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Model for Demurrage Elimination and Port Logistics Efficiency in Emerging Economies

Chineme Scholar Okonkwo [1*], Jibril Agbabiaka [2], Olufunmilayo Ogunwole [3], Winner Mayo [4], Obinna ThankGod Okeke [5]

[1] PESO Energy Services Limited, Lagos State, Nigeria
[2] Babban Gona Farmer Services, Lagos, Nigeria
[3] Krones LCS Center West Africa Limited, Lagos, Nigeria
[4] Amazon, UAE
[5] Ventlio, Lagos, Nigeria

Corresponding Author: **Chineme Scholar Okonkwo**

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Abstract
This proposes a comprehensive model for demurrage elimination and port logistics efficiency tailored to the structural and institutional realities of emerging economies. Persistent demurrage costs in these contexts are driven by port congestion, fragmented information flows, inefficient customs procedures, limited infrastructure capacity, and weak coordination among port stakeholders. These challenges not only increase logistics costs but also undermine trade competitiveness and economic growth. The proposed model adopts a systems-based approach that integrates operational, technological, regulatory, and institutional dimensions of port logistics to address the root causes of demurrage rather than its symptoms. The model is structured around four interrelated pillars. The first pillar focuses on process optimization, emphasizing streamlined vessel berthing, cargo handling, documentation, and cargo clearance workflows. The second pillar addresses digital integration through port community systems, real-time cargo tracking, and data-sharing platforms that improve visibility and coordination among shipping lines, terminal operators, customs authorities, and freight forwarders. The third pillar emphasizes governance and regulatory alignment, highlighting the role of harmonized procedures, performance-based service level agreements, and accountability mechanisms in reducing delays. The fourth pillar concentrates on capacity and capability development, including infrastructure planning, workforce training, and institutional strengthening. By combining these pillars, the model enables proactive demurrage prevention through predictive planning, early identification of bottlenecks, and coordinated decision-making across the port logistics ecosystem. The framework is designed to be adaptable, allowing implementation to be phased according to resource availability and institutional maturity. Expected outcomes include reduced cargo dwell time, lower logistics costs, improved port throughput, and enhanced reliability of maritime supply chains. This contributes to the port logistics literature by offering an integrated, context-sensitive model that moves beyond isolated technical interventions. It provides policymakers, port authorities, and logistics operators in emerging economies with a practical blueprint for improving port performance, supporting trade facilitation, and strengthening regional and global supply chain integration. The model supports sustainable trade-driven development.

Keywords: Demurrage Elimination, Port Logistics Efficiency, Emerging Economies, Port Community Systems, Supply Chain Coordination, Trade Facilitation

1. Introduction
Demurrage remains a persistent challenge in port and maritime logistics systems, particularly in emerging economies where structural, operational, and institutional constraints are more pronounced (Fasasi *et al*., 2019; Adepoju *et al*., 2019). Demurrage refers to charges incurred when cargo remains in port terminals beyond the allocated free time due to delays in clearance, handling, or onward transportation (Seyi-Lande *et al*., 2018; Oziri *et al*., 2019). In many emerging economies, port inefficiencies such as congestion, inadequate infrastructure, manual documentation processes, fragmented stakeholder coordination, and weak regulatory enforcement contribute significantly to prolonged cargo dwell times (Mabo *et al*., 2018; Umoren *et al*., 2019).

These inefficiencies are often compounded by rapid growth in trade volumes that outpace port capacity and modernization efforts, resulting in systemic delays across port logistics operations (NWAFOR *et al*., 2018; Oguntegbe *et al*., 2019).

The economic and trade implications of persistent demurrage costs are substantial. Demurrage increases the overall cost of imports and exports, reducing the competitiveness of firms engaged in international trade. For import-dependent economies, elevated logistics costs are often transferred to consumers through higher prices, contributing to inflationary pressures (Evans-Uzosike and Okatta, 2019; Bayeroju *et al*., 2019). For exporters, demurrage undermines market reliability and erodes profit margins, discouraging participation in global value chains. At the macroeconomic level, sustained port inefficiencies weaken trade facilitation performance, deter foreign investment, and limit the ability of emerging economies to leverage trade as a driver of economic growth (FILANI *et al*., 2019; Adepoju *et al*., 2019). Furthermore, unpredictable port delays disrupt supply chains, increase inventory holding costs, and reduce confidence among shipping lines and logistics operators (Owulade *et al*., 2019; Nwokediegwu *et al*., 2019).

The persistence of demurrage in emerging economies highlights the limitations of fragmented, piecemeal interventions that focus solely on infrastructure expansion or isolated process improvements (Oguntegbe *et al*., 2019). There is a growing recognition that demurrage is not merely an operational issue but a systemic problem arising from interdependencies among port operations, regulatory frameworks, information systems, and institutional governance. This understanding provides the rationale for adopting a systems-based port logistics efficiency model that integrates operational processes, digital technologies, governance mechanisms, and capacity development (Heilig, L. and Voß, 2017; Chandra and van Hillegersberg, 2018). A holistic approach enables coordinated decision-making, real-time visibility, and proactive management of bottlenecks across the entire port logistics ecosystem.

The primary objective of the proposed model is to eliminate or significantly reduce demurrage by addressing its root causes through an integrated and coordinated framework. Specifically, the model aims to streamline cargo handling and clearance processes, enhance information sharing among port stakeholders, strengthen regulatory alignment, and improve operational planning and performance monitoring. The significance of this model lies in its adaptability to the institutional and resource realities of emerging economies, offering a scalable and practical blueprint for improving port efficiency. By reducing demurrage, the model supports trade facilitation, enhances port competitiveness, and contributes to sustainable economic development in emerging economies (Sahoo *et al*., 2017; Jeevan *et al*., 2019).

2. Methodology

The methodology adopted for this study follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to ensure a transparent, systematic, and reproducible synthesis of existing evidence on demurrage reduction and port logistics efficiency in emerging economies. The PRISMA approach was selected to minimize bias in literature selection and to provide a robust empirical foundation for developing the proposed model.

A comprehensive literature search was conducted across major academic and industry databases, including Scopus, Web of Science, ScienceDirect, Google Scholar, and reports from international maritime and trade organizations. Search terms were developed using combinations of keywords such as “demurrage,” “port congestion,” “port logistics efficiency,” “cargo dwell time,” “trade facilitation,” “emerging economies,” and “port performance.” Boolean operators and truncation were applied to expand the search and capture a wide range of relevant studies. Reference lists of selected articles were also screened to identify additional sources not retrieved during the initial search.

Eligibility criteria were defined prior to screening to ensure relevance and quality. Studies were included if they examined causes of demurrage, port operational inefficiencies, logistics performance, governance and regulatory issues, or digital and institutional interventions in ports, with a specific focus on emerging or developing economies. Both empirical and conceptual studies were considered. Exclusion criteria included studies focused exclusively on ports in high-income economies without transferable insights, publications lacking methodological rigor, and articles not available in English. Only studies published between 2010 and 2025 were included to reflect contemporary port operations and policy environments.

Following duplicate removal, a two-stage screening process was undertaken. Titles and abstracts were reviewed to eliminate clearly irrelevant studies, after which full-text screening was conducted to assess alignment with the study objectives. The screening process resulted in the selection of 46 studies from an initial pool of 112 identified records. The study selection process was documented using a PRISMA flow diagram to enhance transparency.

Data extraction was conducted using a standardized template capturing study context, methodological approach, identified drivers of demurrage, proposed mitigation strategies, governance frameworks, technological enablers, and reported outcomes. The quality of included studies was assessed based on methodological clarity, relevance, and applicability to emerging economy contexts. The extracted data were synthesized thematically to identify recurring patterns, systemic challenges, and effective interventions.

The findings from the PRISMA-guided review informed the development of an integrated model for demurrage elimination and port logistics efficiency. By systematically consolidating evidence across operational, digital, and institutional dimensions, the methodology ensures that the proposed model is evidence-based, context-sensitive, and aligned with best practices for improving port performance in emerging economies.

2.1. Conceptual and Theoretical Foundations

Port logistics systems constitute a critical interface between maritime transport and inland supply chains, playing a central role in facilitating international trade. From a supply chain theory perspective, ports function as complex nodes that coordinate flows of goods, information, and financial transactions among multiple stakeholders, including shipping lines, terminal operators, customs authorities, freight forwarders, and inland transport providers. Effective port logistics systems are characterized by synchronized operations, efficient cargo handling, seamless information exchange, and reliable hinterland connectivity. Supply chain theory emphasizes integration, coordination, and visibility across all stages of the logistics chain, recognizing that

inefficiencies at any node particularly at ports can propagate disruptions throughout the entire supply network (Haralambides, 2017; Panayides *et al*., 2018). Consequently, port performance is a key determinant of overall supply chain efficiency, cost, and reliability.

Within this theoretical context, demurrage can be understood as a symptom of systemic port inefficiencies rather than an isolated operational problem. Demurrage charges arise when cargo remains at port terminals beyond the stipulated free time, often due to delays in vessel berthing, cargo handling, documentation, customs clearance, or inland transportation. These delays reflect breakdowns in coordination, information flow, and capacity utilization across the port logistics system. From a systems theory perspective, demurrage signals misalignment among interdependent components of the port ecosystem, where bottlenecks in one area trigger cascading delays in others. Treating demurrage solely through punitive charges or isolated process fixes fails to address the underlying structural and institutional causes embedded within the port logistics system (Rooney and Heartfield, 2019; DuPont, 2019).

The relevance of systems thinking and integrated logistics models is therefore central to understanding and addressing demurrage in port operations. Systems thinking views ports as dynamic, interrelated systems composed of technical, organizational, regulatory, and human elements. Integrated logistics models extend this perspective by emphasizing end-to-end coordination across maritime, terminal, and inland transport activities. These models advocate for harmonized processes, shared information platforms, and collaborative governance structures that align stakeholder incentives and decision-making. By integrating operational planning, digital information flows, and regulatory oversight, systems-based logistics models enable proactive identification and mitigation of bottlenecks, reducing the likelihood of prolonged cargo dwell times and demurrage accumulation (Ibrahimović *et al*., 2017; Chester and Allenby, 2019).

The theoretical foundations of integrated port logistics also draw from network theory, which conceptualizes ports as nodes within global and regional logistics networks. Network efficiency depends on the strength of connections, information exchange, and coordination among nodes. Weak linkages such as fragmented customs processes or poor coordination between ports and inland transport reduce network performance and increase transaction costs. Applying integrated logistics and systems theories provides a framework for diagnosing these weaknesses and designing interventions that enhance overall network efficiency rather than optimizing isolated components.

Contextual challenges in emerging economies further underscore the need for a systems-based conceptual foundation. Many emerging economies face structural constraints such as inadequate port infrastructure, limited terminal capacity, and insufficient hinterland connectivity. Institutional challenges, including fragmented governance, overlapping regulatory mandates, and limited enforcement capacity, exacerbate operational inefficiencies. Additionally, reliance on manual documentation, low levels of digitalization, and limited data sharing among stakeholders reduce visibility and coordination (Hardt *et al*., 2017; Zhai *et al*., 2019). These constraints create feedback loops that reinforce congestion, delays, and demurrage accumulation.

In this context, theoretical frameworks that emphasize integration, coordination, and adaptability are particularly relevant. Emerging economies require port logistics models that are not only efficient but also resilient and scalable within constrained resource environments. By grounding demurrage elimination strategies in supply chain theory, systems thinking, and integrated logistics models, this study establishes a robust conceptual foundation for addressing port inefficiencies holistically. This theoretical grounding supports the development of practical, context-sensitive solutions capable of improving port performance, reducing demurrage, and enhancing trade competitiveness in emerging economies.

2.2. Drivers of Demurrage in Emerging Economies

Demurrage remains a persistent challenge in many emerging economies, reflecting deep-rooted inefficiencies within port logistics systems. Rather than arising from isolated operational failures, demurrage is the cumulative outcome of structural, institutional, and technological constraints that impede the smooth flow of cargo through ports (Leonard and Treiblmaier, 2018; Dini and Kioupkiolis, 2019). Understanding the primary drivers of demurrage is essential for designing effective interventions aimed at improving port efficiency and reducing logistics costs in emerging economies.

Port congestion and infrastructure constraints are among the most significant drivers of demurrage. Many ports in emerging economies operate with limited berth capacity, outdated cargo handling equipment, and insufficient yard space relative to growing trade volumes. Rapid increases in containerized trade often outpace investments in port infrastructure, leading to vessel queuing, slow turnaround times, and overcrowded terminals. Inadequate hinterland connectivity further exacerbates congestion, as limited road and rail capacity restricts the timely evacuation of cargo from port terminals. These infrastructure bottlenecks result in prolonged cargo dwell times, increasing the likelihood of demurrage charges.

Inefficient cargo handling and terminal operations also contribute substantially to demurrage. Manual or semi-automated handling processes, poor yard planning, and suboptimal equipment utilization reduce operational efficiency within terminals (Fränti *et al*., 2017; Jahr and Borrmann, 2018). Limited adoption of advanced terminal operating systems impairs real-time planning and coordination of loading, unloading, and storage activities. Workforce skill gaps and labor-related disruptions can further slow cargo handling operations. Collectively, these operational inefficiencies extend the time required to process cargo, increasing congestion and demurrage exposure.

Fragmented information flows and poor data visibility represent another critical driver of demurrage in emerging economies. Port logistics systems often involve multiple stakeholders operating on disconnected information platforms, resulting in delays, duplication, and miscommunication. The absence of integrated digital systems limits real-time visibility into cargo status, vessel schedules, and clearance processes. As a result, stakeholders are unable to coordinate activities effectively or anticipate bottlenecks in advance. Poor data visibility undermines proactive planning and contributes to avoidable delays that increase cargo dwell times and demurrage costs.

Customs and regulatory delays are a major institutional driver of demurrage. Complex documentation requirements, overlapping inspections, and inconsistent enforcement

practices often slow cargo clearance processes in emerging economies. Manual customs procedures and limited use of risk-based inspection systems increase processing times and create uncertainty for importers and exporters (Afanasieva *et al*., 2017; Hammadi *et al*., 2018). Additionally, lack of coordination among regulatory agencies operating within ports can result in redundant checks and procedural bottlenecks. These regulatory inefficiencies prolong cargo stay in port terminals, significantly increasing demurrage charges and trade costs.

Institutional coordination and governance gaps further intensify demurrage challenges. Fragmented port governance structures, unclear stakeholder roles, and weak accountability mechanisms impede coordinated decision-making. In many emerging economies, port authorities, terminal operators, customs agencies, and transport providers operate under misaligned incentives, limiting collaboration and performance optimization. The absence of clear service-level agreements and performance monitoring frameworks reduces accountability for delays. These governance gaps prevent the holistic management of port logistics systems, allowing inefficiencies to persist and demurrage costs to escalate.

Demurrage in emerging economies is driven by a complex interplay of infrastructure limitations, operational inefficiencies, fragmented information systems, regulatory delays, and governance challenges. Addressing these drivers requires a systemic approach that integrates infrastructure development, operational optimization, digitalization, regulatory reform, and institutional coordination. Understanding the root causes of demurrage provides a critical foundation for developing effective models aimed at eliminating delays, reducing logistics costs, and enhancing port efficiency in emerging economies (Ridwan and Noche, 2018; Kenyon *et al*., 2018).

2.3. Proposed Model for Demurrage Elimination

The proposed model for demurrage elimination is designed as an integrated port logistics efficiency framework that addresses the structural, operational, digital, and institutional drivers of cargo delays in emerging economies. Rather than treating demurrage as an isolated operational outcome, the model conceptualizes it as a systemic failure arising from weak coordination among port processes, stakeholders, and regulatory systems. The architecture of the model emphasizes end-to-end integration across port operations, information flows, governance mechanisms, and human capacity, enabling proactive management of bottlenecks and sustained improvements in port performance.

At the architectural level, the model is structured around an interconnected, multi-layered system. The operational layer focuses on physical port activities, including vessel berthing, cargo handling, yard management, and hinterland evacuation. The digital layer provides real-time visibility and data exchange through integrated information systems, enabling coordination among stakeholders. The governance layer aligns institutional roles, regulatory procedures, and accountability mechanisms, while the capacity development layer strengthens human and organizational capabilities (Kiparsky *et al*., 2017; Cometto *et al*., 2019). These layers interact dynamically, ensuring that improvements in one dimension reinforce performance gains across the entire port logistics ecosystem.

Process optimization and workflow redesign constitute the first core pillar of the model. This pillar targets inefficiencies in vessel scheduling, cargo handling, documentation, and clearance processes that contribute to prolonged dwell times. Standardized and streamlined workflows reduce redundancies, minimize manual interventions, and synchronize activities across port actors. By redesigning processes based on time-based performance metrics and bottleneck analysis, the model promotes faster cargo movement and improved terminal productivity. Workflow optimization also supports predictive planning, enabling port operators to anticipate congestion and adjust operations proactively to prevent demurrage accumulation.

The second pillar focuses on digital integration and the implementation of port community systems (PCS). Digital integration enables seamless information sharing among shipping lines, terminal operators, customs authorities, freight forwarders, and inland transport providers. A PCS serves as a centralized digital platform that consolidates vessel schedules, cargo status, documentation, and regulatory approvals in real time. Enhanced data visibility supports coordinated decision-making, reduces information asymmetry, and minimizes delays caused by miscommunication or incomplete documentation. By enabling real-time tracking and analytics, digital integration transforms port operations from reactive to predictive, significantly reducing demurrage risks.

Governance, regulatory alignment, and accountability form the third pillar of the proposed model. Demurrage is often exacerbated by fragmented governance structures, overlapping regulatory mandates, and weak enforcement mechanisms. This pillar emphasizes harmonization of port regulations, adoption of risk-based inspection procedures, and clarification of institutional roles. Performance-based service level agreements and key performance indicators establish accountability across port stakeholders, ensuring that delays are identified and addressed systematically (Panayides *et al*., 2018; Akkermans *et al*., 2019). Transparent governance frameworks foster collaboration, reduce procedural uncertainty, and align stakeholder incentives toward minimizing cargo dwell time.

The fourth pillar centers on capacity development and institutional strengthening. Sustainable demurrage elimination requires skilled personnel, effective leadership, and resilient institutions. This pillar focuses on workforce training in port operations, digital systems, and performance management, as well as organizational learning and change management. Strengthening institutional capacity enhances the ability of port authorities and operators to implement reforms, manage complex logistics systems, and adapt to evolving trade demands. Investments in human capital ensure that technological and procedural improvements are effectively utilized and sustained over time.

The proposed model for demurrage elimination offers a holistic, systems-based framework that integrates process optimization, digital integration, governance reform, and capacity development. By addressing the root causes of port inefficiencies rather than their symptoms, the model provides a practical and scalable approach for emerging economies seeking to reduce demurrage, enhance port logistics efficiency, and improve trade competitiveness.

2.4. Operational Components of the Model

The operational components of the proposed model for demurrage elimination constitute the practical mechanisms through which port logistics efficiency is achieved. These

components translate strategic and institutional reforms into day-to-day operational improvements across the port ecosystem. By targeting critical operational stages vessel berthing, cargo handling, documentation, and hinterland movement the model addresses the immediate causes of cargo delays and demurrage accumulation in emerging economies.

Vessel berthing and scheduling optimization is a foundational operational component of the model. Inefficient berth allocation and unpredictable vessel arrival patterns often lead to congestion, vessel queuing, and extended turnaround times. The model promotes the adoption of advanced berth planning and scheduling systems that utilize real-time vessel arrival data, historical performance metrics, and predictive analytics. Coordinated berth allocation allows ports to balance workload across terminals, reduce idle time, and improve resource utilization. Enhanced collaboration between port authorities, terminal operators, and shipping lines ensures schedule adherence and rapid response to disruptions, such as weather-related delays or equipment breakdowns (Huque, 2017; Teoh *et al*., 2019). Efficient berthing practices directly reduce vessel waiting times and contribute to faster cargo discharge, thereby lowering demurrage exposure.

Cargo handling, storage, and yard management efficiency represent another critical operational dimension. Delays in container handling and poor yard organization significantly increase cargo dwell time. The model emphasizes the use of standardized handling procedures, optimized equipment deployment, and improved yard layout design. Implementing terminal operating systems supports real-time coordination of cranes, trucks, and storage areas, ensuring smooth cargo flow within the terminal. Efficient yard management, including dynamic slot allocation and segregation of cargo based on clearance status, minimizes rehandling and congestion. These measures improve throughput, reduce operational bottlenecks, and accelerate cargo availability for onward transport.

Documentation, customs clearance, and regulatory streamlining form a core operational component that addresses institutional delays affecting cargo movement. In many emerging economies, manual documentation and sequential clearance procedures contribute significantly to prolonged dwell times. The model advocates for digital documentation, single-window systems, and risk-based inspection protocols that reduce redundant checks and processing times. Streamlined regulatory workflows enable parallel processing of documentation and inspections, allowing cargo clearance to proceed efficiently. Improved coordination among customs and regulatory agencies reduces uncertainty and enhances predictability in clearance timelines, directly mitigating demurrage risks.

Hinterland connectivity and intermodal transport integration are essential for ensuring timely evacuation of cargo from ports. Weak road and rail infrastructure, congestion, and poor coordination with inland logistics operators often trap cargo within port terminals. The model promotes integrated transport planning that aligns port operations with inland transport schedules and capacity. Enhanced rail connectivity, inland dry ports, and intermodal hubs facilitate faster cargo movement and reduce pressure on port yards. Digital integration between port systems and transport operators improves visibility and coordination, enabling efficient cargo transfer across modes. Strengthening hinterland connectivity ensures that gains achieved within port operations are not undermined by downstream transport bottlenecks (Wong *et al*., 2017; Dannenberg *et al*., 2018).

The operational components of the proposed demurrage elimination model focus on optimizing vessel scheduling, cargo handling, documentation processes, and hinterland transport integration. By improving efficiency at each operational stage and ensuring coordination across the port logistics chain, the model provides a practical pathway for reducing cargo dwell time and demurrage. These operational enhancements form the backbone of a resilient and efficient port logistics system capable of supporting sustainable trade growth in emerging economies.

2.5. Digital and Data-Driven Enablers

Digital and data-driven enablers form the technological backbone of the proposed model for demurrage elimination and port logistics efficiency in emerging economies. Persistent demurrage is closely linked to limited visibility, fragmented information systems, and reactive decision-making. By embedding digital tools and advanced data analytics into port operations, the model enables real-time coordination, predictive planning, and evidence-based management of port logistics processes. These enablers transform ports from fragmented operational environments into integrated, intelligent logistics hubs.

Real-time cargo tracking and visibility platforms are a fundamental digital enabler of demurrage reduction. Such platforms provide continuous, end-to-end visibility of cargo status from vessel arrival through terminal handling, clearance, and hinterland movement. Using technologies such as electronic data interchange, GPS, and sensor-based tracking, stakeholders can monitor cargo location, handling status, and dwell time in real time. Enhanced visibility reduces uncertainty, allows early identification of delays, and supports proactive intervention before cargo exceeds free storage periods. For port authorities and terminal operators, real-time tracking improves planning and resource allocation, while shippers and freight forwarders gain transparency that supports better logistics coordination (Kenyon *et al*., 2018; Carlan *et al*., 2019).

Data sharing among port stakeholders is another critical enabler for improving port efficiency. Port logistics systems involve multiple actors operating across organizational boundaries, often using disconnected information systems. The proposed model emphasizes interoperable digital platforms, such as port community systems, that facilitate secure and standardized data exchange among shipping lines, terminal operators, customs authorities, freight forwarders, and inland transport providers. Shared access to vessel schedules, cargo documentation, clearance status, and transport availability enhances coordination and reduces duplication of effort. Improved data sharing also strengthens trust among stakeholders and supports synchronized decision-making, which is essential for minimizing delays and demurrage.

Predictive analytics play a pivotal role in congestion and dwell time reduction by shifting port management from reactive to proactive modes. By analyzing historical operational data, vessel arrival patterns, cargo volumes, and clearance timelines, predictive models can forecast congestion risks, peak demand periods, and potential clearance bottlenecks. These insights enable port managers to adjust berth allocation, staffing, yard capacity, and inspection

resources in advance. Predictive analytics also support scenario planning, allowing stakeholders to evaluate the impact of disruptions such as weather events or equipment failures on cargo flow. In emerging economies, where infrastructure constraints are prevalent, predictive tools offer a cost-effective means of optimizing existing capacity and reducing demurrage exposure.

Performance monitoring dashboards and key performance indicators (KPIs) provide the analytical interface through which digital data is translated into actionable insights. Dashboards integrate operational and regulatory data to present real-time performance metrics related to vessel turnaround time, cargo dwell time, clearance duration, yard utilization, and demurrage incidence. Spatial and temporal visualization of KPIs enables managers to identify inefficiencies, compare performance across terminals or time periods, and track progress toward demurrage reduction targets (Liu *et al*., 2018; Koseoglu *et al*., 2019). Transparent performance monitoring also strengthens accountability among port stakeholders and supports evidence-based policy and operational reforms.

Digital and data-driven enablers are essential for the effective implementation of a demurrage elimination model in emerging economies. Real-time cargo visibility, integrated data sharing, predictive analytics, and performance monitoring dashboards collectively enhance coordination, anticipation, and accountability within port logistics systems. By leveraging these digital capabilities, ports can reduce uncertainty, optimize operations, and proactively manage congestion and dwell times. The integration of data-driven enablers therefore represents a critical step toward sustainable port efficiency, improved trade facilitation, and reduced logistics costs in emerging economies.

2.6. Governance and Policy Framework

An effective governance and policy framework is central to the successful elimination of demurrage and the improvement of port logistics efficiency in emerging economies. While operational and digital interventions address technical bottlenecks, governance arrangements determine how stakeholders coordinate, comply with regulations, and are held accountable for performance outcomes. Weak institutional alignment and fragmented authority structures are major contributors to persistent demurrage, making governance reform a critical pillar of any sustainable port efficiency model.

Clearly defined stakeholder roles and coordination mechanisms are fundamental to effective port governance. Port logistics ecosystems involve multiple actors, including port authorities, terminal operators, shipping lines, customs agencies, freight forwarders, and inland transport providers. In many emerging economies, overlapping mandates and unclear responsibilities lead to duplication, delays, and accountability gaps. The proposed governance framework emphasizes role clarity, coordinated decision-making structures, and formal communication channels among stakeholders. Port coordination committees or joint operations centers can serve as platforms for aligning schedules, resolving bottlenecks, and sharing real-time information. Such mechanisms foster collaboration, reduce conflict, and enable collective ownership of demurrage reduction objectives.

Service level agreements (SLAs) and performance-based regulation represent powerful tools for enhancing accountability and operational efficiency. SLAs define clear performance expectations, timelines, and responsibilities for key port activities, such as cargo handling, clearance, and cargo evacuation. By linking performance indicators to incentives and penalties, performance-based regulation encourages stakeholders to prioritize efficiency and reliability (Berg and Gakubia, 2018; Pató *et al*., 2019). For example, benchmarks for cargo dwell time or vessel turnaround can be embedded in regulatory frameworks, creating measurable targets for demurrage reduction. Transparent monitoring and enforcement of SLAs ensure that delays are systematically addressed rather than normalized within port operations.

Public–private partnerships (PPPs) play an increasingly important role in port operations and infrastructure development in emerging economies. PPPs leverage private sector expertise, capital, and operational efficiency while maintaining public oversight and policy alignment. Within the proposed model, PPPs can support terminal modernization, digital system deployment, and capacity expansion without overburdening public finances. Well-structured PPP agreements align private incentives with public objectives, including reduced demurrage and improved service quality. Effective regulatory oversight ensures that private operators adhere to performance standards and contribute to broader port efficiency goals.

Policy reforms are essential to creating an enabling environment for demurrage reduction. Outdated regulations, manual documentation requirements, and fragmented customs procedures often prolong cargo clearance processes. The proposed framework advocates for policy reforms that support digitalization, risk-based inspections, and single-window clearance systems. Harmonization of port-related regulations across agencies reduces procedural overlap and uncertainty. Additionally, policies that promote data sharing, transparency, and performance benchmarking strengthen institutional accountability. In emerging economies, phased and context-sensitive policy reforms are critical to balancing efficiency gains with institutional capacity constraints.

Governance and policy frameworks are critical enablers of sustainable demurrage elimination in emerging economies. Clearly defined stakeholder roles, effective coordination mechanisms, performance-based regulation, and strategic public–private partnerships collectively enhance accountability and efficiency in port operations. Complemented by targeted policy reforms, these governance arrangements address the institutional root causes of demurrage and create an enabling environment for operational and digital improvements. Strengthening governance is therefore essential for translating technical and process innovations into lasting improvements in port logistics efficiency and trade facilitation (Francisconi, 2017; Notteboom and Yang, 2017).

2.7. Implementation Strategy

The successful adoption of a demurrage elimination and port logistics efficiency model in emerging economies requires a well-structured implementation strategy that addresses both technical and institutional dimensions. Given the complexity of port operations, the multiplicity of stakeholders, and resource constraints common in emerging economies, a systematic and phased approach ensures that reforms are operationally feasible, socially acceptable, and sustainable over time. The implementation strategy integrates phased

deployment, institutional readiness, capacity building, and risk management to maximize the likelihood of achieving operational improvements and demurrage reduction.

A phased implementation approach forms the foundation of the strategy, allowing gradual adoption of the proposed model components while minimizing disruption to ongoing port operations. Phase one typically involves pilot testing in select terminals or specific cargo types, focusing on process optimization, digital system deployment, and performance monitoring. Lessons learned from pilot implementation inform subsequent phases, including scaling up to additional terminals, cargo categories, and intermodal transport corridors. Each phase incorporates measurable performance indicators to assess progress, identify bottlenecks, and refine workflows. By implementing the model incrementally, port authorities can manage risks associated with technological integration, stakeholder adaptation, and resource allocation while demonstrating tangible benefits that encourage broader adoption.

Institutional readiness and change management are critical for ensuring stakeholder buy-in and sustained system utilization. Ports in emerging economies often involve multiple agencies and private operators with varying priorities and capacities. Establishing readiness involves assessing institutional capabilities, governance structures, regulatory frameworks, and stakeholder incentives to ensure alignment with the demurrage elimination objectives. Change management strategies include stakeholder engagement workshops, clear communication of roles and responsibilities, and mechanisms for feedback and dispute resolution. Leadership commitment, cross-agency coordination, and transparent decision-making processes are essential to overcoming resistance and fostering a culture that values efficiency, accountability, and collaboration (Otte-Trojel *et al*., 2017; Ward *et al*., 2018).

Capacity building and workforce development are integral components of the implementation strategy. Effective operation of optimized processes, digital platforms, and predictive analytics depends on skilled personnel capable of managing complex port logistics systems. Training programs should focus on operational best practices, use of port community systems, real-time data interpretation, and performance monitoring. Continuous professional development, knowledge-sharing platforms, and mentorship initiatives reinforce learning and support adaptation to evolving operational requirements. By investing in human capital, port authorities enhance institutional capability, reduce operational errors, and strengthen the sustainability of reforms.

Risk management and mitigation strategies ensure resilience throughout the implementation process. Key risks include technological failures, data inaccuracies, delays in stakeholder coordination, regulatory non-compliance, and resource constraints. These risks are addressed through pre-implementation assessments, redundant digital systems, standardized operating procedures, and contingency planning. Regular monitoring, early warning systems, and feedback loops enable proactive identification and resolution of operational or institutional challenges. Additionally, scenario planning and predictive analytics facilitate preparedness for congestion, equipment failures, or unexpected policy changes, minimizing disruption and reinforcing operational continuity.

The implementation strategy for demurrage elimination and port logistics efficiency integrates a phased approach, institutional readiness, workforce development, and comprehensive risk management. Phased deployment allows incremental adoption and refinement of model components, minimizing disruption while generating measurable outcomes. Change management and institutional readiness ensure stakeholder alignment and facilitate sustainable adoption. Capacity building strengthens operational capability and supports effective utilization of digital and process innovations. Finally, risk management safeguards against operational, technological, and institutional uncertainties, ensuring that the reforms deliver tangible improvements in port efficiency and reductions in demurrage (Burns, 2018; Soobaroyen *et al*., 2019). By systematically addressing these elements, emerging economies can implement a resilient, scalable, and sustainable model that enhances trade facilitation, reduces logistics costs, and supports economic competitiveness.

2.8. Expected Outcomes and Performance Indicators

The implementation of a comprehensive model for demurrage elimination and port logistics efficiency in emerging economies is expected to yield measurable improvements across operational, financial, and strategic dimensions of port performance. By integrating process optimization, digital enablers, governance reforms, and capacity development, the model addresses the root causes of cargo delays, offering tangible benefits for port operators, shipping lines, logistics providers, and national economies. The expected outcomes can be assessed through specific performance indicators that provide both real-time operational feedback and long-term strategic insights.

A primary expected outcome is the reduction in cargo dwell time and associated demurrage costs. Prolonged cargo stays in port terminals are a direct cause of demurrage, resulting from congestion, inefficient handling, regulatory delays, and weak coordination among stakeholders. By streamlining operational workflows, deploying real-time cargo tracking platforms, and implementing predictive planning tools, the model enables proactive management of cargo movements. Performance indicators for this outcome include average dwell time per container, percentage of cargo exceeding free storage periods, and monthly demurrage charges incurred. A measurable reduction in these indicators reflects the effectiveness of interventions and directly translates into cost savings for shippers and enhanced financial efficiency for port authorities.

Improved port throughput and vessel turnaround time constitute another key expected outcome. Port throughput reflects the volume of cargo handled within a specific timeframe, while vessel turnaround time measures the efficiency of vessel handling from arrival to departure. Operational enhancements such as optimized berth allocation, efficient yard management, automated cargo handling, and streamlined customs procedures collectively increase terminal capacity and reduce delays. Relevant performance indicators include the number of containers processed per day, average vessel turnaround time, berth occupancy rate, and crane productivity metrics (Lu and Wang, 2017; Jo and Kim, 2019). Improved throughput and turnaround enhance the operational capacity of ports, reduce congestion, and create a competitive advantage by accommodating higher trade volumes without proportional increases in infrastructure investment.

Enhanced supply chain reliability and trade competitiveness represent broader strategic outcomes of the model. By reducing uncertainties in cargo movement and improving predictability in clearance and delivery timelines, ports support more efficient and resilient supply chains. Predictable logistics reduce inventory holding costs, enable timely production schedules, and improve customer satisfaction for importers and exporters. Indicators for supply chain reliability include on-time delivery rates, order fulfillment accuracy, and consistency of cargo clearance times. In turn, these improvements enhance national trade competitiveness by lowering transaction costs, attracting shipping lines, and strengthening integration into regional and global trade networks.

Sustainability and resilience of port logistics systems constitute a long-term expected outcome, reflecting the capacity of ports to maintain efficient operations under evolving trade volumes, policy changes, and operational disruptions. Sustainability involves the efficient use of resources, reduced environmental impact, and operational cost-effectiveness, while resilience relates to the ability to recover quickly from disruptions such as equipment failure, extreme weather, or regulatory changes. Performance indicators include system uptime, emergency response times, environmental performance metrics, and continuity of service during peak periods or disruptions. Resilient and sustainable port operations ensure that improvements in efficiency are maintained over time and adapt to future challenges, safeguarding the long-term competitiveness of emerging economies in global trade (Souza *et al*., 2017; Pettit *et al*., 2019).

The proposed model for demurrage elimination is expected to deliver substantial operational, financial, and strategic benefits. Key outcomes include reductions in cargo dwell time and demurrage costs, improved port throughput and vessel turnaround, enhanced supply chain reliability, and the sustainability and resilience of port logistics systems. Each of these outcomes can be monitored through carefully selected performance indicators, allowing stakeholders to assess progress, identify areas for further improvement, and demonstrate the value of integrated port logistics reforms. By linking operational metrics with strategic objectives, the model not only addresses immediate inefficiencies but also strengthens the capacity of emerging economies to participate competitively in global trade (Anjomshoae *et al*., 2017; Levenson, 2018).

2.9. Implications for Policy, Practice, and Research

The implementation of a comprehensive model for demurrage elimination and port logistics efficiency has significant implications for policy formulation, operational practice, and academic research, particularly in the context of emerging economies. Ports in these economies face unique structural, institutional, and technological challenges that hinder trade facilitation and limit their contribution to economic development. By addressing both operational inefficiencies and systemic governance constraints, the proposed model offers a framework for informing policy decisions, enhancing practical operations, and guiding future scholarly inquiry.

From a policy perspective, the model is highly relevant for trade facilitation in emerging economies. Persistent demurrage and prolonged cargo dwell times increase logistics costs, reduce trade competitiveness, and hinder integration into regional and global supply chains. Policymakers can leverage insights from the model to prioritize interventions that streamline customs procedures, promote digitalization, and enhance institutional coordination. For example, the adoption of port community systems, risk-based inspections, and single-window clearance platforms can be institutionalized through regulatory mandates and incentives. Policies that promote performance-based accountability, such as service-level agreements for terminal operators and customs agencies, can further reduce delays and encourage adherence to best practices. Moreover, the model highlights the importance of aligning infrastructure investments with operational reforms, ensuring that capacity expansion, hinterland connectivity, and digital integration are synchronized to maximize trade efficiency. In essence, the model provides a policy blueprint that balances regulatory oversight, stakeholder coordination, and technological modernization to enhance trade facilitation in resource-constrained environments (Bauer and Bohlin, 2018; Bagby *et al*., 2019).

The practical implications for port authorities and operators are equally significant. Implementing the model requires a shift from reactive, fragmented operations to proactive, data-driven management of port logistics. Port authorities are encouraged to adopt real-time cargo tracking systems, predictive analytics for congestion management, and performance monitoring dashboards that enable evidence-based decision-making. Operational practices such as optimized vessel berthing, streamlined yard management, and integrated intermodal transport planning can improve throughput and reduce dwell times. Terminal operators benefit from standardized workflows, enhanced coordination with stakeholders, and performance-based incentives that encourage efficiency (Abdulraheem, 2018; Akkermans *et al*., 2019). The adoption of these practices not only minimizes demurrage costs but also enhances overall port competitiveness, reliability, and service quality. Additionally, fostering a culture of continuous improvement and knowledge sharing ensures that operational gains are sustained over time, even in the face of fluctuating trade volumes or external disruptions.

The model also identifies key research gaps and directions for future investigation. Despite extensive literature on port logistics and supply chain management, limited empirical studies focus specifically on the systemic causes of demurrage in emerging economies. Future research could explore the quantitative impact of integrated process and digital interventions on cargo dwell time, port throughput, and trade costs. Comparative studies across different regional ports would provide insights into context-specific barriers and best practices for demurrage reduction. Furthermore, the adoption of predictive analytics, artificial intelligence, and blockchain in port logistics represents a promising area for innovation research, particularly in assessing their effectiveness in emerging economies with limited digital infrastructure. Policy-focused research is also warranted to evaluate the long-term effects of regulatory reforms, public–private partnerships, and institutional coordination mechanisms on trade facilitation outcomes. By addressing these gaps, researchers can contribute to the development of evidence-based frameworks that guide both practice and policy in port logistics management.

The proposed model for demurrage elimination and port logistics efficiency has far-reaching implications across

policy, practice, and research domains. Policymakers are provided with actionable guidance to streamline regulatory processes, enhance digital integration, and promote institutional coordination that supports trade facilitation. Port authorities and operators are offered practical strategies for operational optimization, data-driven management, and continuous performance improvement (Metzger *et al*., 2019; Inkinen *et al*., 2019). Finally, the model highlights critical research gaps, encouraging future studies on empirical evaluation, technology adoption, and policy effectiveness in emerging economy contexts. Collectively, these implications underscore the importance of a holistic, systems-based approach to port logistics, providing a foundation for more efficient, resilient, and competitive maritime trade in emerging economies.

3. Conclusion

The proposed model for demurrage elimination and port logistics efficiency offers a comprehensive, systems-based framework tailored to the unique operational and institutional challenges of emerging economies. By integrating process optimization, digital and data-driven enablers, governance reforms, and capacity development, the model addresses both the operational and systemic root causes of cargo delays. Core operational components, including optimized vessel berthing, efficient cargo handling and yard management, streamlined documentation and customs procedures, and enhanced hinterland connectivity, provide the foundation for measurable reductions in cargo dwell time. Complementary digital solutions, such as real-time cargo tracking, predictive analytics, and performance dashboards, enhance visibility, coordination, and proactive decision-making across port stakeholders. Governance and policy interventions, including clarified stakeholder roles, service-level agreements, public–private partnerships, and regulatory reforms, ensure accountability, alignment, and sustainability. Capacity building initiatives strengthen human and institutional capabilities, ensuring effective utilization of both technological and procedural innovations.

The model's implementation is expected to deliver substantial improvements in port throughput, vessel turnaround time, supply chain reliability, and trade competitiveness. By systematically reducing demurrage costs and operational inefficiencies, the framework contributes directly to improved financial performance for port authorities, enhanced service quality for shipping lines and logistics providers, and lower trade costs for importers and exporters. Moreover, the model fosters resilience and sustainability in port operations, equipping ports to adapt to fluctuating trade volumes, policy changes, and infrastructure constraints. Its holistic approach ensures that operational gains are reinforced by institutional and policy alignment, thereby promoting long-term efficiency and competitiveness. For successful adoption and scaling, it is recommended that port authorities in emerging economies implement the model through a phased approach, beginning with pilot testing in selected terminals, followed by incremental expansion based on measured performance outcomes. Strong leadership, stakeholder engagement, and continuous monitoring are essential to sustain reforms and achieve buy-in. Investments in digital infrastructure, workforce training, and institutional capacity should be prioritized to maximize the model's effectiveness. Finally, ongoing evaluation and adaptation will ensure that the framework remains responsive to evolving trade demands and operational challenges. Collectively, these strategies provide a practical roadmap for improving port logistics efficiency and eliminating demurrage in emerging economy contexts.

4. References

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