

# Strategizing Green Ports for a Sustainable Maritime Future: The Case Study of Makassar Port

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## ABSTRACT

This study examines the environmental challenges caused by activities in different ports focusing on Makassar Port, deploying a qualitative research approach, supported by primary and secondary data sources. First, the initial data were collected through interviews with port stakeholders, while secondary data were collected from official reports, literature reviews, and port performance documents. The research applied Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis to examine the possibilities of adopting a green strategy in Makassar Port. The results show that Makassar port is positioned in quadrant I of the Cartesian SWOT model, which proposes the use of an aggressive Strengths-Opportunities (S-O) strategy. This strategy uses the port's existing capabilities in order to promote sustainable and environmentally friendly operations and economic growth. The study concludes that combining sustainable strategies with operational processes is necessary to improve port efficiency and reduce negative environmental impacts.

*Keywords-sustainability; green port strategies; SWOT analysis; port operations optimization*

## I. INTRODUCTION

Global trading relies over 80% on the maritime transport system [1]. However, the International Maritime Organization (IMO) reports an increase in carbon emissions from 2.76% in 2012 to 2.89% in 2018, showing the urgent need for sustainable practices. Ports face the combined challenge of efficient operations and environmental sustainability [2], integrating ecological, economic, and social issues into maritime and port operations [3]. Effective sustainable

practices influence various aspects of the operations, from production volumes and costs [4] to equipment longevity and environmental outcomes [5]. This requires aligning operational objectives with business strategies and establishing key performance indicators that take into account economic, environmental, and social factors [6]. In addition, sustainability reporting and innovative performance metrics are critical to achieving accountability [7]. Adopting sustainable practices in maritime transport and port operations requires a holistic

approach that integrates environmental protection, operational efficiency, and social responsibility [8]. According to the International Association of Ports and Harbors (IAPH) [9], the green port model is a collaborative effort aiming to develop and operate ports using green economy strategies [10], including energy conservation and environmental protection methods [11-13]. In order to reduce carbon emissions in maritime transport systems using the Sustainable Development Goals (SDGs) port authorities must take proactive initiatives to reduce the environmental damage caused by port operations, such as enhancements in service performance [14]. This requires dealing with pollution from port construction, and organizing operations demanding the adoption of a green seaport operational model. In order to maintain their efficiency and competitiveness, but also comply with the environmental sustainability, port construction and operation, must reduce the carbon emissions. Indonesia highly depends on maritime transportation due to its geographical position, and thus realizes the urgency of transitioning to sustainable port models [15], complying with the country's commitment to achieving the SDGs [16]. During 2020-2024, Indonesia tried to meet the SDGs through the National Medium-Term Development Plan (RPJMN), leading to greater development and improvement of life quality for next generations. This plan attempted to reduce regional differences, while focusing on high growth, enhancing global competitiveness, preserving cultural identity, and strengthening infrastructure. While SWOT analysis has been used in previous studies, there is a gap in the literature regarding green ports in Indonesia. This study aims to address this gap by not only identifying the key internal and external factors affecting the successful adoption of green port initiatives, but also proposing specific strategies to leverage strengths, reduce weaknesses, and address threats. The novelty of this study lies in its focus on the specific context of Makassar Port and the development of a strategic framework for green port practices that contributes to both academic understanding and practical application in the pursuit of sustainable maritime transportation. By integrating the SWOT analysis, this research will provide a valuable tool for port authorities and stakeholders in Makassar to achieve a more sustainable and environmentally responsible maritime transport system.

## II. STATE OF THE ART

SWOT analysis is a critical strategic planning tool used to assess the strengths, weaknesses, opportunities, and threats of a business or project [17]. It helps to understand how these internal and external factors interact to make strategic decisions [18, 19]. By identifying these elements, organizations can better understand their capabilities and limitations in the context of external challenges, and align with their goals for a stable and adaptive strategy. SWOT analysis provides a structured approach to understanding the factors that affect its direction and goals. It allows organizations to identify opportunities for growth, address weaknesses, and prepare for potential threats [20]. Therefore, SWOT analysis plays a significant role in taking decisions that guide an organization toward its long-term goals. A SWOT analysis examines four key elements: strengths, which include financial resources, brand image, market leadership, or strong buyer/supplier

relationships [21]. On the other hand, the limitations or deficiencies in a company's resources or capabilities compared to its competitors, are weaknesses that hinder its ability to meet customer needs [22]. These may include inadequate infrastructure, insufficient managerial skills, or misaligned marketing capabilities. Opportunities are favorable external situations that provide ways for growth and competitive advantage [23], such as market trends, overlooked market segments, and changes in regulations or technology. Threats are adverse external situations that challenge a company's current position or future aspirations [24]. These can include new competitors, slow market growth, increased bargaining power of buyers or suppliers, and technological disruptions. The qualitative SWOT matrix, introduced by Kearns, as shown in Table I, provides a dynamic framework for strategic evaluation [25]. It consists of eight interrelated cells: Opportunities and Threats (external factors), Strengths and Weaknesses (internal factors), and the strategic issues that arise from their combination: S-O, Strengths-Threats (S-T), Weaknesses-Opportunities (W-O), and Weaknesses-Threats (W-T). This framework provides a comprehensive analysis that allows organizations to strategically position themselves to maximize opportunities and effectively address challenges. This study uses the SWOT framework to analyze the specific context of Makassar port and develop a targeted strategic framework for green port implementation. It identifies the port's internal strengths and weaknesses related to green initiatives, as well as the external opportunities and threats posed by the evolving maritime landscape and regulatory environment. By examining the interaction of these factors, the present study aims to propose strategies that leverage the port's strengths to benefit from opportunities, mitigate weaknesses, and address threats, ultimately contributing to a more sustainable maritime transport system at the Port of Makassar.

TABLE I. KEARNS SWOT MATRIX WITH A QUALITATIVE APPROACH

Internal \ External	Opportunity	Threats
Strength	Comparative advantage	Mobilization
Weakness	Divestment/Investment	Damage control

## III. METHODOLOGY

### A. Location and Time of the Research

The research focuses on two prominent ports located in Makassar, South Sulawesi, Indonesia. The study was conducted from July 2022 to December 2022, allowing for a comprehensive data collection, and analysis of port operations and their environmental impacts. These ports, which serve as critical links in the region's maritime and logistics network, play a critical role in facilitating trade and economic activity, not only locally, but also in connecting global supply chains. Over the designated research timeframe, the study thoroughly examined the operations, challenges and potential for adopting green port practices in alignment with global sustainability goals. The extended timeline enabled the researchers to observe seasonal variations and long-term operational trends, ensuring a stable foundation for practical solutions.

B. Research Population

The population of this study was determined using the method of purposive sampling. This method entails the selection of respondents based on predetermined criteria, ensuring the relevance and representativeness of the collected data in relation to the research objectives. This methodological approach enables researchers to focus on individuals with direct involvement in Makassar port, thereby ensuring the reliability of the findings [26]. The determination of the sample size is based on known sampling principles. In instances where the population is less than 100, it is proposed to include all members to ensure that the data reflect the entire population. Conversely, when the population is larger, a sample ranging from 10%-15% or 15%-25% is recommended to maintain data validity while optimizing resources. Roscoe's guidelines further propose that an ideal sample size for research lies between 30 and 500 participants. These considerations ensure methodological consistency and facilitate the acquisition of meaningful insights from the selected respondents, as shown in Table II.

TABLE II. DISTRIBUTION OF RESPONDENTS BY AGENCY

No.	Instance	Total
1	Pt. Pelabuhan Indonesia Makassar Branch	46
2	Port Authority Makassar	9
3	Makassar Main Harbor Master	7
4	Service User Companies	15
5	Universities	20
6	Community	10
	Total	107

IV. RESULTS AND DISCUSSION

A. Questionnaire Results and Ratings

The data collected from the questionnaire responses, which include the number of respondents who evaluated internal and external factors on a numerical scale, are outlined in Tables III and IV, which form a significant basis for the analysis. That is, they provide a clear quantitative overview of the participants' perceptions, and ratings of the factors under study. They offer a more detailed understanding of how internal and external factors influence the issue by describing the distribution of responses across different rating scales. This detailed data presentation helps identify trends and patterns, and provides the empirical evidence needed to support subsequent strategic recommendations. The incorporation of systematically organized data ensures transparency, reliability, and a solid ground for interpreting the findings, hence underscoring the significance of data-driven decision-making in addressing the identified issues.

B. Weight Calculation

Table V presents the results of the weighting calculations for the internal factors, providing a comprehensive overview of their assigned importance. By methodically identifying and assigning weights to these elements, the company can enhance its knowledge of the internal capabilities and limitations, and guide strategic initiatives to strengthen competitive advantages while addressing areas for improvement. This structured

evaluation forms the foundation for developing targeted and effective business strategies. The calculation of the weight for external factors, context of the company, opportunities and threats, is performed by assigning a value based on the level of importance or attention required. This process uses a scale ranging from 0.000 (not important) to 1.000 (extremely important), thereby ensuring that the total combined weight of all factors does not exceed a score of 1.000. The determination of these weights involves assessing the relevance and impact of each factor on the company's strategic goals. Table VI presents the outcomes of this calculation, providing a detailed listing of the weighted scores for the identified external factors. This methodology is essential for prioritizing actions and resources to help the company respond effectively to external opportunities and reduce potential threats while maintaining strategic balance.

TABLE III. QUESTIONNAIRE RESULTS DATA AND RATING OF INTERNAL FACTORS

No.	Strengths	Rating				
		1	2	3	4	5
S1	Increasing the efficiency of the role and resources of the port	0	0	3	50	54
S2	Increasing the quality of the port environment	0	0	5	32	70
S3	Guaranteeing the future of the port	0	0	12	33	62
S4	Supporting the industrial, economic, tourism, and trade sectors	0	0	4	47	56
S5	Increasing the operational standards of the port	0	0	9	31	67
S6	Support from the central and regional governments	0	0	10	29	68
S7	Support for port digitalization	0	0	6	28	73
S8	Increasing the traffic of goods and passengers	0	0	12	28	67
No.	Weaknesses					
W1	High cost of developing and implementing new technologies	4	11	27	31	34
W2	Programs with high uncertainty	22	31	23	14	17
W3	Weaknesses in implementation due to differences between ports	10	33	26	20	18
W4	Lack of trained resources	4	11	26	32	34
W5	Impact of changes in operational digitalization systems	4	12	26	31	34
W6	Control and monitoring of digital systems	22	31	22	14	18

TABLE IV. QUESTIONNAIRE DATA RESULTS AND RATING OF EXTERNAL FACTORS

No.	Opportunities	Rating				
		1	2	3	4	5
O1	Opportunity for the port to upgrade its image	2	0	12	45	48
O2	Increased port profits by opening new business lines in developing markets	0	6	16	44	41
O3	Increased opportunities for increased investment in the port	2	2	10	44	49
O4	Increased number of job opportunities	0	6	16	46	39
O5	Creation of an effective and efficient supply chain	2	2	9	44	50
No.	Threats					
T1	Low level of adaptation to change	22	27	32	16	10
T2	Changes in legislation and regulations	2	13	23	43	26
T3	Vulnerability to cyber threats	6	21	19	41	20
T4	Uncertainty in the international economy	0	13	24	43	27
T5	Changes in political and institutional elements	6	21	20	40	20

TABLE V. INTERNAL FACTOR WEIGHTING CALCULATION RESULTS

No.	Strengths	Questionnaire data processing	Weight
S1	Increasing the efficiency of the role and resources of the port	479	0.080
S2	Increasing the quality of the port environment	493	0.082
S3	Guaranteeing the future of the port	478	0.080
S4	Supporting the industrial, economic, tourism, and trade sectors	480	0.080
S5	Increasing the operational standards of the port	486	0.081
S6	Support from the central and regional governments	486	0.081
S7	Support for Port digitalization	495	0.083
S8	Increasing the traffic of goods and passengers	483	0.081
<b>Strengths</b>		<b>3,880</b>	<b>0.647</b>
No.	Weaknesses		
W1	High cost of developing and implementing new technologies	401	0.067
W2	Programs with high uncertainty	294	0.049
W3	Weaknesses in implementation due to differences between different ports	324	0.054
W4	Lack of trained resources	402	0.067
W5	Impact of changes in operational digitalization systems	400	0.067
W6	Control and monitoring of digital systems	296	0.049
<b>Weaknesses</b>		<b>2,117</b>	<b>0.353</b>
<b>Total internal factors</b>		<b>5,997</b>	<b>1.000</b>

TABLE VI. EXTERNAL FACTOR WEIGHTING CALCULATION RESULTS

No.	Opportunities	Questionnaire Data Processing	Weight
O1	Opportunity for the port to upgrade its image	458	0.112
O2	Increased port profits by opening new business lines in developing markets	441	0.108
O3	Increased opportunities for increased investment in the port	457	0.112
O4	Increased number of job opportunities	439	0.108
O5	Creation of an effective and efficient supply chain	459	0.112
<b>Opportunities</b>		<b>2,254</b>	<b>0.552</b>
No.	Threats		
T1	Low level of adaptation to change	286	0.070
T2	Changes in legislation and regulations	399	0.098
T3	Vulnerability to cyber threats	369	0.090
T4	Uncertainty in the international economy	405	0.099
T5	Changes in political and institutional elements	368	0.090
<b>Threats</b>		<b>1,827</b>	<b>0.448</b>
<b>Total external factors</b>		<b>4,081</b>	<b>1.000</b>

C. Internal Strategic Factors Analysis Summary and External Strategic Factors Analysis Summary Matrix Calculation

Calculating the Internal Strategic Factors Analysis Summary (IFAS) matrix is important for determining the weight, rating, and score of strategic factors. It is necessary that the total weight of the factors does not exceed 1.000. The rating of each factor is evaluated on a scale ranging from 1.000 to 5.000, where 1 signifies below-average significance or low

importance, and 5 indicates high significance or high importance. This step enables the identification and prioritization of internal strategic factors that influence the performance of the organization. Table VII, displays the results of the IFAS matrix calculation and provides an overview of the weighted values, ratings, and scores assigned to each factor. The matrix is a critical tool in strategic planning, ensuring a structured and balanced analysis of strengths and weaknesses to align with broader organizational goals.

TABLE VII. IFAS MATRIX CALCULATION RESULTS

No.	Strengths	Weight	Rating	Score
S1	Increasing the efficiency of the role and resources of the port	0.080	4.477	0.358
S2	Increasing the quality of the port environment	0.082	4.607	0.379
S3	Guaranteeing the future of the port	0.080	4.467	0.356
S4	Supporting the industrial, economic, tourism, and trade sectors	0.080	4.486	0.359
S5	Increasing the operational standards of the port	0.081	4.542	0.368
S6	Support from the central and regional governments	0.081	4.542	0.368
S7	Support for port digitalization	0.083	4.626	0.382
S8	Increasing the traffic of goods and passengers	0.081	4.414	0.364
<b>Strengths</b>		<b>0.647</b>		<b>2.933</b>
No.	Weaknesses			
W1	High cost of developing and implementing new technologies	0.067	3.748	0.251
W2	Programs with high uncertainty	0.049	2.748	0.135
W3	Weaknesses in implementation due to differences between different ports	0.054	3.028	0.164
W4	Lack of trained resources	0.067	3.757	0.252
W5	Impact of changes in operational digitalization systems	0.067		0.249
W6	Control and monitoring of digital systems	0.049	3.738	0.137
<b>Weaknesses</b>		<b>0.353</b>	<b>2.766</b>	<b>1.187</b>
<b>Total internal factors</b>		<b>1.000</b>		<b>4.120</b>

The calculation of the Strategic Factors Analysis Summary (EFAS) matrix is similar to the calculation of the IFAS matrix. Both methods include determining the weight, rating, and score for each factor, ensuring that the total weight does not exceed 1,000. The EFAS matrix is used to evaluate the external factors that influence strategic decisions, such as opportunities and threats, by assigning ratings to each factor. These ratings range from 1.000 (below average or insignificant) to 5.000 (excellent or highly significant). A key feature of the EFAS matrix is the contrasting nature of the ratings for opportunities and threats. Higher ratings are assigned to opportunities that provide significant strategic advantages, whereas lower ratings reflect the severity or impact of threats. In a similar manner, strengths and weaknesses are inversely rated, thus ensuring that the analysis accurately presents their opposing influence on organizational strategy. The results of the EFAS analysis, shown in Table VIII, provide a thorough analysis of the external environment and help decision-makers develop strategies that will take advantage of opportunities while effectively minimizing threats. This structured approach is critical for aligning organizational objectives with external market dynamics and ensuring sustainable competitive advantage.

TABLE VIII. EFAS MATRIX CALCULATION RESULTS

No.	Opportunities	Weight	Rating	Score
O1	Opportunity for the port to upgrade its image	0.112	4.280	0.480
O2	Increased port profits by opening new business lines in developing markets	0.108	4.121	0.445
O3	Increased opportunities for increased investment in the port	0.112	4.271	0.478
O4	Increased number of job opportunities	0.108	4.103	0.441
O5	Creation of an effective and efficient supply chain	0.112	4.290	0.482
<b>Opportunities</b>		<b>0.552</b>		<b>2.328</b>
No.	Threats	Weight	Rating	Score
T1	Low level of adaptation to change	0.070	2.673	0.187
T2	Changes in legislation and regulations	0.098	3.729	0.365
T3	Vulnerability to cyber threats	0.090	3.449	0.312
T4	Uncertainty in the international economy	0.099	3.785	0.376
T5	Changes in political and institutional elements	0.090	3.439	0.310
<b>Threats</b>		<b>0.448</b>		<b>1.549</b>
<b>Total external factors</b>		<b>1.000</b>		<b>3.877</b>

The calculation of the IFAS and EFAS matrix scores indicates that the total strength score is 2.933 and the total weakness score is 1.187. To obtain the internal factor coordinates:

$$X - \text{coordinate (IFAS)} = \frac{\text{Total Score for Strengths} - \text{Total Score for Weaknesses}}{2} \tag{1}$$

and by substituting:

$$\text{IFAS} = \frac{2.933 - 1.187}{2} = 1.746 \tag{2}$$

A similar method is used to calculate the Y-coordinate based on opportunities and threats for the external factors. The total score for opportunities is 2.328, and the total score for threats is 1.549, so the Y-coordinate is:

$$Y - \text{coordinate (EFAS)} = \frac{\text{Total Score for Opportunities} - \text{Total Score for Threats}}{2} \tag{3}$$

and by substituting:

$$\text{EFAS} = \frac{2.328 - 1.549}{2} = 0.778 \tag{4}$$

These coordinates can be plotted on the SWOT Cartesian diagram to assess the strategic position of the organization. In this case, the internal and external factor scores provide insights that can be used to effectively guide the strategic decision-making process. Subsequent to determining the coordinates of each internal and external factor, is to identify the strategic positioning within the SWOT analysis diagram. This process is the positioning of the factors into one of four quadrants: I, II, III, or IV, as depicted in Figure 1. The strategic approach is classified and defined by the quadrant into which each factor is placed. Aggressive strategy (quadrant I) is characterized by a strong and assertive approach, while diversification (quadrant II) involves a strategic shift towards new areas or markets. A turn-around strategy (quadrant III) describes a radical change in the existing strategy, and a defensive strategy (quadrant IV) is focused on protecting the existing strategy. The strategic direction that is ultimately chosen is determined by the placement of the factors within each quadrant.

SWOT Cartesian Diagram

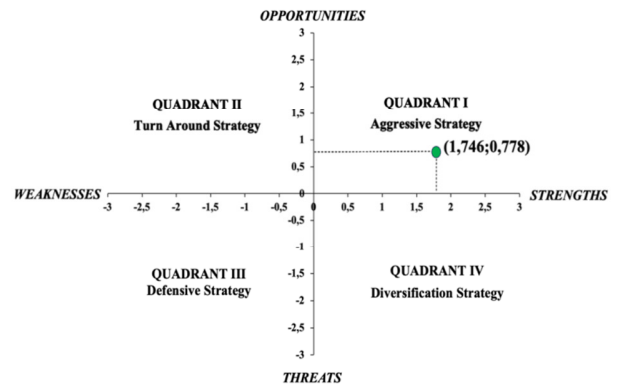


Fig. 1. SWOT Cartesian diagram.

This study’s results indicate that the priority strategy is situated in quadrant I, which corresponds to an aggressive strategy. This finding suggests that the green port strategy uses strong internal factors to benefit from the identified opportunities, hence increasing the effectiveness of green port implementation in Makassar port. The SWOT matrix serves as the primary analytical instrument for defining alternative strategies for the organization. The SWOT analysis diagram is used to derive combinations within the matrix by plotting the total scores of internal and external factors. These combinations result in proposed alternative strategies aimed at advancing green port practices in Makassar port. The results from the combination of internal and external indicators are presented in Table IX, highlighting the potential strategic actions to optimize the implementation of green port initiatives. Following the completion of the SWOT matrix, a quantitative model analysis to ascertain the aggregate scores for each strategic factor in the S-O, W-O, S-T, and W-T strategies is performed as follows:

- The S-O framework is a tool used to assess the viability of the potential opportunities and strengths of a given entity. The total score is the sum of the strengths and opportunities, amounting to 2.933 and 2.328 respectively, resulting in a total score of 5.261. This high score indicates a high potential for leveraging internal strengths to capitalize on external opportunities.
- The W-O analysis provides a different perspective. The weaknesses score is 1.187, which, when combined with the opportunities score of 2.328, yields a total of 3.514. This strategy is focused on minimizing internal weaknesses while taking advantage of the available opportunities.
- The S-T analysis reveals a noteworthy finding with the summation of the strengths of 2.933 and 1.549, resulting in a total of 4.483. This calculation reflects the capacity to leverage internal strengths to counterbalance potential external threats.
- The W-T analysis, with the weaknesses score of 1.187 added to the threats score of 1.549, results in a total of 2.736. This calculation puts emphasis on addressing weaknesses while reducing the risks posed by external threats.

TABLE IX. SWOT ANALYSIS OF GREEN PORT IMPLEMENTATION AT MAKASSAR PORT

SWOT	Strengths	Weaknesses
	Increasing the efficiency of the role and resources of the port. Increasing the quality of the port environment. Guaranteeing the future of the port. Supporting the industrial, economic, tourism, and trade sectors. Increasing the operational standards of the port. Support from the central and regional governments. Support for port digitalization. Increasing the traffic of goods and passengers.	High cost of developing and implementing new technologies. Programs with high uncertainty. Lack of trained resources. Impact of changes in operational digitalization systems. Control and monitoring of digital systems
Opportunities	S-O strategies	W-O strategies
Opportunity for the port to upgrade its image. Increased port profits by opening new business lines in developing markets. Increased opportunities for increased investment in the port. Increased number of job opportunities. Creation of an effective and efficient supply chain.	Improving the efficiency of port roles and resources to sustain environmental quality through the green port concept, allowing the port to upgrade its reputation: (S1, S2, O1). Enhancing support for the digital transformation of ports through the smart port concept to capitalize on new business lines in emerging markets, aiming to increase port profitability for its future sustainability: (S2, S7, O2). Increasing support from both the central and local governments in the implementation of green and smart port initiatives to boost investment opportunities at the port, which will support the industrial, economic, tourism, and trade sectors, thereby creating new job opportunities: (S4, S6, O3, O4). Improving operational service standards at the port to increase the volume of cargo and passenger traffic, hence creating a more effective and efficient supply chain: (S5, S8, O5).	Enhancing efforts to develop and implement cost-effective new technologies to establish an upgraded reputation, thereby increasing port investment and creating more job opportunities: (W1, O1, O3, O4). Addressing the high uncertainty in the green port program by increasing the volume of training related to green ports to improve the number of trained human resources, reducing discrepancies in green port implementation across different ports, and achieving an effective and efficient supply chain: (W2, W3, W4, O5). Making the most changes in digital operational systems and improving control and monitoring of digital systems to boost port profits, opening new business lines in emerging markets: (W5, W6, O2).
Threats	S-T Strategies	W-T Strategies
Low level of adaptation to change. Changes in legislation and regulations. Vulnerability to cyber threats. Uncertainty in the international economy. Changes in political and institutional elements.	Improving the efficiency of port roles and resources aims to enhance the port's environmental quality and its adaptability to changes in legislation, regulations, as well as political and institutional factors: (S1, S2, T1, T2, T5). Strengthening support from the central and regional governments is essential to enhance the port's role as a key supporter of industries, the economy, tourism, and trade, ensuring the port's future amidst global economic uncertainties: (S3, S4, S6, T4). Supporting the transformation of port digitalization through the smart port concept is crucial for improving operational service standards to cope with increased cargo and passenger traffic while minimizing vulnerability to cyber threats:(S5, S7, S8, T3).	Enhancing efforts to develop and implement cost-effective new technologies to improve the port's adaptability to changes: (W1, T1). Addressing high uncertainty factors in the green port program, including changes in regulations, laws, and political and institutional factors, by increasing the volume of training related to green port initiatives. This will help increase the number of trained human resources, enabling ports to manage differences in green port implementation and mitigate the impact of international economic uncertainties: (W2, W3, W4, T2, T4, T5). Effectively leveraging the digitalization of operational systems and improving control and monitoring of digital systems to minimize vulnerabilities to cyber threats: (W5, W6, T3).

Table X presents a Quantitative Strategic Planning Matrix (QSPM) for the application of green port initiatives at Makassar port. This tool methodically integrates diverse strategic factors to ascertain the most suitable approaches for achieving sustainable port operations. The integration of the QSPM framework provides a structured system for prioritizing strategies based on their potential impact and feasibility. The QSPM assists decision-makers in aligning environmental objectives with operational goals, thereby ensuring a balance between economic efficiency and ecological sustainability. This comprehensive tool underscores the necessity of adopting innovative practices to address the environmental issues affecting ports, especially in urban coastal environments, such as Makassar. The study identifies several key strategies that leverage Makassar port's strengths to pursue opportunities in the maritime sector. First, enhancing port efficiency through the green port concept can increase environmental sustainability while positioning the port as a leader in green operations. This approach is in alignment with global trends, wherein ports are undergoing a transition to greener practices in order to comply with international environmental standards.

The implementation of these strategies has the potential to enhance Makassar Port's competitiveness and attract investors.

TABLE X. QUANTITATIVE STRATEGY COMBINATION PLANNING MATRIX FOR GREEN PORT IMPLEMENTATION AT MAKASSAR PORT

EFAS/MFAS	Strengths	Weaknesses
Opportunities	S-O strategies: using strengths to take advantage of opportunities = 5.261.	W-O strategies: minimizing weaknesses by taking advantage of opportunities = 3.514.
Threats	S-T strategies: using strengths to overcome threats = 4.483.	W-T strategies: minimizing weaknesses and avoiding threats = 2.736.

Secondly, the digital transformation enabled by the smart port concept allows for improved operational efficiency and the potential to expand into new business markets. Research on port digitalization has shown that smart technologies can improve cargo handling, reduce congestion, and lower operational costs. For instance, the integration of smart systems at Makassar Port has the potential to reinforce its position as a vital trade hub in eastern Indonesia and improve its long-term profitability. The right level of government support is also

critical to the successful adoption of green and smart port initiatives. By securing backing from both central and local authorities, Makassar port can attract greater investment, supporting various sectors, such as industry, trade, tourism, and logistics, creating job opportunities and promoting regional economic growth. Finally, enhancing operational service standards is important for increasing cargo and passenger volumes, leading to a more effective and efficient supply chain. Ports that prioritize service improvements often experience increased shipping traffic and stronger partnerships with global logistics providers. For Makassar port, the streamlining of operational procedures can reinforce its position as a strategic maritime gateway in Indonesia, therefore strengthening its regional economic impact.

## V. CONCLUSIONS

This study proposes a novel integration of the green port concept with smart port development strategies, a combination that has not been extensively explored in previous research. The novelty of this study lies in the application of a comprehensive Strengths, Weaknesses, Opportunities and Threats (SWOT) Cartesian analysis to develop an effective strategy that not only focuses on environmental sustainability, but also embraces digital transformation to enhance the port's competitiveness. This approach was achieved by identifying key actions that align port operations with emerging market opportunities, government support, and improved service standards. The study's significance lies in its contribution to the existing body of knowledge by addressing the existing gap between sustainability and technological advancement in port management, providing a practical framework that can be used to complete and extend the existing body of research on green and smart ports. The study's findings offer practical strategies that can attract investment, increase profitability, and create new job opportunities, thereby supporting similar efforts in maritime logistics and highlighting its relevance and applicability in both local and international contexts.

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## REFERENCES

- [1] *Review of Maritime Transport 2021*. Geneva, Switzerland: UNCTAD, 2021.
- [2] N. Ahmadi, T. Kusumastanto, and E. I. Siahaan, "Strategi Pengembangan Pelabuhan Berwawasan Lingkungan (Greenport) Studi Kasus: Pelabuhan Cigading-Indonesia," *Warta Penelitian Perhubungan*, vol. 28, no. 1, Oct. 2024, Art. no. 9, <https://doi.org/10.25104/warlit.v28i1.697>.
- [3] V. B. Samuel, P. Agamuthu, and M. A. Hashim, "Indicators for assessment of sustainable production: A case study of the petrochemical industry in Malaysia," *Ecological Indicators*, vol. 24, pp. 392–402, Jan. 2013, <https://doi.org/10.1016/j.ecolind.2012.07.017>.
- [4] R. A. Hraiga, A. M. M. A. Fadel, and A. A. Abbas, "Balanced scorecard integration and green process re-engineering to optimize the performance of economic units," *Economics, Management and Sustainability*, vol. 8, no. 1, pp. 16–33, May 2023, <https://doi.org/10.14254/jems.2023.8-1.2>.
- [5] A. N. Hustim, S. A. Adisasmita, S. H. Aly, Muralia, "Green Port Performance Criteria Model in A Sustainable Maritime Transportation System in Makassar Port," *International Journal of Engineering Trends and Technology - IJETT*, vol. 72, no. 2, pp. 154–162, 2024, <https://doi.org/10.14445/22315381/IJETT-V72I2P117>.
- [6] F. A. Shaikh, M. S. Shahbaz, and N. Odhano, "A Short Review on Green Supply Chain Management Practices: The Impact on Operational and Environmental Performance," *Engineering, Technology & Applied Science Research*, vol. 10, no. 2, pp. 5367–5370, Apr. 2020, <https://doi.org/10.48084/etasr.3382>.
- [7] J. A. Felício, R. Rodrigues, and V. Caldeirinha, "Green Shipping Effect on Sustainable Economy and Environmental Performance," *Sustainability*, vol. 13, no. 8, Jan. 2021, Art. no. 4256, <https://doi.org/10.3390/su13084256>.
- [8] M. C.-P. Poo, W. Zhang, L. Kamalian, T. Wang, Y. Lau, and T. Z. Xu, "Resilience of Chinese Ports to Tropical Cyclones: Operational Efficiency and Strategic Importance," *Climate*, vol. 12, no. 12, Dec. 2024, Art. no. 214, <https://doi.org/10.3390/cli12120214>.
- [9] M. De Martino, "Value Creation for Sustainability in Port: Perspectives of Analysis and Future Research Directions," *Sustainability*, vol. 13, no. 21, Jan. 2021, Art. no. 12268, <https://doi.org/10.3390/su132112268>.
- [10] A. S. Alamouh, A. I. Olçer, and F. Ballini, "Ports' role in shipping decarbonisation: A common port incentive scheme for shipping greenhouse gas emissions reduction," *Cleaner Logistics and Supply Chain*, vol. 3, Mar. 2022, Art. no. 100021, <https://doi.org/10.1016/j.clscn.2021.100021>.
- [11] H. P. Nguyen, P. Q. P. Nguyen, and T. P. Nguyen, "Green Port Strategies in Developed Coastal Countries as Useful Lessons for the Path of Sustainable Development: A case study in Vietnam," *International Journal of Renewable Energy Development*, vol. 11, no. 4, pp. 950–962, Nov. 2022, <https://doi.org/10.14710/ijred.2022.46539>.
- [12] L. Cavalli *et al.*, "Addressing Efficiency and Sustainability in the Port of the Future with 5G: The Experience of the Livorno Port. A Methodological Insight to Measure Innovation Technologies' Benefits on Port Operations," *Sustainability*, vol. 13, no. 21, Jan. 2021, Art. no. 12146, <https://doi.org/10.3390/su132112146>.
- [13] N. P. Hariram, K. B. Mekha, V. Suganthan, and K. Sudhakar, "Sustainalism: An Integrated Socio-Economic-Environmental Model to Address Sustainable Development and Sustainability," *Sustainability*, vol. 15, no. 13, Jan. 2023, Art. no. 10682, <https://doi.org/10.3390/su151310682>.
- [14] H. Winnes, L. Styhre, and E. Fridell, "Reducing GHG emissions from ships in port areas," *Research in Transportation Business & Management*, vol. 17, pp. 73–82, Dec. 2015, <https://doi.org/10.1016/j.rtbm.2015.10.008>.
- [15] R. Bergqvist and J. Monios, *Green Ports: Inland and Seaside Sustainable Transportation Strategies*, 1st ed. Elsevier, 2018.
- [16] B. P. Nauli, "Sustainable Development Goals (SDGs) 9: Industry, Innovation, and Infrastructure during the COVID-19 Pandemic in Indonesia," *Jurnal Hubungan Internasional*, vol. 10, no. 2, pp. 96–107, Jan. 2022, <https://doi.org/10.18196/jhi.v10i2.12196>.
- [17] R. W. Puyt, F. B. Lie, and C. P. M. Wilderom, "The origins of SWOT analysis," *Long Range Planning*, vol. 56, no. 3, Jun. 2023, Art. no. 102304, <https://doi.org/10.1016/j.lrp.2023.102304>.
- [18] L. Pereira, M. Pinto, R. L. da Costa, Á. Dias, and R. Gonçalves, "The New SWOT for a Sustainable World," *Journal of Open Innovation: Technology, Market, and Complexity*, vol. 7, no. 1, Mar. 2021, Art. no. 18, <https://doi.org/10.3390/joitmc7010018>.
- [19] Y. A. Solangi, C. Longsheng, and S. A. A. Shah, "Assessing and overcoming the renewable energy barriers for sustainable development in Pakistan: An integrated AHP and fuzzy TOPSIS approach," *Renewable Energy*, vol. 173, pp. 209–222, Aug. 2021, <https://doi.org/10.1016/j.renene.2021.03.141>.
- [20] B. Phadermrod, R. M. Crowder, and G. B. Wills, "Importance-Performance Analysis based SWOT analysis," *International Journal of Information Management*, vol. 44, pp. 194–203, Feb. 2019, <https://doi.org/10.1016/j.ijinfomgt.2016.03.009>.

- 
- [21] I. Farida and D. Setiawan, "Business Strategies and Competitive Advantage: The Role of Performance and Innovation," *Journal of Open Innovation: Technology, Market, and Complexity*, vol. 8, no. 3, Sep. 2022, Art. no. 163, <https://doi.org/10.3390/joitmc8030163>.
- [22] D. J. Teece, "A capability theory of the firm: an economics and (Strategic) management perspective," *New Zealand Economic Papers*, vol. 53, no. 1, pp. 1–43, Jan. 2019, <https://doi.org/10.1080/00779954.2017.1371208>.
- [23] A. Schulze, J. D. Townsend, and M. B. Talay, "Completing the market orientation matrix: The impact of proactive competitor orientation on innovation and firm performance," *Industrial Marketing Management*, vol. 103, pp. 198–214, May 2022, <https://doi.org/10.1016/j.indmarman.2022.03.013>.
- [24] Y. Wu and J. Tham, "The impact of environmental regulation, Environment, Social and Government Performance, and technological innovation on enterprise resilience under a green recovery," *Heliyon*, vol. 9, no. 10, Oct. 2023, Art. no. e20278, <https://doi.org/10.1016/j.heliyon.2023.e20278>.
- [25] C. Vladoš, "On a correlative and evolutionary SWOT analysis," *Journal of Strategy and Management*, vol. 12, no. 3, pp. 347–363, May 2019, <https://doi.org/10.1108/JSMA-02-2019-0026>.
- [26] L. A. Palinkas, S. M. Horwitz, C. A. Green, J. P. Wisdom, N. Duan, and K. Hoagwood, "Purposeful sampling for qualitative data collection and analysis in mixed method implementation research," *Administration and policy in mental health*, vol. 42, no. 5, pp. 533–544, Sep. 2015, <https://doi.org/10.1007/s10488-013-0528-y>.