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A Study on Sustainable Waste Management Facilities (Reception Facilities) at Ports: A Case Study of Tanjung Priok Port

Yunita Fahmi[1]*, Haruki Agustina[2], Evi Frimawaty[3]
Universitas Indonesia, Jakarta, Indonesia[1,2,3]
E-mail: yoenfahmi.eei@gmail.com

***Correspondence:** yoenfahmi.eei@gmail.com

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ABSTRACT

This study investigates the effectiveness of hazardous (B3) and non-hazardous (Non-B3) waste management at Tanjung Priok Port through the implementation of Reception Facilities (RF) to support the Green Port initiative. Although the RF infrastructure complies with the Ministerial Regulation of Environment (Permen LH) No. 05 of 2009, Article 5, its utilization remains significantly low at only 0.27%. This inefficiency is attributed to high operational costs, limited awareness among ship operators, and insufficient waste processing capacity. Waste composition is dominated by hazardous materials such as used lubricant oil, sludge oil, and solid oil slop, while non-hazardous waste includes domestic, plastic, and organic waste. Furthermore, only 52% of personnel are adequately trained in waste management practices, highlighting a critical human resource gap. Used SWOT analysis, the strategic position of the RF system falls within the Strength–Threat (S–T) quadrant, indicating the need for a defensive diversification strategy. This strategy emphasizes leveraging existing infrastructure and regulatory compliance to address external challenges such as policy enforcement and operational constraints. The findings suggest improving RF utilization through cost reduction, stakeholder engagement, and capacity building will enhance the port's environmental performance. This study contributes to the broader implementation of Sustainable Development Goals (SDGs) 6 (clean water and sanitation), 12 (responsible consumption and production), and 14 (life below water), offering a replicable framework for other ports in Indonesia and globally.

Introduction

Indonesia, as an archipelagic nation with more than 17,000 islands, relies heavily on the sea as a unifying element across its vast territory, playing a crucial role in shaping the country's geopolitical integrity (Fatimah & ST MT PhD, 2024; Sutisna et al., n.d.; Wahyuni & Muninggar, 2022). Since its independence, Indonesia's maritime governance

has been influenced by the Territorial Zee en Maritime Kringen Ordonantie 1939 (TZMKO, 1939), a legacy of Dutch colonial maritime law that continues to exert influence today. Ports in Indonesia hold a strategic position as key nodes in the national logistics distribution network and serve as hubs of maritime transportation activity. According to Jinca (2011), ports not only function as logistics facilities but also play a central role in industrial development and sustainable growth (Özdoğan Albahnasawi A. M. Ağır H. Arslan S. Gunaydin O. Gürbulak E. Eyvaz M. & Yüksel E., 2021; Priadi Tristanti Sunaryanto & Habli M. H., 2017; Svaetichin & Inkinen T., 2017; Zorpas, 2020).

However, effective port management must go beyond operational efficiency and also prioritize environmental sustainability (Amasuomo & Baird J., 2016; Andjioe Nuhman & Subianto A., 2014; Becker, 2012). As a core component of aquatic ecosystem balance, the sea faces serious threats from pollution caused by human activity, including domestic and industrial waste, oil spills, and ship debris. This pollution poses significant risks to marine ecosystems, which, if left unaddressed, can have long-term detrimental effects on marine life and coastal communities dependent on ocean resources. A notable example is the Deepwater Horizon oil spill in the Gulf of Mexico in 2010, which caused widespread ecological damage and affected marine mammal populations (Nursyamsu A. M. Dewi A. K. & Sutryani H., 2022).

Despite various environmental protection laws in Indonesia—such as Law No. 32 of 2009 and Government Regulation No. 21 of 2010—marine pollution remains an issue. An example of such an incident occurred in the waters of Masalembu, Sumenep, in early 2022, highlighting lapses in environmental management and weak enforcement by relevant authorities. This incident underscores the urgent need for more effective preventive measures and stricter law enforcement to safeguard marine ecosystems (Lu Nakicenovic N. at al., 2015).

Marine pollution is also exacerbated by waste generated from ship and port operations. Therefore, proper waste management in maritime activities is of paramount importance. One strategic initiative is the provision of waste management facilities at ports, such as Reception Facilities (RF), which are designed to collect and process waste generated by ships (Kurniaty Widagdo S. Rachmawati Madjid Y. Reyhan Al Kharji R. & Imanda Putri A., 2023). These facilities must comply with both national and international environmental regulations (Nurohman, 2019).

Although regulations in Indonesia mandate that all ports provide waste management facilities, various operational challenges persist. At Tanjung Priok Port—the country's largest and busiest port—waste management infrastructure is in place, but issues such as high operational costs and low utilization rates by shipping operators remain. These challenges increase the risk of marine pollution and threaten the long-term sustainability of marine ecosystems (Enders & Remig M., 2014; Fatimah Tyas W. M. Widyabakti M. A. & Ma'rifah N., 2020; Hart & Higgins A., 2015).

Two prior studies have provided insights into port waste management systems that support this research. First, *Lai, Lun, Wong, and Cheng (2011)* examined the environmental management practices in container terminals and emphasized the importance of port waste reception facilities in aligning with sustainable port development (Bognar, 2018; Djalante, 2011)Their study found that underutilization of such facilities was common in Asia due to cost concerns and a lack of operator awareness—challenges that mirror those observed at Tanjung Priok Port. Second, Perera et al. (2020) highlighted that human resource limitations, particularly in training and awareness, significantly hinder the effective implementation of Green Port strategies in

developing countries. They suggested that targeted training and stakeholder coordination are key enablers in enhancing operational efficiency.

This study adds to existing literature by integrating a SWOT-based strategic framework to analyze RF utilization specific to Indonesia's busiest port, offering a practical model for improving waste reception infrastructure within the Green Port paradigm. Unlike earlier studies, it combines regulatory assessment, waste composition analysis, human capital evaluation, and strategic planning in one comprehensive approach, emphasizing compliance and operational efficiency.

This study aims to analyze the operational conditions of waste management facilities at Tanjung Priok Port, including the characteristics of generated waste, the impact of human resource capacity on waste management effectiveness, and sustainable strategies for handling hazardous (B3) and non-hazardous (non-B3) waste through the use of Reception Facilities (RF). The research seeks to identify solutions to enhance waste management effectiveness, strengthen related policies and regulations, and optimize the implementation of sustainable port practices. With the right strategies, Tanjung Priok Port is expected to evolve into a more efficient and environmentally friendly port that better supports marine ecosystem preservation.

Research method

This research used a mixed-methods approach, integrating quantitative and qualitative approaches to explore the dynamics of waste management at ports and formulate effective strategies. This approach allows for the combination of numerical and narrative data, providing a more comprehensive and in-depth analysis, align with Creswell's (2009) view that mixed methods enable research to be more adaptive to developing conditions during data collection.

Through in-depth interviews and secondary data collection, the qualitative method is used to collect data on waste management, characteristics, and the volume of hazardous and non-hazardous waste generated by ships. Meanwhile, data regarding human resources (HR) capacity in waste management is measured using a quantitative approach with Likert scale questionnaires. This data collection aims to measure HR awareness regarding waste management and the effectiveness of technology implementation in managing hazardous and non-hazardous waste at the port (Moleong, 2018).

This research was conducted at Tanjung Priok Port, Indonesia's largest and busiest port. This port plays a significant role in Indonesia's economy, with a large capacity to handle more than 30% of Indonesia's non-oil and gas commodities and 50% of the goods flow in and out of the country. The research is carried out over eight months, from April to December 2024, covering various stages, from literature studies to field data analysis.

The population for this research includes workers directly involved in hazardous and non-hazardous waste management at the port, as well as HR working on ships and at the port. Data is collected using purposive sampling techniques and the completion of questionnaires by respondents who meet specific criteria, aiming to gather relevant data on waste management.

To analyze waste management at the port, the research used descriptive analysis for qualitative data and binary logistic regression analysis for quantitative data. This analysis is used to identify relationships between existing variables, such as knowledge, attitudes, information, and HR capabilities in managing hazardous and non-hazardous waste at the port and ships (Sudjana, 2013).

Additionally, quantitative SWOT analysis was used to formulate effective waste management strategies at the port. In this analysis, internal and external factors are assessed using a Likert scale to determine the strengths, weaknesses, opportunities, and threats present. The collected data is then analyzed using a SWOT matrix to identify strategies that can leverage strengths, address weaknesses, capitalize on opportunities, and avoid threats (Rangkuti, 2004; Sasoko & Mahrudi, 2010). These analysis steps aim to provide valid and actionable recommendations for sustainable waste management at the port, in line with the main goal of environmental sustainability.

Results and Discussion

Condition of the Reception Facility (RF)

The operational condition of the waste management facility (Reception Facility/RF) at Tanjung Priok Port faces several challenges but also holds significant potential. The current Reception Facility (RF) is equipped with sufficient infrastructure to support waste management from ships docking at the port. PT Pelabuhan Indonesia (Persero), Tanjung Priok Branch, has provided waste management facilities that include tugboats, barges, storage tanks, temporary storage facilities (TPS), and oil booms, all with adequate capacity to support the operations of the Port Reception Facility (PRF).

Table 1. Waste management facilities at Tanjung Priok Port, including tugboats, barges, storage tanks, temporary storage facilities (TPS), and oil booms, along with their respective capacities to support Port Reception Facility (PRF) operations.

Facility	*Unit*	*Capacity*	*Description*
1. Tugboat			
TB. Tanjung V	2	350 HP	3 Nahkoda, 3 KKM, 3 ABK
KT. Tanjung VII	2	350 HP	
2. Barge			
TK. BPP 105	2	285 ton	6 ABK
TK. RF I		300 ton	
3. Storage Tank	2	3 ton	Steel Material
		3 ton	Concrete Material
4. Temporary Storage Facility (TPS)		5 m^3	
5. Oil Boom	1	200 m	

Source: PT Pelabuhan Indonesia (Persero) Tanjung Priok Branch

The management of hazardous and toxic waste (B3) is one of the critical aspects of port operations. In this regard, Tanjung Priok Port has provided a Reception Facility (RF) to accommodate the B3 waste generated by docked vessels. However, the capacity of the existing RF at Tanjung Priok Port is currently insufficient to contain all the hazardous and toxic waste produced by ships docking at the port.

To overcome this limitation, several additional Temporary Storage Facilities (TPS) for B3 waste have been established at various terminal locations within the port. These additional TPS units are illustrated in Table 2.

Table 2. Additional Temporary Storage Facilities (TPS) for B3 Waste at Several Terminals

No.	Facility	Capacity	Description
1		54 m^2	

No.	Facility	Capacity	Description
	TPS for B3 Waste – Regional 2, Tanjung Priok		Facility equipment complies with applicable regulations/requirements
2	TPS for B3 Waste – PT PTP	19,5 m²	
3	TPS for B3 Waste – PT JICT	225 m²	
4	TPS for B3 Waste – KOJA	60 m²	

Source: Main Harbormaster Office of Tanjung Priok

All of these TPS (Temporary Storage Facilities) have been equipped in accordance with applicable regulations and standards, enabling them to support safe and standardized waste management. However, in addition to capacity issues, the hazardous and toxic waste (B3) management facilities at the Reception Facility (RF) of Tanjung Priok Port face a major challenge: low utilization by ship operators. According to data obtained from shipping agents at Tanjung Priok Port, there are three main types of B3 waste generated: Used Lubricating Oil (B105D), Sludge Oil (A332-1), and Solid Oil Slop (A307-3). Despite the availability of adequate waste management facilities, the usage rate remains very low—less than 0.27% of total ship visits.

The low utilization rate is primarily due to the high waste management fee charged to users, approximately IDR 250,000 per cubic meter. This fee is considered expensive by most ship operators, leading many to opt for alternatives such as self-managed waste handling or direct disposal through third parties outside of the official RF mechanism. This condition poses a significant challenge that must be addressed promptly to improve the effectiveness of B3 waste management at Tanjung Priok Port.

To address this issue, several studies have reported that PT Pelabuhan Indonesia and related stakeholders have considered various scenarios to enhance the appeal of the RF, such as offering incentives or refunds. These alternatives aim to reduce the financial burden on ships and encourage more operators to utilize the RF facilities officially. In doing so, B3 waste generated from ship activities can be managed more effectively and with greater environmental responsibility. However, implementing these measures has proven difficult, and thus has not significantly increased the number of ships delivering their waste to the existing Reception Facility.

Therefore, the evaluation of B3 waste management at Tanjung Priok Port highlights several challenges, including suboptimal facility capacity and low levels of ship participation in waste delivery. Although the waste management facilities are supported by infrastructure such as tugboats, barges, and storage tanks, the utilization rate remains below 0.27% of total ship calls.

Additionally, although 96% of ships report the presence of waste, only 0.53% actually submit their waste. To improve waste management, recommendations include implementing service fee subsidies, strengthening regulations with strict sanctions, and increasing infrastructure capacity to accommodate projected waste volume growth. A comprehensive approach—covering environmental, economic, social, and regulatory aspects—is needed to optimize port waste management, including strengthening oversight and ensuring ship compliance in reporting and submitting waste.

Characteristics and Volume of Waste

Based on interviews with shipping agents, it was found that the ships managed by these agents generate three main types of waste during their operations. These three types fall into the category of B3 waste (Hazardous and Toxic Substances), meaning they

require special handling to avoid negative impacts on the environment. Waste management must follow the procedures and regulations in force in Indonesia to ensure ecosystem sustainability and prevent pollution.

The first type of waste is Used Lubricating Oil (Waste Code: B105D). This waste comes from lubricating oil that is no longer effective due to quality degradation from repeated use in ship engines. Used lubricating oil can pollute the environment, particularly water bodies, if not managed carefully. Therefore, it must be treated following appropriate procedures to avoid damaging aquatic ecosystems.

The second type is Sludge Oil (Waste Code: A332-1). This waste is an oily sludge residue produced from the separation of water and oil on ships, as well as from routine cleaning of fuel tanks. Sludge oil ranges from liquid to semi-solid and contains a high concentration of oil, making it hazardous to the environment if mishandled. It contains complex hydrocarbon compounds that can contaminate soil and water unless treated in accordance with B3 waste management standards.

The third type is Solid Oil Slop (Waste Code: A307-3). This consists of solid materials contaminated with oil, such as used rags, absorbent pads, and other materials used to clean up oil spills on ships. Despite being solid, it is still classified as B3 waste due to its high pollution potential. Improper handling can result in significant environmental contamination.

Thus, all three types of waste require strict management, from collection, temporary storage, to processing or disposal, in accordance with Indonesia's B3 waste regulations. Proper and standardized handling is essential to preserve the environment and prevent broader damage.

According to data collected during the observation period, the average amount of domestic waste generated per ship is around 1 to 2 kilograms per day per crew member. Liquid waste, such as used oil and bilge water, was recorded at approximately 50 to 150 liters per day per ship. This volume of liquid waste highlights the significant pollution potential if not managed properly. Therefore, ship waste management requires special attention and adherence to appropriate procedures to mitigate environmental risks, especially in marine environments.

Table 3. Number of Ship Arrivals and Number of Ships Reporting Waste

No	Month	Number of Ship Arrivals (units)	Number of Ships Reporting Waste (units)	Percentage (%)
1	January	1,193	1,155	96.81
2	February	1,034	1,000	96.71
3	March	1,191	1,135	95.30
	Q1 Total	**3,418**	**3,290**	**96.26**
4	April	1,070	1,028	96.07
5	May	1,021	987	96.67
6	June	1,144	1,108	96.85
	Q2 Total	**3,235**	**3,123**	**96.54**
7	July	1,160	1,128	97.24
8	August	1,331	1,281	96.24
9	September	1,268	1,218	96.06
	Q3 Total	**3,759**	**3,627**	**96.49**
	Q1+Q2+Q3 Total	**10,412**	**10,040**	**96.43**

Source: Researcher, 2024

Table 3 shows that approximately 80–90% of ships arriving at Tanjung Priok Port report the waste they carry. However, the data also reveals that only around 0.53% of docked vessels submit their waste to the port authorities for management. Among the ships that submit their waste, 78% are foreign vessels, while 22% are domestic. The discrepancy between the number of waste reports and actual waste submissions illustrates the challenges in enforcing regulations at the port, which may hinder effective waste management efforts.

In addition to ships' waste, port activities produce solid waste. This solid waste mainly consists of packaging materials, leftover cargo, and waste generated from loading and unloading operations. Based on port observations, the amount of solid waste generated averages between 500 and 800 kilograms daily, varying depending on the volume and type of goods handled. Meanwhile, liquid waste at the port usually originates from domestic wastewater from port facilities and wash water from port equipment and facilities, averaging around 1,000 to 1,500 liters per day.

The amount of waste generated by both ships and port operations highlights the importance of integrated and regulation-compliant waste management to preserve the environment around the port area.

Table 4. Projection of Cargo Flow and Ship Traffic from 2016 to 2040

Year	Cargo Flow (tons)	Ship Traffic (units)
Existing		
2016	142.625.806	8.213
2017	154.518.327	8.375
2018	166.935.619	7.808
2019	167.283.233	8.020
2020	180.875.914	8.713
2021	191.796.592	8.741
Short		
2022	203.708.597	9.284
2023	216.701.916	9.528
2024	230.874.704	10.521
2025	246.334.030	11.226
2026	263.196.678	11.993
2027	280.593.008	12.786
Medium		
2028	299.447.610	13.750
2029	319.937.616	14.579
2030	342.184.807	16.301
2031	366.340.255	16.964
2032	391.038.794	17.823
2033	417.732.361	18.974
Long		
2034	446.582.104	20.348
2035	477.662.140	21.703
2036	511.460.851	23.303
2037	547.881.526	25.134
2038	587.244.087	26.753
2039	629.784.163	28.763
2040	675.764.582	24.545

Source: PT Pelabuhan Indonesia (Persero) Cabang Tanjung Priok

It is explained that cargo flow and ship traffic at Tanjung Priok Port are projected to increase significantly up to the year 2040. Based on the available data, by 2025, the volume of cargo expected to pass through the port is estimated to reach approximately 246,334,030 tons. Additionally, the number of ships projected to dock at Tanjung Priok Port in 2030 is estimated to reach 15,593 units.

The projection of waste flow at the port is calculated by multiplying the projected ship traffic by the average waste production per ship and the average proportion of ships using the Reception Facility (RF). The average waste production per ship is obtained by dividing the total waste generated by RF users by the number of RF-using ships and the years considered in the analysis.

To calculate the average number of ships using the Port Reception Facility (PRF), the method involves dividing the total number of ships utilizing the facility by the total ship traffic during the specified period. This projection provides insight into the port's waste management situation, which is crucial for planning more effective waste management strategies in line with the increasing flow of ships and cargo through the port.

This data is further detailed in Table 5 which presents a breakdown of waste flow projections and PRF facility usage from 2016 to 2040.

Table 5. Projection of Cargo Flow and Ships Using PRF from 2016 to 2040

Year	Waste Flow (tons)	Number of Ships Using (units)
2016	27,911	6,222
2017	26,088	5,928
2018	26,886	7,484
2019	29,183	7,192
2020	30,996	7,462
2021	32,969	7,862
2022	35,126	8,172
2023	37,480	8,677
2024	40,081	9,150
2025	42,488	9,568
2026	45,556	10,500
2028	52,050	11,991
2029	55,730	11,551
2030	59,480	12,240
2031	63,532	12,348
2032	67,765	13,509
2033	72,766	14,993
2034	77,963	15,670
2035	83,337	16,456
2036	88,920	17,305
2037	94,852	18,187
2038	102,783	19,005
2039	107,785	19,931
2040	112,791	20,208

Source : PT Pelabuhan Indonesia (Persero) Cabang Tanjung Priok

Based on the projected flow of goods and ships, the amount of waste generated by port reception facilities (Port Reception Facilities/PRF) is expected to increase significantly up to 2040. In 2027, the waste produced is estimated to reach 48,675 tons, in line with the growth in port activities and the number of docked vessels. Meanwhile, in 2025, the number of ships expected to use PRF facilities is projected to be 9,568 units.

The utilization of PRF facilities is also projected to increase. By 2027, the utilization rate of tugboats and barges is estimated to reach 32.47%, indicating a rise in facility use. Similarly, the utilization of storage tanks in 2025 is projected to reach 2.60%. Furthermore, the utilization of temporary storage facilities (TPS) located at four main docks — namely TPS Limbah B3 Regional 2 Tanjung Priok, TPS Limbah B3 PT. PTP, TPS Limbah B3 PT. JICT, and TPS Limbah B3 KOJA — is projected to reach 28.40% by 2026.

The waste management service fee set by PT Pelabuhan Indonesia (Persero), Tanjung Priok Branch, is Rp 250,000 per ton of waste unloaded. Therefore, optimal waste management is crucial to minimize environmental impact, maintain the sustainability of port operations, and ensure smooth ship operations at Tanjung Priok Port.

As such, waste management at Tanjung Priok Port covers both B3 waste (such as used lubricating oil, sludge oil, and solid oil slop) and non-B3 waste (primarily domestic waste). Although the majority of ships (96.43%) report the presence of waste, only 0.53% actually submit it to the facility managers. Waste flow projections up to 2040 show a significant increase. To improve sustainable waste management, it is recommended to integrate modern waste treatment technologies, apply circular economy principles, and involve active participation from coastal communities in waste monitoring and oversight, with a continuous focus on awareness-raising and education.

Human Resources Capacity of the Reception Facility (RF) at Tanjung Priok Port

Based on the analysis of variables such as knowledge, information, attitude, and ability in managing B3 and non-B3 waste, it can be concluded that most respondents have a fairly good understanding, although there are still challenges in the dissemination of information and the implementation of optimal practices.

1) 52% of respondents have good knowledge of waste management, while 48% are still lacking.
2) Information access is also split, with 56% of respondents having poor access, while 44% have sufficient access.
3) 66% of respondents show a positive attitude, although 34% are still lacking.
4) Lastly, 52% of respondents have good ability in waste management, but 48% still require skill improvement.

In conclusion, although there is a decent level of understanding, improvements are needed in information dissemination and skills development to optimize waste management.

Table 6. Correlation Matrix of the Relationships Between the Studied Variables

Variable	Age	Waste (tons)	Knowledge	Information	Attitude
Knowledge	0.597	0.053			
Information	0.632	-0.001	0.554		
Attitude	0.551	0.057	0.688	0.624	
Ability	0.649	0.087	0.723	0.558	0.900

Note: KMO and Bartlett's Test= 0.743, Approx. Chi-Square 254.652

The results of the correlation analysis show a significant relationship between knowledge, information, attitude, and ability in the management of B3 and non-B3 waste. Individuals with better knowledge tend to have better access to information, more positive attitudes, and higher abilities in managing waste.

Significant correlations were found between:

1) Knowledge and information (0.554),
2) Knowledge and attitude (0.688), and
3) Knowledge and ability (0.723).

This indicates that good knowledge is closely associated with better attitudes and abilities. Information also positively correlates* with attitude (0.624), although its influence on ability is not significant. The strongest relationship was found between attitude and ability (0.900), which suggests that a positive attitude greatly influences an individual's ability to apply waste management practices.

Overall, these findings emphasize the importance of a holistic approach, which includes improving knowledge, access to information, attitudes, and skills in order to optimize waste management. A comprehensive training program can help achieve better and more sustainable waste management outcomes.

Reception Facility (RF) Management Strategy – SWOT Analysis

Internal Factors:

The IFAS (Internal Factor Analysis Summary) is used to evaluate internal factors in the management of waste facilities (Reception Facility) at Tanjung Priok Port. The focus is on identifying strengths and weaknesses that influence the operational effectiveness of these facilities, with the aim of formulating effective strategies.

Table 7. IFAS (Internal Factor Analysis Summary Matrix)

No	Factor	Weight	Rating	Score
Strengths (S)				
S1	Adequate infrastructure facilities	0.05	3	0.15
S2	Strategic location	0.06	3	0.18
S3	Environmental regulatory support	0.06	4	0.24
S4	Potential as a national model	0.05	3	0.15
	Total Strength Score			**0.72**
Weaknesses (W)				
W1	Low facility utilization rate	0.07	2	0.14
W2	Non-competitive service fees	0.08	2	0.16
W3	Lack of outreach and education	0.05	2	0.10
W4	Limited monitoring and oversight	0.05	3	0.15
	Total Weaknesses Score			**0.55**
	Score Difference			**0.17**

Source: Researcher, 2024

However, there are weaknesses, such as the suboptimal capacity of waste management facilities, with a low utilization rate (less than 0.27%). The participation of vessels in waste management is also low (only 0.53%), and the waste management fee is considered expensive. In addition, the dissemination of waste management information to human resources (HR) is still uneven. The results of the IFAS analysis indicate that the strengths of the Reception Facility (0.72) are more influential than the weaknesses (0.55).

External Factors

The EFAS (External Factor Analysis Summary) was used to evaluate the external factors affecting the management of waste facilities (Reception Facility) at Tanjung Priok Port. The primary focus of this analysis is on the opportunities and threats that could influence the port's sustainability and competitiveness.

From the opportunity side, the projected increase in ship traffic and waste volume up to 2040 offers significant growth potential, with an estimated 48,675 tons of waste by 2027. Other opportunities include the economic potential of B3 and non-B3 waste processing, such as the utilization of treated B3 liquid waste. Policy support from the Ministry of Environment (KLH) for the direct treatment of domestic waste at the Reception Facility also opens up strategic opportunities, in line with the global trend of adopting the Green Port concept (Adisasmita, 2011).

However, there are also looming threats, such as high waste management costs, which may encourage ships to opt for illegal alternatives in waste disposal. Dependence on final disposal sites (TPA) for non-B3 waste also poses a high risk of environmental pollution. The increasing volume of waste is not matched by the expansion of Reception Facility capacity, which may lead to further issues. Additionally, lack of awareness among ship operators in complying with waste management regulations is a significant threat.

The results of the EFAS analysis indicate that opportunities (2.2) have more influence than threats (1.4) in the waste management of Tanjung Priok Port.

Table 8. EFAS (External Factor Analysis Summary Matrix)

No	Factor	Weight	Rating	Score
Opportunities (O)				
O1	Global Sustainability Trend	0.2	4	0.8
O2	Government Support	0.1	2	0.2
O3	Regional Collaboration	0.2	4	0.8
O4	Technological Innovation	0.1	4	0.4
Total				2.2
Threats (T)				
T1	Regional Competition	0.2	4	0.8
T2	International Market Pressure	0.03	2	0.06
T3	Risk of Environmental Pollution	0.07	2	0.14
T4	Dependency on High Operational Costs	0.1	4	0.4
Total				1.4
Score Difference				0.8

Source: Researcher, 2024

The SWOT matrix is used to formulate a comprehensive waste management strategy at Tanjung Priok Port by identifying internal and external factors. Internal factors include strengths and weaknesses, while external factors consist of opportunities and threats.

Based on the analysis, four strategies are aligned with each quadrant in the SWOT matrix:

1) Quadrant I (positive internal and external factors): Implements an aggressive strategy to maximize waste management potential by leveraging existing strengths and opportunities.
2) Quadrant II (positive internal, negative external): Uses a diversification strategy to counter external threats by utilizing internal strengths and exploring new opportunities.
3) Quadrant III (negative internal, positive external): Adopts a turnaround strategy to address internal weaknesses by capitalizing on external opportunities.
4) Quadrant IV (negative internal and external): Applies a defensive strategy to reduce risks and handle challenges with more cautious management.

This analysis helps design effective waste management strategies, ensuring sustainability and improved efficiency in managing waste at Tanjung Priok Port. The SWOT analysis resulted in the following quadrant chart:

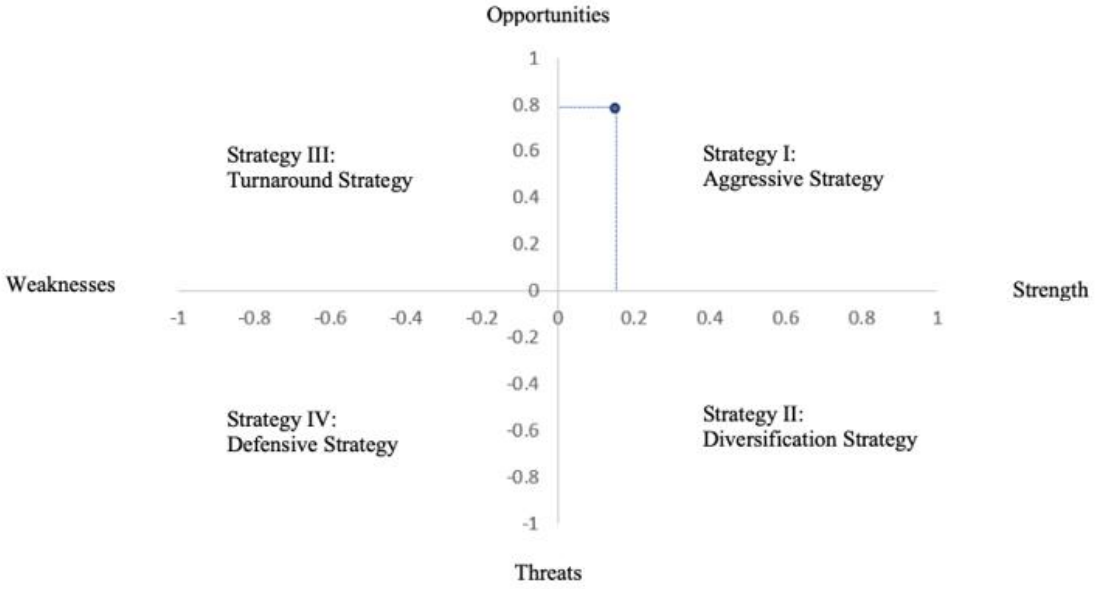

Figure 1. SWOT Quadrant Matrix

Based on the analysis, the x-axis value derived from the difference between the internal factors (strengths and weaknesses) is 0.17, while the y-axis value, obtained from the difference between external factors (opportunities and threats), is 0.8. Using the SWOT matrix, the sustainable waste management strategy for hazardous and non-hazardous waste (Reception Facility) at Tanjung Priok Port falls into Quadrant I, which supports the implementation of an aggressive strategy. This position indicates that the Reception Facility at Tanjung Priok Port possesses sufficient internal strength to take advantage of significant external opportunities.

With an aggressive strategy, the focus is on strengthening internal aspects to take the initiative and leverage available opportunities effectively. This internal strengthening includes improving the quality and quantity of facilities, operational efficiency, monitoring system optimization, and enhancing human resource capacity. Additionally, collaboration with stakeholders is crucial to ensure sustainable waste management and to support the Sustainable Development Goals (SDGs), such as:

1) SDG 6 (Clean Water and Sanitation),
2) SDG 12 (Responsible Consumption and Production), and

3) SDG 14 (Life Below Water),

to ensure environmentally friendly waste management in the port.

Conclusion

The analysis of waste management facilities at Tanjung Priok Port identified several issues hindering operational effectiveness in supporting the sustainable port concept. Although the facility meets infrastructure standards, its utilization is low, with only 0.53% of waste reported by ships handed over to the facility, despite 96.43% of vessels reporting their waste. Key factors for this low utilization include high service fees, low awareness among ship operators, and limited infrastructure capacity. Most generated waste consists of hazardous liquid waste (B3), such as used lubricating oil and sludge, with oily bilge water often dumped illegally. Solid B3 waste includes electronic equipment and used packaging, while non-B3 waste comprises domestic waste and plastics. With waste volume projected to increase significantly by 2040, facility capacity needs to expand. Human resources at the port also play a crucial role, as only about 52% of personnel have good knowledge of waste handling, highlighting the need for regular training. Based on SWOT analysis, the waste management strategy falls into Quadrant I (Strength–Opportunity), focusing on internal strengthening to leverage external opportunities, such as selecting appropriate waste treatment technologies. This includes MARPOL-compliant monitoring systems, operational efficiency improvements, and capacity development. Cross-stakeholder collaboration is essential to support sustainable facility operations, aiming to achieve sustainable development goals, particularly SDG 6 (clean water and sanitation), SDG 12 (responsible consumption and production), and SDG 14 (marine ecosystems), ensuring compliant, efficient, and environmentally friendly waste management.

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