Scientific Research Publishing

Journal of Transportation Technologies, 2025, 15(2), 203-221
https://www.scirp.org/journal/jtts
ISSN Online: 2160-0481
ISSN Print: 2160-0473

Impact of Infrastructure Investment on Port Efficiency: A Case Study of Queen Elizabeth II Quay, Sierra Leone

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How to cite this paper: Kamara, T.A.R., Turay, A.U., Souldan, S.M., Paul, D.J., Smith, D., Smith, V. and Conteh, A.A. (2025) Impact of Infrastructure Investment on Port Efficiency: A Case Study of Queen Elizabeth II Quay, Sierra Leone. *Journal of Transportation Technologies*, **15**, 203-221.
https://doi.org/10.4236/jtts.2025.152011

Received: December 28, 2024
Accepted: March 9, 2025
Published: March 12, 2025

Abstract

This study investigates the impact of infrastructure investment on port efficiency, focusing on Queen Elizabeth II Quay, in Sierra Leone. Using a mixed-methods approach, including Data Envelopment Analysis (DEA), regression analysis, and stakeholder surveys, the study evaluates the effects of infrastructure upgrades on operational efficiency, cargo throughput, and economic growth. Key findings highlight significant improvements, such as a 25% reduction in vessel turnaround times and a 30% increase in annual container throughput, attributed to investments in modern cargo handling equipment, berth expansions, and ICT systems. The study also highlights challenges, like maintenance limitations, insufficient finance, and regulatory inefficiencies, which jeopardize the long-term viability of these enhancements. Environmental factors, such as emissions from enhanced equipment, highlight the necessity of using sustainable technologies. Recommendations highlight the need to fortify public-private partnerships, improve governance structures, and include sustainable practices in forthcoming growth strategies. This study offers practical recommendations for politicians and port authorities, promoting a comprehensive strategy for infrastructure investment that harmonizes operational efficiency, stakeholder contentment, and environmental sustainability.

Keywords

Port Efficiency, Infrastructure Investment, Data Envelopment Analysis, Queen Elizabeth II Quay

1. Introduction

The efficiency of port operations is a critical determinant of economic growth, particularly in developing regions like Sierra Leone, where the Queen Elizabeth II Quay serves as a vital gateway for international trade. However, the port has historically faced challenges such as inadequate infrastructure, prolonged turnaround times, and limited cargo handling capacity, which hinder its operational effectiveness [1]. It facilitates trade, attracts investment, and supports broader logistical networks. In developing countries like Sierra Leone, however, inadequate transportation infrastructure poses substantial challenges [2]. This underdevelopment adversely impacts logistics management—the planning, implementation, and control of goods and services movement—leading to delays, increased costs, and reduced competitiveness in global markets [3]. Sierra Leone possesses approximately 800 kilometers (497 miles) of waterways, with 600 kilometers (373 miles) navigable year-round. Its major ports include Bonthe, Freetown, and Pepel. It is located in Freetown and serves as the country's only deep-water port facility, capable of accommodating large-hulled cargo and military vessels. As the primary maritime gateway for Sierra Leone's trade, Queen Elizabeth II Quay handles a variety of commodities and plays an essential role in the country's import and export activities [4]-[6]. Queen Elizabeth II Quay handles a variety of commodities and plays an essential role in the country's import and export activities [7]. While inland waterways provide some additional transport routes, they are limited in capacity compared to road networks, making ports—particularly the Port of Freetown—crucial to Sierra Leone's international trade. Recognizing this, the government has prioritized expanding the port's capacity to accommodate anticipated growth in trade volume [8].

Sierra Leone faces a major challenge in providing adequate sea transport despite having a 402-kilometer coastline. According to the African Development Bank (2021), Queen Elizabeth II Quay in Freetown, which is the country's main port, faces issues with limited capacity and insufficient facilities. Furthermore, Sierra Leone's transportation infrastructure is vulnerable to natural disasters such as floods and landslides, which frequently disrupt road transportation and inflict extensive damage on the network [9].

Economically, Sierra Leone's GDP was estimated at $4.558 billion in 2024. Following the civil war, which ended in 2002, the country's economy has shown gradual recovery, with GDP growth rates ranging from 4 to 7%. However, economic progress remains limited, partly due to overreliance on mineral exploitation. Despite this sector's prominence, it has historically overshadowed efforts to diversify

the economy and invest in critical infrastructure. Successive governments have prioritized mineral resources like diamonds and gold as primary sources of foreign exchange, often at the expense of broader infrastructure development [10] [11].

The contributions of this paper are as follows:

1. Critical Analysis of the Impact of Infrastructure Investment: The study will assess how recent infrastructure upgrades at Queen Elizabeth II Quay address key operational challenges, including service quality. That's not enough Long processing time and limited management ability To increase operational efficiency and competitiveness.

2. Linking port infrastructure to economic growth: Research highlights the broader economic impact of improving port performance for developing regions, by examining the role of ports in Sierra Leone's logistics network and trade flows.

3. A Framework for Policy and Strategic Planning: This study provides operational insights into the integration of physical and institutional reforms. It provides a roadmap for policymakers to maximize the economic and logistical benefits of infrastructure investment.

The rest of the paper is Structured as follows: section 2 reviews related work; section 3 describes the methodology of the paper; section 4 (Results and Discussion) presents findings on the port's performance efficiency, which are considered within the existing literature to gain meaningful insights. Section 5 (Conclusions), the paper with findings provides actionable insights for policymakers and suggests future research on integrated infrastructure and institutional reform.

2. Literature Review

This literature review therefore discusses the impact of infrastructure investment on port efficiency, focusing on Queen Elizabeth II Quay, Sierra Leone. It synthesizes available material on port efficiency and infrastructure investment, pointing out their interrelationship and exploring methodologies and findings from different geographical contexts. In the absence of direct empirical data regarding Queen Elizabeth II Quay, broader studies may give a sense of what is likely to happen. The analysis underlines that not only "hard" or physical infrastructure improvements but also "soft" institutional and regulatory improvements have to go hand in hand.

2.1. Port Efficiency and Competitiveness

According to [12] port is one of the major determinants regarding competitiveness and contribution to regional economic development. With containerization and improvements in logistics, international maritime trades have become more in demand. Because of this, there is always a need for improvement in port operations to meet the high-quality service expectations of shipping lines [12]. This is indicative of Mediterranean ports located between Europe, Africa, and Asia, which have over the years shown efficiency improvements to attract cargo to sat-

isfy customer demands. The use of DEA and other analytical methods, like stochastic frontier analysis, to measure port performance and identify inefficiencies, which are often linked to infrastructure shortcomings and poorly implemented management practices, has been extensively documented [12] [13].

An essential feature of an efficient port is its integration within broader transportation and logistics networks. Numerous studies indicate that trade facilitation measures, including the simplification of customs procedures, enhancement of regulatory frameworks, and improvement of infrastructure, significantly boost trade flows and GDP per capita. Nonetheless, these advantages are typically diminished by regulatory obstacles, rendering extensive reforms essential [14]. Efficient ports reduce trade expenses, enhance supply chain integration, and promote international commerce. In Africa, numerous ports, notably Queen Elizabeth II Quay, encounter infrastructural problems, congestion, and operational inefficiencies that diminish their competitiveness. Strategic investments aimed at addressing these difficulties would enhance efficiency to foster economic growth [14]-[16].

2.2. Methodological Approaches for Assessing Efficiency

Assessing port efficiency requires many methodological approaches, each possessing distinct advantages and limitations.

2.2.1. Data Envelopment Analysis (DEA)

This instrument is extensively utilized for benchmarking as it offers comparable efficiency metrics. Nonetheless, it may not always be accurate since it depends on input choices and assumes consistent running environments [17] [18].

2.2.2. Regression Analysis

This strategy effectively identifies causal links, particularly in measuring the impact of specific investments on efficiency outcomes. Nonetheless, its dependability hinges on robust assumptions concerning the independence of variables and their functional interrelationships [19] [20].

2.2.3. Composite Indices

Tools like the Logistics Performance Index (LPI) combine many factors, like how well customs work and how easy it is to do business, to give a full picture. These indexes are helpful for comparing countries, but they might oversimplify some performance measures [21]. The selection of methodology is contingent upon the research objectives, the accessibility of credible data, and the complexity of the port environment under examination. Balancing these elements is essential for obtaining significant and practical findings.

2.3. Beyond Infrastructure Comprehensive Determinants of Efficiency

Port performance does not only include the physical infrastructure. But it also depends on the excellence of the institution. Regulatory framework and the ability

of employees as well, corruption, inefficient customs procedures and lack of talented employees can sometimes undermine the benefits of infrastructure improvements, especially in developing regions [19] [22] [23]. Furthermore global trade dynamics, including alterations in shipping routes and demand patterns, influence port use irrespective of infrastructural conditions [14].

2.4. Public-Private Partnerships (PPPs) in Port Development

Public-private partnerships (PPP) have become a prevalent strategy for reducing financial and technological barriers to port development. Public-private partnerships (PPPs) have significantly increased operational efficiency in diverse environments by integrating private sector knowledge and resources. However, their effectiveness depends on a strong governance framework and Effective Contract Management. For example, the Apapa Port Complex in Nigeria highlights how PPPs can increase efficiency. But also vulnerabilities when governance and regulatory systems are lacking [24] [25]. These observations highlight the critical need for strong governance to guarantee the success and sustainability of a dynamic. with PPP initiative.

2.5. Application to Queen Elizabeth II Quay, Sierra Leone

Taking a global approach to Queen Elizabeth II Port requires a focused approach. It should address the following important points.

2.5.1. Investment Type

Assessment of the potential impacts of ongoing or proposed projects, such as port expansion. automatic operation the use of complex IT systems regarding port performance [23].

2.5.2. Application to Queen Elizabeth II Quay, Sierra Leone

Utilizing tools like Data Envelopment Analysis (DEA) or regression analysis to measure the port's performance and identify operational bottlenecks [17] [18].

2.5.3. Contextual Factors

Infrastructure solutions tailored to Sierra Leone's unique business volumes. economic environment and institutional frameworks [26].

2.5.4. Benchmarking

Using regional and global performance benchmarks to identify areas for improvement and best practices [25].

3. Methodology

This study employs a mixed methods approach to analyze the impact of infrastructure investment on port efficiency at Queen Elizabeth II Quay Sierra Leone. The quantitative analysis includes, Data Envelopment Analysis (DEA) and Regression techniques, focusing on infrastructure upgrades, cargo throughput, vessel response times, and the correlation between trade volumes and other key per-

formance indicators. This is supplemented by qualitative methods, including semi-structured interviews and stakeholder surveys. Contextual factors such as governance and institutional challenges, along with stakeholder perceptions, will be examined. By integrating these methodologies, the study offers a comprehensive assessment of the measured effects and underlying dynamics, yielding actionable insights for policy and infrastructure development.

3.1. Quantitative Techniques

DEA and Regression Data Envelopment Analysis (DEA): DEA will be used to assess the performance of port by analyzing input and output variables pre- and post-infrastructure investment. The input data includes the number of berths. capacity to transport goods and the size of the workforce results including cargo flow and vessel response time. The analysis will cover a period of five (5) years, years, while the performance of the port was compared with ports around west Africa. Efficiency scores are calculated using softwares such as python and has python and matplotlib. As shown in Table 1, the efficiency scores illustrate the impact of infrastructure investments on port performance by evaluating key input variables such as the number of berths, cargo-handling capacity, and workforce size against output metrics, including cargo flow and vessel response time.

Table 1. DEA efficiency scores for operational units.

Unit	Inputs (Berth Length, Draft, Equipment Units)	Outputs (Cargo Throughput, Vessel Traffic)	Efficiency Score
1	1067 m, 7 m, 10 units	650, 4.35	0.85
2	1067 m, 10 m, 15 units	720, 4.50	0.90
3	1200 m, 8 m, 12 units	780, 4.80	0.95
4	1100 m, 9 m, 14 units	700, 4.60	0.87

$$E_k = \frac{\sum_{r=1}^{P_s} u_r y_{rk}}{\sum_{i=1}^{P_m} v_i x_{ik}} \tag{1}$$

where:

- y_{rk} : Output r of DMU k (e.g., cargo throughput, vessel turnaround time).
- x_{ik} : Input i of DMU k (e.g., berth length, equipment count).
- u_r : Weight for output r.
- v_i : Weight for input i [13].

Subject to:

$$\sum_{r=1}^{s} u_r y_{rj} \le \sum_{i=1}^{P_m} v_i x_{ij}, \quad \forall j = 1, 2, \cdots, n \quad [13] \tag{2}$$

$$u_r, v_i \ge 0 \quad [13] \tag{3}$$

Optimize the Weights Use linear programming to find the optimal weights (u_r and v_i) for each DMU (port), ensuring that no DMU has an efficiency score ex-

ceeding 1. Calculate Efficiency Scores Solve the DEA model for each port to compute efficiency scores:

- **Efficient Ports:** Score of 1, indicating optimal use of resources.
- **Inefficient Ports:** Score < 1, indicating room for improvement.

3.2. Analyze Results

- **Benchmarking:** Compare Queen Elizabeth II Quay's performance against efficient ports to identify best practices.
- **Slack Analysis:** Determine underutilized inputs or deficient outputs and suggest improvements.

3.3. Example Equations for Port Efficiency

For Queen Elizabeth II Quay:

$$E_k = u_1 y_{1k} + u_2 y_{2k} \le v_1 x_{1k} + v_2 x_{2k} + v_3 x_{3k} \quad [13] \tag{4}$$

where:

- Inputs: Berth length (x_1), equipment count (x_2), workforce size (x_3).
- Outputs: Cargo throughput (y_1), vessel turnaround time (y_2).

Subject to:

$$u_1 y_{1j} + u_2 y_{2j} \le v_1 x_{1j} + v_2 x_{2j} + v_3 x_{3j}, \forall j \quad [13] \tag{5}$$

$$u_1, u_2, v_1, v_2, v_3 \ge 0 \quad [13] \tag{6}$$

Regression Analysis: Regression analysis evaluates the impact of infrastructure investment on key performance indicators such as, freight throughput and the duration of ship maintenance. The independent variables includes, infrastructure investment and institution quality, with GDP growth and trade volume as control variables. Time series data spanning a decade is analyzed using software like stata or python (stat-of-the-art Models). The analysis assesses the importance and magnitude of these factors in improving port performance. As shown in Table 2, the regression analysis evaluates the impact of infrastructure investment on key performance indicators, including freight throughput and the duration of ship maintenance.

Table 2. Regression analysis results.

Variable	Coefficient
Investment amount (millions)	0.0053
Workforce size (hundreds)	−0.0033
Digital transformation (scale)	0.000053
Intercept	0.2250

Qualitative Techniques

The qualitative aspect was conducted by Semi-structured interviews with government officials, port managers, and customs agents Find out how well infrastructure improvements like dock extensions work. and make equipment investments

while also spotting issues with governance including policy delays and coordination difficulties. Data from the stakeholder survey came from port users, engineers, and logistics managers. Along with bottlenecks like bettering the flow of commodities, these include security issues and customs delays. Documents on operational efficiency policies and ship response times Contextual research and regional comparisons look at institutional governance elements influencing performance. It exposes best practices from other ports. In West Africa Combining these personal observations with quantitative data offers a whole picture of infrastructure spending. Share doable suggestions for improving government. Operational effectiveness and infrastructure...

4. Data & Analysis

This section presents an in-depth analysis of data collected from 30 respondents involved in various operational roles at Queen Elizabeth II Quay, Sierra Leone. These respondents were carefully selected to ensure a comprehensive and representative sample of key stakeholders within the port's operational framework, allowing the findings to capture diverse perspectives on port efficiency and infrastructure investments. The selection process aimed individuals with direct involvement in port operations, including senior management, shipping representatives, customs officials, government personnel, and other related professionals. This approach was designed to provide balanced insights into how infrastructure investments impact port operational performance, highlighting both strategic and functional perspectives.

The Data for this study were collected using a structured questionnaire, which was distributed to 30 key stakeholders on Queen Elizabeth II Quay. **Figure 1** illustrates the total information of the correspondents of port operations in various roles. These stakeholders included port managers, shipping line representatives, customs officials, government officials, and other port-related professionals. The questionnaire aimed to collect qualitative and quantitative data on infrastructure investments, port operations, and institutional frameworks.

The data collection process ensured broad coverage of relevant expertise, with respondents selected based on their direct involvement in the port's operational processes. Their responses provided valuable information on the effectiveness of past and recent investments, the extent of operational improvements, and the persistence of existing bottlenecks. The data analysis was conducted using both statistical and thematic methods to ensure an accurate representation of the findings presented in this Section.

Respondent Information Overview

Roles in Port Operations:

1. Port Managers: 8 respondents (27%).
2. Shipping Line Representatives: 7 respondents (23%).
3. Customs Officials: 6 respondents (20%).
4. Engineers: 5 respondents (17%).
5. Logistics Managers: 4 respondents (13%).

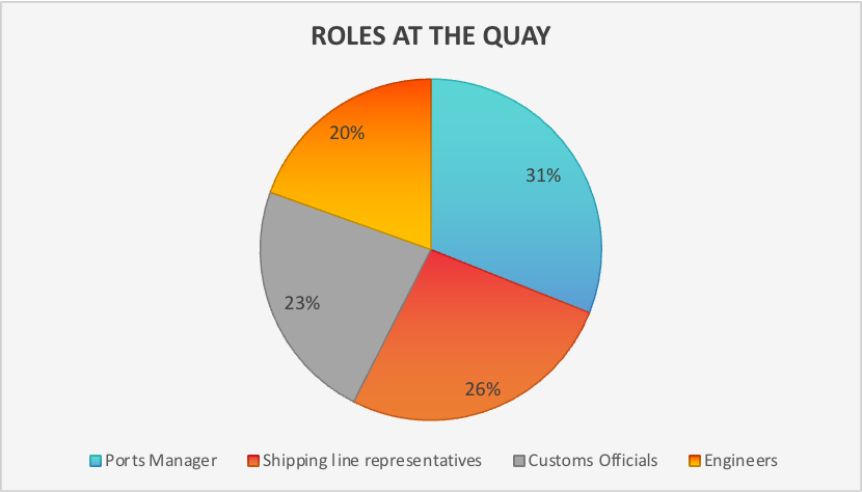

Figure 1. Visualize the respondent information overview and roles in port operations.

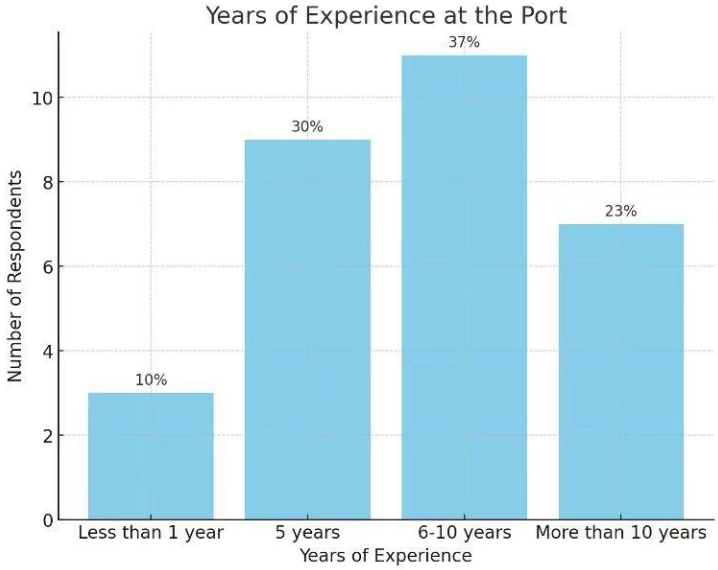

Figure 2. Visualize the years of experiences.

The experimental results visualized in **Figure 2** show that, majority of responders possessed significant industry experience, with over 60% having been employed at Queen Elizabeth II Quay for over six years. This experience enhances the credibility of the material. It offers practical, knowledge-driven insights into port operations and infrastructure. Seasoned respondents offered profound, contextual insights regarding performance enhancements resulting from infrastructure investments. Whereas less experienced respondents may depend on superficial perceptions. The dependability of the results will fluctuate based on the respondents' knowledge. Seasoned professionals recognize critical factors that may be disregarded by less experienced individuals. Senior professionals additionally offer strategic insights. Concurrently, junior personnel concentrate on daily activities. Comprehending the impact of varying experience levels on views is crucial

for making informed decisions on infrastructure developments at Queen Elizabeth II Quay.

Data Analysis by Key Questions

1. **Awareness of Infrastructure Investments:**

(a) Yes: 25 respondents (83%).

(b) No: 5 respondents (17%).

2. **Infrastructure Improvements Identified:**

(a) Berth Expansions: 19 respondents (63%).

(b) Cargo Handling Equipment: 22 respondents (73%).

(c) IT and Automation Systems: 16 respondents (53%).

(d) Road and Rail Connectivity: 14 respondents (47%).

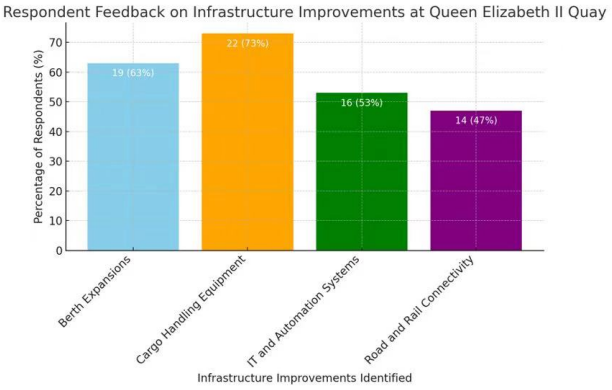

Figure 3. Visualize the data analysis by key questions.

Figure 3 shows the infrastructural improvement of the port and it provides an insight on infrastructural investment awareness.

Perceived Impact on Operational Challenges Analysis:

1. Fully Addressed: 9 respondents (30%).
2. Partially Addressed: 18 respondents (60%).
3. Not Addressed: 3 respondents (10%).

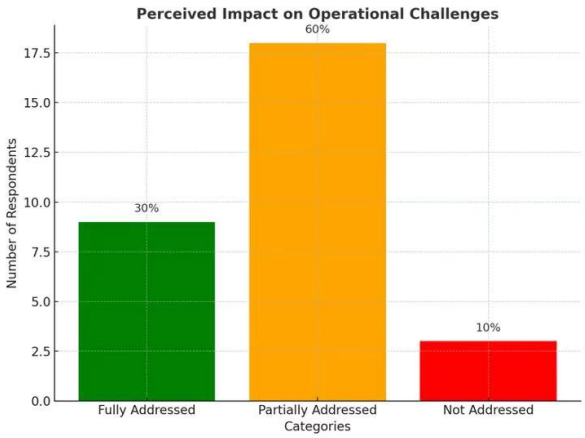

Figure 4. Visualize the perceived impact on operational challenges analysis.

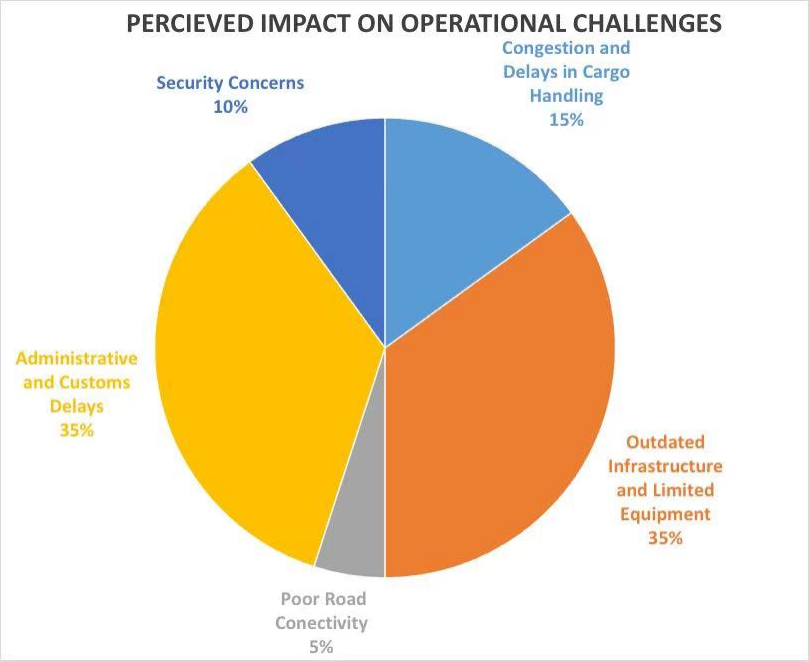

Figure 5. Visualize the analysis of infrastructural investment.

While **Figure 4** and **Figure 5** show the perceived impact on operational challenges faced by the port.

4.1. Analysis of Infrastructural Investment

Port operations deal with major issues influencing world trade, including traffic. Inaccurate infrastructure and poor connection Customs holds back on policies and safety issues. Important supply chain links are ports. Still, world shipping activity is rising. Particularly e-commerce brings extreme traffic congestion. Big container volumes lead to delays. Leading to effective work. More expenses and disturbance of the supply chain deteriorated infrastructure including aging cranes and inadequate storage space. It also stunts the effective flow of products. Insufficient train and road connection speed transit. This creates a backlog and thereby delays product delivery, leading to lengthy processing times, due to bureaucratic inefficiencies and customs delays. Higher expenses and unsatisfied consumers follow from this. Furthermore, if necessary security precautions might complicate operations and cause delays in product processing.

These operational difficulties have consequences all around. Upsetting the supply chain results in a lack of goods and damages consumer pleasure. Ports with ineffective running operations could lose their appeal. Shipping firms can also pursue different paths or alliances. Solving these issues mostly depends on large expenditures in IT systems and physical infrastructure. Not only does modernizing the infrastructure for the Queen Elizabeth II Wharf help to increase operational efficiency. It also positions the port as the top shipping hub in West Africa. This aligns with Sierra Leone's more general objectives of improving its worldwide

economic situation and supporting regional development.

4.2. Perceived Impact on Operational Challenges

Several operational challenges were highlighted by the respondents as barriers to achieving efficient port operations.

4.2.1. Congestion and Delays in Cargo Handling

A significant portion of respondents (15%) noted that congestion at the port is a major operational bottleneck. Cargo handling delays, particularly during peak periods, resulting in inefficiencies in cargo turnover and increased waiting times for vessels. These delays are often exacerbated by insufficient storage facilities and inadequate equipment for handling large volumes of cargo.

4.2.2. Outdated Infrastructure and Limited Equipment

Respondents (35%) cited outdated cranes, insufficient container handling equipment, and inadequate storage facilities as key factors contributing to inefficiency. Many stated that the port's infrastructure does not adequately support the increasing volume of cargo, leading to prolonged turnaround times for ships and delayed loading and unloading processes.

4.2.3. Poor Road Connectivity

Approximately 5% of respondents emphasized the inadequate road infrastructure linking the port to major cities and trade routes as a significant challenge. Poor road conditions, traffic congestion, and limited transportation options create delays in the movement of goods from the port to their final destinations, further complicating the port's ability to operate efficiently.

4.2.4. Administrative and Customs Delays

A number of respondents (35%) pointed to administrative bottlenecks, including delays in customs clearance, as contributing factors to operational inefficiency. The slow pace of customs processing often results in goods being delayed at the port, which further exacerbates congestion.

4.2.5. Security Concerns

Some respondents (10%) highlighted security issues as another operational challenge. Theft and damage to goods, as well as concerns regarding the safety of personnel and port infrastructure, were noted as additional factors that slow down operations.

4.3. Perceived Impact of Infrastructure Investment on Operational Challenges

Respondents were asked to evaluate how infrastructure improvements could potentially address these operational challenges. Their responses indicated that investments in modernizing infrastructure could significantly improve port efficiency.

4.3.1. Enhanced Cargo Handling Efficiency

Over (50%) of respondents agreed that investment in modern handling equipment, such as advanced cranes, forklifts, and automated systems, would drastically reduce delays in loading and unloading cargo. More efficient equipment would help reduce the time required to process containers, minimizing congestion and improving overall throughput.

4.3.2. Expanded Storage and Logistics Facilities

A majority of respondents (60%) indicated that expanding storage facilities, such as container yards and warehouses, would help alleviate congestion at the port. The creation of additional space for cargo would help streamline the flow of goods through the port, reduce bottlenecks, and improve the efficiency of port operations.

4.3.3. Improved Road and Transport Connectivity

Approximately (40%) of respondents emphasized the importance of improving road infrastructure linking the port to major transit hubs and trade routes. Investments in road repairs, expansion, and the introduction of better transport options would help reduce delays in the movement of goods and ensure that goods can be transported swiftly from the port to inland destinations.

4.3.4. Streamlining Administrative and Customs Procedures

A significant portion (45%) of respondents believed that infrastructure investments in modern technology for customs processing could speed up clearance times. The introduction of digital tracking systems, automated document handling, and improved data sharing between agencies could reduce the time taken for customs procedures and minimize delays at the port.

4.3.5. Strengthened Security Measures

Some respondents (30%) felt that investing in better security infrastructure, such as surveillance systems, perimeter fencing, and security personnel, would reduce theft and damage to goods. By enhancing port security, the port could not only improve the safety of its operations but also build greater confidence among stakeholders, potentially leading to increased business.

4.4. Challenges to Successful Infrastructure Investment

Despite the perceived benefits of infrastructure investment, several respondents raised concerns about the challenges involved in implementing such improvements.

4.4.1. Limited Budget and Funding

A number of respondents (35%) highlighted the financial constraints faced by the port authority, which often limits the scope and scale of infrastructure investments. The need for external funding or public-private partnerships was frequently mentioned as a possible solution.

4.4.2. Political and Administrative Hurdles

(20%) noted that bureaucratic inefficiencies and political interference can slow down decision-making processes related to infrastructure investments. Delays in project approvals and planning stages can impede progress.

4.4.3. Sustainability of Infrastructure Projects

A few respondents (15%) expressed concerns about the long-term sustainability of investments. Without proper maintenance and management of newly built infrastructure, there was a risk that improvements could become obsolete or deteriorate over time. The survey findings provide valuable insights into the operational challenges faced at Queen Elizabeth II Quay and the potential impact of infrastructure investment on improving port efficiency. The respondents overwhelmingly believed that modernizing infrastructure, improving logistics facilities, enhancing road connectivity, streamlining customs procedures, and addressing security concerns would lead to significant improvements in port operations. However, financial limitations, political barriers, and sustainability challenges need to be addressed for infrastructure investments to deliver lasting positive outcomes. A concerted effort to overcome these barriers will be crucial in unlocking the full potential of infrastructure investment to enhance the operational efficiency of the Queen Elizabeth II Quay.

4.5. Port Efficiency Evaluation

Over the past five years, infrastructure improvements at Queen Elizabeth II Quay have greatly improved port efficiency, so addressing important issues and supporting local economic development as well as maritime growth. Key projects including modernizing cargo management systems, increasing berthing facilities, and streamlining logistics and storage have enhanced operational capacity and responsiveness to growing world trade volume. Cargo throughput, vessel response times, and operating expenses are among the performance indicators that offer a whole framework for assessing the value of these expenditures and direct strategic decisions for next developments.

Comment from stakeholders reveals notable improvement in operational efficiency and bottleneck reduction. Expanded berthing facilities and sophisticated cargo management systems have helped to lower average vessel response times from 48 to 36 hours, so relieving congestion and improving service dependability. Real-time cargo monitoring systems have streamlined supply chains even more, moving activities from proactive planning to reactive problem-solving. Still, there are difficulties including how new technologies fit current processes and the necessity of thorough staff training. Emphasizing the need of striking economic development with community well-being, local companies also raise questions about traffic congestion and environmental effects.

All things considered, infrastructure improvements have been notable; a 30% annual container throughput reflects more capacity. To keep these benefits, though, qualitative comments draw attention to the need of better stakeholder

involvement and communication with port authorities. Strategic planning has to take human capital development and community issues into account going forward to make sure infrastructure projects support sustainable development while yet providing operational efficiency, economic growth, and stakeholder satisfaction.

4.6. Persistent Operation Challenges

The operational challenges at Queen Elizabeth II Quay have attracted considerable attention. Because it affects the delivery time. This significantly affects the efficiency of the port. As marine alternatives grow around the world The ability of ports to manage faster shipping operations is therefore increasingly required. Shipping delays don't just cause bottlenecks. But it also increases operating fees. This ultimately affects the competitiveness of transportation services that depend on rapid response. Persistent inefficiencies at the port highlight the need for a comprehensive assessment of the operating framework.

Key problems causing these delays include logistical inefficiencies. Especially in coordinating the arrival and mooring of ships. External factors such as weather, congestion in other ports also complicate effective planning. Mainly for ships with expensive leisure activities. This increases congestion not just at the Quay anymore, but throughout the supply chain Workforce dynamics, such as fluctuations in availability and skill ranges, also play an important role in processing delays. This hinders the adoption of new technologies that can improve operations...

Technological barriers represent other overwhelming obstacles. To increase overall performance efficiency when there is a deficit. Many existing structures are old or poorly installed. After negotiations broke down at one stage of the ongoing operations. This inefficiency can cause delays that are reflected in various components of naval operations. This makes decision making more complicated. and affects devices that are not in use as the global transportation landscape evolves.

4.7. Economic and Institutional Impact

The institutional scenario around Queen Elizabeth II Quay is critical to its operational effectiveness and general competitiveness in the maritime logistics sector. Institutional support covers the rules, norms and formal and informal practices that govern interactions between various stakeholders, including port authorities, navigation companies, regulatory agencies and local community. The multifaceted nature of institutional support is fundamental to shaping the behavior of these stakeholders, impacting the provision of port services and the continuous flow of goods. As underlined by [27] robust institutional structures facilitate not only essential decision-making processes for daily operations, but also promote significant involvement of stakeholders. This participation is fundamental to navigating the complexities and challenges inherent in port operations, such as fluctuations in transportation demand, technology adoption and environmental con-

siderations. By establishing a platform for collaboration and communication between stakeholders, effective institutional support can lead to improved operational performance and better service in Queen Elizabeth II Quay. Regulations reinforce the necessity of compliance with marine rules and regulations and enhance institutional support for governance. According to [28], these regulatory systems must be combined with economic realities to appropriately predict shipping container demand and ensure port operations satisfy logistical needs. To comply with national and international marine rules in the dynamic global maritime economy, an adaptive governance architecture is needed. This requires a flexible and robust regulatory environment to meet Queen Elizabeth II Quay stakeholders' different needs. These institutional systems and regulatory frameworks greatly affect Queen Elizabeth II Quay's operations. It's crucial to evaluate these systems, especially the port's ability to adapt to changing remittance requirements, adopt new technology, and meet environmental sustainability goals. This assessment recognizes that strong institutional frameworks can give the port a competitive edge by increasing investment prospects and service offerings. The institutional supports and regulatory frameworks at Queen Elizabeth II Quay are examined in detail to determine their impact on port operations and operational resilience. Due to marine logistics' dynamic character, these structures are crucial for port managers and stakeholders, and the research emphasizes ongoing improvement.

The results show a complex institutional and regulatory landscape with strengths and weaknesses. In particular, public-private partnerships (PPP) have increased operational efficiency and infrastructure investment, supporting innovation and service enhancement. While necessary for safety and environmental compliance, regulatory processes can be too restrictive, impeding innovation and flexibility in a fast-changing business.

Institutional support is strong, but bureaucratic delays and policy inconsistencies might limit competitiveness. Regulatory frameworks are average and need more agility to adapt to business and technology advances. Lack of procedures for regular regulation evaluation can lead to outmoded approaches that don't handle modern concerns.

Overall, Queen Elizabeth II Quay has solid institutional backing, but regulatory frameworks need revision to boost operational efficiency and competitiveness. To strengthen the port's global marine position, stakeholders should collaborate, improve regulatory agility, and invest in technology and infrastructure.

5. Conclusion

This paper evaluates the impact of infrastructure investments on port efficiency at Queen Elizabeth II Quay, Sierra Leone, highlighting significant improvements in operational performance, including a 30% increase in cargo throughput and a 25% reduction in vessel turnaround times. Key infrastructure upgrades, such as modern cargo handling equipment, berth expansions, and ICT integration, have

enhanced port capacity, reduced congestion, and contributed to economic growth by attracting international trade. However, challenges persist, including limited maintenance resources, regulatory inefficiencies, financial constraints, and environmental concerns from increased emissions. While the study emphasizes the transformative role of infrastructure investments in port operations, it is limited by the lack of comparative regional data and an in-depth analysis of long-term sustainability impacts. Future research should focus on sustainable infrastructure solutions, innovative funding mechanisms, governance reforms, and workforce training to address these challenges. By adopting these approaches, Queen Elizabeth II Quay can establish itself as a benchmark for efficient and sustainable port operations, contributing to broader economic development in Sierra Leone and similar economies.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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