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Strategies to Improve Machine Maintenance Effectiveness to Minimize Downtime at PT. MNO, a Tableware Ceramics Manufacturer

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ABSTRACT

The objective of this research is to enhance the productivity of PT MNO to reduce the downtime, as it can be done by good machine maintenance strategy. This study is a mixed method research by analyzing data on some machineries with critical conditions of the Kiln and Oven at PT MNO for 2022 - 2024 using Overall Equipment Effectiveness and root cause analysis. The study's findings reveal a decline in OEE of 42.75% by 2024 due to the "Best tools oldest" affecting availability of spare parts. Strategic improvements with method 5W+1H: are to gain the OEE and bring back to 79% that year. The contribution implication of this research is to provide as a reference stakeholders, PT. MNO, and State-Owned Enterprises to maintain the stable supply of national ceramic product.

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INTRODUCTION

The ceramic tableware manufacturing industry is highly reliant on the reliability of thermal machines such as kilns and drying ovens. A prominent ceramic producer, PT MNO, exemplifies this sector. Ensuring the effectiveness of machine maintenance is a critical issue for the company, impacting its supply chain stability and competitiveness in the market. Despite having a Preventive Maintenance (PM) schedule for machines with a compliance rate exceeding 90%, there are several anomalies observed in the field.

Operational data from the year 2024 has revealed a concerning number of damage cases: 282 cases of Corrective Maintenance (CM) and 28 cases of Breakdown Maintenance (BM). The high frequency of damage events has a detrimental impact on unplanned downtime, leading to delays in product shipments and increased operational costs. Financial losses due to unplanned downtime are estimated to range from Rp2,000,000 to Rp25,000,000 per delayed batch, in addition to repair costs that can reach Rp55,000,000 per machine per case. These issues indicate that the current maintenance strategy is not adequately effective in mitigating machine failure risks.

Therefore, this research aims to achieve three primary objectives: measure the effectiveness of the main Kiln and Process Oven machines using Overall Equipment Effectiveness (OEE), identify the root causes of machine unplanned downtime using Root Cause Analysis, and formulate a comprehensive improvement strategy to minimize absenteeism in the future.

LITERATURE REVIEW

Maintenance Concept and TPM

This research is based on the philosophy of Total Productive Maintenance (TPM) introduced by Nakajima. Total Productive Maintenance is not merely an improvement method; rather, it is a holistic approach that involves efforts at every level of the organization to maximize equipment effectiveness. In the case of PT MNO, the transition from reactive maintenance to preventive maintenance is prioritized to reduce wastage due to operational downtime.

Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness (OEE), the expression OEE and the 6 Big Losses Overall Equipment Effectiveness, also known as OEE value, is used as a global standard metric to evaluate manufacturing performance. OEE is calculated by the ratio of total variation time in a period to productive time. Some factors contributing to OEE losses are as follows:

- Availability is a loss due to breakdown processes and setup time.
- Performance is a loss due to machines running slowly, such as reduced speed and downtime or momentarily halted machines known as idle time.
- Quality is a loss due to product defects and rework.

Root Cause Analysis (RCA)

In addition to quantitatively measuring the OEE level, this research utilizes RCA as a qualitative analysis tool. RCA helps uncover the root causes of issues behind equipment failures. Tools used include the Fishbone Diagram

(Ishikawa) to map causal factors based on the 5M categories and the 5-Why analysis to trace cause-effect relationships to the deepest layers.

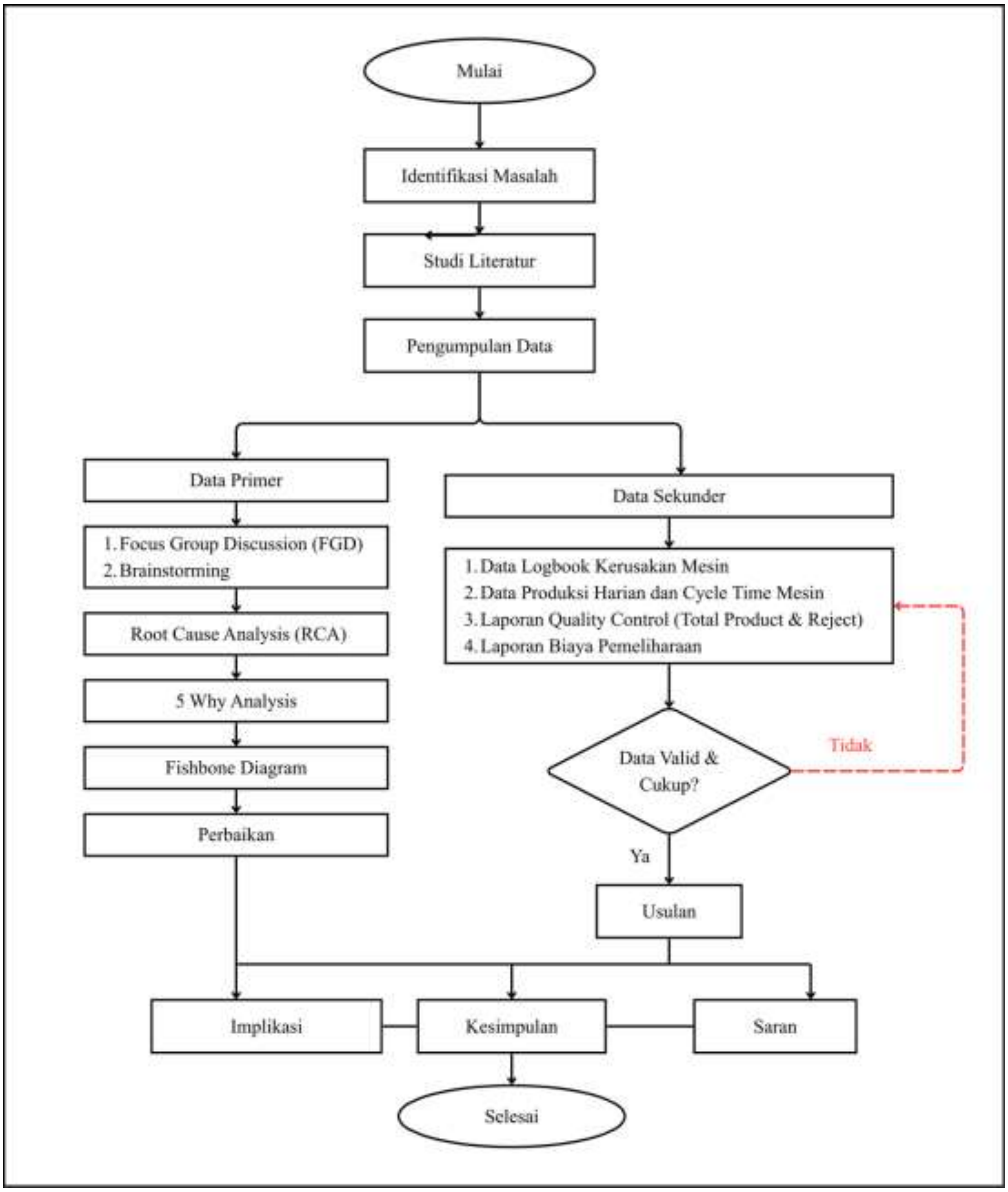

Figure 1. Research Flow

METHODOLOGY

This study utilizes a mixed-method approach with an explanatory sequential design. Sequential, based on that, the sequential explanatory mixed method involves quantitative findings followed by qualitative explanations to understand events to the extent possible. The first stage employs a quantitative descriptive method aiming to objectively measure machine performance based on numerical data. The second stage involves a qualitative method used to create real conditions that enable the understanding of the root causes of issues uncovered in the first stage. This approach is chosen because qualitative data answers the question "what happened", while qualitative data answers: "why did it happen".

Population and Sample

The research population includes all machines and production equipment operating in PT MNO's facility totaling 160 machine units. As for the sample, a Purposive Sampling technique is used for sample selection based on criteria of front-line failure risk levels after conducting a risk analysis. Based on these criteria, the study will focus only on 2 critical machine units, namely the Roller Kiln and Tunnel Oven units identified to have the highest frequency of failures and downtime impact.

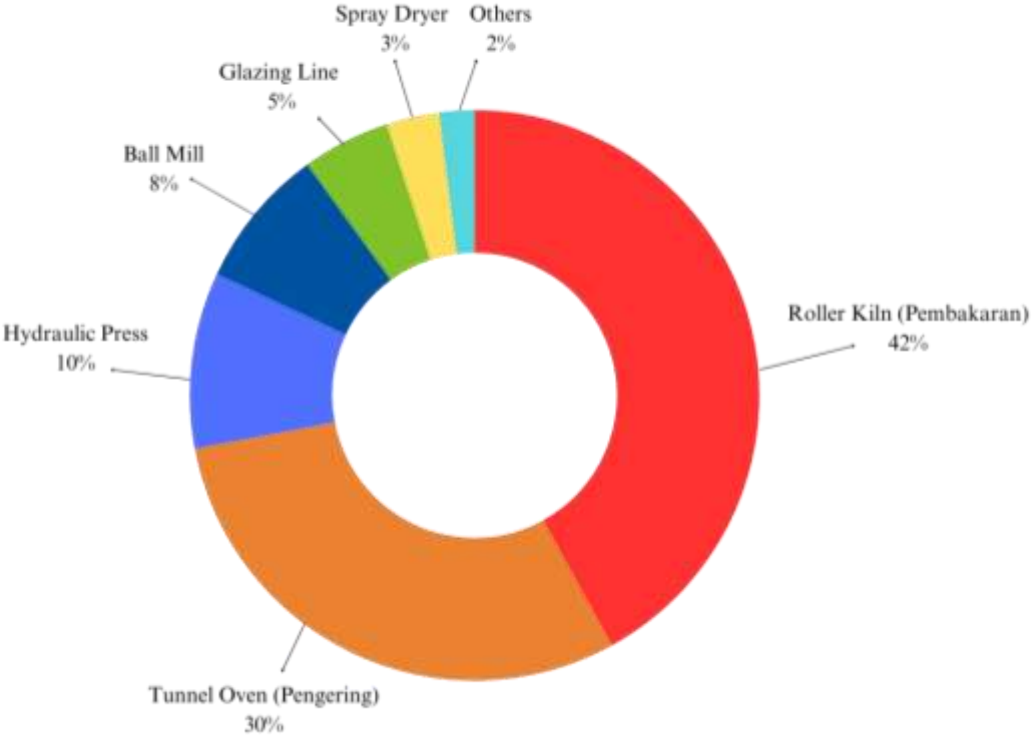

Figure 2. Main Machines with Problems at PT.MNO.

Data Collection

Data is collected from two primary sources:

- Secondary Data: Secondary data consists of historical maintenance logbook records, daily production reports, and repair cost data from January 2022 to December 2024.
- Primary Data: Primary data is obtained through direct observations in the production line and Focus Group Discussions. FGD participants are purposively selected key personnel from the pilot project pamphlet (Technical Manager, Production Manager, QA), and employees with a minimum of 3 years of work experience are chosen to validate field findings.

Data Analysis Instruments

Three main instruments are used to analyze the collected data progressively:

- Overall Equipment Effectiveness: Used to calculate machine effectiveness based on three indicators: Availability, Performance Efficiency, Quality Rate.
- Root Cause Analysis: Utilized to identify the root causes of the decline in OEE value. A Fishbone Diagram is used to map the 5M factors and the 5-Why Analysis for tracing the deepest root problems.
- 5W+1H Analysis: Used to formulate specific corrective action strategies to enhance machine performance in the future.

RESEARCH RESULT

Empirical Findings on Machine Performance Degradation at PT MNO

The following empirical findings pertain to the degradation of machine performance at PT MNO over a three-year period since the observation period: Appendix. The study is detailed into three crucial steps to address downtime issues at PT MNO: [1] measuring the performance of existing machines using the OEE method, [2] diagnosing root causes of problems using RCA 5-Why, and [3] formulating improvement strategies using the 5W+1H method.

Calculation of Overall Equipment Effectiveness (OEE)

The level of effectiveness of the main machine utilization in the production line of PT. MNO, particularly in the Kiln and Drying Oven machines, can be calculated using the value of Overall Equipment Effectiveness. This calculation serves as the sole indicator of how effectively the operational time of the machine is used to produce ceramic products to the maximum extent. Additionally, the value of Availability Ratio can also be calculated as the ratio of the time available for machine operation. The variables needed to calculate the Availability Ratio are as follows:

- Loading Time is the total operating time regulated minus the unaccounted machine setup time.
- Operation Time is Loading Time minus the time for breakdowns.

Based on secondary data, such as the Daily Log Book and Monthly Maintenance Reports, a manual calculation example for the January 2024 period, when the machine conditions experienced a significant performance decline, is as follows:

$$Availabilty = \frac{Loading\ Time - Downtime}{Loading\ Time}\ x\ 100\% \quad (1)$$

Table 1. Total Average Equipment Availability Value of PT. MNO for 2022-2024

No.	Year	Availability Rate (%)
1.	2022	96,25
2.	2023	90,25
3.	2024	75,92

The PE equipment value is obtained by using formula (2), which is to compare the total units produced in a day with the target for the day or shift of operation if it is ideal with the net available operating time and the machine's design capacity. Based on the daily and monthly production report data, the ideal Cycle Time capacity of the Kiln and Oven Machines can be determined and expressed as "hours available in a day 22 units/hour or equivalent to 0.045 hours/unit". The drying process for the kiln and oven machines can be calculated as follows:

$$Performance\ Rate = \frac{Total\ Production\ Output}{Production\ Target} \text{ x } 100\%. \ (2)$$

Table 2. Total Average Equipment Performance Rate tahun 2022-2024

No.	Year	Performance Rate (%)
1.	2022	96,17
2.	2023	90,21
3.	2024	75,13

Based on the summary of the calculation table data above, the average Performance Rate value on the main machine is identified to have significantly decreased in performance from 2022 to 2024. Specifically, the Performance Rate values for Kiln Machine and Dryer Oven dropped from 96% to 75%, as shown in Table 2.4. Equipment Quality Rate Calculation. The equipment's Quality Rate value can also be calculated according to formula (3). Based on the daily and monthly report data, the average daily ceramic production in January 2024 is 144 pcs/day for the Kiln Machine. Therefore, the calculation for the Quality Rate of the Kiln Machine and Dryer Oven in January 2024 can be computed as follows:

1. Kiln Machine Performance Calculation
    - Clean Operating Time: 300 – 18 – 92 = 190 Jam
    - Production Target: 190 Jam x 22 Unit/ jam = 4.180 pcs
    - Total Production Output: 3.135 pcs

    $Quality\ Rate = \frac{3.135-493}{4.180}\ x\ 100\%$ = 75% (3)
2. Calculation of Drying Oven Machine Performance
    - Clean Operating Time: 300 - 17 - 61 = 222 Jam
    - Production Target: 222 jam x 22 Unit/Jam = 4.884 Pcs
    - Total Production Output: 3.760 Pcs
    - Performance Rate:

    $Quality\ Rate = \frac{3.760-440}{4.884}\ x\ 100\%$ = 77% (4)

Table 3. Average Equipment Quality Values for 2022-2024

No.	Year	Performance Rate (%)
1.	2022	98,54
2.	2023	95,33
3.	2024	75,13

After obtaining all three main factors namely *Availability, Performance Efficiency,* and *Quality Rate*, the final OEE value can be calculated by combining them. Here is a summary of the OEE value calculations from 2022 to 2024 on the aforementioned main machines, Kiln and Oven, for each year over the past three years:

- OEE Value for 2022 (Prime Condition):
$$OEE = 0{,}96 \text{ x } 0{,}96 \text{ x } 0{,}98 = 90{,}32\%$$
- OEE Value for 2023 (Beginning to Decline):
$$OEE = 0{,}90 \text{ x } 0{,}90 \text{ x } 0{,}95 = 76{,}95\%$$
- OEE Value for 2024 (Critical Condition):
$$OEE = 0{,}76 \text{ x } 0{,}75 \text{ x } 0{,}75 = 42{,}75\%$$

Following the calculations:

Based on the calculations above, it can be concluded that the main equipment at PT. MNO has experienced a significant degradation in equipment effectiveness: – Based on the global standards set by the Japan Institute of Plant Maintenance JIPM:

1. A World Class classification is assigned to an OEE value of **85%** or higher.
2. An OEE value above **60%** is considered acceptable but indicates significant room for improvement.

From the data, in 2022, the kiln and oven machines at PT. MNO performed very satisfactorily with an OEE value of 90.32%, placing them in the World Class category. However, in 2024, there was a drastic drop in the OEE value to only 42.75%. This figure is well below the industry standard threshold (60%) and indicates severe inefficiencies occurring within the production process.

Given this situation, a more detailed and specific analysis is required to identify the specific factors, namely the Six Big Losses, that contribute to the extremely poor OEE values of the Kiln and Oven machines. This analysis will serve as a reference to determine the corrective actions needed to restore the equipment's performance to its maximum level.

Root Cause Analysis

The next step of this study involves a detailed analysis of determinants that have led to a significant decrease in Overall Equipment Effectiveness on Kiln and Oven machines, the main machines of PT. MNO. The method used includes Focus Group Discussions and structured interviews with experts from the production and maintenance departments. After several discussions and information gathering, problem mapping is carried out using analytical tools as follows:

a. Fishbone Diagram Analysis

The use of Fishbone Diagram is crucial in identifying and mapping all potential causes of issues in a systematic and scientific manner, as characterized by interview results from various parties. Through this diagram, common problems and issues are categorized structurally, and further actions are directed towards their root causes. In interactive two-way discussion exploration, the author leverages empirical experience and technical insights from experts to identify the sources of issues and formulate strategic improvement options.

Synthesizing interview results reveals that the dominant causal factors affecting the machine's performance can be grouped into five main elements, namely:

1. Man, relating to competency, discipline, and fatigue of man: operators or technicians.
2. Machine, regarding equipment age, component fatigue, and outdated technology.
3. Methods, involving work procedures such as SOPs, machine operation duration, and maintenance schedules.
4. Material, consisting of raw material factors for production and spare parts.
5. Money, related to budget constraints on maintenance or reinvestment efforts.

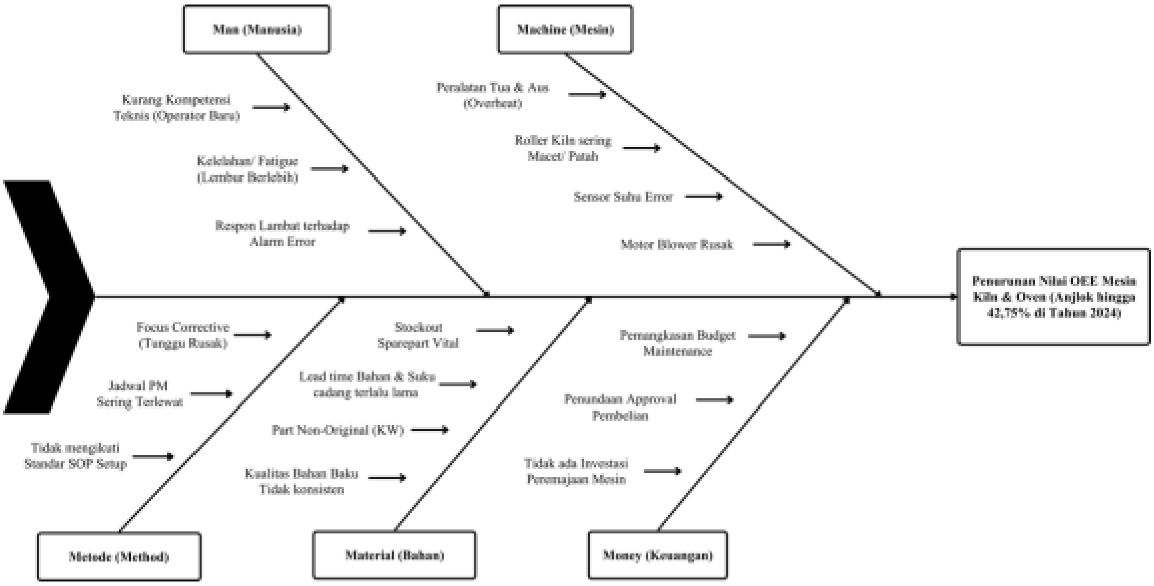

Figure 3. Fishbone Diagram

Afterward, because all factors influencing the decline in Kiln and Oven machine performance have been outlined in the Fishbone Diagram, the next strategic step is the most appropriate place to delve into its root cause and formulate precise solutions. This in-depth analysis is carried out using the 5 Why Analysis method, which is a technique of repeated interrogation to trace the cause-and-effect relationships to the most fundamental problem root, "Spaghetti Diagrams," 2020. With this method, surface symptoms can be isolated so that corrective actions taken actually target the source of the problem directly and prevent its recurrence. The following is the result of the 5 Why analysis on the main issue of OEE decline at PT. MNO.

Table 4. Why Analysis

Category (Fishbone)	Surface Issues (Why 1)	**Why 2**	**Why 3**	**Why 4**	**Why 5 (Root Cause)**
MAN (Human)	Operators are often slow to respond to temperature	Operators have little understanding of machine characteristics and technical error codes.	Many senior technicians retired/resigned, replaced by new operators with minimal experience.	There is no knowledge transfer program or intensive training.	**The training system does not work because there is no allocation of time and a special budget**

	error alarms on the Kiln.				**for HR development.**
MACHINE	*Roller*ceramics often jam and break, causing the machine to stop completely (breakdown).	The buildup of combustion residue hinders the rotation of the roller.	Routine cleaning schedules are often missed or done carelessly.	Machines are forced to operate continuously (overcapacity) in order to meet production targets.	**A production management mindset that prioritizes short-term output (Quantity) over long-term machine health (Asset Care).**
METHOD	The duration of damage repair (downtime) is very long (can be 30-45 days).	Waiting for the arrival of replacement spare parts that are not available in the warehouse.	The procurement procedure is very bureaucratic and takes a long time to be approved.	There is no minimum stock standard (buffer stock) for critical components.	**Poor Sparepart Management SOP that is not integrated with maintenance needs.**
MATERIAL	The heater and sensor components often fail within a short time.	The installed spare parts are of low quality/non-original (KW).	Purchasers are forced to choose the supplier with the lowest price, not the best quality.	The spare part budget was drastically cut.	**Extreme cost reduction policies without considering technical risks.**
MONEY (Finance)	The Kiln and Oven machines have never been completely rejuvenated (overhauled).	Major repair fund applications are consistently delayed or rejected.	Management considers maintenance as just a cost center that is a burden.	Financial priorities are shifted entirely to surviving external issues (e.g., sluggish markets).	**Lack of commitment and understanding of top management regarding the importance of investing in machine reliability (Reliability Investment).**

To address the aforementioned questions and formulate concrete and measurable corrective actions regarding the declining performance of the Kiln and Oven Machines at PT. MNO, this study proceeds with the 5W + 1H Analysis approach (*What, Why, Where, When, Who, How*). This method ensures a wide opening for root cause findings at the 5 Why Analysis stage and acknowledges findings under the field. At this stage, it is still necessary to decompose all people, machines, methods, materials, and money so that each specification of solutions, locations, times, accountabilities, and technical steps are identified. Below is a breakdown of the relevant machine performance improvement roadmap as determined in the 5W + 1H table.

Table 5. W+1H Analysis

Factor	What (What is the problem?)	Why (Why Did It Happen?)	Where (Where?)	When (When?)	Who (Who is PJ?)	How (What is the Corrective Action?)
MAN	Lack of supervision and technical competence in handling machines.	The number of personnel does not match the formation (insufficient) & new technicians do not have special skills certificates.	Kiln & Oven Maintenance Area	Coming Soon (Starting Next Month)	HRD & Head of Engineering Department	1. Internal Recruitment/Rotation: Fulfill technician quota according to formation standards (min. 12 people). 2. Intensive Training: Conducting Combustion System & Thermal Calibration certification training for implementing technicians.
MACHINE	The engine often experiences sudden breakdowns and speed loss.	The machine used is a second-hand unit whose internal components are old/worn out, but is forced to work excessively (overcapacity).	Production Unit (Line Kiln 1 & Oven 2)	Gradual (Annual Shutdown Schedule)	Head of Production & Maintenance	1. Vital Component Restoration: Performing a total overhaul on the old gearbox and heating element. 2. Load Adjustment: Returns the machine's working load to safe design capacity temporarily until repairs are completed.
METHOD	Repair time is very long & damage	Preventive Maintenance SOP is not implemented; the focus	Maintenance Workshop	Daily (Morning Routine)	Maintenance Supervisor	1. Implementation of Autonomous Maintenance: Requires production

	is repeated.	of work is only on repairs when damaged (Corrective).				operators to carry out daily checks (cleanliness, lubrication, loose bolts). 2. SOP revision: Create a component replacement schedule based on working hours (Time-Based Maintenance), not waiting for damage.
MATERIAL	Long downtime due to lack of spare parts.	There is no minimum stock system (buffer stock) for fast-moving parts.	Spare Parts Warehouse	Weekly (Stock Review)	Head of Warehouse & Purchasing	1. Determining Min-Max Stock: Determine the minimum stock limit for critical parts (e.g.: thermocouples, bearings). 2. Vendor Evaluation: Look for alternative vendors with faster lead times.
MONEY (Finance)	Obstacles in purchasing quality spare parts & equipment rejuvenation.	Maintenance budget cuts due to company efficiency policies.	Management Meeting Room	During the Budget Meeting (Q1)	Plant Manager & Finance	1. Cost-Benefit Analysis: Presents data on losses due to production stops (Lost Sales) which are much greater than the cost of purchasing spare parts. 2. Budget Priority: Divert non-essential budget to fund critical machine repairs.

Based on the analysis of the 5W+1H above, recommendations for improvements that need to be adopted by the company in its annual asset maintenance strategy include the following: the key to restoring the performance of critical machines lies in solid collaboration among management, technicians, and third parties. With systematic administration, the reliability of machine performance will return to the specified quality parameters. As a follow-up step, this strategy is scheduled to be included in routine evaluation meetings such as daily, monthly, and annual meetings to ensure consistent and accountable monitoring of target achievements.

DISCUSSION

Systemic Inefficiency Interpretation

The data analysis of OEE for the period 2022–2024 revealed an extreme degradation of operational performance, as the OEE value plummeted from the *World Class* benchmark of 90.32% to a critical level of 42.75%. This decline was predominantly caused by the fall in the *Availability Ratio* to 75.92% and *Performance Efficiency* to 75.13%, both of which confirmed the failure of the reactive maintenance strategy *run-to-fail*. The findings demonstrate that imposing *overcapacity* workloads on aging machines without component renewal actually engenders a cycle of repetitive failures, hastening the depreciation rate of asset functionality.

Managerial Causality: Budgetary Cutbacks Impact

Root cause analysis identifies that technical barrier on the production floor are a misleading symptom; rather than being the primary cause, these obstacles are in turn triggered by misguided financial policies. Once again, it is proven that Money reigns as the judge of all evil roots: budget cuts in maintenance are the primary cause triggering a "neat circle" domino effect: the depletion of spare parts buffer stock stands as Material while the regeneration of technician competency represents Man. These short-term cost-efficient policies have proven to be counterproductive, as today's nominal budget savings from Money are in fact eroded by escalating downtime costs and the substantial loss of production opportunities.

Strategic Implications and Recovery

Simulation of improvement strategies based on the above 5W+1H reveal that transitioning efforts towards Time-Based Maintenance—from reinstating critical stock, selecting processes for key technician competencies in human resources, and embedding performance certifications in HR—will achieve operational stability with a projected OEE of 79%. From a managerial perspective, this research implies the urgent need for a paradigm shift in management at PT MNO to reposition maintenance costs as a profit center, rather than an operational burden. Without assured spare parts availability and technician competencies, achieving efficiency in ceramic tableware production will undoubtedly remain unattainable.

CONCLUSIONS

- Existing Strategy Failure: Critical machinery performance at PT MNO has experienced extreme degradation, with OEE plummeting from 90.32% (2022) to 42.75% (2024), attributed to predominant unplanned downtime.
- Fundamental Root Cause: Technical inefficiency is merely a derivative impact of the cost-cutting maintenance policy (Money). This policy severs the supply chain of spare parts (Material) and impedes the regeneration of technician competencies (Man).

- Recovery Projection: Implementing a 5W+1H-based Preventive Maintenance strategy, in particular, establishing buffer stock procurement and certifying validated technicians, can restore operational stability with a projected OEE increase to 79%.

RECOMMENDATIONS

- Budget Policy Restructuring: Top management must revise the budget policy by prioritizing capital expenditures inclined towards machine upgrades and operational expenses inclined towards critical spare parts procurement. The cost of maintenance should be reframed as an investment.
- Implementing Buffer Stock System: Nearly all fast-moving components such as heaters, bearings, and thermocouples. Safety stock should ideally be reduced from weeks to hours.
- Work Culture Transformation: Executing Autonomous Maintenance implementation rigorously, where production operators must engage in routine daily inspections like cleaning, lubrication, and tightening – to foster ownership and detect signs of damage.
- Competency Enhancement Program: The HRD department should schedule periodic technical certification training and establish a knowledge management system from senior technicians to junior ones – consequently phasing out gradual dependence on third parties.

ADVANCED RESEARCH

The limitation of the scope of this study is the focus solely on critical machines, namely the Kiln and Oven at PT MNO. As a result, the OEE measurements from these machines do not fully represent the overall efficiency capabilities of the entire Total Plant OEE production line. Subsequent studies will be directed towards expanding the scope of analysis to an end-to-end approach, covering from raw material preparation to final packing. This technical research will be complemented by a more in-depth financial analysis such as Cost-Benefit Analysis (CBA) or Return on Investment (ROI) calculations to strengthen the argument for the profitability of preventive maintenance strategy implementation.

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