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Original Article

Green Port Performance Criteria Model in A Sustainable Maritime Transportation System in Makassar Port

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Abstract *- Maritime transport, commonly referred to as the Maritime Transportation System (MTS), encompasses ports and intermodal land connections that facilitate approximately 80% of global trade. This research aims to enhance the concept of a green port model at Makassar Port in South Sulawesi by assessing criteria for green port performance. The methodology involves constructing a green port performance model through the integration of structural equation modeling (SEM). The criteria considered for evaluating green port performance include five aspects: operational management, environmental technical considerations, financial and economic factors, social elements, and the port information system. The research findings indicate the following: (1) operational management significantly and positively influences green port performance, evidenced by a T-statistic value of 0.221 and a p-value of 0.011; (2) environmental technical aspects have a positive and significant impact on green port performance, with a T-statistic value of 0.356 and a p-value of 0.005; (3) financial-economic considerations positively and significantly affect green port performance, supported by a T-statistic value of 0.161 and a p-value of 0.044; (4) the social aspect exhibits a positive and significant correlation with green port performance, as indicated by a T-statistic value of 0.229 and a p-value of 0.016; and (5) the port information system aspect positively and significantly contributes to green port performance, with a T-statistic value of 0.244 and a p-value of 0.021. The resultant green port performance model from this research demonstrates an R-square value of 0.623 and an NFI of 0.318.*

Keywords *- Green port criteria, Green port performance, Makassar port, Structural equation modeling.*

1. Introduction

The global maritime transportation system facilitates approximately 80% of worldwide trade, with seaports serving as pivotal nodes for the entry and exit of goods between nations [1]. The maritime transportation system plays a vital role in global trade and commerce, acknowledged as the most efficient and cost-effective means of transporting goods. However, despite its efficiency, the environmental impact of seaport activities raises significant concerns due to the emissions of gases, wastewater, and solid waste associated with shipping operations. Ships, particularly those powered by fossil fuels, release various pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon dioxide (CO_2), and particulate matter. These emissions contribute to air pollution, climate change, and health issues in the surrounding areas. According to statistics from the International Seaport Association, approximately 70% of emissions during a journey are attributed to ships' activities at ports, underscoring the need to address these environmental concerns both at sea and within ports [2]. Moreover, data from the International Maritime Organization (IMO) reveals that the global share of carbon emissions from the maritime industry has risen from 2.76% in 2012 to 2.89% in 2018.

Despite the relative energy efficiency of international shipping, its increasing contribution to global emissions cannot be overlooked, given its anticipated growth alongside world trade. It is imperative to adopt a coordinated global approach to implement and enforce measures for reducing emissions, foster innovation, and ensure the maritime industry actively participates in mitigating climate change.

It is crucial to acknowledge that addressing climate change requires a multifaceted approach, as no single solution can independently tackle the complex issue. Meaningful progress in mitigating the impacts of climate change necessitates a combination of strategies tailored to the unique circumstances of each region and sector. One key approach involves implementing scalable solutions for mitigation, including transitioning to renewable energy, enhancing energy efficiency, establishing sustainable transportation systems, and advocating for sustainable land use practices. These mitigation strategies are scalable as they can be implemented at various levels, ranging from individual actions to government policies and international agreements. Another essential approach is the development of climate change literacy among individuals, institutions, and societies.

This entails fostering an understanding of the significance of climate change, engaging various stakeholders, addressing challenges, and cultivating a populace well-versed in climate change issues [3]. The third approach involves a shift towards sustainable practices, encompassing the promotion of renewable energy sources such as solar, wind, hydroelectric, and geothermal power.

This includes adopting energy-efficient technologies in various sectors, such as industries, buildings, and transportation. Additionally, embracing sustainable agriculture and forestry practices, along with reducing waste and emissions through the use of environmentally friendly materials, such as sustainable building materials and products with a reduced carbon footprint, contributes to addressing climate change [4].

The fourth approach centers on promoting environmentally friendly technology, recognizing its pivotal role in combating climate change. This encompasses developing and adopting technologies that lower greenhouse gas emissions, enhance energy efficiency, advocate sustainable practices, and minimize environmental impacts.

Moreover, the concept of green ports plays a vital role in addressing carbon emissions within the maritime transportation system, aligning seamlessly with the Sustainable Development Goals (SDGs) outlined in the 2030 Agenda for Sustainable Development. Green ports aim to curtail the environmental impact of port operations and shipping activities while fostering sustainable economic growth.

Given the escalating concerns about environmental sustainability and climate change, the implementation of emerging green port concepts and technologies stands as a critical direction for modern port development. Ports worldwide increasingly recognize the importance of incorporating eco-friendly methods and technologies to mitigate their environmental impact[5].

Implementing the green port initiative has received support through the issuance of Presidential Regulation Number 59 of 2017, focusing on the Achievement of Sustainable Development Goals.

According to Article 21, Paragraph 1 of this decree, national targets for the period 2017 to 2019 are established in the 2015-2019 National Medium-Term Development Plan, which is aligned with sustainable development goals outlined in the appendix and forms an integral part of this presidential regulation. As articulated in Paragraph 1, the primary objective is to ensure sustainable increases in the community's economic welfare while concurrently upholding the sustainability of its social fabric, preserving environmental quality, fostering inclusive development, and enabling the government to enhance the quality of life sustainably for future generations. These overarching goals are translated into seven development agendas, each comprising specific priority programs, activities, and projects. The National Medium-Term Development Plan for 2020-2024 aligns its objectives with the Sustainable Development Goals (SDGs). Furthermore, the targets and indicators of the 17 SDGs are integrated into the seven development agendas, encompassing priorities such as enhancing economic resilience for high-quality growth, reducing regional inequality, improving human resources quality and competitiveness, fostering culture and national identity, reinforcing infrastructure to support economic progress and basic services, safeguarding the environment, enhancing resilience to disasters and climate change, and fortifying the stability of politics, law, defense, security, and public transportation services.

In light of these principles, this research aims to advance the green port concept by evaluating green port performance criteria and constructing a green port performance model at Makassar Port in South Sulawesi. The methodology employs structural equation modeling (SEM) to achieve this objective.

2. Methods

In this research, the SEM-PLS method, a variance-based structural equation analysis technique that facilitates the simultaneous examination of measurement and structural models, was employed for data analysis [6]. This approach addresses challenges associated with data in multiple regression analysis.

The use of SEM-PLS is advantageous due to its soft modeling properties, offering flexibility without the need to adhere to a specific scale size or mean. Additionally, it accommodates smaller sample sizes (less than 100), making it applicable in situations with limited data. The PLS technique, within SEM-PLS, is well-suited for predictive purposes, accepting data of various types, including nominal, categorical, ordinal, interval, or ratio, without necessitating specific distribution requirements [7].

To evaluate the SEM-PLS approach, a comprehensive examination involves assessing both the measurement model (outer model) and the structural model (inner model) before testing hypotheses. The entire theoretical framework will be expounded upon in subsequent sections.

2.1. Outer Model Analysis

The outer model, or outer measurement model, delineates the relationship between manifest variables and latent variables. The evaluation procedure focuses on establishing the convergent and discriminant validity of the manifest variables and assessing the composite reliability of these variables.

2.1.1. Convergent Validity

The assessment of convergent validity relies on the correlation between the manifest value and the construct value. Convergent validity is gauged by the standardized loading factor, or outer loading, indicating the magnitude of the correlation.

Individual reflexive measures are considered satisfactory if the loading score exceeds 0.7. However, a score within the range of 0.5–0.6 is deemed acceptable in the preliminary stages of the research.

2.1.2. Discriminant Validity

Discriminant validity assessments are conducted to ensure that the measured variables or factors are distinct and that the variable acts as an independent variable. Discriminant validity is discerned from the cross-loading between manifests and their corresponding variables. Comparing the indicator correlation with the construct to other variables allows the latent variable to estimate the block's size more accurately than that of the other blocks.

2.1.3. Construct Reliability

The reliability of variables can be evaluated using two types of tests: composite reliability and Cronbach's alpha. Variables are considered reliable if the composite reliability score exceeds 0.7 and the Cronbach's alpha score is above 0.6. The assessment of composite reliability is based on the coefficients of latent variables.

2.2. Analysis of the Inner Model

The inner model, also known as the inner relation or structural model, is employed to assess and determine the significance of the causality relationship for each latent variable. The inner model is described in accordance with the substantive theory, and predictions between latent variables can be made using path coefficients.

The evaluation of the inner model involves the following stages:

- Initially, the inner model is scrutinized by considering the percentage of variance represented through the R-square score (R^2) or the determinant coefficient of the dependent latent variable. The R^2 value falls into the categories of high (0.67), medium (0.33), and low (0.19).
- Subsequently, the Q-Square score (Q^2) is examined for predictive relevance. This test aims to demonstrate that specific variables in the model possess predictive relevance. The Q^2 score evaluates the level of observed scores generated by the model and its estimated parameters. A Q^2 score > 0 indicates predictive relevance, while a Q^2 score < 0 suggests less predictive relevance.

2.3. Hypothesis Test

Hypothesis testing employs the bootstrap resampling method (β, γ, and λ). The acceptance of a hypothesis is determined by comparing the T-Statistic with the T-Table score. The hypothesis is supported if the T-Statistic score exceeds the T-Table score.

Variables in this research refer to factors that can differentiate. The green port criteria variables include the 2019 formulation by the Coordinating Ministry for Maritime Affairs and Investment of the Republic of Indonesia green port certification aspects in Indonesia issued by PT. Sucofindo, and criteria identified in research by several experts on green port performance [8-12].

Table 1 provides a summary of these criteria variables. From the identified criteria variables in the research, five causal correlations, also serving as research hypotheses, can be established, namely: (1) X1: Aspects of Operational Management (AMO) positively influence Y: Green Port Performance (KGP); (2) X2: Environmental Technical Aspects (ATL) positively influence Y: Green Port Performance (KGP); (3) X3: Financial Economic Aspect (AEF) positively influences Y: Green Port Performance (KGP); (4) X4: Social Aspect (AS) positively influences Y: Green Port Performance (KGP); and (5) X5: The Port Information System (APIS) aspect positively influences Y: Green Port Performance (KGP).

The research locations encompass two ports in Makassar, South Sulawesi, specifically Makassar Port in Makassar Municipality, South Sulawesi Province, during the period from March 2022 to December 2022.

The sample for this research was chosen using purposive sampling, a technique that involves selecting participants based on specific criteria to ensure more representative data [13]. The selected samples consist of respondents who are involved with the Port of Makassar and possess knowledge about it.

Determining the sample size adheres to the principle that when dealing with fewer than 100 subjects, it is preferable to include all to ensure the research data accurately represents the population. However, a sample size of 10-15%, 15-25%, or more for larger subject numbers can be considered [14-15].

This aligns with Roscoe's assertion that "an appropriate sample size for research falls between 30 and 500". See Table 2.

3. Results and Discussion

3.1. Results of Measurement Model Test (Outer Model)

The assessment of the measurement model involved conducting tests for convergent validity, discriminant validity, and reliability. Convergent validity was evaluated by examining the loading factor and cross-loading values.

Table 3 presents the loading factor values, all surpassing the rule of thumb's threshold of 0.7, eliminating the need for subjective evaluations. Table 4 displays data indicating that the loading factor for each construct exceeds that of the other constructs, affirming that latent constructs exhibit superior predictability of indicators within their respective blocks compared to those in other blocks. Consequently, based on the results of cross-loading, all indicators are considered valid. The discriminant validity test utilized the Average Variance Extracted (AVE) value, with the results presented in Table 5. All indicators exhibit an AVE value exceeding 0.5, confirming the validity of each indicator.

Table 1. Green port performance criteria variables

Variable	Criteria – Indicator
Y-Green port performance in sustainable maritime transportation (KGP)	▪ Y1-Green port performance in economic aspect (KGPE) ▪ Y2-Green port performance in environmental aspect (KGPL) ▪ Y3-Green port performance in social aspect (KGPS)
X-Green port criteria (GPK)	X1-Management/operational aspect (AMO): ▪ X1.1-Green port implementation commitment and policy (KKGP) ▪ X1.2-Green port promotion (PG)
	X2-Technical/environmental aspect (ATL): ▪ X2.1-Port area management (KP) ▪ X2.2-Management of supporting transportation (TP) ▪ X2.3-Air quality management (KU) ▪ X2.4-Management of seawater, surface water, and sediment quality (KL) ▪ X2.5-Management of soil and groundwater quality (AT) ▪ X2.6-Sustainable dredging and reclamation (PR) ▪ X2.7-Minimization the impact of noise (DK) ▪ X2.8-Energy management (PE) ▪ X2.9-Absorption of carbon emissions and use of clean energy (EB) ▪ X2.10-Natural habitat conservation management (HA) ▪ X2.11-Implementation of occupational safety and health (K3 ▪ X2.12-Waste Management (PL) ▪ X2.13-Application of reduce, reuse, and recycle (3R)
	X3-Economic/financial aspect (AEF): ▪ X3.1-Port performance: waiting time, BOR/YOR, and L/U speed (KPBM) ▪ X3.2-XFinancial performance (KK) ▪ X3.3-Port investment (PI)
	X4-Social aspect (AS): ▪ X4.1-Empowerment of local communities (PM) ▪ X4.2-Impact on the community's economy (DPM)
	X5-Port information system aspect (APIS): ▪ X5.1-Auotomatitaion of loading and unloading equipments (APBM) ▪ X5.2E-commerce and paperless transaction (ECPT) ▪ X5.3Traceability (T)

Table 2. Distribution of respondents by agencies

No.	Agencies	Total
1	Indonesian Port Makassar Branch	46
2	Makassar Port Authority	9
3	Makassar Main Harbour master	7
4	Service User Companies	15
5	Universities	20
6	Communities	10
Sum		**107**

Table 3. Values of loading factor

Criteria	X1 (AMO)	X2 (ATL)	X3 (AEF)	X4 (AS)	X5 (APIS)	Y (KGP)
X1.1 (KKGP)	0,755					
X1.2 (PG)	0,873					
X2.1 (KP)		0,685				
X2.2 (TP)		0,738				
X2.3 (KU)		0,809				
X2.4 (KL)		0,838				
X2.5 (AT)		0,800				
X2.6 (PR)		0,796				
X2.7 (DK)		0,844				
X2.8 (PE)		0,800				
X2.9 (EB)		0,803				
X2.10 (HA)		0,876				
X2.11 (K3)		0,757				
X2.12 (PL)		0,823				
X2.13 (3R)		0,846				
X3.1 (KBM)			0,753			
X3.2 (KK)			0,826			
X3.3 (PI)			0,825			
X4.1 (DPM)				0,791		
X4.2 (PM)				0,852		
X5.1 (APBM)					0,893	
X5.2 (ECPT)					0,796	
X5.3 (T)					0,819	
Y1 (KGPE)						0,786
Y2 (KGPL)						0,728
Y3 (KGPS)						0,754

Table 4. Values of cross-loading

Criteria	X1 (AMO)	X2 (ATL)	X3 (AEF)	X4 (AS)	X5 (APIS)	Y (KGP)
X1.1 (KKGP)	**0,755**	0,192	0,071	0,189	0,105	0,105
X1.2 (PG)	**0,873**	0,258	0,165	0,340	0,255	0,225
X2.1 (KP)	0,065	**0,685**	-0,057	0,086	-0,058	-0,058
X2.2 (TP)	0,147	**0,738**	0,068	0,257	0,111	0,111
X2.3 (KU)	0,354	**0,809**	0,226	0,364	0,272	0,272
X2.4 (KL)	0,144	**0,838**	0,301	0,180	0,298	0,298
X2.5 (AT)	0,128	**0,800**	0,124	0,322	0,170	0,170
X2.6 (PR)	0,313	**0,796**	0,200	0,433	0,250	0,250
X2.7 (DK)	0,146	**0,844**	0,350	0,170	0,311	0,311
X2.8 (PE)	0,196	**0,800**	0,120	0,309	0,190	0,190
X2.9 (EB)	0,344	**0,803**	0,220	0,355	0,266	0,266
X2.10 (HA)	0,204	**0,876**	0,280	0,226	0,345	0,345
X2.11 (K3)	0,161	**0,757**	0,074	0,274	0,241	0,241
X2.12 (PL)	0,338	**0,823**	0,227	0,350	0,288	0,288
X2.13 (3R)	0,199	**0,846**	0,302	0,222	0,386	0,386
X3.1 (KBM)	0,036	0,160	**0,753**	0,194	0,063	0,063
X3.2 (KK)	0,233	0,172	**0,826**	0,176	0,274	0,274
X3.3 (PI)	0,065	0,258	**0,825**	-0,054	0,175	0,175
X4.1 (DPM)	0,253	0,296	0,019	**0,791**	0,063	0,063
X4.2 (PM)	0,295	0,276	0,176	**0,852**	0,344	0,344
X5.1 (APBM)	0,128	0,302	0,250	0,136	**0,893**	0,893
X5.2 (ECPT)	0,143	0,255	0,104	0,257	**0,796**	0,796
X5.3 (T)	0,270	0,241	0,203	0,284	**0,819**	0,819
Y1 (KGPE)	0,314	0,467	0,367	0,481	0,481	**0,786**
Y2 (KGPL)	0,304	0,487	0,182	0,249	0,249	**0,728**
Y3 (KGPS)	0,447	0,449	0,281	0,391	0,391	**0,754**

Table 5. Values of Average Variance Extracted (AVE)

Criteria	AVE Value	Status
X1 (AMO)	0,666	Valid
X2 (ATL)	0,644	Valid
X3 (AEF)	0,643	Valid
X4 (AS)	0,676	Valid
X5 (APIS)	0,701	Valid
Y (KGP)	0,572	Valid

Table 6. Values of composite reliability

Criteria	Composite Reliability Value	Status
X1 (AMO)	0,798	Reliable
X2 (ATL)	0,959	Reliable
X3 (AEF)	0,844	Reliable
X4 (AS)	0,806	Reliable
X5 (APIS)	0,875	Reliable
Y (KGP)	0,800	Reliable

Table 7. Value of R-square

	R-Square	R-Square Adjusted
Y (KGP)	0,623	0,605

Table 8. Value of Q-square

Criteria	SSO	SSE	Q^2 (=1-SSE/SSO)
X1(AMO)	214.000	214.000	
X2 (ATL)	1319.000	1319.000	
X3 (AEF)	321.000	321.000	
X4 (AS)	214.000	214.000	
X5 (APIS)	321.000	321.000	
Y (KGP)	321.000	218.940	**0,318**

The reliability test, focusing on the composite reliability value of the indicator block measuring the construct, is examined. Table 6 demonstrates that the composite reliability value for all constructs surpasses 0.7, indicating that all constructs in the estimated model meet the discriminant reliability criteria.

3.2. Results of Structural Model Test (Inner Model)

The inner model test involved several assessments to determine the coefficient (R-square), predictive relevance (Q-square), and significance of T-statistics and P-values. The R-square calculation in this research yielded a value of 0.623, placing it in the moderate category. However, it was only 0.047 points away from achieving the strong R-square category. This R-square value signifies that Y equals 0.623 times 100%, indicating that green port performance is influenced by variables X1, X2, X3, X4, and X5, accounting for 62.30% of the total. Detailed data can be found in Table 7.The Q-square calculation in this investigation yielded a value of 0.318, equivalent to 31.80%. Consequently, it can be inferred that the employed model possesses significant predictive capacity, interpreting 31.80% of the research data. Refer to Table 8 for detailed information.

The research hypothesis involves five causal correlations between latent variables. Employing a one-tailed p-value test, the influence of one construct on another is considered significant if the t-statistic value exceeds 1.64. Additionally, a significance level (α) or p-value < 0.05 was adopted in this research. With p-values < 0.05, the confidence level of the resulting model is 95%. The results of the T-statistics and P-values significance test can be found in Table 9.

The significance test of T-statistics values and P-values allows for the determination of the causal correlation direction and influence of all criteria, as outlined below: (1) X1: Management/Operational Aspects (AMO) exhibit a positive and significant effect of 0.221 on Y: Green Port Performance (KGP) with a T-statistics value of 2.568; (2) X2: Technical/Environmental Aspect (ATL) demonstrates a positive and significant effect of 0.356 on Y: Green Port Performance (KGP) with a T-statistic value of 2.849; (3) X3: Economic/Financial Aspect (AEF) manifests a positive and significant effect of 0.161 on Y: Green Port Performance (KGP) with a T-statistic value of 2.020; (4) X4: The Social Aspect (AS) contributes positively and significantly with a 0.229 effect on Y: Green Port Performance (KGP) at a T-statistic value of 2.427; finally, (5) X5: The Port Information System (APIS) Aspect exerts a positive and significant effect of 0.244 on Y: Green Port Performance (KGP) at a T-statistic value of 2.324.

These findings indicate that the criteria of Management/ Operational Aspects, Technical/Environmental Aspect, Economic/Financial Aspect, Social Aspect, and Port Information System Aspect exert a positive and significant influence on Green Port Performance in Makassar Port. The positive and significant influence of all these criteria suggests that their implementation will positively impact Green Port's Performance in Makassar Port.

Table 9. Significance test result of T-statistics Values and P-values

Causal Connection	Original Sample (O)	Standard Deviation (STDEV)	T-statistics (O/STDEV)	P-values	Description
AMO → KGP	0,221	0,086	2,568	0,011	Significant
ATL → KGP	0,356	0,125	2,849	0,005	Significant
AEF → KGP	0,161	0,080	2,020	0,044	Significant
AS → KGP	0,229	0,094	2,427	0,016	Significant
APIS → KGP	0,244	0,105	2,324	0,021	Significant

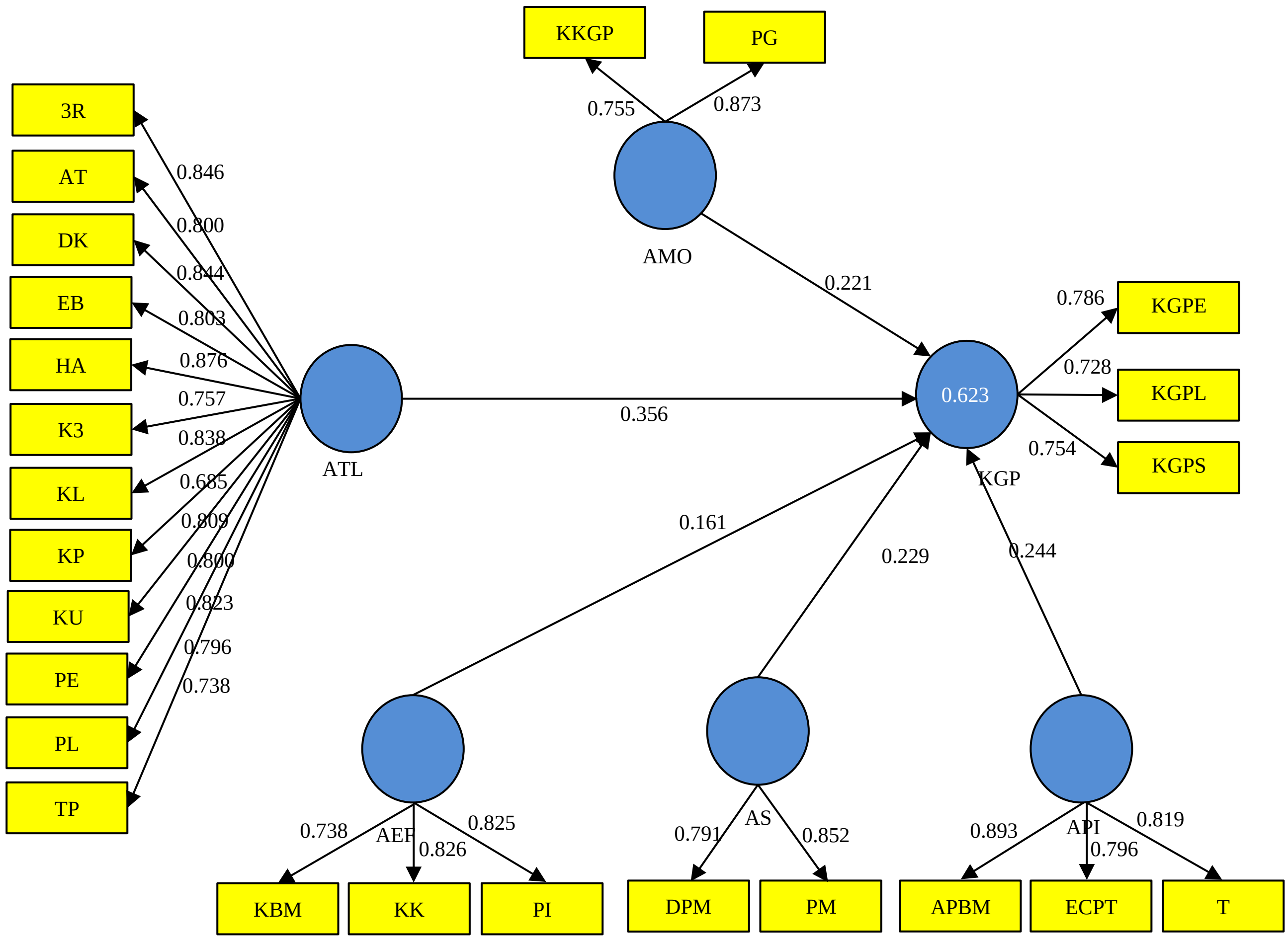

Fig. 1 Fitted model of green port criteria

3.3. Results of the Fitted Model Test

The calculation results reveal that the fitted model value equals the NFI value of 0.318. This indicates that the constructed model is considered good per the NFI value. The percentage of the model fit can be determined by NFI multiplied by 100%, resulting in NFI = 0.318 x 100% = 31.80% for the fitted model. This implies that the constructed green port performance model is 31.80% fit and can be effectively implemented at the Port of Makassar. Refer to Table 10 for detailed information.

A structural equation model was developed based on this research as follows:

$Y = 0{,}221X_1 + 0{,}356X_2 + 0{,}161X_3 + 0{,}229X_4 + 0{,}244X_5$

This research has developed a model for testing its effectiveness. Researchers employed the fitted model to assess the model (see Figure 1)

Table 10. Values of fitted model

	Saturated Model	Estimated Model
SRMR	0,182	0,182
d_ULS	11,634	11,634
d_G	5,010	5,010
Chi-Square	2679,611	2679,611
NFI	0,318	0,318

Concerning the management and operational aspect, a critical factor influencing the performance of a green port, three key considerations must be addressed: the preparation of environmental management programs and action plans, methods for addressing non-compliance with internal and external standards, and the development of an environmental management manual for ports [16].

The technical and environmental aspects are pivotal criteria for assessing the performance of green ports. This encompasses considerations such as water quality, air quality, waste management, energy management, noise control, production processes, eco-efficiency, health and safety, and environmental quality.

Moreover, the text covers essential technical and environmental aspects, including, but not limited to, energy usage, environmental fines, investment in the environmental sector, environmental training, wastewater treatment, solid waste management, recycling methods, potential threats and opportunities arising from global climate change, energy consumption by type, market loss resulting from neglecting environmental issues, and emission control [17].

The economic/financial aspect holds significance in the criteria for green port performance. In this context, industrial economy, local economy, community economy, marketing, and transportation are related criteria [16].

The social aspect is equally crucial in the criteria for green port performance. Criteria related to the quality of life for employees and the community are integral considerations [9]. Furthermore, it is imperative that the anticipated green port project significantly enhances understanding of the local community's circumstances within the operational area of the project. This understanding serves as a foundation for devising effective strategies and approaches to empower the community and ensure their active participation throughout the green port project in Makassar [18]. Regarding the social impact of the green port on the local community, the evaluation should incorporate statistical data to enhance the measurement of public and local community engagement and concerns about the project. Through the use of quantifiable indicators, the research aims to provide a more precise understanding of the various factors influencing community perceptions and preferences [19].

Most ports globally have integrated various computer-based applications for planning the operation of sea transport systems, yards, berths, container and equipment control, and administrative and financial management. Integrating all information and control subsystems creates a comprehensive operational environment in the port, transforming it into a hub for information flows from product manufacturers to end consumers. This inclusive approach covers all aspects and ensures access to essential information [20].

In the advancement of port operations, the necessity for digitalization and integration is evident, encouraging the adoption of innovative Information Technology (IT) and Information Systems (IS). This ensures a high degree of automation and rationalization of port procedures, particularly at container terminals [21]. The fundamental characteristic of automated process integration lies in the presence of integrative information technology that enhances the flow of pertinent information across all processes, facilitating effective and efficient process integration [22].

4. Conclusion

The research outcomes illustrate that the assessed criteria can construct an effective model, meet the criteria for a well-performing model, and can be utilized to establish green port performance criteria. An NFI value of 31.80% signifies the model's suitability for use. Additionally, the criteria influencing the model's development have been identified. All the criteria namely, management/operational aspects, technical/environmental aspects, economic/financial aspects, social aspects, and port information system aspects—have exhibited positive and significant impacts. These can be directly applied in formulating green port performance criteria in Makassar port, carefully considering the studied criteria, thereby facilitating the successful implementation of a green port in a sustainable maritime system.

References

[1] Stanisław Gucma, "Conditions of Safe Ship Operation in Seaports – Optimization of Port Waterway Parameters," *Polish Maritime Research*, vol. 26, no. 3, pp. 22-29, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[2] Hüseyin Bakır et al., "Forecasting of Future Greenhouse Gas Emission Trajectory for India Using Energy and Economic Indexes with Various Metaheuristic Algorithms," *Journal of Cleaner Production*, vol. 360, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[3] Julie Johnston, "Developing Climate Change Literacy to Combat Climate Change and its Impacts," *EGU General Assembly 2021*, pp. 19-30, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[4] Syedesmaeil Mousavi, "Performance of Non-Fired Green Brick Containing Rice Husk as Sustainable Building Material," *International Journal of Engineering*, vol. 29, no. 3, pp. 306-312, 2016. [Google Scholar] [Publisher Link]

[5] Nikolaos Sifakis, and Theocharis Tsoutsos, "Planning Zero-Emissions Ports through the Nearly Zero Energy Port Concept," *Journal of Cleaner Production*, vol. 286, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[6] Marko Sarstedt, and Jun-Hwa Cheah, "Partial Least Squares Structural Equation Modeling Using SmartPLS: A Software Review," *Journal of Marketing Analytics*, vol. 7, no. 3, pp. 196-202, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[7] Joseph F. Hair et al., *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*, 2nd ed., Los Angeles: Sage, pp. 1-384, 2022. [Google Scholar] [Publisher Link]

[8] Nurdin Ahmadi, Tridoyo Kusumastanto, and Edy Ihut Siahaan, "Environmentally Friendly Port Development Strategy (Greenport) Case Study: Cigading Port, Indonesia," *Transportation Research Newsletter*, vol. 28, no. 1, pp. 9-26, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[9] Somchint Pilouk, and Thammarat Koottatep, "Environmental Performance Indicators as the Key for Eco-Industrial Parks in Thailand," *Journal of Cleaner Production*, vol. 156, pp. 614-623, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[10] Min Ho Ha, Zaili Yang, and Man Wook Heo, "A New Hybrid Decision Making Framework for Prioritising Port Performance Improvement Strategies," *The Asian Journal of Shipping and Logistics*, vol. 33, no. 3, pp. 105-116, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[11] Rattaporn Teerawattana, and Yi-Chih Yang, "Environmental Performance Indicators for Green Port Policy Evaluation: Case Study of Laem Chabang Port," *The Asian Journal of Shipping and Logistics*, vol. 35, no. 1, pp. 63-69, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[12] Martí Puig et al., "Benchmark Dynamics in the Environmental Performance of Ports," *Marine Pollution Bulletin*, vol. 121, no. 1-2, pp. 111-119, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[13] John Brewer, Isadore Newman, and Carolyn R. Benz, "Qualitative-Quantitative Research Methodology: Exploring the Interactive Continuum," *Contemporary Sociology*, vol. 28, no. 2, pp. 245-246, 1999. [CrossRef] [Google Scholar] [Publisher Link]

[14] Felicitas Rost, "Q-Sort Methodology: Bridging the Divide between Qualitative and Quantitative. An Introduction to an Innovative Method for Psychotherapy Research," *Counselling and Psychotherapy Research*, vol. 21, no. 1, pp. 98-106, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[15] Yanyi K. Djamba, "Social Research Methods: Qualitative and Quantitative Approaches," *Teaching Sociology*, vol. 30, no. 3, 2002. [CrossRef] [Google Scholar] [Publisher Link]

[16] Hoang Phuong Nguyen, Phuoc Quy Phong Nguyen, and Thanh Phuong 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, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[17] Erica Caetano Roos, and Francisco José Kliemann Neto, "Tools for Evaluating Environmental Performance at Brazilian Public Ports: Analysis and Proposal," *Marine Pollution Bulletin*, vol. 115, no. 1-2, pp. 211-216, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[18] H.B. Sanggoro, S.W. Alisjahbana, and D. Mohamad, "Influence of Project and Affected Local Community Interests Level on Social Conflicts in Indonesian Infrastructure Projects," *International Journal of Engineering*, vol. 35, no. 7, pp. 1217-1226, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[19] H.B. Sanggoro, S.W. Alisjahbana, D. Mohamad, "Soft System Methodology: Project vs Local Community Interests in Project Social Conflict," *International Journal of Engineering*, vol. 34, no. 9, pp. 2107-2115, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[20] Athanassios Ballis, and Antony Stathopoulos, "A Paradigm of Information and Operational Control in Port Management Systems," *IFAC Proceedings Volumes*, vol. 30, no. 8, pp. 829-833, 1997. [CrossRef] [Google Scholar] [Publisher Link]

[21] Leonard Heilig, Silvia Schwarze, and Stefan Voss, "An Analysis of Digital Transformation in the History and Future of Modern Ports," *Proceedings of the 50th Hawaii International Conference on System Sciences*, Hilton Waikoloa Village, Hawaii, pp. 1341-1350, 2017. [Google Scholar] [Publisher Link]

[22] Dong-Wook Song, and Photis M. Panayides, "Global Supply Chain and Port/Terminal: Integration and Competitiveness," *Maritime Policy and Management*, vol. 35, no. 1, pp. 73-87, 2008. [CrossRef] [Google Scholar] [Publisher Link]