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Equipment Efficiency Analysis of Espresso Machine Using the Overall Equipment Effectiveness (OEE) Method and Total Productive Maintenance (TPM) Approach

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Abstract

This study aims to evaluate the equipment efficiency of a La Marzocco espresso machine at Kopi Anak Monopole Coffee Shop by employing the Overall Equipment Effectiveness (OEE) method and the Total Productive Maintenance (TPM) framework. The analysis measures machine performance through three main OEE components: availability, performance, and quality. A quantitative approach was used by collecting eight months of observational data (December 2024–July 2025), including operational time, downtime, setup duration, and the quantity of both good and defective outputs. Data interpretation involved OEE computation, the Six Big Losses framework, Pareto prioritization, and Fishbone root-cause analysis. Findings indicate that before TPM implementation, the espresso machine achieved an average OEE of 30.25%, dominated by idling and minor stoppages (65.61%). After TPM was applied, the OEE increased to 31.01%, showing measurable improvement in machine reliability and operator awareness. The study highlights that the adoption of TPM principles in small-scale coffee shops can enhance operational discipline and efficiency, offering both theoretical and practical insights for service oriented businesses.

Keywords

Overall Equipment Effectiveness (OEE); Six Big Losses; Total Productive Maintenance (TPM); Coffee Shop; Machine Performance

INTRODUCTION

Backgorund Study

The growth of the coffee shop industry in Indonesia has shown remarkable expansion in recent years. Coffee consumption has been increasing steadily in line with lifestyle changes and the rise of the urban middle class. According to the Badan Pusat Statisik (2024), domestic coffee consumption reached approximately 370 thousand tons per year and continues to increase consistently. Supporting this national trend, the International Coffee Organization (2024) also reported an average growth rate of 3.5% per year in Indonesia’s coffee consumption between 2018/2019 and 2023/2024. The global data confirms that Indonesia is part of the worldwide surge in coffee demand driven by younger consumers and the lifestylebased cafe culture.

This phenomenon has encouraged the rapid proliferation of coffee shops across major cities. Reports from Toffin Indonesia (2020) reveal that the number of coffee outlets grew sharply from fewer than 3,000 in 2019 to over 10,000 by 2023 (Purwanto, 2024). This sharp increase illustrates the rapid expansion of the domestic coffee industry.

Coffee shops have evolved beyond their initial role as beverage providers, becoming lifestyle oriented venues where individuals engage in social, professional, and recreational activities.. These dynamics create a competitive environment that demands operational reliability, particularly in key production equipment such as espresso machines (Heizer et al. 2020).

Importance of Machine Reliability in Coffee Shop Operations

The espresso machine functions as the central operational unit in coffee preparation, as it determines both the consistency and quality of the product served to customers (Sitorus, 2020). However, operational

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inconsistencies such as unstable pressure, irregular calibration, and overheating have frequently caused service delays and quality deviations (Haris et al. 2020). The La Marzocco Linea Mini EE espresso machine at Kopi Anak Monopole recorded at least six downtime events during 2022–2024, affecting workflow smoothness and customer satisfaction.

Inadequate preventive maintenance and inconsistent operational handling can lead to reduced productivity, increased maintenance costs, and longer customer waiting times (Muchiri et al. 2011). Therefore, a systematic evaluation of machine performance is essential to ensure stable and efficient operations in daily production processes.

Theoretical Framework of Machine Efficiency Measurement

To systematically assess machine performance, this study applies the Overall Equipment Effectiveness (OEE) approach introduced by Nakajima (1988), which provides a comprehensive indicator combining machine readiness, production speed, and output quality. OEE quantifies the ratio between actual productivity and ideal performance through three indicators: availability, performance, and quality. The internationally recognized OEE benchmark of 85% reflects high efficiency, with individual target values of approximately 90% for availability, 95% for performance, and 99% for quality (Vorne Industries, 2023).

The major sources of OEE reduction, known as the Six Big Losses, consist of (Nakajima, 1988):

(1) equipment failure
(2) setup and adjustment
(3) idling and minor stoppages
(4) reduced speed
(5) defect losses
(6) yield/scrap losses

Analyzing these losses using Pareto and Fishbone (Ishikawa) diagrams allows organizations to identify the dominant causes of inefficiency (Cao, 2007).

Total Productive Maintenance (TPM) as a Solution Framework

The Total Productive Maintenance (TPM) philosophy emphasizes preventive and participatory maintenance to achieve "zero breakdown, zero defect, and zero accident." TPM integrates human factors, equipment condition, and procedural control through its eight core pillars, among which autonomous maintenance and training and education are most crucial for small scale operational environments such as coffee shops (Tortorella et al. 2021).

By implementing TPM, operators are empowered to perform routine inspections, cleaning, and minor repairs independently, reducing reliance on technical maintenance teams and promoting ownership of machine conditions. This cultural shift aligns with Stevenson (2021) concept of lean service operations that prioritize reliability and waste elimination.

RESEARCH METHODS

The research employed a quantitative case study conducted at Kopi Anak Monopole Coffee Shop in Surabaya, Indonesia. The study object, a La Marzocco Linea Mini EE espresso machine, serves as the primary production equipment in daily operations. Observations were carried out from December 2024 to July 2025, capturing parameters such as total loading time, machine downtime, setup duration, production quantity, and defective outputs.

The first seven months (December 2024-June 2025) represent the pre-TPM implementation phase, while the eighth month (July 2025) corresponds to the post TPM implementation phase. Supporting information such as the frequency of minor stoppages, maintenance routines, and operator activities were also recorded to support the Six Big Losses, Pareto, and Fishbone analyses.

Data analysis followed four key stages:

Overall Equipment Effectiveness (OEE)

The calculation of Overall Equipment Effectiveness (OEE) followed the classical formulation by Nakajima (1988), integrating availability, performance, and quality indicators to obtain a single efficiency index.

$$OEE = A \times P \times Q \times 100\%$$

$$\text{Availability} = \frac{\text{loading time} - \text{downtime}}{\text{loading time}} \times 100\%$$

$$\text{Perfomance} = \frac{\text{processed amount} \times \text{ideal cycle time}}{\text{operation time}} \times 100\%$$

$$\text{Quality} = \frac{\text{processed amount} - \text{defect amount}}{\text{processed amount}} \times 100\%$$

Six Big Losses

Inefficiencies were analyzed through the Six Big Losses framework, focusing on the

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categories of breakdowns, setup and adjustment, idling, speed reduction, defects, and yield losses (Yohanes et al. 2019):

1. Equipment Failure Losses
$= \frac{\text{downtime}}{\text{loading time}} \times 100\%$

2. Set Up and Adjustment Losses
$= \frac{\text{set up time}}{\text{loading time}} \times 100\%$

3. Idling and Minor Stoppage Losses
$= \frac{\text{non productive time}}{\text{loading time}} \times 100\%$

4. Reduced Speed Losses
$= \frac{\text{operation time} - \text{ideal production time}}{\text{loading time}} \times 100\%$

5. Defect Losses
$= \frac{\text{ideal cycle time} - \text{product defect}}{\text{loading time}} \times 100\%$

6. Yield/Scrap Losses
$= \frac{\text{ideal cycle time} - \text{scrap}}{\text{loading time}} \times 100\%$

Pareto Diagram

The Pareto diagram was applied to identify dominant loss types contributing most to total inefficiency, based on the 80/20 principle (Cao, 2007), where a small number of factors typically cause most performance reduction. Formula by Yohanes et al. (2019):

$\frac{\text{persentase six big losses}}{100} \times \text{loading time}$

Fishbone Diagram

Fishbone (Ishikawa) diagrams were used to trace the main causes of major losses, categorized into man, machine, method, material, environment, and measurement aspects (Ishikawa, 1986).

Total Productive Maintenance (TPM)

The final stage of analysis was the formulation of improvement strategies under the Total Productive Maintenance (TPM) concept, emphasizing preventive maintenance and operator participation as the core of long term performance enhancement (Tortorella et al. 2021)

RESULTS AND DISCUSSION

Overall Equipment Effectiveness (OEE) Calculation Results

The measurement of the Overall Equipment Effectiveness (OEE) for the La Marzocco Linea Mini EE espresso machine was conducted from December 2024 to June 2025, before the implementation of Total Productive Maintenance (TPM). The OEE calculation used three parameters: availability rate, performance efficiency, and quality rate.

The monthly calculation results are presented in Table 1.

Table 1. Overall Equipment Effectiveness (OEE) Calculation

Month	Availability Rate (%)	Perfomance Efficiency (%)	Rate of Quality (%)	OEE (%)
Dec-24	96,01	30,74	79,47	23,45
Jan-25	95,61	45,39	77,80	33,76
Feb-25	96,46	45,63	78,38	34,49
Mar-25	95,29	38,18	78,94	28,72
Apr-25	94,68	42,30	78,66	31,50
May-25	96,44	44,25	78,80	33,63
Jun-25	96,55	37,11	73,16	26,22
Average	95,86	40,51	77,89	30,25

From the analysis, it can be inferred that the espresso machine operated with minimal downtime, reflected by its high availability rate of 95.86%, indicating minimal downtime. However, the performance efficiency (40.51%) was significantly below the world class standard of 95% (Vorne Industries, 2023), which demonstrates frequent idle periods and reduced production speed. The quality rate (77.89%) was also lower than the 99% world benchmark, implying inconsistency in espresso extraction results.

The overall OEE value before TPM implementation averaged 30.25%, far below the world class benchmark of 85%. This suggests that despite the machine's

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operational readiness, performance losses and quality defects significantly limited overall effectiveness.

Identification of Six Big Losses

To determine the root cause of low performance, the Six Big Losses framework was used to analyze the six categories of production losses. The distribution of losses during the pre-TPM period is presented in Table 2.

Table 2. Six Big Losses Analysis

Month	Equipment Failure Losses (%)	Set Up and Adjustment Losses (%)	Idling Mirror and Stoppages Losses (%)	Reduced Speed Losses (%)	Defect Losses (%)	Yield/ Scrap Losses (%)
Dec-24	0,78	3,21	72,56	6,27	6,06	0,74
Jan-25	0,70	3,69	61,85	-5,49	9,64	0,80
Feb-25	0,56	2,99	61,96	-6,78	9,51	0,77
Mar-25	0,87	3,84	66,57	1,59	7,66	0,79
Apr-25	1,09	4,23	63,17	-0,66	8,55	0,81
May-25	0,58	2,99	62,81	-6,01	9,05	0,75
Jun-25	0,46	2,99	70,33	0,12	9,62	0,78
Average	0,72	3,42	65,61	-1,56	8,58	0,78

From the table, it is evident that the dominant loss category was Idling and Minor Stoppages with an average of 65.61%, followed by Defect Losses (8.58%) and Setup and Adjustment Losses (3.42%). These findings are consistent with the study by Muchiri et al. (2011), which emphasized that short, repetitive stoppages in service equipment often contribute to the largest share of productivity losses.

The frequent idle periods were mainly caused by workflow interruptions such as waiting for beans to be ground, cleaning the portafilter, and short communication gaps among baristas. This condition reduced the effective operation time and slowed the machine's performance efficiency.

Pareto Analysis of Losses

To prioritize improvement efforts, the Pareto diagram was used to identify which loss types contributed most to the overall inefficiency. The cumulative percentage of losses is shown in Table 3.

Table 3. Cumulative Losses

Type of Losses	Average	Persentage	Cumulative
Idling Mirror and Stoppages Losses	65,61%	84,60%	84,61%
Defect Losses	8,58%	11,10%	95,68%
Set Up and Adjustment Losses	3,42%	4,40%	100,09%
Yield/Scrap Losses	0,78%	1,00%	101,09%
Equipment Failure Losses	0,72%	0,90%	102,02%
Reduced Speed Losses	-1,56%	-2,02%	100,00%
Total	77,54%	100,00%	[redacted]

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The Pareto analysis shows that Idling and Minor Stoppages accounted for approximately 84.6% of total losses, followed by Defect Losses (8.6%) and Setup & Adjustment Losses (3.4%). This confirms that improvement initiatives should focus primarily on reducing idle and minor stoppage activities, which are responsible for more than two-thirds of total performance reduction.

These results align with the 80/20 principle Cao (2007), and pareto diagram can be generated using the QI Macros 2025 application in Figure 1.

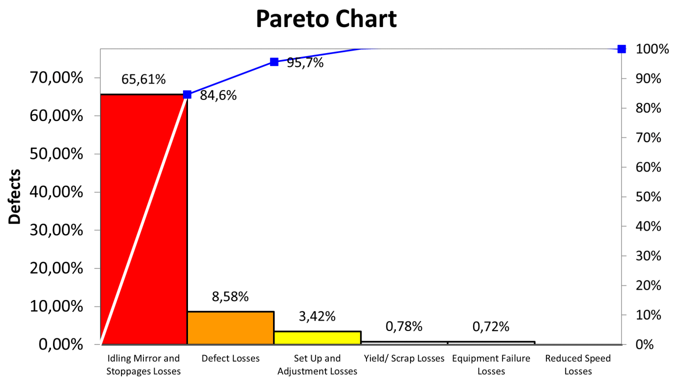

Figure 1. Pareto Chart

Root Cause Analysis Using Fishbone Diagram

To further investigate the dominant loss type, Idling and Minor Stoppages, a Fishbone (Ishikawa) Diagram was developed to identify possible causes in six categories: Man, Machine, Method, Material, Environment, and Measurement. The analysis is summarized in Figure 2.

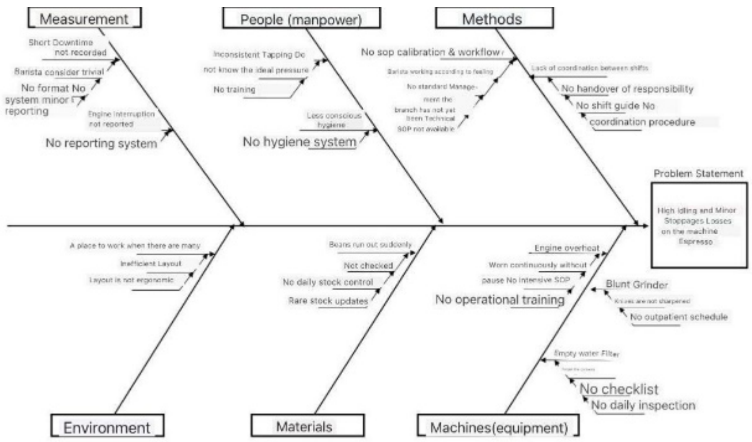

Figure 2. Fishbone Diagram

The diagram revealed several critical contributing factors:

- Man: Lack of communication between baristas during rush hours; insufficient skill in calibration.
- Machine: Overheating boiler and irregular descaling; grinder burr dullness.
- Method: No standardized calibration procedure and unclear cleaning frequency.
- Material: Coffee beans not pre-checked for humidity level; grind inconsistencies.
- Environment: Limited workspace around the espresso counter during peak service.
- Measurement: No downtime records for stoppages shorter than 10 minutes.

These findings highlight the interrelation between human error, machine condition, and procedural inefficiencies that collectively reduce machine utilization.

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Implementation of Total Productive Maintenance (TPM)

Following the analysis, a TPM-based improvement program was introduced in July 2025. The initiative focused on three pillars: autonomous maintenance, planned maintenance, and training and education.

Under the autonomous maintenance pillar, baristas were trained to perform daily cleaning, pressure checks, and filter inspections. Planned maintenance was scheduled weekly for grinder blade sharpening and boiler descaling. Training and education sessions were also conducted to improve calibration consistency and inter-operator coordination.

After TPM implementation, OEE was remeasured, as shown in Table 4.

Table 4. Comparison of OEE values before and after TPM implementation

Parameter	Average before TPM	Average after TPM	JIPM standart
Availability	95,86%	95,99%	90,00%
Perfomance	40,51%	41,36%	95,00%
Quality	77,89%	78,05%	99,00%
OEE	30,25%	31,01%	85,00%

The OEE improved slightly from 30.25% to 31.01%, indicating that TPM produced measurable positive effects on machine reliability and operational consistency. The improvement mainly stemmed from better operator awareness and a reduction in idle periods through daily inspection routines.

These findings are consistent with Tortorella et al. (2021), who demonstrated that TPM enhances equipment reliability and minimizes performance losses through continuous operator engagement and preventive maintenance practices.

Disscusion

The findings confirm that TPM principles are applicable beyond manufacturing contexts, proving beneficial for coffee shop operations by improving machine stability and service consistency. The espresso machine's low OEE score was largely influenced by performance losses rather than equipment failures.

This implies that operational inefficiencies in small scale service industries are primarily human and process related, not purely mechanical. Consequently, improvement strategies must integrate behavioral discipline, skill training, and maintenance routines simultaneously.

In addition, the post TPM improvement, though modest in percentage, reflects a significant cultural change operators have begun to perceive machine care as part of their daily responsibility, aligning with TPM's autonomous maintenance philosophy (Nakajima, 1988).

CONCLUSION

This study concludes that the average OEE of the La Marzocco espresso machine before TPM implementation was 30.25%, increasing to 31.01% after TPM application. While the value has not yet reached the world-class benchmark, the observed increase highlights TPM's role in stabilizing operational performance.

The dominant loss factor was idling and minor stoppages (65.61%), primarily caused by human, machine, and procedural factors. The Fishbone analysis revealed the need for structured operator training, SOP development, and scheduled maintenance to reduce minor disruptions.

The implementation of TPM, particularly through autonomous maintenance and training & education pillars, contributed to reducing inefficiencies, improving work discipline, and stabilizing machine performance. The results reaffirm that TPM can be effectively adapted to the service industry, particularly coffee shops, to enhance machine reliability and service quality.

This research contributes theoretically by extending OEE and TPM application into service-sector operations and

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provides practical recommendations for small coffee shop management. Future research is encouraged to include a longer observation period and multiple objects to validate cross-case improvements statistically.

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