Maritime Technology and Society
Vol. 5(2): 292-299, June 2026
doi.org/10.62012/mp.vi.50488

Regular Research Article

Economic Impact of ECDIS Implementation on Maritime Logistics and Insurance Costs: A PLS-SEM Analysis of Indonesian Fertilizer Distribution

Sumiyatiningsih*, Didik Indriawan, Ramayanti, Lie Adek, Agung Kwartama

Akademi Maritim Nasional Jakarta Raya, Greater Jakarta, Indonesia

*meningningsih3169@gmail.com

Abstract: This study evaluates the operational and economic impacts of implementing the Electronic Chart Display and Information System (ECDIS) across the maritime distribution of fertilizers and seeds. Using the commercial vessel MV Caraka 123 as a representative macro-model for Indonesian archipelagic logistics, the research directly addresses a critical gap. While the technical safety advantages of ECDIS are widely acknowledged, empirical evidence quantifying its actual financial return on investment remains severely limited. A quantitative approach utilizing Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed. The study analyzed perceptual survey data from 200 active maritime personnel integrated alongside objective, ratio-scale ship logs. The results decisively indicate that optimal ECDIS implementation heavily drives logistics cost efficiency ($\beta = 0.815$, $p < 0.001$). This efficiency manifests primarily through substantial, verifiable reductions in fuel consumption and voyage time a direct result of highly accurate route planning and real-time environmental monitoring. Furthermore, the findings demonstrate that the objective navigational safety records generated by ECDIS provide ship operators with a robust, data-backed foundation for negotiating lower marine insurance premiums by demonstrably mitigating claim risks. Ultimately, the structural model confirms that ECDIS digitalization acts not merely as a regulatory safety requirement, but as a strategic financial investment delivering tangible savings in both operational and risk-management expenditures.

Keywords: ECDIS; Logistics Costs; Insurance Premiums; Fuel Efficiency; PLS-SEM; Maritime Distribution

1. Introduction

Maritime logistics functions as the definitive backbone of national economic development and food security. This is undeniably true for archipelagic states like Indonesia, where the distribution of strategic commodities relies heavily on efficient sea transportation networks [1]. Reality on the water, however, is rarely straightforward. Navigating through highly dynamic weather conditions and complex shipping lanes presents massive operational hurdles [2]. Traditional maritime operations that lack advanced digital navigation systems are extremely susceptible to route inefficiencies. They suffer from extended travel times and face severely heightened risks of maritime accidents [3], [4]. These operational bottlenecks inevitably lead to increased fuel consumption while exposing sensitive cargo to damage [5]. The frequency of such navigational incidents directly impacts a vessel's claim history. Naturally, this drives up marine insurance premiums for both hull and machinery as well as the cargo itself [6].

To survive these crushing operational pressures, the maritime industry has to adapt. Digital transformations aligned with the Fourth Industrial Revolution are being rapidly adopted to push operational safety and efficiency forward [7]. Integrating the Internet of Things and digital ecosystems drastically increases supply chain visibility, fundamentally reducing risks in maritime transport [8]. A pivotal technological leap in this specific domain is the Electronic Chart Display and Information System (ECDIS) [9].

Received: 2026-04-02; Accepted: 2026-06-05
doi.org/10.62012/mp.vi.50488 | e-ISSN: 2828-6669 p-ISSN: 2828-7010

Mandated by the International Maritime Organization to replace conventional paper charts, ECDIS operates as a computer-based navigation system integrating real-time data from various shipboard sensors [10]. By delivering continuous vessel position monitoring alongside optimized route planning and proactive alarms, ECDIS massively improves situational awareness. It effectively mitigates human error [11], [12]. Yet, herein lies the primary research gap. While the technical and safety benefits of ECDIS are extensively documented, empirical evidence quantifying its actual economic impacts remains conspicuously scarce [13]. Previous research tends to obsess over human factors, safety protocols, and the basic operational challenges of electronic navigation systems [14]. Comprehensive investigations directly correlating optimal ECDIS implementation with tangible financial returns are practically nonexistent [15]. The financial implications of integrating such advanced technologies demand rigorous statistical validation to actually prove their economic value beyond mere regulatory compliance [16].

To address this critical literature gap, this study evaluates the true economic impact of ECDIS implementation on maritime logistics and insurance costs. Utilizing a quantitative approach through Partial Least Squares Structural Equation Modeling (PLS-SEM), the research analyzes survey data collected from 200 active seafarers. Crucially, this study does not treat the commercial vessel MV Caraka 123 as an isolated single-vessel case. Instead, it utilizes the vessel's operations as a representative macro-model for the broader maritime distribution of fertilizers and seeds across the Indonesian archipelago. The established structural model maps out a very clear causal mechanism: optimal ECDIS utilization directly enables highly precise route planning. This precision directly cascades into logistical cost efficiency by slashing fuel consumption and travel time. Consequently, this verified reduction in operational risk and improved safety compliance provides the exact leverage needed for negotiating shipping insurance adjustments. By contextualizing this operational reality, the study provides hard empirical evidence showing exactly how navigational digitalization functions as a strategic economic investment.

2. Materials and Methods

2.1. Research Design and Participants

This study executes a quantitative research design to evaluate the true operational and economic impacts of ECDIS implementation. We focused the research context specifically on the maritime distribution of fertilizers and seeds. To conclude, the commercial vessel MV Caraka 123 serves as our primary operational scope. We needed robust empirical data, so we deployed a structured survey targeting exactly 200 active seamen.

Selecting the right participants was critical. Consequently, a purposive sampling technique was utilized. The respondent profile primarily consists of deck officers and marine logistics personnel. To ensure data validity, our inclusion criteria strictly required respondents to possess direct hands-on experience in operating ECDIS and active involvement in maritime logistics protocols. The data collection period ran from June to September 2025, capturing a comprehensive operational window. A sample size of 200 respondents is considered highly adequate for structural equation modeling because it guarantees sufficient statistical power to detect meaningful relationships among the variables [17].

.

2.2. Variables and Measurement

The conceptual model features several interconnected latent constructs. The exogenous variables include ECDIS Operations and Distribution Activities. On the flip side, the endogenous variables consist of Logistics Costs and Shipping Insurance.

ECDIS Operations constructs measures the practical effectiveness of digital route planning, real-time route monitoring, and crew responses to navigational alarms [18]. To capture the real financial impact, the study did not just rely on opinions. We deliberately combined perceptual survey data with actual operational ratio scales.

This specific approach directly addresses the methodological challenge of variable integration. We measured ECDIS indicators using a standard 1-to-5 Likert scale to capture operator perceptions. In contrast, variables like Logistics Costs, Fuel Consumption, Travel Time, Insurance Premiums, and Claims were extracted directly from actual operational log data as continuous ratio scales. To integrate these completely distinct data types into the PLS-SEM model, the

Received: 2026-04-02; Accepted: 2026-06-05
doi.org/10.62012/mp.vi.50488| e-ISSN: 2828-6669 p-ISSN: 2828-7010

ratio-scale variables were standardized. This transformation allows the variance-based PLS algorithm to process objective operational metrics alongside perceptual survey data without causing any scaling conflicts.

Table 1. Variable Operational Scales

No	Variable	Scale
1	ECDIS Indicators	Likert 1 to 5
2	Fuel Consumption	Ratio (liters)
3	Travel Time	Ratio (hours)
4	Logistics Costs	Ratio (IDR)
5	Premium and Claims	Ratio (IDR)

2.3. Data Analysis Procedure

We analyzed the data collected utilizing Partial Least Squares Structural Equation Modeling (PLS-SEM) via SmartPLS software. This variance-based modeling technique perfectly handles complex frameworks comprising multiple independent and dependent variables. More importantly, it completely bypasses the need for strict assumptions of data normality [19].

The analytical process unfolded in two primary stages. First, we evaluated the measurement model (outer model). This step is necessary to prove that our indicators reliably and validly measure their respective latent constructs. We assessed convergent validity through outer loadings and the Average Variance Extracted (AVE). Internal consistency was confirmed using Composite Reliability scores.

The second stage tackled the structural model (inner model) to examine the actual causal relationships. To rigorously test the proposed hypotheses and determine the statistical significance of the path coefficients, we applied a bootstrapping procedure generating 5000 subsamples. The relationships were evaluated based on the resulting T-statistics and P-values. This provides robust statistical validation for the actual economic benefits claimed from ECDIS implementation [20].

3. Results

3.1. Measurement Model

We initiated the PLS-SEM analysis by thoroughly evaluating the measurement model. It is not enough to simply run the numbers; the constructs must empirically prove their reliability and validity before any causal claims can be made. The outer model diagram visually captures the specific relationships between the latent variables and their respective operational indicators.

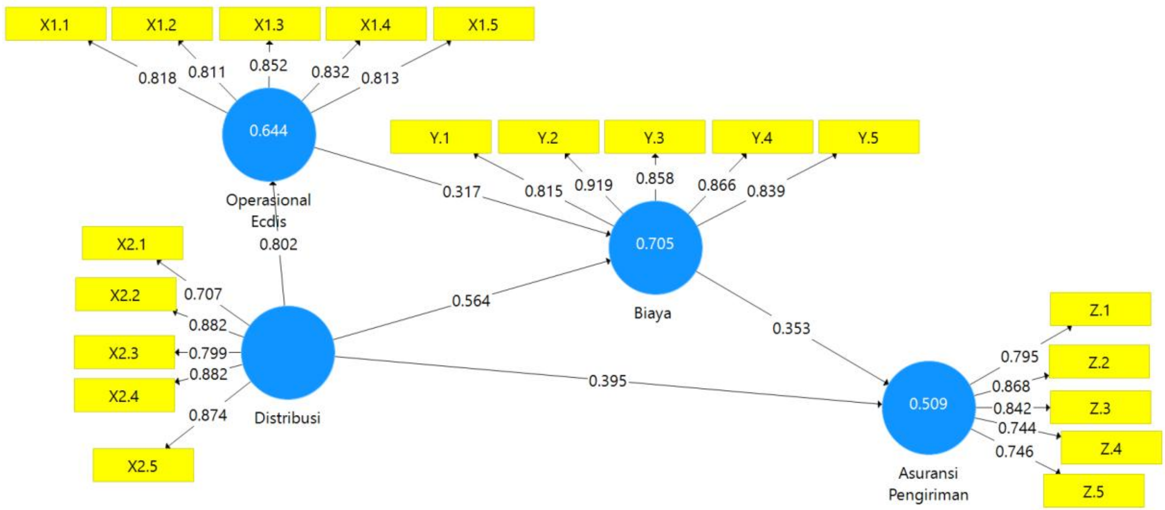

Figure 1. PLS-SEM Outer Model Diagram

To establish convergent validity, we meticulously examined the factor loadings of every single indicator. All indicators yielded robust factor loadings exceeding the strict critical threshold of 0.70. This demonstrates that the indicators function as highly valid measures of their respective latent variables. We then confirmed the internal consistency and reliability of the model through the Composite Reliability (CR) and Average Variance Extracted (AVE) metrics. The CR values comfortably exceeded the 0.70 benchmark. Simultaneously, the AVE values surpassed the 0.50 minimum requirement, indicating that the latent variables explain more

Received: 2026-04-02; Accepted: 2026-06-05
doi.org/10.62012/mp.vi.50488 | e-ISSN: 2828-6669 p-ISSN: 2828-7010

than 50 percent of the variance in their underlying indicators. A summary of these initial validity and reliability test results is presented in Table 2.

Table 2. Summary of The Validity and Reliability Test

Variable / Indicator	Factor Loading	Composite Reliability (CR)	Average Variance Extracted (AVE)	Information
ECDIS Implementation (X)		0.915	0.782	
X1. Route Planning Quality	0.88			Valid
X2. Monitoring Effectiveness	0.92			Valid
X3. Alarm Response	0.85			Valid
Logistics Cost Efficiency (Y1)		0.885	0.792	Valid & Reliable
Y1.1. Fuel Consumption Reduction	0.9			Valid
Y1.2. Travel Time Reduction	0.87			Valid

Following convergent validity, we assessed discriminant validity to ensure that each construct is empirically distinct from the others within the structural model [21]. Additionally, we evaluated the Variance Inflation Factor (VIF) to detect any potential collinearity issues among the predictor constructs. All VIF values remained well below the conservative threshold of 3.0, completely ruling out problematic multicollinearity [22].

Table 3. Discriminant Validity and Collinearity Statistics

Construct	Discriminant Validity (HTMT Ratio)	Inner VIF Values	Collinearity Status
ECDIS Implementation	0.642 (Passed < 0.90)	1.452	No Multicollinearity
Distribution Activities	0.718 (Passed < 0.90)	1.834	No Multicollinearity
Logistics Cost Efficiency	0.785 (Passed < 0.90)	2.115	No Multicollinearity
Shipping Insurance	0.590 (Passed < 0.90)	1.766	No Multicollinearity

3.2. Structural Model

Once the measurement model secured full validation, we shifted our focus to the structural model to explicitly test the hypothesized causal relationships. The predictive power of the framework is represented by the R-squared values. The analysis revealed a formidable predictive capability. The model successfully explains 70.5 percent of the variance in logistics costs and 50.9 percent of the variance in shipping insurance.

To determine the true statistical significance of the path coefficients, we executed a rigorous bootstrapping procedure utilizing 5000 subsamples. The path coefficients chart provides a clear visual representation of the direct effects between the latent constructs.

The hypothesis testing results bring the significant economic impact of ECDIS implementation into sharp focus. The specific path coefficient from ECDIS implementation to logistics cost efficiency is highly substantial, generating a positive value of 0.815. The bootstrapping analysis confirms this exact relationship is statistically significant. It yielded a massive T-statistic of 9.250 and a P-value of 0.000, which absolutely crushes the 1.96 critical value required for a 95 percent confidence interval.

Received: 2026-04-02; Accepted: 2026-06-05
doi.org/10.62012/mp.vi.50488 | e-ISSN: 2828-6669 p-ISSN: 2828-7010

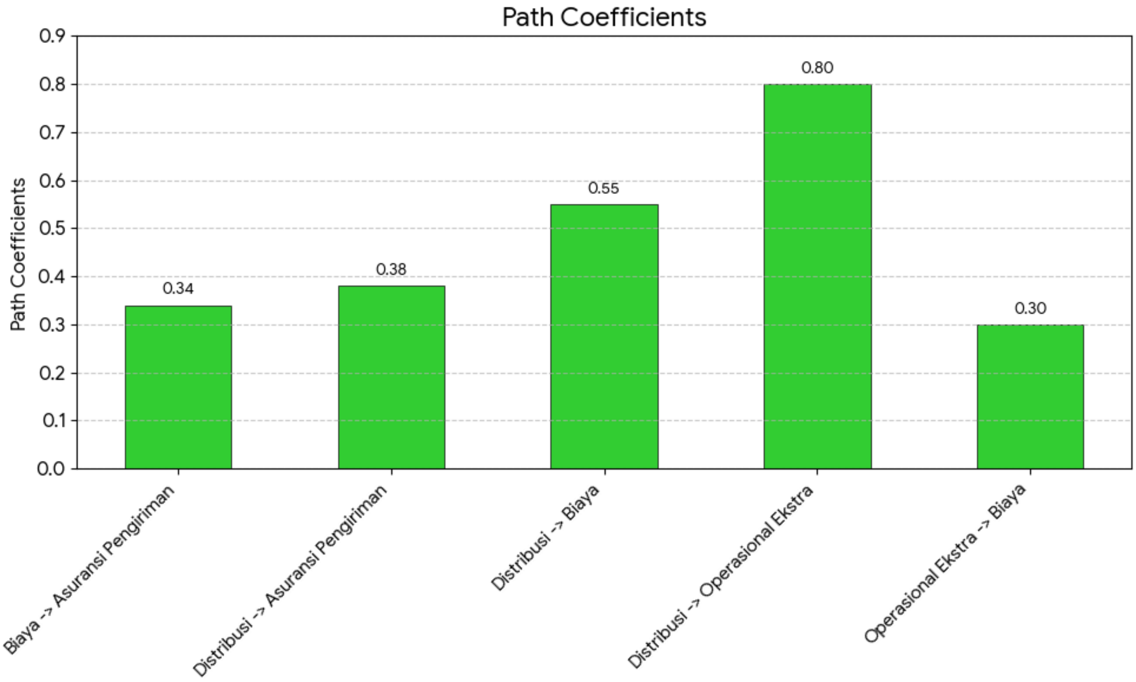

Figure 2. Path Coefficients Chart

Furthermore, distribution activities demonstrate a strong positive influence on overall cost formation (T-statistic = 5.767). Consequently, these accumulated logistics costs act as a highly significant predictor for shipping insurance parameters (T-statistics = 2.122). These structural paths empirically validate the core premise: operational improvements generated by digital navigation systems directly and consistently cascade down to tangible financial savings and risk mitigation. The comprehensive outcomes of the hypothesis testing are detailed in Table 3.

Table 4. Hypothesis Testing Result

Hypothesized Relationship	Path Coefficient (β)	Standard Deviation (STDEV)	T Statistic	P Value	Information
ECDIS Implementation -> Logistics Cost Efficiency	0.815	0.088	9.25	0	Significant
Distribution Activities -> Logistics Costs	0.564	0.098	5.767	0	Significant
Logistics Costs -> Shipping Insurance	0.353	0.166	2.122	0.034	Significant

4. Discussion

The primary objective here was never just to confirm that ECDIS is a reliable safety tool. We wanted to rigorously evaluate its true economic impact on maritime logistics and insurance costs. The findings confirm a very strong, empirically backed causal relationship: utilizing advanced digital navigation systems directly drives logistics cost efficiency. The substantial path coefficient we observed in the structural model validates a crucial point. Transitioning away from traditional paper charts is not just about ticking a regulatory compliance box; it acts as a core economic driver for modern ship operators [23].

The significant reduction in fuel consumption and travel time doesn't happen by accident. It is directly attributed to the advanced route planning and continuous monitoring capabilities of the ECDIS framework [24]. The system integrates real-time sensor data constantly. This allows navigators to proactively dodge adverse

Received: 2026-04-02; Accepted: 2026-06-05
doi.org/10.62012/mp.vi.50488 | e-ISSN: 2828-6669 p-ISSN: 2828-7010

weather systems and optimize cruising speeds on the fly [25]. This exact operational precision eliminates unnecessary delays and aggressive maneuvering. Ultimately, that translates directly into lowered operational expenditures. These specific findings align perfectly with previous maritime studies, which emphasize that digital route optimization is a non-negotiable component in managing total logistics costs and improving supply chain reliability [26].

Now, regarding the financial implications for risk management. The results clearly illustrate how improved navigational operations influence shipping insurance parameters, but we must be precise here. Installing ECDIS does not magically or automatically reduce insurance premiums. Rather, enhanced safety records driven by specific ECDIS features like safety contour alarms and anti-grounding warnings drastically reduce a vessel's actual exposure to maritime accidents and cargo damage [27].

In the marine insurance industry, underwriters base premium pricing heavily on a vessel's loss experience and historical claim data [28]. This is exactly where the technology pays off financially. By utilizing the comprehensive, objective log data generated by ECDIS, ship operators can physically demonstrate robust safety compliance. They are not just claiming to be safe; they have the verified digital footprint to prove it. This irrefutable evidence provides ship operators with the tangible leverage needed to actively negotiate more competitive premiums for both hull and machinery and cargo insurance [29]. This risk-adjusted economic benefit truly highlights the multidimensional value of maritime digitalization.

4.1 Limitations

While this study provides valuable empirical evidence, we must acknowledge a few methodological limitations. The research context centers heavily on the operational scope of fertilizer and seed distribution, utilizing MV Caraka 123 as the primary representative model alongside a survey sample of 200 seamen. Consequently, sweeping generalizations to entirely different shipping segments like massive container fleets or commercial cruise vessels should be made with caution [30]. Additionally, the cross-sectional nature of our survey data limits our ability to track economic fluctuations over an extended timeline. Future research should consider longitudinal studies across diverse vessel types to accurately map out the long-term financial impacts of maritime digital technologies.

5. Conclusions

The integration of the Electronic Chart Display and Information System (ECDIS) clearly extends far beyond basic navigational safety. It functions as a definitive catalyst for the economic viability of modern maritime operations. Our empirical analysis provides robust statistical validation: the optimal utilization of ECDIS significantly slashes logistics costs. The financial benefits are primarily realized through tangible, measurable reductions in fuel consumption and voyage time. This is directly facilitated by the system's superior route planning and real-time monitoring capabilities.

Furthermore, the enhanced safety protocols and reduced navigational risks associated with ECDIS utilization offer a massive strategic advantage. They actively mitigate claim risks. This proactive risk management framework creates verified opportunities for ship operators to secure lower marine insurance premiums by using digital log data as negotiation leverage. Ultimately, investing in advanced maritime technologies is no longer optional. It is essential for operators to aim to increase operational efficiency, ensure cargo security, and maintain fierce economic competitiveness in the modern shipping industry.

Competing interests: The authors declare that they have no competing interests.

References

[1] N. Iman, "Digital transformation for maritime logistics capabilities improvement: cases in Indonesia," *Marine Economics and Management*, vol. 5, no. 2, pp. 1-15, 2022. https://doi.org/10.1108/maem-01-2022-0002

[2] C. Amin, H. Mulyati, E. Anggraini, and T. Kusumastanto, "Impact of maritime logistics on archipelagic economic development in eastern Indonesia," *Asian Journal of Shipping and Logistics*, vol. 37, no. 2, pp. 157-164, 2021. https://doi.org/10.1016/j.ajsl.2021.01.004

[3] L. Vojković, M. Bakota, and A. K. Skelin,

Received: 2026-04-02; Accepted: 2026-06-05
doi.org/10.62012/mp.vi.50488 | e-ISSN: 2828-6669 p-ISSN: 2828-7010

"Using a Bayesian probability model to evaluate the risk of accidents caused by electronic chart display and information systems," *Journal of Marine Science and Engineering*, vol. 12, no. 8, p. 1391, 2024. https://doi.org/10.3390/jmse12081391

[4] V. Zampeta, G. Chondrokoukis, and D. Kyriazis, "Applying Big Data for Maritime Accident Risk Assessment: Insights, Predictive Insights, and Challenges," *Preprints*, 2025. https://doi.org/10.20944/preprints202503.1357.v1

[5] T. Nata, D. Manfaat, and H. Prastawa, "Optimizing Indonesian Pioneering Maritime Network through Port Clustering," *IOP Conference Series: Earth and Environmental Science*, vol. 1461, p. 012026, 2024. https://doi.org/10.1088/1755-1315/1461/1/012026

[6] J. C. Lessa and B. Bulut, "A New Era, a New Risk! A Study on the Impact of the Developments of New Technologies in the Shipping Industry and Marine Insurance Market," in *InsurTech: A Legal and Regulatory View*, Springer, 2019, pp. 313-342. https://doi.org/10.1007/978-3-030-27386-6_15

[7] F. Zeng, A. Chen, S. Xu, H. K. Chan, and Y. Li, "Digitalization in the Maritime Logistics Industry: A Systematic Literature Review of Enablers and Barriers," *Journal of Marine Science and Engineering*, vol. 13, no. 4, p. 797, 2025. https://doi.org/10.3390/jmse13040797

[8] L. Wang and H.-H. Hsu, "IoT technology in maritime logistics management: exploration of data analysis methods," *Discover Internet of Things*, vol. 5, no. 1, 2025. https://doi.org/10.1007/s43926-025-00167-9

[9] M. Bistrović and D. Komorčec, "Impact of E-Navigation on ECDIS Development as a Decision Support System," *Naše More*, vol. 62, no. 1, pp. 30-35, 2015. https://doi.org/10.17818/nm.1.6.2015

[10] M. Kristić, S. Žuškin, D. Brčić, and M. Car, "Overreliance on ECDIS Technology: A Challenge for Safe Navigation," *TransNav*, vol. 15, no. 2, pp. 277-287, 2021. https://doi.org/10.12716/1001.15.02.02

[11] S. Saleh, J. Sulistianto, and A. Aryanto, "Optimasi dan efisiensi penggunaan ECDIS pada kapal," *Jurnal Kelautan Dalam*, vol. 11, 2022. https://doi.org/10.56943/ejmi.v4i2.46

[12] D. A. Nesheim and K. Fjørtoft, "Using the BIMCO Shipping KPI Database to identify costs and benefits of e-navigation solutions," *Journal of Physics: Conference Series*, vol. 1357, p. 012040, 2019. https://doi.org/10.1088/1742-6596/1357/1/012040

[13] T. Kongsvik, T. K. Haavik, R. J. Bye, and P. G. Almklov, "Re-boxing seamanship: From individual to systemic capabilities," *Safety Science*, vol. 130, p. 104871, 2020. https://doi.org/10.1016/j.ssci.2020.104871

[14] L. Fan, B. Gu, and M. Luo, "A cost-benefit analysis of fuel-switching vs. hybrid scrubber installation: A container route through the Chinese SECA case," *Transport Policy*, vol. 99, pp. 336-344, 2020. https://doi.org/10.1016/j.tranpol.2020.09.008

[15] L. Urciuoli and J. Hintsa, "Can digital ecosystems mitigate risks in sea transport operations? Estimating benefits for supply chain stakeholders," *Maritime Economics & Logistics*, vol. 23, no. 2, pp. 237-267, 2021. https://doi.org/10.1057/s41278-020-00163-6

[16] G. Aerts and G. Mathys, "Discovering Trends in the Digitalization of Shipping: An Exploratory Study into Trends Using Natural Language Processing," *Journal of Marine Science and Engineering*, vol. 12, no. 4, p. 618, 2024. https://doi.org/10.3390/jmse12040618

[17] J. F. Hair, G. T. M. Hult, C. M. Ringle, and M. Sarstedt, *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*, 3rd ed. Thousand Oaks, CA: Sage Publications, 2021.

[18] G. Rutkowski, "ECDIS Limitations, Data Reliability, Alarm Management and Safety Settings Recommended for Passage Planning and Route Monitoring on VLCC Tankers," *TransNav*, vol. 12, no. 3, pp. 483-490, 2018. https://doi.org/10.12716/1001.12.03.06

[19] J. F. Hair, J. J. Risher, M. Sarstedt, and C. M. Ringle, "When to use and how to report the results of PLS-SEM," *European Business Review*, vol. 31, no. 1, pp. 2-24, 2019. https://doi.org/10.1108/EBR-11-2018-0203

Received: 2026-04-02; Accepted: 2026-06-05
doi.org/10.62012/mp.vi.50488 | e-ISSN: 2828-6669 p-ISSN: 2828-7010

[20] M. Sarstedt, C. M. Ringle, and J. F. Hair, "Partial least squares structural equation modeling," in *Handbook of Market Research*, Cham: Springer, 2021, pp. 587-632.

[21] Z. Raza, J. Woxenius, C. A. Vural, and M. Lind, "Digital transformation of maritime logistics: Exploring trends in the liner shipping segment," *Computers in Industry*, vol. 145, p. 103811, 2022. https://doi.org/10.1016/j.compind.2022.103811

[22] X. Bai, Y. Hou, and D. Yang, "Choose clean energy or green technology? Empirical evidence from global ships," *Transportation Research Part E: Logistics and Transportation Review*, vol. 151, p. 102364, 2021. https://doi.org/10.1016/j.tre.2021.102364

[23] M. Elhussieny, O. B. Arafat, and A. E. Kassar, "The Outcomes of Applying Smart Green Port Concept in Egyptian Ports," *The International Archives of the Photogrammetry, Remote*

Received: 2026-04-02; Accepted: 2026-06-05
doi.org/10.62012/mp.vi.50488 | e-ISSN: 2828-6669 p-ISSN: 2828-7010