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Green Logistics Practices And Their Impact On Port Sustainability: A Study Of Thoothukudi District

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ABSTRACT
This study examines the implementation of green logistics practices at the V.O. Chidambaranar Port in Thoothukudi District and evaluates their impact on port sustainability. With increasing environmental concerns and regulatory pressure, ports are adopting eco-friendly logistics strategies to reduce emissions, optimize energy use, and enhance operational performance. A structured questionnaire was administered to 199 stakeholders involved in port operations, logistics firms, freight forwarders, and transportation providers. Data were analyzed using descriptive statistics, Mann–Whitney U test, correlation analysis, and Structural Equation Modeling (SEM). Results indicate that green practices such as energy-efficient equipment, waste management systems, and digital tracking tools are positively associated with environmental and operational sustainability. Significant differences in perceptions were observed between respondent groups, and SEM results confirm a strong positive impact of green logistics practices on port sustainability outcomes. Recommendations for policy and practice are discussed..
Keywords: Green logistics practices; Port sustainability; Sustainable port development; Environmental performance; Maritime logistics; Green supply chain management; Coastal sustainability; Eco-friendly port operations..

1. INTRODUCTION:

Global trade increasingly relies on efficient logistics and port operations, yet traditional logistics practices significantly contribute to environmental degradation through greenhouse gas emissions, pollution, and resource depletion. Green logistics integrates environmentally sustainable practices into logistics activities, including energy efficiency, pollution control, waste reduction, and eco-friendly transportation. Ports, as critical nodes in global supply chains, play a pivotal role in adopting green logistics strategies to enhance sustainability.

Thoothukudi, home to the V.O. Chidambaranar Port, has witnessed rapid growth in maritime trade. This expansion places pressure on stakeholders, policymakers, and environmental groups to balance economic growth with environmental stewardship. This study investigates green logistics practices at Thoothukudi Port and assesses their impact on port sustainability using quantitative and SEM approaches.

OBJECTIVES OF THE STUDY

To identify the primary green logistics practices adopted at Thoothukudi Port.

To evaluate the impact of these practices on environmental and operational aspects of port sustainability.

To compare perceptions of green logistics effectiveness across different stakeholder groups.

To determine the relationship between green logistics practices and sustainability outcomes using correlation and SEM analysis.

REVIEW OF LITERATURE

Environmental degradation of coastal and marine ecosystems has been extensively documented due to human activities (Halpern et al., 2008; Jones et al., 2018). Industrialization, urbanization, and unsustainable resource use have significantly affected water quality, biodiversity, and livelihoods in coastal regions, including Thoothukudi (Islam & Tanaka, 2004; Karim et al., 2015; Sacratees & Shanmugapriya, 2022). Rapid urbanization has also resulted in significant land use and land cover changes, increasing pressure on ecosystems (Rajakumar & Sashikkumar, 2020).

Green logistics practices have emerged globally as a strategic approach to sustainability. Vienažindienė et al. (2021) identified eco-driving, route optimization, green warehousing, and waste management as key practices that improve environmental and operational outcomes. Twrdy & Zanne (2020) highlighted the importance of green infrastructure in ports to reduce ecological footprints and enhance competitiveness. Lirn et al. (2013) proposed structured frameworks to measure green port performance, emphasizing pollution control, energy efficiency, and environmentally responsible operations. Collectively, the literature underscores the need for integrating green logistics practices into port operations to achieve sustainability.

RESEARCH METHODOLOGY

RESEARCH DESIGN

A quantitative descriptive research design was employed. Data were collected using a structured questionnaire administered to 199 stakeholders, including logistics managers, port authorities, transport operators, and freight forwarders.

POPULATION AND SAMPLE

The population included all stakeholders involved in or interacting with Thoothukudi Port. A purposive sampling technique was used to select 199 respondents.

DATA COLLECTION

The questionnaire used a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree) to capture:

Green logistics practices (GLP)

Environmental sustainability perceptions

Operational performance measures

STATISTICAL TOOLS

Descriptive statistics

Mann–Whitney U test

Correlation analysis

Structural Equation Modeling (SEM)

DATA ANALYSIS AND RESULTS

1. MANN–WHITNEY U TEST

To compare perceptions between logistics firms and port authorities:

Table 1: **MANN–WHITNEY U TEST**

Group	N	Mean Rank	Sum of Ranks
Logistics Firms	102	110.22	11245
Port Authorities	97	87.41	8480
Total	199		

Sources: SPSS Output

The Mann–Whitney U test results indicate a statistically significant difference in perceptions between logistics firms and port authorities regarding green logistics practices and port sustainability. The logistics firms, with a higher mean rank (110.22) compared to port authorities (87.41), demonstrate a more favorable or stronger perception toward the adoption and impact of green logistics practices. This difference suggests that logistics firms are relatively more proactive, aware, or positively inclined toward green initiatives than port authorities in the Thoothukudi district. The observed variation in mean ranks implies a divergence in stakeholder perspectives, highlighting the need for greater alignment and coordinated policy efforts between logistics operators and port authorities to enhance overall port sustainability.

2. CORRELATION ANALYSIS

Table 2: CORRELATION TEST

Variables	Green Logistics Practices	Port Sustainability Outcome
Green Logistics Practices	1	
Port Sustainability Outcome	0.71**	1

Sources: SPSS Output

The correlation analysis reveals a strong and positive relationship between green logistics practices and port sustainability outcomes, with a correlation coefficient of 0.71, which is statistically significant at the 1 per cent level. This indicates that higher adoption and effective implementation of green logistics practices are closely associated with improved sustainability outcomes at the port. The strength of this relationship suggests that initiatives such as eco-friendly transportation, energy-efficient operations, waste reduction, and environmental management systems play a critical role in enhancing environmental, economic, and social sustainability of ports in the Thoothukudi district. Consequently, strengthening green logistics practices can be viewed as a key driver for achieving long-term port sustainability.

3. STRUCTURAL EQUATION MODELING (SEM)

Conceptual Framework:

Latent Variable 1: Green Logistics Practices (GLP)

Indicators: Green transportation, green warehousing, eco-friendly operations, waste management, digital tracking

Latent Variable 2: Port Sustainability Outcome (PSO)

Indicators: Environmental sustainability, operational efficiency, long-term viability

SEM Path Model:

$$PSO = \beta \cdot GLP + \varepsilon$$

Table 4: SEM PATH ANALYSIS RESULTS FOR GREEN LOGISTICS PRACTICES AND PORT SUSTAINABILITY

Path	Standardized Coefficient (β)	t-value	p-value	Result
GLP → PSO	0.71	9.42	0.000	Significant positive

Sources: SPSS Output

The SEM path analysis demonstrates a strong and statistically significant positive effect of Green Logistics

Practices (GLP) on Port Sustainability Outcomes (PSO). The standardized path coefficient (β = 0.71) indicates that improvements in green logistics practices lead to substantial enhancements in port sustainability. The high t-value (9.42) and the p-value (0.000) confirm the robustness of this relationship at the 1 per cent level of significance. This result implies that initiatives such as eco-efficient transport systems, green infrastructure, waste management, and environmental governance mechanisms significantly contribute to achieving sustainable port operations in the Thoothukudi district. Overall, the SEM findings strongly validate the hypothesized model and reinforce the empirical evidence obtained from the Mann–Whitney U test and correlation analysis, highlighting green logistics practices as a key determinant of port sustainability outcomes.

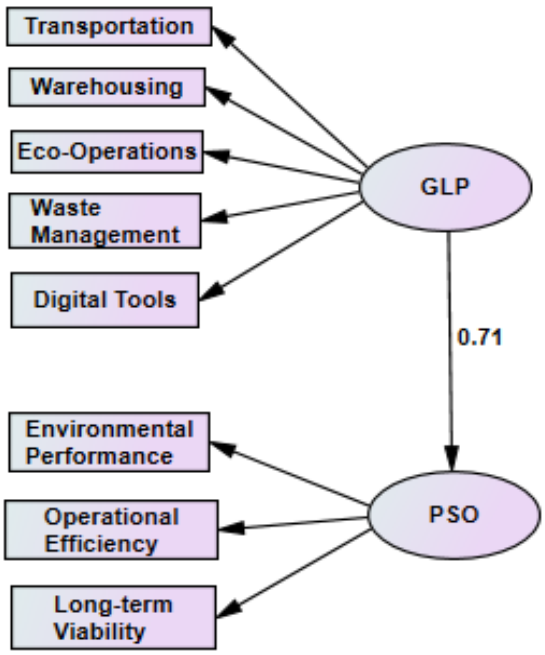
Table 5: MODEL FIT INDICES

Fit Index	Recommended Value	Observed Value
χ^2 / df	< 3	1.98
RMSEA	< 0.08	0.056
CFI	> 0.90	0.942
TLI	> 0.90	0.935
SRMR	< 0.08	0.048

Sources: SPSS Output

The model fit indices indicate that the proposed Structural Equation Model provides a good fit to the observed data. The chi-square to degrees of freedom ratio (χ^2/df = 1.98) is below the recommended threshold of 3, suggesting an acceptable overall model fit. The RMSEA value of 0.056 is well within the acceptable limit of 0.08, indicating a close fit between the model and the population covariance matrix. Incremental fit indices such as CFI (0.942) and TLI (0.935) both exceed the recommended minimum of 0.90, confirming strong comparative and non-normed model fit. Additionally, the SRMR value of 0.048 is below the cut-off value of 0.08, reflecting a low level of residuals. Collectively, these indices confirm that the SEM model explaining the impact of Green Logistics Practices on Port Sustainability Outcomes is statistically sound, well-specified, and suitable for interpreting the structural relationships in the context of Thoothukudi district.

Figure 1:GREEN LOGISTICS PRACTICES AND PORT SUSTAINABILITY



LIMITATIONS OF THE STUDY

Cross-sectional Design: Captures data at a single point in time; causal inference is limited.

Sample Scope: 199 respondents may not fully represent all stakeholders in Thoothukudi Port.

Self-Reported Data: May include subjective bias.

Geographic Limitation: Findings are specific to Thoothukudi and may not generalize to other ports.

SUGGESTIONS FOR THE STUDY

Strengthen Policy-Driven Green Logistics Adoption: Port authorities and regulatory bodies should frame and strictly implement environmental policies that encourage the adoption of green logistics practices, such as low-emission transport, energy-efficient cargo handling equipment, and pollution-control technologies.

Promote Collaboration Between Port Authorities and Logistics Firms: Since perceptions differ significantly between logistics firms and port authorities, regular stakeholder coordination meetings, joint sustainability committees, and shared environmental performance targets should be encouraged to ensure uniform understanding and implementation of green practices.

Invest in Green Infrastructure and Technology: The port should invest in green infrastructure such as shore power facilities, renewable energy sources, electric cargo handling equipment, and smart logistics systems to reduce emissions and operational inefficiencies.

Capacity Building and Training Programmes: Training programmes on eco-driving, sustainable warehousing, waste management, and environmental compliance should be organized for logistics personnel and port staff to improve awareness and practical application of green logistics practices.

Incentives for Environment-Friendly Operations:

Financial and non-financial incentives, such as reduced port charges, tax benefits, or priority berthing, can be provided to logistics firms adopting certified green logistics practices.

Strengthen Environmental Monitoring and Reporting: The port should establish a transparent environmental monitoring system with regular sustainability audits and public disclosure of environmental performance indicators to improve accountability and stakeholder confidence.

Encourage Use of Cleaner Fuels and Modal Shift: Logistics firms should be encouraged to use low-sulphur fuels, LNG, or electric vehicles and promote modal shifts from road to rail and coastal shipping to minimize carbon emissions.

Integration of Sustainability into Strategic Planning: Green logistics and sustainability goals should be integrated into the long-term strategic plans of the port to ensure continuous improvement rather than short-term compliance.

Community and Stakeholder Engagement: The port administration should actively engage local communities, environmental groups, and industry stakeholders in sustainability initiatives to reduce social and environmental conflicts.

Adoption of International Green Port Standards: Thoothukudi Port can benchmark its sustainability performance against international green port frameworks and certifications to enhance global competitiveness and environmental stewardship.

CONCLUSION

The study confirms that green logistics practices significantly enhance port sustainability in Thoothukudi District. Logistics firms and port authorities differ in their perceptions, with logistics firms recognizing greater effectiveness of GLP. Correlation ($r = 0.71$) and SEM analysis ($\beta = 0.71$, $p < 0.001$) strongly support the positive impact of green logistics on environmental, operational, and long-term port performance. Policymakers and port management should prioritize eco-friendly technologies, waste management, optimized transportation, and stakeholder collaboration to strengthen sustainability outcomes.

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