitable organizational capabilities translate into superior operational performance.

The Effect of Overall Equipment Effectiveness (OEE) on Productivity

The results of the study show that Overall Equipment Effectiveness (OEE) has a positive and significant effect on productivity. These findings indicate that an increase in the effectiveness of production equipment will be followed by an increase in the productivity of paper machines. A high OEE reflects the machine's ability to operate with optimal availability, production speeds that meet standards, and consistent product quality. At PT Indah Kiat Pulp and Paper Serang Mill, this condition allows the production process to run more smoothly with minimal operational disruptions, so that the output produced increases without being followed by a proportionate increase in the use of resources.

Theoretically, the relationship between OEE and productivity can be explained through the ability of OEE to measure the efficiency of production asset utilization (Al-gobaisi et al., 2025). As availability increases, effective production time becomes longer due to reduced downtime. Improved performance indicates the machine can operate close to its ideal capacity, while improved quality reduces product defects and the need for rework. The combination of these three components results in more efficient resource utilization so that the company's productivity increases. Thus, OEE not only serves as an indicator of equipment performance, but also as a key driver of increased operational productivity.

The results of this study are in line with the research Asbari (2026) and Kirana et al. (2024) which suggests that the increase in OEE contributes directly to the increase in manufacturing productivity. The findings reinforce the view that equipment effectiveness is an important factor in creating a company's operational excellence. Therefore, companies need to continue to increase the value of OEE through effective maintenance programs, strict quality control, and optimization of production processes to achieve higher and sustainable levels of productivity.

Dynamic Capability theory further enriches this interpretation by emphasizing that firms must develop the ability to sense operational opportunities, seize efficiency gains by reconfiguring maintenance systems, and transform equipment effectiveness into productive output (Cruz-Sánchez et al., 2026; Teece, 2018). In the pulp and paper industry, where demand fluctuates with global commodity cycles, the dynamic capability to rapidly optimize OEE in response to production schedule changes represents a critical source of operational resilience and competitive advantage. The strong $\beta = 0.601$ empirically confirms that OEE improvements translate with high efficiency into productivity gains, validating the importance of building dynamic maintenance capabilities.

The Effect of Productivity on Financial Performance

The results of the study show that productivity has a positive and significant effect on the company's financial performance. This finding indicates that the increase in the productivity of paper machines can contribute to the improvement of the financial performance of PT Indah Kiat Pulp and Paper Serang Mill. The higher the productivity achieved, the greater the company's ability to produce output with more efficient use of resources. This condition has an impact on reducing production costs per unit, increasing capacity to meet market demand, and optimizing the utilization of production assets which ultimately increases the company's profitability.

Theoretically, productivity is one of the main indicators of operational efficiency that is directly related to the company's value creation. Companies that can produce more output with the same or lower inputs will gain a cost advantage over their competitors. In the pulp and paper industry which has the characteristics of capital intensive and high operational costs, increased productivity is an important factor in maintaining profit margins and strengthening the competitiveness of companies. Therefore, productivity not only reflects operational success, but is also a key driver of achieving better financial performance (Asogwa et al., 2023).

The results of this study are in line with the research Albulescu and Turcu (2022) which emphasizes that improving operational efficiency is one of the value drivers that contribute to the company's value creation. These findings are also supported by research Asogwa et al. (2023) which indicates that companies with higher productivity levels tend to have better profitability and financial performance. The similarity of these results strengthens the argument that increased productivity is an important mechanism in transforming operational excellence into

financial benefits. Thus, companies need to continue to encourage productivity increases as a strategy to achieve sustainable financial performance growth.

The Indonesian pulp and paper industry provides a particularly important context for this finding. As one of the world's largest paper-producing nations, Indonesian manufacturers face intense global competition and increasingly stringent environmental standards that raise compliance costs. In this setting, operational productivity becomes a critical internal lever for maintaining profitability when external market conditions are unfavorable. The finding that productivity significantly predicts financial performance ($\beta = 0.514$) suggests that capital-intensive manufacturing companies can partially offset external price pressures through superior internal operational efficiency, a finding with direct implications for strategic planning in Indonesian manufacturing.

The Effect of Preventive Maintenance on Productivity through Mediation of Overall Equipment Effectiveness (OEE)

The results of the study showed that Overall Equipment Effectiveness (OEE) was able to mediate the effect of preventive maintenance on productivity. These findings indicate that the increase in productivity resulting from the implementation of preventive maintenance does not occur directly, but through increasing the effectiveness of production equipment first. Preventive maintenance that is carried out in a planned manner can reduce the frequency of engine breakdowns, reduce unscheduled downtime, and maintain the condition of the equipment to continue operating at optimal capacity. The improvement in the aspects of availability, performance, and quality then increases the value of OEE which ultimately encourages an increase in paper machine productivity.

Theoretically, these results suggest that OEE is an important mechanism that bridges the relationship between maintenance activities and the company's operational results. Preventive maintenance basically aims to maintain the reliability of production assets, but the economic benefits can only be felt when the condition of the more reliable equipment is able to increase the effectiveness of its use. When machines have a high level of availability, operate at optimal speed, and produce products of consistent quality, companies can maximize production output without having to increase resources significantly. Thus, increased productivity is a logical consequence of the increased effectiveness of equipment generated by preventive maintenance programs.

The results of this study are in line with the research Duarte and Santiago (2022), Virk et al. (2020), and Singh et al. (2021) which shows that effective maintenance practices are able to improve OEE, which further impacts increased company productivity (de Morais Silva et al., 2026). These findings reinforce the view that the success of a maintenance program is not only measured by the reduction of engine breakdown, but also by its ability to increase asset effectiveness and generate higher output. Therefore, companies need to manage preventive maintenance consistently and integrate with OEE measurements so that the operational benefits obtained can be translated into sustained productivity improvements.

The Effect of Overall Equipment Effectiveness (OEE) on Financial Performance through Productivity Mediation

The results of the study show that productivity can mediate the influence of Overall Equipment Effectiveness (OEE) on the company's financial performance. These findings indicate that improving equipment effectiveness does not directly result in improvements in financial performance, but rather primarily increases operational productivity. When the OEE value increases through improved availability, performance, and quality, the production machine can operate more optimally resulting in higher output, reducing downtime, and minimizing product defects. This condition contributes to increased productivity which further has an impact on achieving better financial performance.

Theoretically, these results suggest that productivity is a mechanism that explains how operational excellence can be transformed into financial benefits. OEE is essentially an indicator of the effectiveness of the use of production assets, while financial performance reflects the results achieved by a company. The relationship between the two is not always direct because improving the effectiveness of equipment must first result in increased output, efficiency in resource use, and

reduced operational costs. In other words, productivity acts as a liaison that translates improvements in operational performance into increased profitability and company value creation (Liew et al., 2022).

The results of this study are in line with the research Liew et al. (2024) and Monday (2021) which indicates that high equipment effectiveness will increase productivity, and ultimately contribute to improving the company's financial performance. These findings also support the value creation perspective that operational excellence must be realized in the form of increased productivity to have a real economic impact. Therefore, companies need to not only focus on increasing the value of OEEs, but also ensure that the increased effectiveness of the equipment can generate higher productivity to contribute to the sustainable growth of financial performance.

The Effect of Preventive Maintenance on Financial Performance through Chain Mediation, Overall Equipment Effectiveness (OEE) and Productivity

The results of the study showed that preventive maintenance influenced financial performance through the mediation of Overall Equipment Effectiveness (OEE) and productivity chains. These findings indicate that the financial benefits of preventive maintenance are not obtained directly, but rather through a series of interrelated operational processes. Preventive maintenance that is carried out consistently can increase the effectiveness of production equipment which is reflected in increasing availability, performance, and quality. The increase in OEE then encourages higher productivity of paper machines, so that the company can produce greater output with a better level of efficiency. In the end, the increase in productivity contributes to the improvement of the company's financial performance.

Theoretically, these results explain the mechanism of corporate value creation that starts from operational activities at the machine level to generating economic benefits at the organizational level. From a technology management and operations management perspective, preventive maintenance is a strategic investment that aims to maintain the reliability of production assets. However, economic value will only be created when that reliability increases the effectiveness of asset use, which then translates into higher productivity and ultimately results in increased profitability. Thus, OEE and productivity serve as important links that link maintenance activities to the achievement of the company's financial performance (Samadhiya & Agrawal, 2023).

This research explicitly clarifies how preventive maintenance transitions from an operational maintenance function, where its value is measured by MTBF and downtime reduction, to an organizational value-creation mechanism where its strategic contribution is measured by sequential improvements in OEE, productivity, and ultimately corporate financial performance. This conceptual repositioning invites maintenance management researchers to adopt value-creation frameworks (RBV and Dynamic Capabilities) as theoretical lenses, rather than limiting analysis to technical maintenance metrics alone.

This research provides theoretical implications by strengthening the literature on operations management, maintenance management, and technology management that explains that preventive maintenance not only plays a role in maintaining equipment reliability, but also becomes a strategic factor in the company's value creation process. The findings of the study prove the existence of a chain mediation mechanism through Overall Equipment Effectiveness (OEE) and productivity that links maintenance activities with the company's financial performance. Thus, this study expands the conceptual understanding of the relationship between operational performance and financial performance, as well as provides empirical evidence that the economic benefits of preventive maintenance are obtained through improved asset effectiveness and operational productivity.

Practically, the results of the study provide input for the management of PT Indah Kiat Pulp and Paper Serang Mill and other manufacturing companies to view preventive maintenance as a strategic investment, not just an operational cost center. Companies need to improve the quality of planning and implementation of preventive maintenance programs, as well as periodically monitor OEE indicators as a tool to evaluate the effectiveness of production assets. In addition, increasing OEE needs to be directed to produce higher productivity so that it can have a real impact on the company's financial performance. By integrating maintenance policies, asset

management, and productivity improvement strategies, companies can strengthen operational efficiency, increase competitiveness, and support sustainable corporate value creation. Specifically for the Indonesian pulp and paper sector, the following operational recommendations are proposed: (1) Establish a Maintenance Excellence Unit responsible for preventive maintenance scheduling optimization and real-time OEE monitoring; (2) Implement digital OEE dashboards integrated with production control systems for rapid identification of availability, performance, and quality losses; (3) Develop performance-based maintenance budgeting that links investment levels to target OEE improvements and expected financial returns, enabling quantification of maintenance ROI; (4) Create a knowledge management system to institutionalize maintenance best practices across different paper machine lines.

CONCLUSION

Theoretically, this research advances maintenance management and operations management literature by introducing an empirically validated value-creation chain that extends Resource-Based View and Dynamic Capability perspectives to maintenance strategy, and by establishing serial mediation as the operative mechanism linking maintenance activities to corporate financial outcomes. Practically, manufacturing companies in capital-intensive industries are recommended to reframe preventive maintenance as a strategic investment by integrating real-time OEE monitoring with maintenance planning, adopting performance-based maintenance budgeting, and aligning maintenance strategy with measurable productivity and financial performance targets. Future research should broaden generalizability by involving multiple companies and industry sectors, employ longitudinal designs to capture dynamic changes across the maintenance–OEE–productivity–financial performance chain, and explore the moderating effects of Industry 4.0 technologies and sustainability performance on the studied relationships.

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AUTHOR CONTRIBUTION STATEMENT

Oviyan Patra contributed to the conceptualization, research design, methodology, data collection, data analysis, and preparation of the original manuscript. Firman Pratama contributed to supervision, validation, theoretical framework development, and critical review of the manuscript. Evan Nugraha contributed to technical analysis, interpretation of findings, manuscript refinement, and final evaluation.

REFERENCES

Achouch, M., Dimitrova, M., Ziane, K., Sattarpanah Karganroudi, S., Dhouib, R., Ibrahim, H., & Adda, M. (2022). On Predictive Maintenance in Industry 4.0: Overview, Models, and Challenges. *Applied sciences*, *12*(16), 8081. https://doi.org/10.3390/App12168081

Al-Gobaisi, S., Al-Nassar, A., & Alkahtani, M. S. (2025). Effect Of Overall Equipment Effectiveness In The Supply Chain Management For A Petrochemical Company In Saudi Arabia : A Case Study. *Proceedings Of The 6th African International Industrial Engineering And Operations Management Conference Rabat*, 806–813. https://doi.org/10.46254/AF6.20250181

Albulescu, C. T., & Turcu, C. (2022). Productivity, Financial Performance, And Corporate Governance: Evidence From Romanian R&D Firms. *Applied Economics*, *54*(51), 5956–5975. https://doi.org/10.1080/00036846.2022.2056125

Alexander, Y., Putra, F. E., & Sari, P. A. (2024). Implementation Of Total Productive Maintenance On Frame Welding Machine Maintenance Using The Overall Equipment Effectiveness (OEE) Method At PT Electronics Components Indonesia. *International Journal Of Innovative Science And Research Technology*, *9*(6), 353–363.

Asbari, M. (2026). Systematic Literature Review : Implementasi Overall Equipment Effectiveness (OEE) Terhadap Kinerja Industri Manufaktur Di Indonesia. *International Journal Of Social And Management Studies*, *1*(1), 67–88.

Asogwa, J. O., Chike, N. E., & Nkechinyere, C. (2023). Firms in Nigeria. *International Journal Of Social Sciences And Management Review*, *6*(1), 110–138.

Bahçelerli, N. M. (2026). 20 Resource-Based Approach Theory. *Theories And Models In Tourism And Hospitality Research*, 130.

Barney, J. B. (2018). *Why Resource-Based Theory's Model Of Profit Appropriation Must Incorporate A Stakeholder Perspective*. https://doi.org/10.1002/Smj.2949

Bozionelos, N., & Simmering, M. J. (2022). Methodological Threat Or Myth? Evaluating The Current State Of Evidence On Common Method Variance In Human Resource Management Research. *Human Resource Management Journal*, *32*(1), 194–215.

Calandreli, P. R., Valle, P. D., & Deschamps, F. (2025). Maximizing Operational Efficiency With Industry 4.0 Technology: Integrating OEE As A Performance Indicator. *The International Journal Of Advanced Manufacturing Technology*, *138*(3), 855–872. https://doi.org/10.1007/S00170-025-15408-Y

Chaurey, S., Kalpande, S. D., Gupta, R. C., & Toke, L. K. (2021). A Review On The Identification Of Total Productive Maintenance Critical Success Factors For Effective Implementation In The Manufacturing Sector. *Journal Of Quality In Maintenance Engineering*, *29*(1), 114–135. https://doi.org/10.1108/JQME-11-2020-0118

Cruz-Sánchez, O., Cruz-Cázares, C., & Hernandez-Vivanco, A. (2026). Business Model Innovation From Dynamic Capabilities Perspective: A Systematic Literature Review. *Journal Of Business Research*, *204*, 115835.

De Morais Silva, G. J., Moore, S., & Mcdermott, O. (2026). A Systematic Literature Review Of OEE Research: Trends In Performance Metrics And Digital Integration In Manufacturing. *The TQM Journal*, *38*(11), 178–201.

Demir, S., & Uşak, M. (2025). Analyzing The Implementation Of PLS-SEM In Educational Technology Research: A Review Of The Past 10 Years. *Sage Open*, *15*(2). https://doi.org/10.1177/21582440251345950

Duarte, A. L. C. M., & Santiago, S. M. R. S. (2022). Maintenance Practices And Overall Equipment Effectiveness: Testing The Moderating Effect Of Training. *Journal Of Quality In Maintenance Engineering*, *29*(2), 442–459. https://doi.org/10.1108/JQME-04-2021-0033

Erbiyik, H. (2022). Definition Of Maintenance And Maintenance Types With Due Care On Preventive Maintenance. In G. Lambert-Torres, E. L. Bonaldi, & L. E. Oliveira (Eds.), *Maintenance Management - Current Challenges, New Developments, And Future Directions* (Pp. 1–164). Intechopen. https://doi.org/10.5772/Intechopen.106346

Franke, G., & Sarstedt, M. (2019). *Heuristics Versus Statistics In Discriminant Validity Testing: A Comparison Of Four Procedures*. https://doi.org/10.1108/Intr-12-2017-0515

Guidotti, D., Pandolfo, L., & Pulina, L. (2025). A Systematic Literature Review Of Supervised Machine Learning Techniques For Predictive Maintenance In Industry 4.0. *IEEE Access*.

Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. *European business review*, *31*(1), 2-24. https://doi.org/10.1108/EBR-11-2018-0203

Hair, J. F., Hult, G. T. M., Ringle, C. M., Sarstedt, M., Danks, N. P., & Ray, S. (2021). *Partial Least Squares Structural Equation Modeling (PLS-SEM) Using R: A Workbook*.

Hair Jr, J. F., Sabol, M., Islam, M. S., & Murshed, F. (2026). Conditional Mediation (Come) Models With PLS-SEM: An Update, Review, And Best-Practice Recommendations. *Australasian Marketing Journal*, *34*(2), 178–191.

Handayani, P., & Suseno. (2026). Analisis Perhitungan Total Produktive Maintenance (TPM) Menggunakan Overall Equipment Effectiveness (OEE) Di PT ABC. *Jurnal Ilmiah Research Student*, *3*(1), 360–368.

Harfoush, A., Fan, Z., Goddik, L., & Haapala, K. R. (2024). A Review Of Ice Cream Manufacturing Process And System Improvement Strategies. *Manufacturing Letters*, *41*, 170–181. https://doi.org/10.1016/J.Mfglet.2024.09.021

Hubley, A. M. (2024). Discriminant Validity. In *Encyclopedia Of Quality Of Life And Well-Being Research* (Pp. 1847–1850). Springer.

Istan, M., Husainah, N., Dadan, A., & Siswanti, I. (2021). The Effectsof Production and Operational Costs, Capital Structure and Company Growth On The Profitability: Evidence From

Manufacturing Industry. *Accounting*, *7*, 1725–1730. https://doi.org/10.5267/J.Ac.2021.4.025

Jurewicz, D., Dąbrowska, M., Burduk, A., Medyński, D., Machado, J., Motyka, P., & Kolbusz, K. (2024). *Implementation Of Total Productive Maintenance (TPM) To Improve Overall Equipment Effectiveness (OEE) - Case Study BT - Intelligent Systems In Production Engineering And Maintenance III* (A. Burduk, A. D. L. Batako, J. Machado, R. Wyczółkowski, E. Dostatni, & I. Rojek (Eds.); Pp. 543–561). Springer Nature Switzerland.

Khalili, A., Ismail, M. Y., & Ruzman, M. A. (2023). Planned Preventive Maintenance Effects On Overall Equipment Effectiveness: A Case Study In Malaysian Industry. *International Journal Of Productivity And Quality Management*, *38*(3), 332–360. https://doi.org/10.1504/IJPQM.2023.129614

Kirana, A. T., Widiasih, W., Studi, P., Industri, T., Teknik, F., Pumpungan, M., Mortar, R., Losses, S. B., & Mesin, E. (2024). Analisis Perhitungan Overall Equipment Effectiveness (OEE) Untuk Meningkatkan Efisiensi Mesin Haloong (Studi Kasus : PT Benteng Api Technic, Gresik). *Jurnal Tekstil*, *7*(1), 59–68.

Liew, C. F., Prakash, J., & Ong, K. S. (2022). Integration Of Financial Performance Measure With Overall Equipment Effectiveness For Assessing Operational Performance: A Structured Literature Review. *International Journal Of Productivity And Quality Management*, *37*(1), 119–142. https://doi.org/10.1504/IJPQM.2022.126008

Liew, C. F., Prakash, J., & Ong, K. S. (2024). Equipment Cost Efficiency: A Comprehensive Metric For Evaluating Operational And Financial Performance In Manufacturing. *Manufacturing Letters*, *39*, 16–19. https://doi.org/10.1016/J.Mfglet.2023.12.002

Liu, H., Wu, S., Zhong, C., & Liu, Y. (2020). The Sustainable Effect Of Operational Performance On Financial Benefits: Evidence From Chinese Quality Awards Winners. In *Sustainability* (Vol. 12, Issue 5, P. 1966). https://doi.org/10.3390/Su12051966

Mehrabi, S., Mahdad, M., Bijman, J., Cholez, C., Mesa, J. C. P., & Giagnocavo, C. (2025). Microfoundations Of Dynamic Capabilities Enabling Scaling Pathways Of Sustainability-Oriented Innovation Business Models. *Business Strategy And The Environment*, *34*(1), 849–871.

Monday, E. E. (2021). Impact Of Overall Equipment Effectiveness On Return On Investment In The Nigerian Cement Manufacturing Industry 1 Introduction 2 Research Objectives And Hypotheses 3 Literature Review. *Frontiers In Management And Business*, *2*(1), 87–94. https://doi.org/10.25082/FMB.2021.01.003

Nugroho, I. H., Salahudin, X., & Hilmy, F. (2025). Optimasi Produktivitas Mesin Microfeed Melalui Pendekatan Overall Equipment Effectiveness (OEE): Studi Kasus di Industri Manufaktur. *Jurnal Teknologi Dan Manajemen Industri Terapan*, *4*(1), 63–68.

Samadhiya, A., & Agrawal, R. (2023). Total Productive Maintenance And Sustainability Performance: Resource-Based View Perspective. *Benchmarking: An International Journal*, *31*(7), 2177–2196. https://doi.org/10.1108/BIJ-10-2022-0635

Ringo, M. A. B. S., & Kuriniawan, D. (2022). Penyusunan Prosedur Perawatan Mesin Welding Auto di PT Panasonic Industrial Devices. *Jurnal Bisnis Mahasiswa*, *2*(3), 294-301.

Singh, S., Khamba, J. S., & Singh, D. (2021). Analysis and directions of OEE and its integration with different strategic tools. *Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering*, *235*(2), 594-605. https://doi.org/10.1177/0954408920952624

Singh, S., Agrawal, A., Sharma, D., Saini, V., Kumar, A., & Praveenkumar, S. (2022). Implementation of total productive maintenance approach: Improving overall equipment efficiency of a metal industry. *Inventions*, *7*(4), 119. https://doi.org/10.3390/Inventions7040119

Suseno, B. D., Sugianto, E., Purnamasari, E., & Supriadi, A. (2023). Analysis Of The Application Of Operational Management In Manufacturing Companies In Bandung City: The Effect Of Production Efficiency, Product Innovation, And Customer Satisfaction On Financial Performance. *West Science Journal Economic And Entrepreneurship*, *1*(11), 339–350.

Teece, D. J. (2018). *Business Models And Dynamic Capabilities*. https://doi.org/10.1016/J.Lrp.2017.06.007

Tehseen, S., Ramayah, T., & Sajilan, S. (2017). Testing and controlling for common method

variance: A review of available methods. *Journal of management sciences*, *4*(2), 142-168. https://doi.org/10.20547/Jms.2014.1704202

Tiddens, W., Braaksma, J., & Tinga, T. (2020). Exploring Predictive Maintenance Applications In Industry. *Journal Of Quality In Maintenance Engineering*, *28*(1), 68–85. https://doi.org/10.1108/JQME-05-2020-0029

Tsarouhas, P. H. (2019). Overall Equipment Effectiveness (OEE) Evaluation For An Automated Ice Cream Production Line: A Case Study. *International Journal Of Productivity And Performance Management*, *69*(5), 1009–1032. https://doi.org/10.1108/IJPPM-03-2019-0126

Ullah, R., Molla, S., Siddique, I., & Siddique, A. A. (2023). Optimizing Performance: A Deep Dive Into Overall Equipment Effectiveness (OEE) For Operational Excellence. *Journal Of Industrial Mechanics*, *8*(3), 26–40.

Virk, S. I., Khan, M. A., & Indher, A. A. (2020). Review Of Total Productive Maintenance (TPM) & Overall Equipment Effectiveness (OEE) Practices In Manufacturing Sectors. *Proceedings Of The International Conference On Industrial & Mechanical Engineering And Operations Management*, 1–11.

Vital, J. C. M., & Lima, C. R. C. (2020). Total Productive Maintenance And The Impact Of Each Implemented Pillar In The Overall Equipment Effectiveness. *International Journal Of Engineering And Management Research*, *2*(2), 142–150.

Zonta, T., Da Costa, C. A., da Rosa Righi, R., De Lima, M. J., Da Trindade, E. S., & Li, G. P. (2020). Predictive Maintenance in The Industry 4.0: A Systematic Literature Review. *Computers & Industrial Engineering*, *150*, 106889. https://doi.org/10.1016/J.Cie.2020.106889