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Optimizing Environmental Sanitation Management at The Perawang Container Terminal to Achieve A Healthy Port

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Abstract

Environmental sanitation management in port areas has become increasingly important amid the growing intensity of global logistics activities. Perawang Container Terminal (PCT), one of the major ports in Riau Province, continues to face several unresolved sanitation issues, including the absence of a waste segregation system, temporary waste storage facilities that do not meet technical standards, irregular monitoring of clean water quality, management of hazardous and toxic waste (Bahan Berbahaya dan Beracun [B3]) without the required permits, and the absence of a disease vector control program. These conditions indicate a gap between current practices and healthy port standards as stipulated in Indonesian Ministry of Health Regulation No. 44 of 2014. This study aimed to assess the existing condition of environmental sanitation management at PCT, identify supporting and inhibiting factors, and formulate optimization strategies to achieve a sustainable healthy port. A qualitative case study approach was employed, involving 10 key informants selected through purposive sampling from PCT management, the Class I Health Quarantine Office of Pekanbaru, and the surrounding port community. Primary data were collected through observations using the Healthy Port Self-Assessment Form, semi-structured interviews, and document review, while secondary data were obtained from relevant institutional records. Existing conditions were analyzed descriptively, followed by SWOT analysis and the Analytic Hierarchy Process (AHP) to determine priority optimization strategies. These strategies were integrated with the Triple Bottom Line framework, encompassing environmental, social, and economic dimensions, to support the development of a sustainable healthy port.

INTRODUCTION

Environmental sanitation management in port areas has received increasing attention alongside the expansion of global logistics networks, including the movement of goods, trade, and the distribution of industrial products (Alavi-Borazjani et al., 2025; Alzate et al., 2024; Du et al., 2023; Sarkar et al., 2023; Varese et al., 2022; Zhang, 2023). Perawang Container Terminal, as one of the region's major logistics nodes, continues to face several sanitation problems that have not been adequately addressed. Based on field surveys, these problems include the absence of a waste segregation system, temporary waste storage facilities (Tempat Penampungan Sementara [TPS]) that do not meet technical standards, irregular monitoring of clean water quality, management of hazardous and toxic waste (Bahan Berbahaya dan Beracun [B3]) without the required permits, and the absence of a disease vector control program. These conditions indicate a discrepancy between current practices and the environmental sanitation standards that should be implemented in port areas.

Port activities in Indonesia have grown significantly due to increasing global trade flows and domestic economic development (Amin et al., 2024; Berkah, 2026; Pratikto et al., 2022; Prayoga, 2022; Ramadan & Nugraha, 2026; Sibali & Jainuddin, 2024). Consequently, ports not only contribute to national economic growth but also generate social and environmental impacts on surrounding communities (Boyke et al., 2025; Buonomano et al., 2024; Ogara et al., 2025; Qu et al., 2023; Roberts et al., 2023).

Perawang Container Terminal is one of the major logistics centers and strategic ports in Riau Province. It officially began operations in May 2012 and was managed by PT Pelabuhan Indonesia I (Pelindo I). The terminal is located in Pinang Sebatang Timur Village, Tualang District, Siak Regency, Riau Province (Pelindo, 2024). Environmental sanitation management in port areas differs from that in conventional urban settings because container terminal operations involve logistics activities, internal transportation, cargo handling, and supporting facilities that may generate environmental pressures requiring systematic management.

In response to these environmental pressures, the concept of a healthy port has been promoted as an approach to balancing economic activity with environmental sustainability (Argyriou et al., 2022; Liu et al., 2025; Platias et al., 2025; Qu et al., 2023; Sogut & Erdoğan, 2022). According to Regulation of the Minister of Health of the Republic of Indonesia Number 44 of 2014, a healthy port is characterized by a clean, safe, comfortable, and healthy environment for port workers and surrounding communities. This concept supports not only environmental protection but also the sustainability of port operations in line with the Sustainable Development Goals (SDGs), particularly Goal 3 on good health and well-being and Goal 11 on sustainable cities and communities (United Nations, 2015).

The implementation of the healthy port concept has ecological, social, and economic implications. From an ecological perspective, sanitation and environmental management can help reduce greenhouse gas emissions, prevent water and soil pollution, and protect biodiversity around port areas (Dirmansyah et al., 2024). From a social perspective, a healthy and safe port environment can improve worker and community well-being, reduce health risks, and support a better quality of life. Economically, improved energy efficiency, waste management, and environmentally friendly technologies may reduce operational costs and strengthen port competitiveness at national and international levels.

Several previous studies have examined environmental management in port areas. Dirmansyah et al. (2024) showed that sanitation optimization at the Surabaya Container Terminal was implemented through a green port approach focusing on the management of solid waste, wastewater, and B3 waste, thereby contributing to improved environmental cleanliness. Meanwhile, Nisa and Fadilah (2023) reported persistent deficiencies in solid waste and wastewater management at the Port of Tanjung Perak, indicating the need for sustainable sanitation strategies to achieve healthy port standards. Ardiati (2024), in a study at the Semarang Container Terminal, found that although B3 waste and air emissions had been managed, challenges remained in monitoring and managing non-B3 wastewater and dust emissions. However, most previous studies have focused on large ports, while qualitative investigations examining environmental sanitation management comprehensively in smaller or regional container terminals remain limited (Ardiati, 2024).

According to the 2024 Perawang Container Terminal Healthy Port Assessment Monitoring Report, several environmental health indicators at Perawang Container Terminal had not yet met the required standards, particularly those related to B3 waste management, wastewater drainage, solid waste management, clean water quality, and disease vector control.

The Perawang Terminal Port Environmental Monitoring Report for the first semester of 2024 also indicated the need to provide adequate domestic waste containers throughout the terminal area and to implement waste segregation according to waste type. These deficiencies may hinder the development of a healthy port environment and increase the risks of disease transmission and environmental degradation.

METHOD

This study employed a qualitative approach to obtain an in-depth understanding of environmental sanitation management at Perawang Container Terminal in achieving a healthy port. The approach was used to describe existing sanitation conditions, identify internal and external factors contributing to management problems, and formulate optimization strategies based on key informant perspectives and field findings.

A case study design was employed to examine environmental sanitation management at Perawang Container Terminal within its real-world context. This design enabled an intensive analysis of sanitation practices, existing deficiencies, and contextual factors affecting the implementation of healthy port standards (Yin, 2018).

RESULTS AND DISCUSSION

TPK Perawang Environmental Sanitation Management Optimization Strategy in Realizing a Healthy Port

The formulation of an optimization strategy for environmental sanitation management at the Perawang Container Terminal is carried out through a SWOT analysis approach that integrates internal factors in the form of strengths and weaknesses with external factors in the form of opportunities and threats. This analysis begins with the preparation of the Internal Factor Analysis Summary (IFAS) and External Factor Analysis Summary (EFAS) Matrix, followed by the determination of strategic positions through the Cartesian SWOT Diagram, then the preparation of alternative strategies through the SWOT Matrix. After obtaining alternative strategies from the SWOT matrix, then an AHP analysis is carried out to determine the strategic priorities of the alternative strategies that have been obtained, so that they can focus on which strategies must be prioritized in optimizing environmental sanitation management at TPK Perawang in realizing a healthy port.

IFAS and EFAS Matrix Analysis

The IFAS and EFAS analysis is a systematic step to give weight and rating to each strategic factor that has been identified, both from the internal and external environment. The weighting process was carried out based on the consideration of key informants through in-depth interviews, which reflected the level of relative importance of each factor to the success of the environmental sanitation management of TPK Perawang. Ratings are given to describe the actual state of management in question, with a scale of 1 (poor) to 4 (excellent) for strengths and opportunities, and an inverted scale for weaknesses and threats.

IFAS (*Internal Factor Analysis Summary) Matrix Analysis*

The IFAS matrix was compiled based on the identification of eight strength factors and seven weakness factors that TPK Perawang has in environmental sanitation management. The results of the complete IFAS matrix analysis are presented in Table 1 below:

Table 1. IFAS Matrix for Environmental Sanitation Management of TPK Perawang

No	Strength	Weight	Rating	Score
1	Availability of adequate sanitation facilities	0,08	3	0,24
2	Availability of sufficient human resources	0,10	3	0,30
3	Internal budget allocation available	0,07	3	0,21
4	The existence of leadership commitments and policies as well as supervision	0,07	4	0,28
5	The involvement of TPK Perawang in sanitation practices	0,10	3	0,30
6	Organizational culture supports PHBS	0,10	3	0,30
7	Maintenance of sanitation facilities	0,08	3	0,24
8	Regulatory compliance	0,08	4	0,32
	Quantity			2,19
No	**Disadvantages**	**Weight**	**Rating**	**Shoes**
1	There have been no independent vector control and BPP control efforts	0,05	2	0,10
2	The waste sorting system is not optimal	0,05	3	0,15
3	There is no environmental sanitation program yet	0,05	3	0,15
4	Environmental sanitation SOPs are not yet available	0,05	2	0,10
5	There is no regular clean water quality check	0,02	3	0,06
6	B3 waste management constrained by licensing	0,05	3	0,15
7	Limited environmental sanitation training and education	0,05	2	0,10
	Quantity			0,81
	Total Score			3

Source: Primary data processed from interviews and observations (2025)

Based on the results of the IFAS matrix analysis as presented in Table 1, it is known that the total strength score *of* TPK Perawang reached 2.19, while the total weakness score was 0.81. This condition shows that overall, the internal factors of TPK Perawang are in a relatively strong position to support optimal environmental sanitation management.

Among the eight strength factors identified, two factors received the highest rating, namely 4, namely the commitment and policies of the leadership as well as supervision (score 0.28) and compliance with regulations (score 0.32). This indicates that committed leadership and obedience to the rules are the main foundations that support the running of the sanitation system at TPK Perawang. This achievement is in line with the results of a study by Fahmi et al. (2025) which states that the success of port sanitation management is not solely determined by the completeness of technical infrastructure, but is also greatly influenced by the commitment of top management and consistency in internal regulatory enforcement.

The factors of involvement of TPK Perawang in sanitation practices and the availability of sufficient human resources each obtained a score of 0.30. These two factors show that TPK Perawang has adequate social capital and resource capacity to carry out environmental sanitation programs. The availability of adequate sanitation facilities (score 0.24) and maintenance of sanitation facilities (score 0.24) also make a significant contribution, reflecting that the physical aspects of sanitation facilities have received attention from the management. The organizational culture that supports PHBS (score 0.30) and the availability of internal budget allocation (score 0.21) complement the overall solid internal foundation for efforts to optimize environmental sanitation management.

On the other hand, there are seven weakness factors that collectively result in a total score of 0.81. Although these weakness scores are relatively small compared to strengths, some weaknesses are structural and have the potential to hinder the achievement of healthy port standards if not followed up immediately. The absence of a structured environmental sanitation program (score 0.15) and the unavailability of environmental sanitation SOPs (score 0.10) are the most fundamental weaknesses, because without a clear program framework and procedures, the implementation of sanitation will be reactive and inconsistent. This is in line with the findings of Pramawati et al. (2024) who stated that weak plan and coordination structures are the main obstacles in port sanitation management.

Other weaknesses that need further attention are the lack of independent vector control and BPP efforts (score 0.10) and limited environmental sanitation training and education (score 0.10). Vector control is a mandatory component in the healthy port standard based on the Minister of Health Regulation No. 44 of 2014, so the absence of the TPK Perawang program in this field is a significant gap. Meanwhile, the limitations of training reflect the aspect of human resource capacity development that is not optimal, even though the quantity of human resources is quite sufficient. B3 waste management that is constrained by licensing (score 0.15) and non-optimal waste sorting system (score 0.15) are two factors of technical-administrative weakness that contribute to the gap in the quality of overall sanitation management.

Analysis of the matrix's EFAS (*External Factor Analysis Summary)*

The EFAS matrix was compiled based on the identification of eight opportunity factors and seven threat factors originating from the external environment of TPK Perawang. The results of the complete EFAS matrix analysis are presented in Table 2 below.

Table 2. Environmental Sanitation Management EFAS Matrix TPK Perawang

No	Opportunities	Weight	Rating	Shoes
1	Government regulations/regulations	0,11	4	0,44
2	The potential for sanitation management technology innovation	0,08	3	0,24
3	The parent company's commitment to green ports in anticipation of climate change	0,11	3	0,33
4	Technical capacity support from partners	0,11	3	0,33
5	Standardization of sanitation aspects to improve the quality of the port.	0,08	2	0,16
6	Global and regional environmental policy changes	0,08	2	0,16
7	Public health policy (Healthy ports)	0,08	3	0,24
8	Organic waste management innovation	0,11	2	0,22
	Quantity			2,12
No	**Threats**	**Weight**	**Rating**	**Shoes**
1	Low awareness and sanitation knowledge of the port community	0,03	2	0,06
2	Regional economic developments increase the volume of operational activities	0,05	3	0,15
3	Risk of environmental pollution (dust, noise, oil spills)	0,02	3	0,06
4	Natural disasters and accidents	0,05	1	0,05
5	Health risks from environmental contamination	0,02	3	0,06

6	External financing	0,02	1	0,02
7	Sanctions for violations of regulatory standards	0,05	2	0,10
	Quantity			0,50
	Total Score			2,62

Source: Primary data processed from interviews and observations (2025)

Based on the results of the EFAS matrix analysis as presented in Table 2, the total Opportunity score of TPK Perawang reached 2.12, while the total threat score was 0.50. The overall external environmental condition is very conducive to efforts to optimize the environmental sanitation management of TPK Perawang, considering that the available opportunities are much more dominant than the threats that must be faced.

Among the eight opportunity factors identified, the government regulatory/regulatory factor obtained the highest score of 0.44 with a rating of 4. This high score reflects that the applicable regulatory framework, especially the Indonesian Minister of Health Regulation Number 44 of 2014 concerning the Implementation of Healthy Ports and Airports as well as various relevant environmental regulations, provides a strong and clear legal basis for TPK Perawang to develop a comprehensive sanitation system. Public health policies in the context of healthy ports also received a score of 0.24, indicating that the healthy port agenda promoted by the government is an opportunity that can be used to encourage systematic sanitation improvement.

The parent company's commitment to *green ports* in facing the challenges of climate change obtained a score of 0.33, this illustrates the company's support for sustainable environmental management opens up space for TPK Perawang to develop sanitation programs that are in line with the parent company's green agenda. This is relevant to the *Triple Bottom Line framework* put forward by Elkington (1994), which emphasizes that organizational sustainability can only be achieved if environmental, economic, and social aspects are managed in a balanced manner. Technical capacity support from partners (score 0.33) and potential innovations in sanitation management technology (score 0.24) are instrumental opportunities that can accelerate the improvement of the quality of sanitation management, especially in overcoming existing technical weaknesses.

The innovation factor of organic waste management scored 0.22, reflecting the opportunity to apply recycling and composting technology that can support the efficiency of solid waste management. Meanwhile, standardization of sanitation aspects in order to improve port quality (score 0.16) and changes in global and regional environmental policies (score 0.16) are medium-term opportunities that can be external motivation for TPK Perawang to continue to improve its environmental sanitation standards.

On the threat side, the relatively small total score (0.50) shows that the external environment of TPK Perawang does not present too big a threat. Regional economic developments that increase the volume of operational activities earned the highest score among existing threats (0.15), indicating that the growth of port loading and unloading activities that is not balanced by an increase in sanitation capacity has the potential to worsen hygiene conditions and increase the waste load. Sanctions for violations of regulatory standards (score of 0.10) are a threat that needs to be anticipated, considering the increasingly stringent enforcement of environmental laws both at the national and international levels.

Other threats such as environmental pollution risks, public health risks, and low port community awareness received relatively small scores, but still needed to be considered in the preparation of comprehensive mitigation strategies.

Diagram Kartesius SWOT

The determination of the strategic position of TPK Perawang in an effort to optimize environmental sanitation management was carried out through plotting the results of IFAS and EFAS on the Kartessius SWOT Diagram. The value used as a coordinate is the difference between the total positive factor score (strength and opportunity) and the total negative factor score (weakness and threat) as follows:

Internal analysis coordinates:

X-axis = $\sum$ Strength - $\sum$ Weakness = 2.19 - 0.81 = 1.38

External analysis coordinates:

Y-axis = $\sum$ Chance - $\sum$ Threat = 2.12-0.50 = 1.62

A cartesian diagram for the determination of strategy at the quadrant point can be seen in Figure 1.

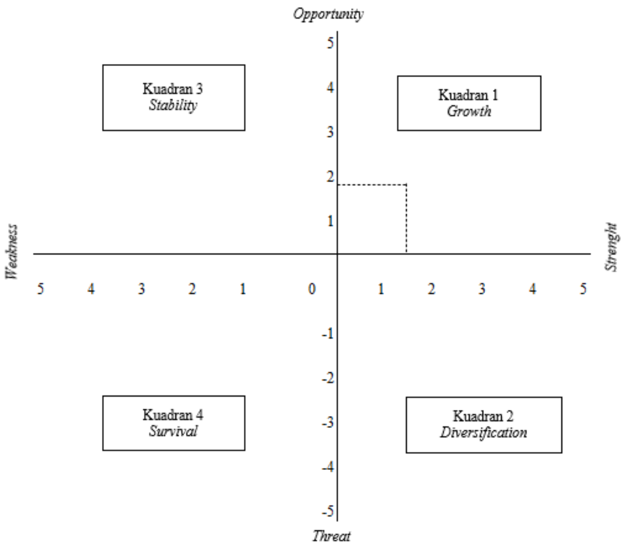

Figure 1. Cartesian SWOT Chart

Source: Primary data processed from IFAS and EFAS analysis results (2025)

The intersection point coordinates on the Cartesian SWOT Chart are at (+1.38; +1.62), which places TPK Perawang in Quadrant I (*Growth/Aggressive*). These results consistently indicate that the environmental sanitation management conditions of TPK Perawang are in a favorable situation, where the internal strengths are greater than the existing weaknesses, while the external opportunities available far exceed the threats faced.

A larger value of the Y-axis (+1.62) than the value of the X axis (+1.38) indicates that the pressure of external factors, in particular the magnitude of the available opportunities, provides a stronger boost than existing internal capacity. This condition strengthens the argument for the need for a growth-oriented strategy with priority on maximizing the use of external opportunities. Furthermore, the distance of the point from the coordinate center is quite far (positive coordinates above 1.0 for both axes) reflects that TPK Perawang is not just in a safe zone, but has a strong momentum to carry out systemic transformation in sanitation management.

The position in Quadrant I, which is referred to as *the Growth zone*, is the best position in the SWOT cartesian chart. According to Rangkuti (2017), the position in this quadrant supports the implementation of an aggressive growth strategy (*Growth-Oriented Strategy*), where organizations are encouraged to make the most of their internal strengths to seize existing external opportunities. In the context of this research, this means that TPK Perawang has the right capacity and momentum to aggressively expand and improve the quality of sanitation management, relying on leadership commitment, regulatory compliance, and the availability of existing human resources and facilities.

SWOT Matrix and Alternative Strategies

Based on the strategic position in Quadrant I (Growth), the main strategy recommended is the S-O (Strength-Opportunity) strategy, which is to utilize internal strengths to aggressively seize external opportunities. However, in order to formulate a comprehensive strategy and anticipate various scenarios, the four strategy cells in the SWOT Matrix are still formulated, including S-O, W-O, S-T, and W-T strategies. The SWOT matrix compiled based on the results of IFAS and EFAS analysis is presented in Table 3 below.

Table 3. SWOT Matrix of Optimization Strategy for Environmental Sanitation Management of TPK Perawang in Realizing Healthy Ports

Internal Factors	Strength (S)	Disadvantages (W)
External Factors	1. Availability of adequate sanitation facilities; 2. Sufficient human resource availability; 3. Internal budget allocation is available; 4. The existence of leadership commitments and policies as well as supervision; 5. The involvement of TPK Perawang in sanitation practices; 6. The organizational culture supports PHBS; 7. Maintenance of sanitation facilities; 8. Regulatory compliance.	1. There have been no independent vector control and BPP control efforts; 2. The waste sorting system is not optimal; 3. There is no environmental sanitation program yet; 4. There are no SOPs for environmental sanitation yet; 5. There has been no regular inspection of the quality of clean water; 6. B3 waste management is constrained by licensing; 7. Limited environmental sanitation training and education.
Odds (O)	**Opportunity Power Strategy (SO)**	**Opportunity Weakness (WO) Strategy**
1. **The existence of government regulations;** 2. **The potential for sanitation management technology innovation;** 3. **The parent company's commitment to green ports in anticipation of climate change;** 4. **Technical capacity support from partners;**	1. Utilizing leadership commitment and compliance with internal regulations as the foundation for building an integrated sanitation management system, synergizing with government regulations and healthy port policies (S4, S8, O1, O7) 2. Optimize internal budget allocation to encourage	1. Formulate and establish comprehensive environmental sanitation SOPs by utilizing government regulatory support and technical guidance from partners as a reference for its preparation (W3, W4, O1, O4) 2. Establish a self-sustaining vector control and BPP program by leveraging

5. **Standardization of sanitation aspects to improve port quality (competition between ports);** 6. **Global and regional environmental policy changes;** 7. **Public health policy (healthy ports);** 8. **Innovation in organic waste management.**	innovation in organic waste and waste management, relying on technical capacity support by partners (S3, S7, O4, O8) 3. Designing a green technology-based sanitation program by optimizing the support of the parent company in the green port agenda and utilizing the development of sanitation management technology innovations (S1, S3, O2, O3) 4. Strengthening the involvement of all internal components of TPK Perawang in a structured sanitation program to meet sanitation standards in order to improve the quality of the port (S5, S6, O5, O7)	technological innovation opportunities and technical capacity support from partners (W1, O2, O4) 3. Integrate optimal waste sorting systems with organic waste management innovations and leverage global environmental policy changes as a driver of improvement (W2, O6, O8) 4. Organize regular sanitation training and education programs by utilizing partner support, public health policies, and healthy port regulations (W7, O1, O4, O7) 5. Conducting regular clean water quality checks and solving B3 waste licensing obstacles by utilizing existing government regulations (W5, W6, O1)
Threat (T)	**Threat Strength (ST) Strategy**	**Threat Weakness (WT) Strategy**
1. Low awareness and sanitation knowledge of the port community; **2. Regional economic developments increase the volume of operational activities;** **3. The risk of environmental pollution;** **4. Natural disasters and accidents;** **5. Public health risks and environmental contamination;** **6. External financing;** **7. Sanctions for violations of regulatory standards.**	1. Optimizing leadership commitment and compliance with internal regulations as protection against the threat of sanctions for violations of regulatory standards and public health risks (S4, S8, T7, T5) 2. Utilizing the strength of human resources, sanitation facilities, and organizational culture that supports PHBS to reduce the risk of environmental pollution due to the increase in port operational volume (S1, S2, S6, T2, T3) 3. Maintain consistent maintenance of sanitation facilities in anticipation of the risk of damage due to natural disasters and work accidents (S7, T4) 4. Strengthen the involvement of all internal components in sanitation programs to raise awareness and reduce port public health risks (S5, S6, T1, T5)	1. Develop a sanitation contingency plan to deal with the risk of natural disasters and accidents, while minimizing the weaknesses of the absence of SOPs and structured sanitation programs (W3, W4, T4, T5) 2. Seek alternative (external) financing sources to overcome the limitations of training, education, and completion of B3 waste licensing to reduce the threat of regulatory sanctions (W6, W7, T6, T7) 3. Integrate self-contained vector control programs and optimal waste sorting systems in response to environmental pollution risks and regional economic development (W1, W2, T2, T3)

Source: Primary data processed from IFAS and EFAS analysis results (2025)

Based on the position of Quadrant I in the Cartesian Diagram, the S-O strategy is a strategy that should be implemented by TPK Perawang. This strategy is designed to maximize the synergy between the internal strengths possessed and the external opportunities available. The first strategy resulting from this synergy is to utilize leadership commitment and compliance with internal regulations as the basis for the development of an integrated sanitation management system, in synergy with government regulations and healthy port policies (S4, S8, O1, O7). This strategy is the most critical foundational strategy because without an integrated management system, other sanitation programs will not be able to run synergistically and sustainably.

The second strategy in the S-O cell is to optimize internal budget allocation for the development of organic waste and waste management innovations, supported by the technical capacity of partners, which is a tangible manifestation of the circular economy approach contained in the *Triple Bottom Line framework*.

The third strategy is to design a green technology-based sanitation program by utilizing the parent company's support for *green ports* and environmental sanitation management technology innovations. This strategy is in line with the research of Hezkia and Firmansyah (2024) which states that the implementation of *green initiatives* not only has an impact on reducing environmental burden, but also increases operational efficiency and worker welfare at the same time. In the context of TPK Perawang, the momentum of *the green port* commitment by the parent company needs to be used concretely in the form of investment in modern waste treatment technology, sensor-based sanitation monitoring systems, and structured recycling programs.

The fourth strategy is to strengthen the involvement of all internal components in the structured sanitation program to meet sanitation standards in order to increase port competitiveness. Competition between ports in terms of sanitation standards and healthy port certification is an external incentive that can encourage sustainable internal improvement.

Analytical Hierarchy Process (AHP)

Alternative strategies obtained through the SWOT matrix, then analysis is carried out using *the Analytical Hierarchy Process* (AHP) to determine the priority of the strategy. AHP is a multicriteria decision-making method developed by Saaty (1990), which works by arranging problems into a hierarchy consisting of goals, criteria, and alternatives and then conducting assessments through paired comparisons. AHP in this study is used to determine which alternative SO strategy should be a priority based on the criteria that have been set, so that it can provide measurable recommendations to the Perawang Container Terminal.

The hierarchical structure in this study is arranged into three levels. The first level is the main goal, namely, determining priority strategies for optimizing environmental sanitation management at TPK Perawang in realizing a healthy port. The second level is the assessment criteria which consists of four main criteria as a result of needs analysis and expert consideration. The third level is an alternative strategy which is the fourth SO strategy resulting from the SWOT Matrix.

The criteria used as the basis for assessment in AHP consist of several main aspects that are interrelated. The first criterion (K1) is facilities and technical environmental sanitation management, which focuses on the availability and condition of sanitation facilities, waste management, waste treatment, and maintenance of facilities such as drainage applied in the field. The second criterion (K2) is environmental regulations and policies that focus on the level of suitability and effectiveness of strategies in implementing and responding to various environmental management regulations and policies, including healthy harbor guidelines, namely the Minister of Health of the Republic of Indonesia Number 44 of 2014. Furthermore, the third criterion (K3) is the capacity of human resources which includes the availability of human resources, competency levels, and involvement in supporting the implementation of environmental sanitation programs. Finally, the fourth criterion (K4) is economics and partnerships which include financing dimensions, budget efficiency, as well as the involvement and support of partners (across sectors and government agencies) in strengthening the sustainability of environmental sanitation to realize healthy ports.

Data for AHP was obtained through a paired comparison questionnaire filled out by four expert respondents consisting of the terminal head of TPK Perawang, the operation manager of TPK Perawang, the head of the environmental health risk factor monitoring team of BKK Class I Pekanbaru, and the coordinator of the work area of the BKK Class I Pekanbaru. Based on the results of the processing of the data of the four experts obtained from the paired comparison matrix for the criterion level, the results presented in the following table are obtained.

Table 4. Results of Weighting Strategy Criteria

No.	Criteria	Weight	Percentage (%)
1	Environmental sanitation management facilities and techniques (K1)	0,47	47
2	Environmental regulation and policy (K2)	0,26	26
3	Capacity of human resources in sanitation management in organization (K3)	0,18	18
4	Economics and partnerships (K4)	0,09	9
	Quantity	**1,00**	**100**

Source: Primary data processed from AHP questionnaire results (2025)

Based on the results of AHP data processing on the criteria, it shows that the first criterion, namely facilities and technical management, has the highest weight, which is 0.47 or 47% of the total. These findings show that experts assess the aspects of physical facilities and technical capacity as the main factors that are most influential in determining the success of sanitation system optimization efforts at TPK Perawang. In other words, the quality of facilities and the effectiveness of technical management are the main foundations in achieving optimal sanitation targets. Furthermore, the criteria for environmental regulations and policies are in second place with a weight of 0.26 or 26%. This indicates that the conformity of sanitation management strategies with applicable environmental regulations and policies has an important role in ensuring the sustainability and compliance of the implemented system.

The criteria for human resource capacity received a weight of 0.18 or 18%, while the fourth criterion, namely economy and partnerships, received a weight of 0.09 or 9%. The weighting pattern is in line with the existing conditions at TPK Perawang, where technical problems such as waste management, B3 waste management, availability of handwashing facilities, garbage cans and toilets and drainage systems are critical indicators based on the results of observations using *the healthy port* self-assessment form.

The validation of the AHP assessment depends on the level of consistency of the paired comparisons conducted by the expert *(expert*). Saaty (1990) established a paired comparison matrix to be consistent if the *Consistency Ratio* (CR) value ≤ 0.1. The CR result for the criterion comparison matrix was 0.023. Meanwhile, the CR result for the alternative comparison matrix to criteria one to criterion four in a row was 0.024; 0,025; 0,012; and 0.011. The results of all paired comparison matrices in this study have a CR value of ≤ 0.1, so it can be said that the data has been consistent. A consistent CR value can be interpreted as an expert assessment that is the result of logical and interconnected considerations.

Alternative Priority Strategy

Based on the results of the calculation of alternative strategies, it is known that the strategy for developing sanitation programs based on green technology occupies the highest position with a weight of 0.3279 or 32.79%, followed by the strategy of leadership commitment and compliance with internal regulations as the basis for the development of a sanitation system with a weight of 0.2430 or 24.3%. The results of the strategy priority ranking are shown in table 5 below.

Table 5. Alternative Priority Results of Strategies Based on AHP

No.	Code	Alternative Strategies	Weight	Status
1	SO3	Designing a green technology-based sanitation program by optimizing the support of the parent company in the green port agenda and taking advantage of the development of sanitation management technology innovations.	0,3279	Priority 1
2	SO1	Utilizing leadership commitment and compliance with internal regulations as the foundation for building an integrated sanitation management system, in synergy with government regulations and healthy port policies.	0,2430	Priority 2
3	SO2	Optimize internal budget allocation to encourage innovation in organic waste and waste management, relying on technical capacity support by partners.	0,2203	Priority 3
4	SO4	Strengthening the involvement of all internal components of TPK Perawang in a structured sanitation program to meet sanitation standards in order to improve the quality of the port.	0,2088	Priority 4

Source: Primary data processed from AHP questionnaire results (2025)

The advantages of the SO3 strategy as the first priority cannot be separated from the weighting structure of the criteria that have been set beforehand. In Criterion 1 (facilities and technical environmental sanitation management), which has the most dominant weight of 0.47, SO3 also recorded the highest local score compared to other alternatives, namely 0.47. This shows that proportionally, SO3 is considered the most effective in responding to the need to improve facilities and sanitation technical systems at TPK Perawang. This finding becomes even more relevant when it is associated with existing conditions that show that four of the twelve indicators of healthy ports, namely waste management, B3 waste management, handwashing facilities, and drainage systems are still in the poor category. These four aspects are directly related to the dimensions of physical facilities and the technical aspects of sanitation management.

From the perspective of Criterion 1, the green technology approach that is at the core of SO3 includes the application of modern waste treatment technologies, digital-based sanitation monitoring systems, as well as the integration of recycling programs and more systematic organic waste management. Fahmi et al. (2025) emphasized that technological innovations such as biofilters and integrated wastewater treatment systems are able to significantly increase the effectiveness of sanitation management in port areas. In line with that, Van and Anh (2024) also show that the use of technology-based environmental monitoring systems can support more effective port sanitation management while meeting applicable international standards. In the context of TPK Perawang, the existence of a well-functioning Sewage Treatment Plant (STP) can be used as an initial foundation to be further developed towards a technology-based integrated sanitation system.

Another important aspect that distinguishes the SO3 strategy from other alternative strategies is the alignment of this strategy with the commitment of the parent company PT Pelindo Terminal Petikemas to the green *port concept*. Research by Hezkia and Firmansyah (2024) revealed that the implementation of *green port* initiatives at container terminals not only has an impact on reducing environmental impact, but also contributes to improving worker welfare and operational efficiency. Thus, this strategy is not only oriented towards fulfilling healthy port standards, but also provides added value from economic and social aspects that are in line with the concept of *the Triple Bottom Line* (Elkington, 1994). The successful experience of the Surabaya Container Terminal documented by Dirmansyah (2024), especially in reducing carbon emissions and improving the quality of waste management through *a green port approach*, can be used as a relevant implementation reference for TPK Perawang.

The implementation of green technology-based strategies inherently requires an increase in the capacity of human resources that support it. The implementation of new technology will not run optimally without the support of a workforce that has adequate competence and training. This condition is in line with the internal weakness of TPK Perawang, namely the lack of special training related to environmental sanitation, so that a technology-based approach will automatically encourage strengthening the capacity of human resources as a prerequisite for implementation. Pramawati et al. (2024) also emphasized that social factors in the form of low knowledge and awareness of port workers about sanitation are one of the main causes of sanitation problems, so that strategies that integrate technical aspects and human resource development such as SO3 have a more comprehensive impact.

The strategy utilizes leadership commitment and compliance with internal regulations as the basis for the development of an integrated sanitation management system, in synergy with government regulations and healthy port policies, ranks second with a weight of 0.2430. Although the difference is quite significant with SO3, SO1's position in second place is not just an administrative ranking. Substantively, SO1 serves as a policy pillar that determines whether all other sanitation programs, including SO3, can run consistently, measurably, and sustainably. Without a structured management foundation, the implementation of green technology as sophisticated as it may be has the potential to fail because it lacks a binding governance framework.

The relevance of this strategy to the existing conditions of TPK Perawang is very high. One of the most fundamental weaknesses identified in this study is the absence of specific Standard Operating Procedures (SOPs) for environmental sanitation and the absence of sanitation policies that stand as a separate domain. All informants from TPK Perawang consistently admitted that the sanitation aspect is currently still integrated into the general HSSE policy, without a separate sanitation performance measurement standard. This condition creates a situation where sanitation is reactive and unprogrammed, so that the repairs that occur have not been systematically automated. Fahmi et al. (2025) emphasized that the success of port sanitation management is greatly influenced by the commitment to regulations and policies from port authorities, and that without commitment from the leadership level, the implementation of sanitation programs in the field tends to be inconsistent and unsustainable.

Strategy Implementation Recommendations

Based on the results of the AHP ranking, there are two alternative strategies that are the first and second priorities. From the two strategies, strategic implementation recommendations are outlined according to the priorities produced, as follows:

1. The first priority is the strategy of designing a sanitation program based on green technology by optimizing the support of the parent company in the green port agenda and taking advantage of the development of sanitation management technology innovations. The recommended steps include: (1) the preparation *of* a green technology-based sanitation master plan as a medium-term planning document that contains a roadmap for technology investment, performance indicator targets, and financing sources; (2) Submission of proposals to PT Pelindo Terminal Petikemas to access *the green port* program from the parent company, as well as open *co-funding* in the procurement of modern waste management technology; (3) Adopt automatic waste sorting technology, upgrade drainage system, and expand existing STP capacity; (4) Installation of *real-time environmental quality monitoring* sensors, especially for air dust (PM10) parameters, groundwater quality, and drainage conditions; and (5) Development of a full-scale organic waste composting system as a continuation of the innovation that has begun.
2. The second priority is the strategy of utilizing leadership commitment and compliance with internal regulations as the basis for building an integrated sanitation management system, in synergy with government regulations and healthy port policies. This strategy ranks second as the foundation of policy and governance that drives the success of the strategy at the first priority at the operational level. Recommendations for the implementation of this strategy include: (1) The preparation of a separate environmental sanitation policy that is separate from the general HSSE document, as an internal legal basis for all sanitation programs at the Perawang Container Terminal; (2) Preparation and ratification of specific Environmental Sanitation Standard Operating Procedures (SOPs), including waste management procedures, oil spill handling, vector control, water quality inspection, and sanitation emergency response; (3) Integration of periodic (semester) clean water quality checks into the ongoing environmental monitoring agenda; and (4) Accelerating the completion of B3 waste TPS licensing and the signing

of MoUs with licensed third parties as a regulatory compliance measure that cannot be delayed. This strategy is in line with the WHO's statement (2022) that weaknesses at the policy and supervisory levels are the main obstacles to sanitation management of port environments globally.

CONCLUSION

Based on the analysis of environmental sanitation management at Perawang Container Terminal (PCT), the existing conditions still showed a substantial gap from the healthy port standards stipulated in Indonesian Ministry of Health Regulation No. 44 of 2014. The main problems identified included the absence of a waste segregation system, temporary waste storage facilities that did not meet technical standards, irregular monitoring of clean water quality, management of hazardous and toxic waste (Bahan Berbahaya dan Beracun [B3]) without the required permits, and the absence of a disease vector control program. The Internal Factor Analysis Summary (IFAS) and External Factor Analysis Summary (EFAS) results showed that PCT had a strength score of 2.19 and an opportunity score of 2.12, exceeding the weakness score of 0.81 and the threat score of 0.50. The SWOT Cartesian diagram placed PCT in Quadrant I (growth/aggressive strategy), indicating a relatively strong internal position and favorable external conditions for optimizing environmental sanitation management. Based on the Analytic Hierarchy Process (AHP), the highest-priority strategy was the development of a green technology-based sanitation program by leveraging support from the parent company’s green port agenda and adopting innovative sanitation management technologies (SO3), with a weight of 0.3279 (32.79%). This was followed by strategies that utilized leadership commitment and regulatory compliance as the foundation for an integrated environmental sanitation management system.

Based on these findings, the study recommends developing a green technology-based sanitation master plan as a medium-term planning framework encompassing technology investment, performance targets, and financing mechanisms. Support from PT Pelindo Terminal Petikemas should also be leveraged through its green port program to facilitate co-funding for environmentally sustainable waste-management technologies. Priority interventions should include improved waste segregation systems, drainage upgrades, expansion or optimization of sewage treatment plant (STP) capacity where required, and environmental monitoring systems for relevant parameters such as particulate matter (PM10), groundwater quality, and drainage conditions. Organic waste management through composting may also be developed according to operational needs and waste-generation capacity. In addition, PCT should establish a dedicated environmental sanitation policy and specific standard operating procedures (SOPs), integrate periodic clean water quality testing into routine environmental monitoring, and accelerate the completion of licensing requirements for B3 temporary storage facilities (Tempat Penampungan Sementara [TPS]) and formal agreements with appropriately licensed waste-management service providers. Further research should evaluate the effectiveness of these strategies and develop a monitoring and evaluation framework for sustainable healthy port management.

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