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Effectiveness of Soetta Airport STP Performance

Rosalendro Eddy Nugroho[1]; Yudha Prawira[2]

[1]Lecturer of Postgraduate Management, Universitas Mercu Buana Jakarta, Indonesia
[2]Section Head, Airport Sanitation Facility-Soeta, Tangerang, Indonesia

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Abstract: In the last five years, Soekarno-Hatta International Airport's operating efficiency (OEE) has significantly improved from 59.7% in 2019 to 92.3% in 2024. Initially, the COVID-19 pandemic in 2020 adversely affected STP's performance—OEE fell to 59.7% as a result of airport closures and a significant reduction in passenger traffic. The volume of waste decreased by 13%, necessitating operational reductions. Nonetheless, following 2021, recovery commenced as aviation transport returned to normalcy. Two principal initiatives propelled the increase in efficiency: firstly, the execution of preventative maintenance, which diminished downtime (2023–2024); secondly, the optimization of biological processes, including enhanced aeration, leading to a consistent effluent quality above 95%. By 2024, the STP approached full capacity, with a mere 7.7% deficit. The volume of waste increased by 15% from 2022 to 2023 due to a resurgence in airport traffic, achieving peak efficiency of 94.7% in 2023. Despite compliance with quality standards typically exceeding 80%, problems persist, including changes in COD/BOD during peak seasons and the maintenance of TSS filters. To attain the 95% compliance objective, investment in technology and the development of human resources are essential, drawing insights from the resilience demonstrated during the COVID crisis.

Keywords: *OEE; STP; COVID; COD; Preventive Maintenance.*

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I. INTRODUCTION

Indonesia's geography, which consists of thousands of islands spanning nearly two million square kilometers, makes air transport a critical mode of connectivity. Airports function as central nodes that accommodate aircraft movements, passenger flows, and cargo logistics between regions. According to national aviation regulations (SKEP/124/VI/2009), airports are formally recognized as designated areas of land or water prepared for flight operations and supporting services, thereby ensuring smooth inter-island and international mobility.

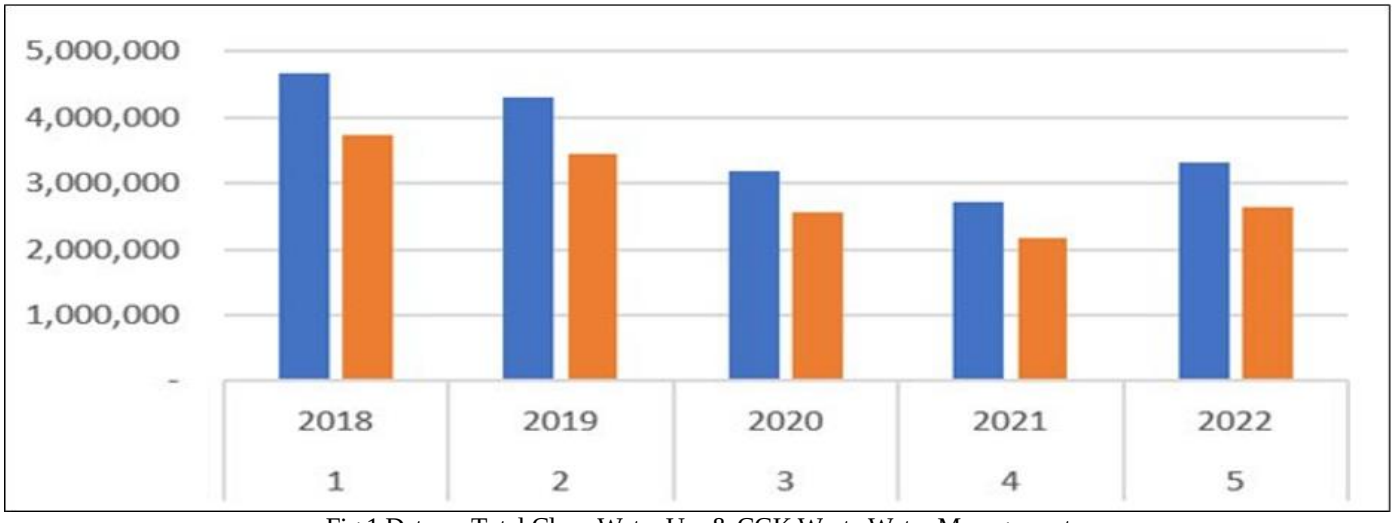

Fig 1 Data on Total Clean Water Use & CGK Waste Water Management

Figur 1. A transfer mode transport that is equipped with facility safety and security flight, as well as facility principal and facilities support other. The airport is managed by PT. Angkasa Pura Indonesia (Persero), one of several management operations in Indonesia. PT. Angkasa Pura Indonesia (Persero) has been an active state-owned enterprise

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in the sphere of business service service airports and services related to existing airports since August 13, 1984. Establishment of PT. Angkasa Pura Indonesia. At present, PT. Angkasa Pura II (Persero) is committed to mitigating the impact of any emergent environmental consequences on its operations. Company operations generate environmental impacts; therefore, efforts are implemented to mitigate them to the greatest extent feasible in order to preserve the environment. The Company Regulation No. 38 regarding the PT Angkasa Pura II Eco-Airport Master Plan, which was established in the Directors' Decision Number: KEP.02.04/10/2012, is the document that organizes and stipulates the policies. The purpose of this rule is to safeguard the environment from the effects of airport operations and development. The regulation of the environment and adjacent areas is based on the framework management of the airport. Naturally, the successful attainment of the aforementioned parameter results necessitates the presence of equipment performance that is also functional. Consequently, operational patterns and equipment maintenance patterns are indispensable. In liquid waste management, the term "Sewage Treatment Plant" (STP) is used to describe the apparatus. It is the general function of this apparatus to convert wastewater into water that is suitable for disposal in accordance with the specific parameters that are managed by the Sanitation Facility Unit. Naturally, in order to obtain satisfactory parameter results as specified above, it is necessary to follow them with apparatus performance that is functional.

Equally important in sustaining airport facilities is the consistency of operational routines and equipment maintenance. The Sewage Treatment Plant (STP) functions as the primary system for handling wastewater, ensuring that effluent released into the environment complies with parameters established by the Sanitation Facility Unit. To maintain this compliance, the reliability of STP equipment must be preserved through scheduled evaluations and upkeep. National regulations, particularly the decree of the Directorate General of Civil Aviation (SKEP/157/IX/03), mandate annual inspections that serve to plan repairs, secure spare parts, and arrange for equipment replacement. This structured maintenance framework is essential for ensuring long-term system effectiveness and regulatory adherence.

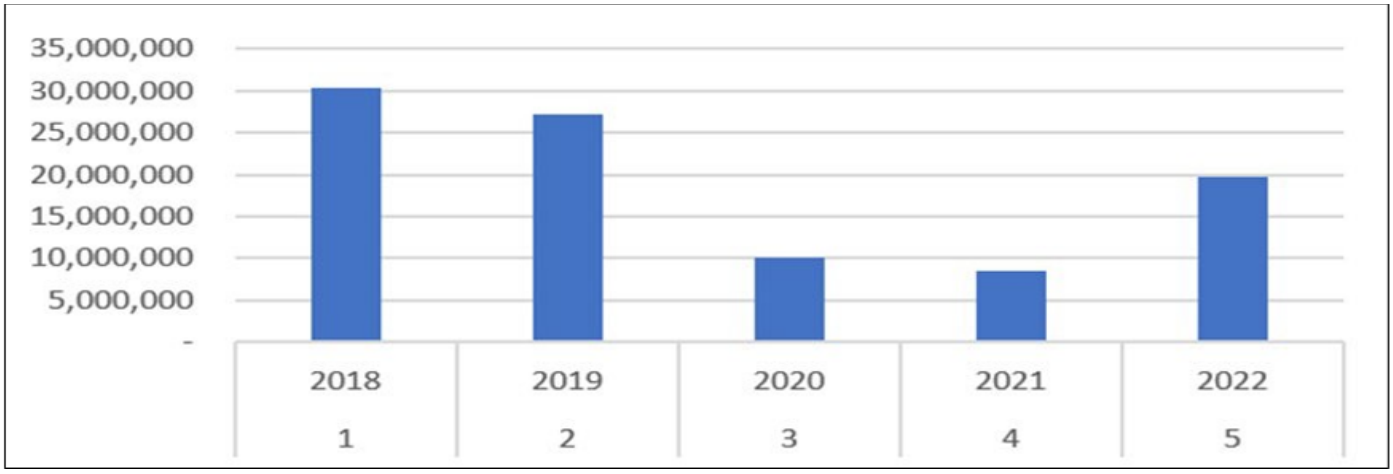

Fig 2 Number of Departing Passengers

Figur 2. Statistics from the Central Bureau of Statistics (BPS) show a sharp decline in passenger departures at Soekarno–Hatta International Airport, falling from 30.4 million travelers in 2018 to only 8.6 million in 2021. This contraction was primarily attributed to the COVID-19 pandemic, when restrictions and stay-at-home advisories significantly reduced mobility. By 2022, however, passenger volume began to recover, reaching nearly 19.8 million departures. In response to the downturn, the airport authority adjusted its terminal operations by implementing limited service patterns and various cost-efficiency measures to maintain operational sustainability during periods of reduced demand.

II. LITERATURE REVIEW

A. *Definition of Airport*

Given Indonesia's position as one of the largest archipelagic states, transportation systems play a vital role in linking its regions. Within this system, airports represent a crucial node that enables air travel across domestic and international routes. Together with air navigation and service networks, airports form an integrated infrastructure that supports both national and global air transportation services (Suharno, 2009).

B. *Wastewater Treatment*

According to Government Regulation No. 82 of 2001, wastewater is defined as liquid waste generated by human or industrial activities. Sources can be broadly categorized into domestic and industrial streams. In industrial operations, wastewater is an inevitable by-product, thus requiring proper treatment to prevent environmental degradation (Asmadi & Suharno, 2012). Within airports, passenger and service activities contribute substantially to domestic-type wastewater. This effluent typically contains more than 99% water mixed with dissolved and suspended organic and inorganic substances. Such wastewater is generally assessed through three main dimensions: physical, chemical, and biological properties, which must be managed to comply with regulatory quality standards.

Domestic waste comprises a complex mixture primarily consisting of water (typically exceeding 99%) along with

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organic and inorganic substances, including both dissolved and settled solids. Wastewater characteristics are classified into three primary categories: physical, chemical, and biological.

C. Equipment Maintenant

Maintenance activities are an essential element of airport operations, particularly for equipment that directly supports flight safety and reliability. Effective maintenance ensures that facilities operate in optimal condition, thereby sustaining service quality for passengers. Mobley (2011) emphasizes that maintenance is a fundamental responsibility within any industrial or service facility, as it secures operational continuity. According to Kiameh (2011), maintenance can be broadly categorized into two types: scheduled maintenance, which includes preventive and corrective actions carried out systematically, and unscheduled maintenance, which is performed reactively when breakdowns occur. To evaluate the effectiveness of such maintenance efforts, Overall Equipment Effectiveness (OEE) is widely used as a comprehensive performance indicator that integrates availability, performance, and quality dimensions (Felecia & Limantoro, 2013).

D. Root Cause Analysis

Okes (2019) describes Root Cause Analysis (RCA) as a structured approach aimed at identifying underlying factors that contribute to past incidents, with the goal of improving future performance. Within the Lean Six Sigma methodology, RCA is frequently applied as a diagnostic tool to uncover fundamental problems and support continuous improvement initiatives (Latino et al., 2019). As such, RCA serves as an essential technique in systematic problem-solving processes.

KC Latino et al. (2020) emphasize that structured measures are required to guide teams in identifying the fundamental causes behind existing problems. Fantin (2014) further explains that root causes may stem from diverse elements such as events, circumstances, and organizational conditions that trigger undesirable outcomes. Similarly, Barsalou (2014) highlights RCA as a practical Lean tool that helps teams trace underlying issues, even in relatively minor problems. These perspectives reinforce the role of RCA as a systematic technique for diagnosing and resolving performance-related challenges.

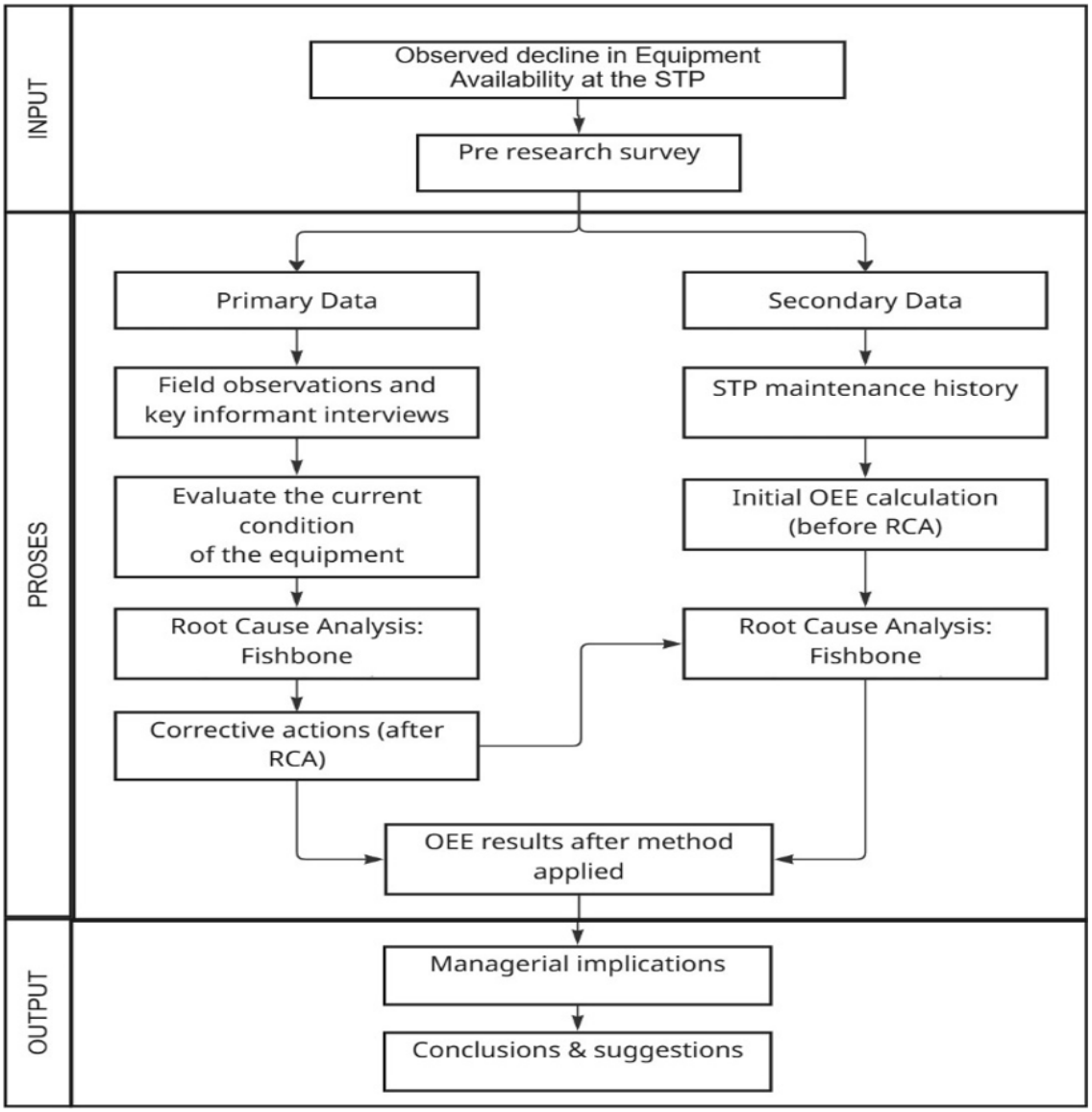

Fig 3 Framework Thinking

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III. RESEARCH METHODOLOGY

This study applies a quantitative descriptive approach to evaluate the performance of Sewage Treatment Plant (STP) equipment at Soekarno–Hatta International Airport. The primary objective is to calculate Overall Equipment Effectiveness (OEE) within the framework of Total Productive Maintenance (TPM). The analysis focuses on quantifying equipment downtime and efficiency through OEE metrics, thereby providing an overview of operational performance. Findings from this descriptive analysis are expected to generate managerial insights that support decision-making at PT Angkasa Pura Indonesia (API).

The background of this research lies in the limited reliability of Sewage Treatment Plant (STP) equipment at Soekarno–Hatta Airport, where several units demonstrate suboptimal quality. Observations supported by company operational records indicate frequent downtime that often renders the system non-functional. This study is therefore designed to identify and analyze the factors contributing to reduced equipment availability within the STP facility.

This study applies a non-probability sampling approach with purposive sampling, where respondents are selected based on predetermined criteria. A total of five key informants at the implementation level, including supervisory staff, were chosen to provide relevant insights.

The analysis focuses on examining the performance, availability, and quality aspects of STP equipment over a three-year observation period. To further diagnose performance issues, Root Cause Analysis (RCA) tools such as the Fishbone Diagram and the "5 Whys" method were employed to trace contributing factors. The evaluation also incorporates the 5W+1H framework to propose corrective measures aimed at improving Overall Equipment Effectiveness (OEE), which had previously been recorded at a low level. All collected data are then synthesized to design enhancement strategies and to assess the potential improvement in OEE following the implementation of maintenance actions at Soekarno–Hatta Airport.

IV. RESULTS

❖ *Data Analysis*

A. Calculation of Overall Effectiveness Equipment (OEE)

➢ *Calculation of Availability Values Equipment*

The availability of equipment is calculated by comparing total loading time, which reflects the planned monthly operating hours, with the actual operating time achieved. For this study, the calculation was based on secondary data obtained from daily and monthly reports related to the aeration and stabilization units of the Sewage Treatment Plant (STP) at Soekarno–Hatta International Airport. The computation is presented as follows:

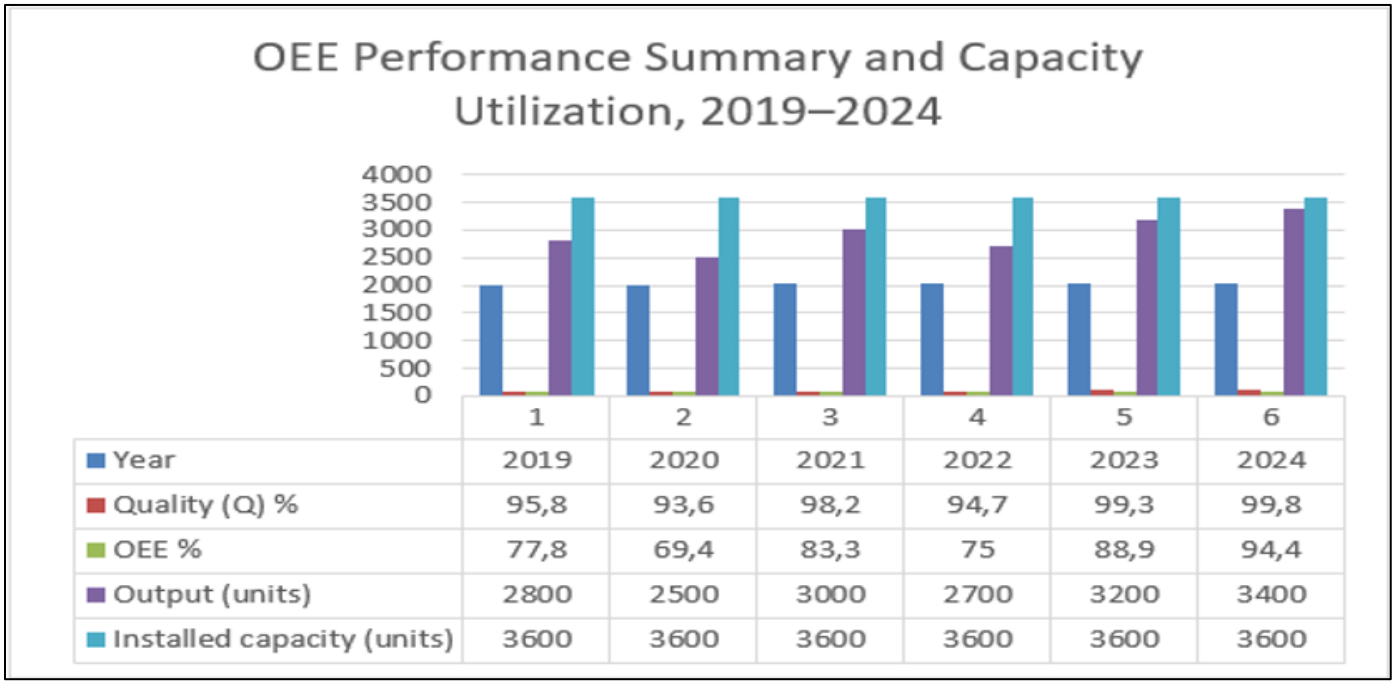
- *Availability of Aeration Equipment Number 1 in February 2022:*

$$\frac{672 - 240}{672} \times 100\% = 64{,}28\%$$

- *Availability of Stabilization Equipment Number 2 in March 2022:*

$$\frac{744 - 168}{744} \times 100\% = 77{,}41\%$$

The results of calculating the availability of aeration and stabilization equipment using the same calculation method from 2020 to 2022 can be seen from the following Figure 3 imag



	1	2	3	4	5	6
Year	2019	2020	2021	2022	2023	2024
Quality (Q) %	95,8	93,6	98,2	94,7	99,3	99,8
OEE %	77,8	69,4	83,3	75	88,9	94,4
Output (units)	2800	2500	3000	2700	3200	3400
Installed capacity (units)	3600	3600	3600	3600	3600	3600

Fig 4 Performance of OEE STP-Soeta

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Figure 4. demonstrates between 2019 and 2024, the Overall Equipment Effectiveness (OEE) of the company demonstrated a steady upward trajectory, rising from 70.1% in 2019 to 92.3% in 2024. In the initial year, the system still showed a capacity gap of 29.9%, mainly driven by limitations in performance (77.8%) and quality (94%). The situation worsened in 2020, when OEE dropped sharply to 59.7% due to lower performance (69.4%) and a decline in availability (93.6%), conditions largely attributed to operational disruptions and the COVID-19 pandemic, which severely reduced airport passenger traffic and disrupted the supply chain. By 2021, performance began to rebound, with OEE improving to 78.5%, supported by higher availability (98.2%) and performance (83.3%) alongside the revival of cargo and logistics activities. Although 2022 recorded a temporary decline to 66.1%, the trend reversed again in 2023 with OEE reaching 85.6%, culminating in 92.3% by 2024. This peak performance was driven by near-optimal availability (99.8%), performance (94.4%), and quality (98%), combined with process optimization, improved maintenance practices, and stronger coordination with airport logistics networks. Overall, the results highlight a consistent improvement path toward operational excellence.

B. Soekarno Hatta Airport STP Operation Performance

As Indonesia's main aviation hub, Soekarno–Hatta Airport is regularly assessed in terms of regulatory compliance, operational efficiency, and the performance of its Sewage Treatment Plant (STP). Over the five-year period from 2019 to 2023, the evaluation focused on several critical indicators, including effluent quality compliance, monthly average performance, peak and minimum output levels, and overall system efficiency.

Table 1 Monthly Data Analysis Results (2020–2023)

Parameter	Average	Maximum	Minimum	% Compliance
pH	7.2	8.9	5.8	92%
COD	85 mg/L	210 mg/L	30 mg/L	78%
BOD	45 mg/L	120 mg/L	15 mg/L	83%
TSS	40 mg/L	95 mg/L	10 mg/L	88%

Table 1. presents The control of TSS and pH parameters demonstrates a relatively mature system, with compliance levels above 88%. In contrast, COD and BOD management remain areas of concern, reflecting notable performance gaps. Addressing fluctuations in organic loading through targeted pre-treatment processes and adaptive real-time monitoring is expected to improve reliability. Although the current STP performance satisfies regional regulatory standards, further technological improvements are required to achieve more than 95% compliance across all indicators by 2025.

To address these gaps, improvements in pre-treatment processes and the integration of adaptive, real-time monitoring technologies are considered essential. Such measures would help stabilize organic load variations and reduce the risk of non-compliance in COD and BOD parameters. Although the current performance already meets regional regulatory thresholds, the long-term objective is to exceed 95% compliance across all parameters by 2025.

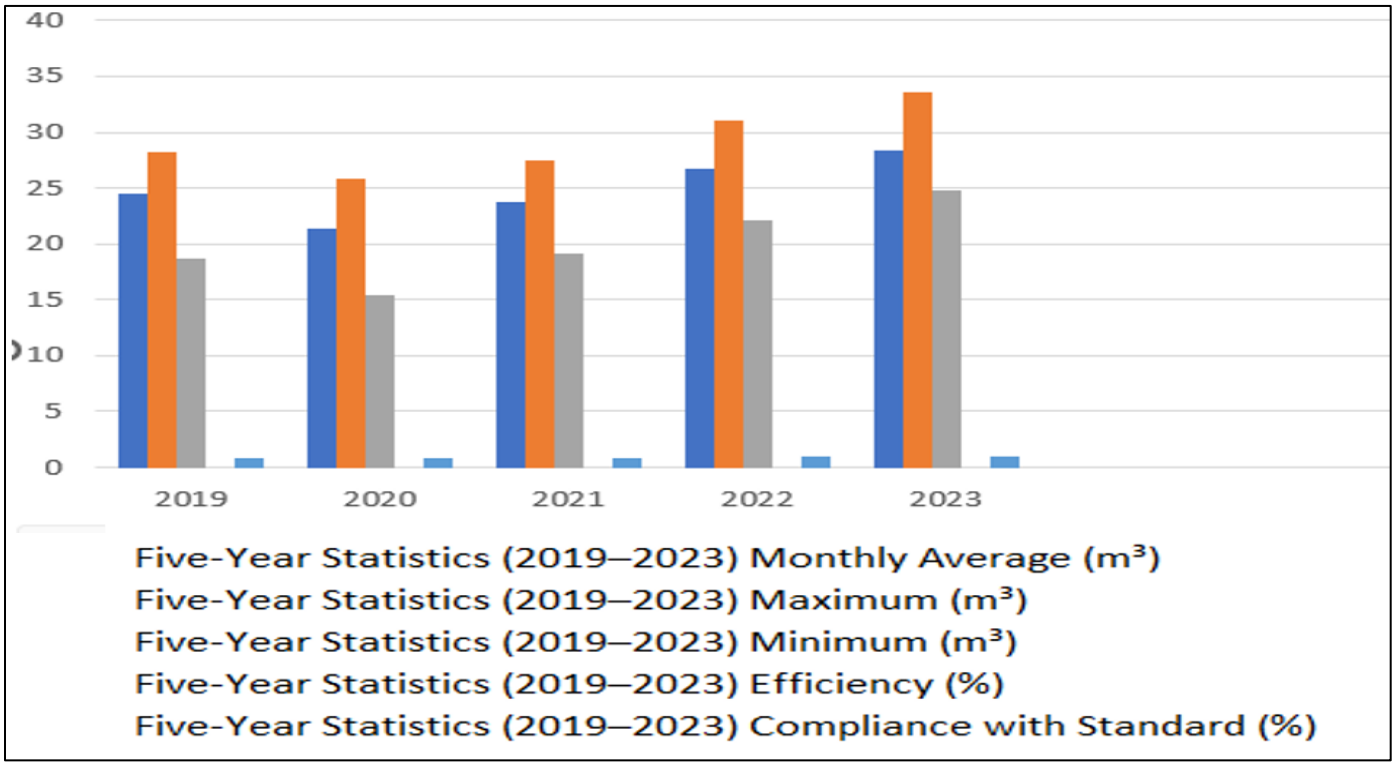

Fig 5 Soeta Airport Performance of STP Facility 2019- 2023

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Figure 5 Soekarno–Hatta International Airport (Soetta) has demonstrated progressive improvements in water resource management between 2019 and 2023. In 2019, average water consumption reached 24,500 m³ per month, with efficiency recorded at 81.7% and compliance at 85%. The following year, during the pandemic, usage decreased to around 21,300 m³ per month, as part of broader infrastructure adjustments. By 2021, the introduction of water recycling practices supported recovery, raising efficiency to 79.3% and compliance to 88%. A significant milestone was achieved in 2022 with the deployment of smart water metering, which increased efficiency to 89% and compliance to 91%. In 2023, the implementation of rainwater harvesting and centralized wastewater treatment enabled the airport to reach 94.7% efficiency, positioning Soetta as a leading example of sustainable airport water management in Southeast Asia.

C. Root Cause Analysis

The next phase of this study involves conducting a stage-by-stage analysis to identify the factors contributing to the decline in Overall Equipment Effectiveness (OEE) of the Sewage Treatment Plant (STP) at Soekarno–Hatta Airport. This assessment was carried out through Focus Group Discussions (FGD) and expert interviews, which produced the following findings:

➢ *Fishbone Diagrams*

The analysis using Fishbone diagrams was applied to systematically trace possible causes through expert interviews. Problems were first outlined in general terms, then categorized and examined in greater depth to uncover root factors. Through collaborative discussions between researchers and specialists, the team was able to draw on expert knowledge to clarify underlying issues and propose incremental improvements. These interviews provided detailed insights into the main causal elements that affect the performance of the STP equipment.

Findings from the expert interviews highlighted five principal categories contributing to performance issues in the STP system: human factors, machinery-related conditions, procedural or methodological aspects, material availability, and financial constraints.

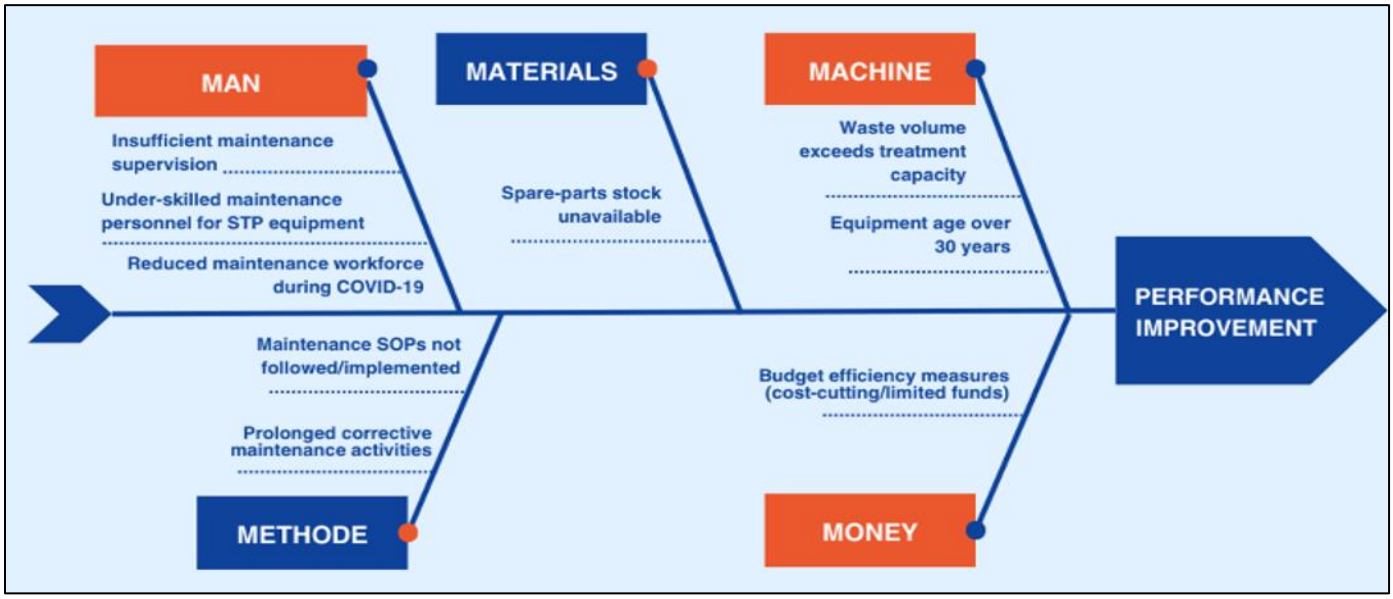

Fig 6 Fish Bone Soeta Airport STP Facility 2019-2024

Soekarno–Hatta International Airport (Soetta) faces a range of operational challenges that hinder overall performance. These include limited oversight in maintenance activities, reduced availability of skilled personnel during the pandemic, and the absence of standardized operating procedures for equipment upkeep. The situation is further exacerbated by aging infrastructure—much of the equipment has been in use for more than three decades—along with shortages of spare parts, which prolong repair times and reduce efficiency. Growing passenger volumes that exceed facility capacity, coupled with budgetary constraints, also limit the ability to upgrade infrastructure. Without timely intervention, these issues risk undermining passenger comfort and the reliability of airport operations. Addressing them will require strengthened workforce training, procurement of modern equipment, and improved spare-part availability to restore and sustain performance levels.

V. DISCUSSION

➢ *Results of Analysis of Factors Causing Decreased Performance Values of STP Equipment*

An evaluation of the declining performance of the STP equipment at Soekarno–Hatta Airport identified five critical contributing factors: human resources, machinery, operational methods, material supply, and financial support. These insights were derived from focus group discussions and collaborative brainstorming, enriched with supporting literature, and further examined using the 5 Whys analytical framework to trace the root causes.

➢ *Results of Analysis of Corrective Actions / Improvements*

The application of the 5 Whys technique revealed five fundamental factors responsible for the declining performance of the STP equipment at Soekarno–Hatta Airport. These root

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causes require immediate resolution to avoid further complications in the coming years. The identified elements include human, machine, method, material, and financial-related issues, all of which collectively contribute to reduced operational effectiveness.

- Human factor: The availability of skilled personnel was inadequate, both in terms of carrying out equipment repairs and overseeing routine maintenance activities
- Machine factor: Much of the equipment has surpassed its intended economic life cycle, resulting in reduced reliability and higher risk of failure.
- Method factor: Standard operating procedures for equipment maintenance were not consistently or effectively implemented.
- Material factor: Spare parts and essential materials were often unavailable when needed, causing delays in repairs and prolonged downtime.
- Financial factor: Maintenance budgets were constrained between 2020 and 2022, leading to efficiency-driven cost reductions that limited the scope of repair and replacement efforts.

After determining the root issues across the five contributing factors, targeted corrective and improvement measures have been formulated. These actions are intended to be implemented within the current year and the following period to restore and enhance the performance of the STP equipment at Soekarno–Hatta Airport.

➢ *Managerial Implications*

The application of Overall Equipment Effectiveness (OEE) as a performance measurement tool, combined with structured root cause analysis and corrective action planning, is expected to deliver long-term benefits for the organization. Through OEE evaluation, the STP equipment at Soekarno–Hatta Airport can be categorized according to reliability, with units demonstrating fewer breakdowns reaching an availability level of 95%. This aligns with the civil aviation regulatory framework (SKEP/157/IX/03), which emphasizes systematic maintenance and reporting requirements. Furthermore, the integration of the 5 Whys and 5W+1H methods enhances the identification of root problems and provides a practical foundation for designing corrective strategies that address performance deficiencies in a sustainable manner..

The evaluation indicated that the OEE of STP equipment at Soekarno–Hatta Airport improved significantly, increasing from 68% in 2022 to 79% in 2023. Based on the benchmark set by the Japan Institute of Plant Maintenance (JIPM), an OEE score of 85% represents world-class performance, whereas 60% is considered the minimum acceptable standard. With its current level at 79%, the STP facility has demonstrated positive progress but still requires further improvement. Achieving the 85% benchmark will demand consistent effort, strong organizational commitment, and the implementation of continuous improvement initiatives to align with global best practices.

The findings show that the OEE of STP equipment at Soekarno–Hatta Airport improved from 68% in 2022 to 79% in 2023. Referring to standards established by the Japan Institute of Plant Maintenance (JIPM), a score of 85% reflects world-class performance, while 60% is regarded as the minimum acceptable threshold. With the current achievement of 79%, the facility is positioned above the acceptable level but still below international best practice. Attaining the 85% benchmark will require sustained improvement efforts and strong collective commitment from all stakeholders.

VI. CONCLUSION

This study assessed the performance of the Sewage Treatment Plant (STP) equipment at Soekarno–Hatta International Airport using the Overall Equipment Effectiveness (OEE) framework. The results show fluctuations in equipment effectiveness during the observation period, with values of 87% in 2020 and 2021, a sharp decline to 68% in 2022, and a recovery to 79% in 2023. These findings highlight that although the STP system is capable of achieving high performance under stable conditions, it remains vulnerable to external disruptions and operational constraints.future.

The analysis using Fishbone Diagrams, the 5 Whys, and the 5W+1H method revealed five key factors influencing equipment effectiveness: human resources, machinery age, maintenance practices, material availability, and financial support. The most pressing challenges were related to limited technical personnel, aging equipment that has exceeded its economic life, and shortages of spare parts. Addressing these issues requires a structured improvement program, including enhanced training for maintenance staff, modernization of equipment, and adequate budget allocation for spare parts. Such interventions are essential to sustain the reliability of the STP and ensure that airport operations remain environmentally compliant and cost-effective.

From an academic perspective, this research contributes by demonstrating the application of OEE combined with root cause analysis tools in the context of airport wastewater management—an area with limited prior study in Indonesia. The findings underscore the importance of aligning technical performance evaluation with managerial decision-making. Future research may extend this study by integrating predictive maintenance models, digital monitoring systems, and comparative analyses with other international airports. These directions will strengthen both the theoretical understanding and practical implementation of sustainable airport wastewater management.

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