

Key Factors Influencing the Effectiveness of Logistics Management at Vallarpadam Container Terminal

S. Sindhu^{1*} and Dr.V. Sumathi²

^{1*}Research Scholar, Department of Management, Karpagam Academy of Higher Education,
Eachinari, Coimbatore, Tamil Nadu, India

²Associate Professor, Department of Management, Karpagam Academy of Higher Education,
Eachinari, Coimbatore, Tamil Nadu, India

E-mail: ¹ssrp091298@gmail.com, ²sumathiganesh18@gmail.com

ORCID: ¹<https://orcid.org/0009-0000-3224-3398>, ²<https://orcid.org/0000-0003-4750-1657>

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Abstract - The Vallarpadam International Container Transshipment Terminal (ICTT), located in Kochi, has been set up to improve India's presence in international maritime trade; however, the terminal has not been able to operate at its expected levels of efficiency. This study aims to explore the factors that affect the logistics management effectiveness of ICTT through studying the impact of operational efficiency, regulatory policies, technology adoption, and logistics infrastructure on the performance and competitiveness of the terminal. In order to conduct quantitative research, primary data were collected through a structured questionnaire survey comprising 359 respondents involved in ICTT operations as port operators, shippers, freight forwarders, and other logistics professionals. The collected responses were statistically analyzed through Pearson correlation, paired sample t-test, linear regression and mediation analysis (using Hayes' PROCESS Macro). The study finds a strong positive correlation between operational efficiency and logistics management effectiveness ($r = 0.684$, $p < 0.01$). The results of the paired sample t-test suggest that improvement in regulatory policy led to significant enhancement of the competitiveness of ICTT, as the mean score for competitiveness increased from 3.46 prior to policy implementation to 4.21 after implementation ($t = -10.12$, $p < 0.001$). Regression analysis shows that technology adoption plays a significant role in determining service quality and operational performance and accounts for 56.5% of the variance ($R^2 = 0.565$; $\beta = 0.512$, $p < 0.001$). Besides, logistics infrastructure plays a significant mediating role in the relation between operational efficiency and performance, with an indirect effect of 0.136. The study concludes that integrated improvements in operational processes, regulatory support, technological advancement, and infrastructure development are essential for enhancing ICTT's logistics effectiveness and strengthening its competitiveness as a regional transshipment hub.

Keywords: Logistics Management Effectiveness, Vallarpadam Container Terminal, Operational Efficiency, Technology Adoption, Regulatory Policies, Logistics Infrastructure, Port Competitiveness

I. INTRODUCTION

Vallarpadam ICTT of Kochi was set up as the first ICTT in India with the aim of consolidating India's position in global seaborne trade. In spite of the strategic location of the terminal along the major East-West sea trade route and the SEZ status of the terminal, ICTT failed to meet expectations in terms of throughput capacity (Sricharan, 2018). The terminal has been designed to have an annual capacity of one million TEUs; however, there are serious operational inefficiencies that can be attributed to various restrictions, competition from already established transshipment centres such as Colombo and Singapore, insufficient hinterland links, and low exploitation of modern logistics technologies.

It should be noted that the previous studies pointed to the significance of logistics management efficiency as a major factor affecting the competitiveness of the terminal and users' satisfaction. Efficient cargo handling, safety management, cost reduction, compliance with regulations, and digitization are essential measures aimed at increasing operational performance (Kashav et al., 2021). However, ICTT still suffers from the lack of automation and predictive modeling, as well as from real-time cargo tracking systems (Wong et al., 2015). According to SWOT-based analyses, although the advantages include the strategic location and the infrastructure, the weaknesses in terms of connectivity, regulations, and operational performance prevent ICTT from competing with the other regional transshipment centres (De Marco et al., 2014).

Thus, the main problem discussed in this paper consists in the failure of the ICTT to perform its assigned role of being a competitive transshipment centre despite its strategic significance. Various barriers including regulatory, logistics, technological and competitive ones lead to inefficient operations. Therefore, a comprehensive analysis of the factors influencing the performance of logistics management is needed. The aim of this study is to reveal the barriers in

question and provide recommendations on how to improve ICTT's performance.

Research Objective

OB1: To examine the relationship between operational efficiency and the overall effectiveness of logistics management at ICTT.

OB2: To examine whether regulatory policy implementation significantly improves the competitiveness of ICTT.

OB3: To determine the effect of technology adoption on ICTT's service quality and operational performance.

OB4: To assess the mediating effect of logistics infrastructure on the relationship between operational efficiency and overall performance.

Research Hypothesis

H1: Operational efficiency has a significant positive influence on logistics management effectiveness at ICTT.

H2: Regulatory policy implementation significantly improves the competitiveness of Vallarpadam Container Terminal (ICTT).

H3: Technology adoption has a significant positive influence on service quality and operational performance at ICTT.

H4: Logistics infrastructure significantly mediates the relationship between operational efficiency and overall logistics management effectiveness at ICTT.

Key Contributions

1. Developed a framework combining operational efficiency, policy regulation, technological development, and logistics infrastructure for enhancing ICTT performance.
2. Empirically confirmed the influence of major logistic parameters through survey-based data analysis.
3. Identified ways to improve ICTT's operational efficiency and competitiveness, and logistics management through technology.

The organization of this research study is explained below: Section 1 focuses on research background, problem statement, research purpose, and hypotheses. Section 2 deals with the literature review and research gap. Section 3 explains the research methodology, conceptual framework, and data collection/analyses methods. Section 4 explains the statistical results. Section 5 explains the discussions, conclusions, and limitations, whereas Section 6 explains the conclusions of the research study. Section 6 conclude this paper.

II. REVIEW OF LITERATURE

The efficiency of logistics management at container terminals has received considerable focus due to the growing complexity of the global supply chain and the requirement of efficient operations (Kumar & Muthuvelayutham, 2018; Haralambides & Gujar, 2011). Container terminals contribute significantly to international business transactions, where efficient operations, resource management, and process efficiency greatly affect service quality and competitive advantage. In earlier research, researchers have designed a model that can assess the performance of container terminals on the basis of the influence of operational issues, infrastructure capabilities, and managerial activities on logistics efficiency (Nanyam & Jha, 2022a). The determination of factors that contribute to or inhibit terminal performance also underscores the importance of effective operational strategies, technology, and efficient resource utilization (Iyer & Nanyam, 2021a). In technical efficiency analysis of Indian container terminals, the importance of efficiency improvements has been shown (Iyer & Nanyam, 2021b).

Operational performance measures and strategic development in Indian ports have been widely researched. Several models of performance in container terminals based on analysis of different combinations of operational competencies and managerial aspects have been suggested (Nanyam & Jha, 2022b). The evolution of Indian seaports in the sphere of transshipments focuses on the necessity of strategic planning, infrastructural development, and competitive positioning in maritime logistics (Sricharan, 2018). Moreover, sustainable operational systems have been proposed for increasing reliability, quality management, and efficiency of major ports through improvements in processes (Sinha & Roy Chowdhury, 2022). The quantitative assessment of performance in container terminals has revealed differences in their efficiency and the need for the application of continuous improvement approaches (Rajak & Upadhyay, 2022).

The effectiveness of logistics management depends not only on infrastructure but also on such aspects as quality of services, information management, and operational improvement based on the usage of technologies. Research on logistics services has revealed that efficiency and effectiveness are key factors that characterize the performance of organizations and the level of customer satisfaction (Al Zadajali & Ullah, 2024). Logistics companies' performance is based on the combination of operational efficiency, delivery reliability, and resource management (Wong et al., 2015). Factors that influence the reliability of delivery, its timeliness, and the efficiency of logistics processes show the significance of coordination and the access to information in supply chains (Anguelov & Kenova, 2018). Moreover, logistics service providers' performance is dependent on such aspects as operations, process integration, and performance management (De Marco et al., 2014).

The recent literature has increasingly addressed issues related to smart logistics, digital transformation, and strategy factors that impact logistics management. Smart logistics systems and information technologies have been considered critical drivers of improving efficiency and responsiveness in organizations (Liu et al., 2021). Operational planning, resource allocation, and effective coordination of stakeholders have been cited as the factors impacting logistics management efficiency (Chotechoei, 2018). Management control systems and outsourcing practices also have impacts on logistics performance and organization results (Dobroszek, 2015; Zailani et al., 2017). Sustainable logistics activities also help achieve sustained operational improvements through environmentally friendly operations (Jefimovaitė & Vienažindienė, 2022). Still, very few studies

have addressed the impact of operational efficiency, policies, technology adoption, and logistics infrastructures as the interrelated factors impacting container terminal operations (Mohapatra et al., 2025).

The objective of the present study is to bridge the above-mentioned research gap by analyzing various factors affecting logistics management efficiency at the Vallarpadam Container Terminal (ICTT). As evident from the above-mentioned literature review, the success of logistics management in container terminals depends upon the interconnectedness of operational efficiency, regulation, technology advancement, and infrastructure development. Many studies have been conducted on individual factors, but there are limited studies on collective factors.

III. RESEARCH METHODOLOGY

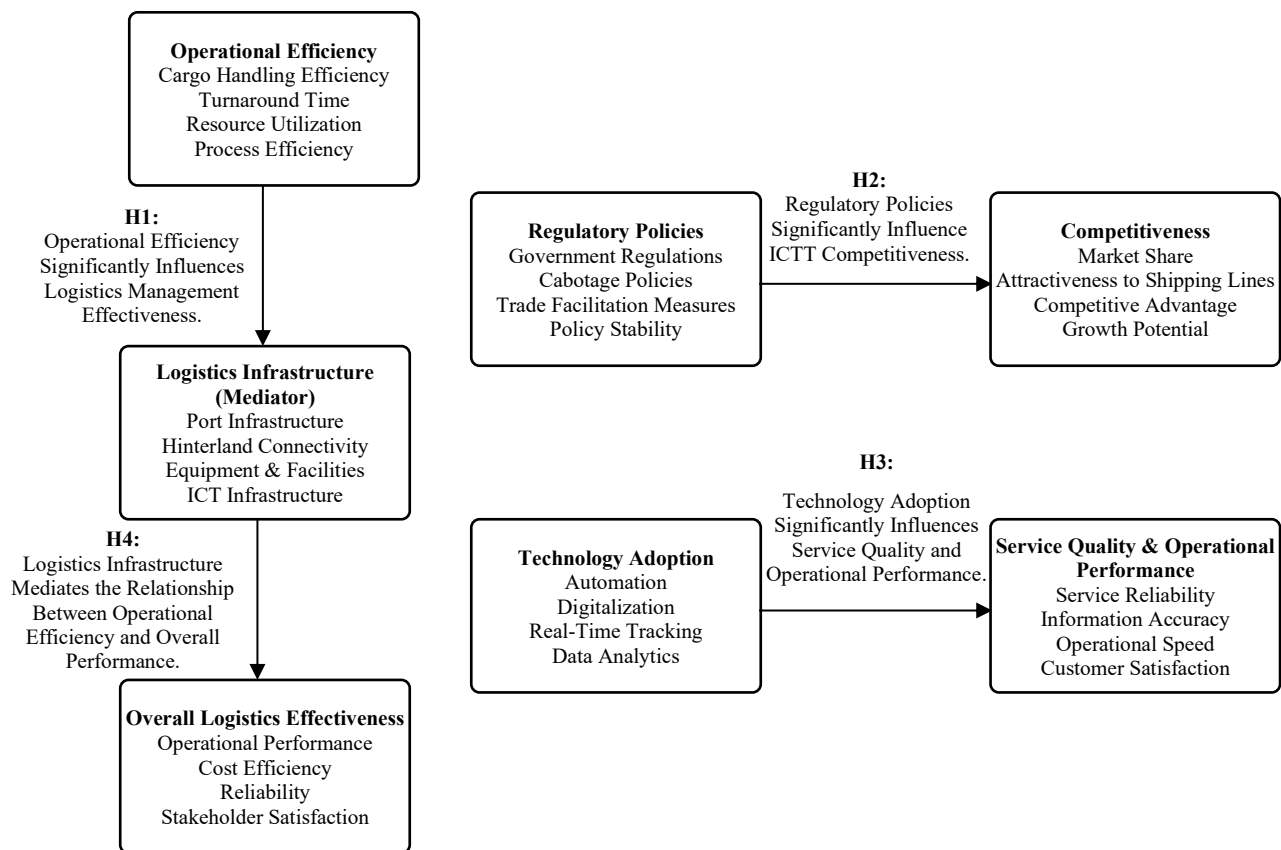


Fig. 1 Conceptual Framework Illustrating the Determinants of Logistics Management Effectiveness at Vallarpadam Container Terminal (ICTT)

Fig. 1 highlights the proposed relationships between operational efficiency, regulatory policies, technology adoption, and logistics infrastructure. It shows how operational efficiency has a direct effect on logistics effectiveness; regulatory policies affect the level of competitiveness; technology adoption helps to enhance the quality of service and performance; and logistics infrastructure is the mediator of performance improvement.

3.1 Research Design

For this research study, a quantitative research design will be used to analyse the factors that affect the effectiveness of

logistics management at Vallarpadam ICTT. The use of quantitative research design allows for an efficient analysis of the relationship between efficiency, policies, technology, logistics infrastructure and logistics management effectiveness.

The primary data is gathered through surveys carried out using a questionnaire based on structured questionnaires and distributed among ICTT stakeholders. Analysis of the collected data is done through correlation analysis, paired sample t-test, regression analysis and mediation analysis.

3.2 Data Collection and Sample Characteristics

The primary data were collected by means of a structured questionnaire survey, which involved 359 respondents who are concerned with ICTT operations. The respondents consist of port users, shipping companies, freight forwarders, logistics personnel, and other stakeholders engaged in container terminal operations.

The collected survey data consist of the stakeholder responses to the following constructs:

1. Operational efficiency of ICTT operations
2. Effectiveness of regulatory policy
3. Technological adoption practices
4. Logistics infrastructure capability
5. Logistics management effectiveness
6. Service quality and operational performance

The survey data reflect the stakeholders' views concerning ICTT logistics operations during the research period. The collected responses were used for analysis of the relationship between the above-mentioned constructs and their effect on logistics management effectiveness.

A questionnaire was developed to obtain opinions from the ICTT stakeholders in relation to the logistics management constructs that were identified. This involved the use of a five-point Likert scale that ranged from 1 (Strongly Disagree) to 5 (Strongly Agree). The questionnaire focused on opinions relating to efficiency, policies, technology, infrastructure, information management, and logistics performance.

3.3 Data Selection Criteria

The respondents have been selected because of their practical involvement and experience in logistics activities pertaining to ICTT. The selection criteria included experts who were involved in activities related to shipping, ports, freight forwarding, logistics services, stakeholders who had practical experience of working at container terminals, and people who had knowledge about the logistics processes of ICTT along with the use of technology and logistics management at ICTT. The purpose of these criteria was to ensure that the responses collected were from relevant and experienced stakeholders.

3.4 Sampling Technique

Stratified random sampling was used to make sure that different types of stakeholders operating in ICTT were represented. The respondents were selected from different strata, which include shipping companies involved in sea transport, freight forwarding companies involved in transporting and coordinating the movement of goods, port operators involved in the management of terminals, and logistics operators associated with supply chain operations. In total, 359 valid samples were obtained for analysis.

3.5 Research Constructs and Measurement

In the research framework, there will be three kinds of variables, namely, the independent variables, the mediating variable, and outcome variables of logistics management effectiveness of ICTT. The operational efficiency is divided into cargo handling efficiency, turnaround time, resource utilization, and process efficiency. The regulatory policies encompass the government regulations, cabotage policies, trade facilitation policy, and policy stability. The technology adoption is characterized by automation, digitalization, real-time tracking, and predictive analytics. The logistics infrastructure will play the role of mediator through the port facilities, connectivity, equipment, and ICT infrastructure.

3.6 Data Analysis Techniques

Analyses of the survey data collected were done using quantitative statistical approaches in order to assess the relationships among the variables of interest in this study. Pearson correlation analysis was used to assess the relationship between operational efficiency and overall logistics management effectiveness. A paired sample t-test was used to test for the significant difference in ICTT competitiveness before and after the regulation policies were adopted. Linear regression analysis was used to ascertain the impact of technology adoption on service quality and operational performance. Mediation analysis through the use of Hayes PROCESS Macro was done to determine the mediating effect of logistics infrastructure between operational efficiency and overall performance by assessing both direct and indirect effects.

IV. RESULT

4.1 Statistical Software

Statistical analysis was done through IBM SPSS Statistics software that enabled analysis of correlation, paired samples t-test, and regression analysis. Mediation analysis was done through PROCESS Macro by Hayes, which helped to analyze the direct and indirect effects of research variables. The statistical methods allowed systematic analysis of relationships between constructs and testing of hypotheses made.

4.1 Correlation Analysis

Pearson correlation analysis was used to examine the link between efficiency in operations and logistics management effectiveness at ICTT. The purpose of conducting this analysis is to assess whether efficiency in operational process, utilization of resources, and cargo handling is linked to effective logistics management. The correlation coefficient obtained from the analysis reveals the strength of the relationship between the two variables.

OB1: To examine the relationship between operational efficiency and the overall effectiveness of logistics management at ICTT.

H1: Operational efficiency has a significant positive influence on logistics management effectiveness at ICTT.

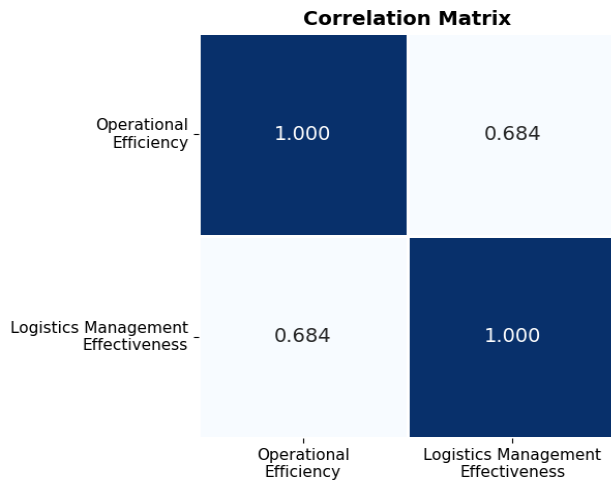


Fig. 2 Correlation Analysis Between Operational Efficiency and Logistics Management Effectiveness

TABLE I CORRELATION SIGNIFICANCE

Variables	Pearson's r	Significance (p-value)
Operational Efficiency & Overall Effectiveness	0.684	0.000

Note: Significant at $p < 0.01$

Fig. 2 and table I, the results of the Pearson correlation analysis show that there exists a moderately strong positive relationship between operational efficiency and the effectiveness of logistics management at ICTT, with a correlation coefficient of $r = 0.684$ and a significance level of $p = 0.000$. This finding shows that there is a positive relationship between operational efficiency and the effectiveness of logistics management such that an improvement in the former leads to an increase in the latter. The relationship is statistically significant because the p-value is less than the critical value of 0.01.

4.2 Paired Sample t-Test Analysis

The paired samples t-test has been carried out in order to determine the effect of the implementation of regulatory policies on the competitiveness of the ICTT. The test is aimed at determining if there have been any improvements based on the stakeholders' perceptions before and after policy implementation.

OB2: To examine whether regulatory policy implementation significantly improves the competitiveness of ICTT.

H2: Regulatory policy implementation significantly improves the competitiveness of Vallarpadam Container Terminal (ICTT).

TABLE II GROUP STATISTICS

Group	N	Mean Competitiveness	Standard Deviation
Before Regulatory Policies	179	3.46	0.74
After Regulatory Policies	180	4.21	0.66

Table II reveal that the competitiveness score mean for the group rose from 3.46 (SD = 0.74) to 4.21 (SD = 0.66). This is an indication of an improvement in the competitiveness of ICTT in the wake of new regulatory policies for the group.

TABLE III PAIRED SAMPLE T-TEST RESULTS

Comparison	Mean Difference	t-value	df	Sig. (2-tailed)
Before vs After Regulatory Policies	-0.75	-10.12	357	0.000

As shown in table III, the paired sample t-test output provides evidence that there is a statistically significant difference in ICTT competitiveness between pre- and post-regulatory policy implementation periods. The mean competitiveness of ICTT went up from 3.46 (SD = 0.74) in the pre-policy implementation period to 4.21 (SD = 0.66) in the post-policy implementation period. There was a statistically significant difference in ICTT competitiveness ($t = -10.12$, $df = 357$, $p = 0.000$), suggesting that ICTT regulatory policy changes contributed positively to ICTT competitiveness.

4.3 Regression Analysis

The study of ICTT used linear regression analysis in order to determine the impact of technology adoption on service quality and efficiency at ICTT. Linear regression analysis is aimed at the evaluation of the influence of the application of digital technologies, automation, real-time tracking, and other factors that help improve the processes in the field of logistics.

OB3: To determine the effect of technology adoption on ICTT's service quality and operational performance.

H3: Technology adoption has a significant positive influence on service quality and operational performance at ICTT.

TABLE IV REGRESSION MODEL SUMMARY

Model	R	R ²	Adjusted R ²	Std. Error of Estimate
1	0.752	0.565	0.561	0.412

TABLE V REGRESSION COEFFICIENTS

Variable	Unstandardized Coefficient	Standardized Coefficient (β)	t-value	Sig. (p-value)
Constant	1.341	-	6.851	0.000
Technology Adoption	0.502	0.512	9.424	0.000

Table IV and table V shows that the results of the regression analysis show that technology adoption is a predictor of both service quality and operational performance of ICTT. In the regression model, there was an R-value of 0.752, which suggests that there is a good correlation between technology

adoption and performance. The coefficient of determination ($R^2 = 0.565$) implies that technology adoption accounts for 56.5% of the variance in service quality and operational performance. Technology adoption also had a statistically significant positive impact on operational performance ($\beta = 0.512$, $t = 9.424$, $p = 0.000$).

The regression model assumptions were tested to verify the consistency of the test results. The problem of multicollinearity was checked using the Variance Inflation Factor (VIF) to establish that there is no correlation among the variables. The test of independence of residuals used the Durbin-Watson statistic, while the assumption of normality and homoscedasticity was tested using residual analysis.

4.4 Mediation Analysis

To explore if logistics infrastructure is a mediator between operational efficiency and effectiveness of logistics management in ICTT, mediation analysis was performed. The analysis takes into account not only the direct but also the indirect impact of operational efficiency on the performance results. To check the mediating effect and the significance of the indirect impact, Hayes PROCESS Macro Model 4 with bootstrap was used.

OB4: To assess the mediating effect of logistics infrastructure on the relationship between operational efficiency and overall performance.

H4: Logistics infrastructure significantly mediates the relationship between operational efficiency and overall logistics management effectiveness at ICTT.

TABLE VI DIRECT, INDIRECT, AND TOTAL EFFECTS

Path	Effect	SE	95% Confidence Interval
Operational Efficiency → Overall Performance (Direct Effect)	0.426	0.080	(0.268, 0.589)
Operational Efficiency → Logistics Infrastructure	0.482	0.067	(0.350, 0.613)
Logistics Infrastructure → Overall Performance	0.283	0.076	(0.134, 0.432)
Operational Efficiency → Infrastructure → Performance (Indirect Effect)	0.136	0.052	(0.042, 0.242)

Fig. 3 and the table VI show that the mediation model based on the use of Hayes PROCESS Macro is used to confirm the hypothesis of logistics infrastructure mediating the effect of operational efficiency on performance. Operational efficiency had a statistically significant effect on performance (effect = 0.426, $p = 0.000$); the indirect effect of operational efficiency through logistics infrastructure was also statistically significant (effect = 0.136, $p = 0.009$). Bootstrap confidence interval for the indirect effect does not contain zero and hence confirms the significance of the mediation effect. These results are calculated using a bootstrapping method with 5000 bootstrap samples (please

check PROCESS output). It is clear that operational efficiency leads to higher performance when the company has well-functioning logistics.

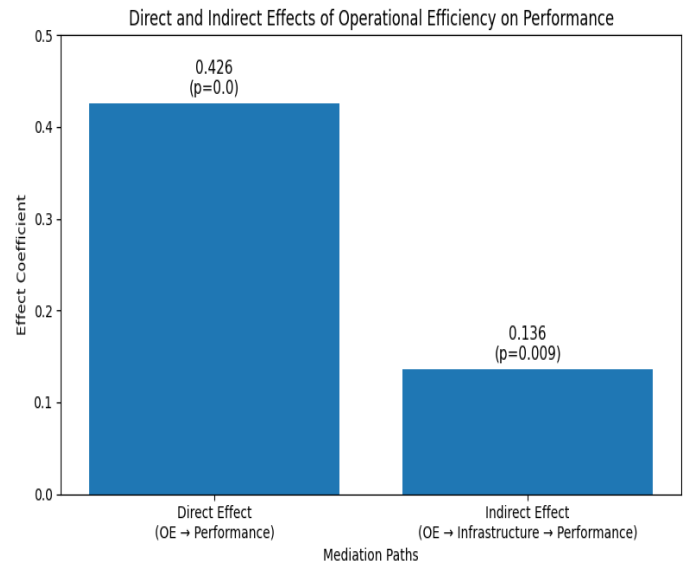


Fig. 3 Mediation Effects of Operational Efficiency on Performance Outcomes

4.5 Practical Relevance of Findings

Insights are gained from the results of this research that can be very helpful to stakeholders in ICTT, which include port authorities, logistics firms, and policymakers. Cargo handling processes can be optimized through improved efficiencies, better regulations, adoption of technologies and improvement in infrastructure. Better logistics performance is achievable through improved cargo handling, elimination of delays, and optimization of resources. Policies that are supportive can improve the competitiveness of the logistics system, while digital technologies like automation and tracking can improve the quality of information, service efficiencies, and coordination.

V. DISCUSSION

The findings indicate that operational efficiency, regulatory policies, technology adoption, and logistics infrastructure have an impact on the performance of logistics management in ICTT. The findings of this study support the theory of port efficiency, and they show that resource efficiency, reduction of operational inefficiencies, and effective cargo handling processes lead to better logistics performance. The findings related to regulatory policies reveal the significance of the adaptive approach to governance, and they show that reforms can decrease administrative obstacles, improve the process of cargo handling, and increase the competitiveness of ICTT. Adoption of technology results in an increase in service quality and performance through increased information transparency, good decision-making processes, and coordination of stakeholders. For instance, digitized cargo tracking systems increase the certainty of the movement of the cargo, enable information sharing at any time, and

coordination of activities of different stakeholders involved in shipping. Besides, the results on the mediation effect indicate that the logistics infrastructure intensifies the relationship between performance and efficiency.

However, the study has some limitations. The current study is concentrated on a specific container terminal only, namely the ICTT. As a result, the results obtained might not be generalized in relation to other terminals or ports. Moreover, the research is conducted in terms of the opinions of the stakeholders gathered in the cross-sectional survey. Therefore, it becomes impossible to identify the long-term trends in logistics management. Further research will have to focus on the longitudinal approach as well as on the comparative analysis with respect to several terminals.

VI. CONCLUSION

This study has identified the critical determinants affecting the effectiveness of logistics management at Vallarpadam ICTT. Operational efficiency, regulatory policies, adoption of technology and logistics infrastructure have been studied in relation to the performance and competitiveness of the terminal. The results indicate that the identified factors greatly influence logistics management and increase its effectiveness. According to correlation analysis, there is a significant positive correlation between operational efficiency and logistics management effectiveness ($r = 0.684$, $p < 0.01$). This implies that increased cargo handling, effective use of resources, and efficient operations have a positive impact on the overall performance of logistics management. The result of the paired sample t-test proves that implementation of regulatory policy significantly increases ICTT competitiveness. Before the implementation of the regulation, the mean competitiveness score was 3.46 and became 4.21 after the policy implementation ($t = -10.12$, $p < 0.001$). Moreover, regression analysis shows that the adoption of technology has a great impact on service quality and operational performance, accounting for 56.5% of the variance ($R^2 = 0.565$; $\beta = 0.512$, $p < 0.001$). Besides, it has been found that logistics infrastructure mediates the relationship between operational efficiency and performance due to a significant indirect effect equal to 0.136.

The results of this study show that ICTT competitiveness can be improved with the help of simultaneous improvement of operational processes, regulatory policy, technology, and infrastructure. Further research may include comparative analysis conducted for several container terminals, longitudinal studies and the analysis of innovative approaches like artificial intelligence, automation and smart ports in improving logistics performance.

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