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ASSESSMENT OF THE IMPACT OF AUTOMATED CARGO HANDLING SYSTEMS ON THE EFFICIENT CARGO OPERATIONS

By

Michael Mkumba Mjunguli[1], Dr. Meli Mbeba[2]

[1,2]Master's in Maritime Transport and Nautical Science at Dar es Salaam Maritime Institute, P.O. BOX 6727, Dar es Salaam-Tanzania

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Abstract

This study assessed the impact of automated cargo handling systems (ACHS) on cargo operations efficiency at Dar es Salaam Port. It specifically examined the systems' role in reducing cargo congestion, enhancing customer satisfaction, and the challenges encountered in automation implementation. A sample of 60 respondents, including port operators, customs officials, shipping agents, and terminal staff, participated in the study. Using a mixed-methods approach, data were collected through questionnaires, interviews, and documentary reviews. Descriptive statistics, regression analysis, and reliability tests were employed to analyze the data. The findings indicate that the Automated Cargo Handling System significantly improved cargo operations. Over 90% of respondents reported that automated cranes, terminal management systems, and Radio Frequency Identification (RFID) tracking reduced cargo handling times, minimized container delays, and enhanced logistical coordination. Regression results showed that cargo congestion reduction and customer satisfaction are significant predictors of effective automation, explaining 64.2% of the variation in ACHS performance. Automation also improved gate throughput, payment processing, and stakeholder communication, aligning the port with global standards for efficient operations. Despite these operational gains, 98.33% of respondents identified major implementation challenges, including inadequate regulatory frameworks, technical failures, limited staff training, system integration gaps, and infrastructure constraints. Interview findings reinforced these challenges and recommended policy reforms, targeted training, and infrastructural investment to ensure sustainable automation. Overall, the study concludes that ACHS has significantly enhanced cargo efficiency and customer satisfaction at Dar es Salaam Port, but strategic interventions are required to overcome institutional and technical barriers for long-term operational success.

Keywords: *Automated System, Automated Cargo Handling Systems, Efficient Cargo Operations, Customer Satisfaction*

Introduction

Automated cargo handling systems have transformed port operations around the world, leading to notable gains in efficiency, cost savings, and environmental sustainability. Major ports like Rotterdam and Singapore have implemented advanced automation technologies, such as automated stacking cranes, robotic systems for container handling, and terminal management software, to improve their operations. Research by Kon et al. (2021) indicated that automated container terminals boost productivity by minimizing manual tasks and optimizing the flow of cargo, which is essential for meeting the increasing demands of global trade. These systems also help reduce operational delays and enhance resource use, making them vital for contemporary port management.

In developing regions, the uptake of automated systems has been slower due to financial limitations and a lack of technical skills. Nevertheless, studies indicate that automation can greatly benefit ports in these areas by tackling issues like congestion and inefficiencies. For example, research conducted during the COVID-19 pandemic showed that fully automated container terminals had better performance in terms of throughput and ship turnaround times compared to non-automated terminals. This highlights the resilience and adaptability of automated systems in overcoming disruptions and ensuring stable operations during challenging times. Ports

*Corresponding Author: **Michael Mkumba Mjunguli**

in Africa, such as Dar es Salaam, can use these findings to improve their cargo handling capabilities and enhance their competitiveness in global trade (Porteconomics, 2023).

Automated cargo handling systems are increasingly recognized as pivotal instruments for improving port efficiency globally, with their implementation gaining traction in Africa. Various ports on the continent, such as those in Durban and Mombasa, have started to incorporate automation technologies to tackle problems like congestion, delays, and operational inefficiencies. The study by Muro et al. (2024) emphasized that automated systems, including container cranes and Radio Frequency Identification (RFID) tracking, can significantly enhance cargo flow and alleviate operational bottlenecks. These innovations are especially pertinent for African ports, which frequently contend with infrastructure challenges and rising demands from international trade. By embracing automation, ports can boost their competitiveness and support regional economic development.

Customer satisfaction serves as a crucial result of effective cargo operations, as the ultimate beneficiaries of automation are port users, including shipping companies, freight forwarders, and import/export businesses (Magenge, 2020). Automated cargo handling systems help decrease dwell times, lessen documentation mistakes, and facilitate real-time cargo tracking, which all contribute to enhancing the user experience at the port. The timely, dependable, and transparent services that customers receive reflect the efficiency of the port's operations; thus, customer satisfaction is intertwined with the benefits stemming from automation at Dar es Salaam Port.

Historically, issues such as delays, congestion, and manual mistakes at Dar es Salaam Port have compromised customer trust. However, by integrating automated technologies like RFID tracking, electronic data interchange (EDI), and automated cranes, the port can resolve these operational challenges and offer quicker and more reliable services (James, 2021). Increased satisfaction among users indicates that automation is fulfilling its objective of boosting efficiency. Consequently, customer satisfaction serves as both an indicator of operational efficiency and a catalyst for maintaining the port's competitiveness in regional and international trade.

The pace of adopting automated systems in Tanzania has lagged behind global trends; however, recent research underscores their potential advantages. For example, Mapunda (2020) examined factors influencing cargo handling at Dar es Salaam Port and identified automation as a pivotal solution for enhancing port efficiency. The study pointed out that automated technologies, such as electronic data interchange (EDI) and Radio Frequency Identification (RFID) tracking, can significantly decrease cargo dwell times and optimize storage capabilities. Despite these benefits, the implementation of such systems has been impeded by financial limitations, technical obstacles, and resistance from various stakeholders, which restricts the port's capacity to fully exploit automation.

Beyond operational efficiency, automated cargo handling systems can greatly enhance customer satisfaction among port users. Research by Muro et al. (2024) demonstrated that automation improves transparency, minimizes errors, and accelerates cargo clearance processes. These enhancements are particularly vital for Dar es Salaam Port, which acts as a crucial transit hub for goods heading to neighboring countries. By embracing automation, the port can reinforce its status as a regional trade center and contribute to Tanzania's economic development. However, the study also identified challenges such as insufficient training and support for personnel involved in the transition to automated systems.

Literature Review

Automated System

Automated systems in port operations are technology-driven platforms designed to reduce manual effort in cargo handling and clearance (Msheiz, 2020). Examples include automated cranes, Terminal Management Systems (TMS), Radio Frequency Identification (RFID) tracking, Electronic Data Interchange (EDI), and electronic payment systems. These systems support real-time monitoring, accurate documentation, fewer human errors, and better communication among stakeholders.

Automated Cargo Handling Systems

Automated cargo handling systems involve the integration of cutting-edge technology and machinery, including robotic cranes, electronic tracking systems, and terminal management software, to enhance the efficiency of loading, unloading, and overseeing cargo operations at ports. These systems aim to boost productivity, decrease reliance on manual labor, and optimize operational workflows within the maritime industry (McGrew, 2023).

Efficient Cargo Operations

Efficient cargo operations are characterized by the seamless and prompt transfer of goods within a port or logistics terminal, effectively reducing delays, congestion, and operational hindrances. The level of efficiency is assessed through various metrics, such as cargo throughput, dwell time, and customer satisfaction, which collectively reflect the effectiveness and dependability of cargo handling activities (Prosertek, 2021).

Customer Satisfaction

Customer satisfaction pertains to the degree to which users of port services including shipping companies, freight forwarders, and logistics providers evaluate the quality, efficiency, and responsiveness of operations. This metric serves as a vital indicator of service excellence and significantly influences the reputation and competitive edge of a port (Michael, 2021).

*Corresponding Author: **Michael Mkumba Mjunguli**

Theoretical Review

Resource-Based View (RBV)

The Resource-Based View (RBV) is a strategic management framework introduced by Jay Barney in 1991. It posits that a firm's competitive advantage stems from its distinctive resources and capabilities, which must be valuable, rare, inimitable, and non-substitutable, as outlined in the VRIN framework. RBV prioritizes internal resources, including human capital, technology, and organizational processes, over external market factors.

In the context of this research, RBV is related as it underscores the significance of utilizing automated cargo handling systems as a strategic asset to improve operational efficiency at Dar es Salaam Port. By implementing automation technologies, the port can secure a competitive advantage through optimized cargo operations, reduced congestion, and enhanced customer satisfaction, in line with RBV principles.

Technology Acceptance Theory

The Technology Acceptance theory, formulated by Fred Davis in 1989, is a theory within information systems that elucidates how users come to accept and utilize technology. Technology acceptance theory highlights two primary factors that affect technology adoption: perceived usefulness (the extent to which a user believes the technology improve their performance) and perceived ease of use (the degree to which a user finds the technology simple to operate).

This theory is relevant to the current study as it offers a framework for examining the adoption of automated cargo handling systems at Dar es Salaam Port. By evaluating port users' perceptions regarding the usefulness and ease of use of automation technologies, the research can identify obstacles to adoption and suggest strategies to enhance acceptance, thereby facilitating successful implementation and improved operational efficiency.

Empirical Review

Studies from Developed Countries

Extensive empirical research from developed nations has investigated the implementation and effects of automated cargo handling systems on port efficiency. For example, a study by Kon et al. (2021) analyzed fully automated container terminals across Europe and Asia, revealing their capacity to significantly lower operational costs and enhance cargo throughput. These systems, which encompass automated stacking cranes and robotic container handling, have demonstrated their effectiveness in optimizing resource use and reducing human error. The research highlighted that automation not only boosts operational efficiency but also promotes environmental sustainability by decreasing energy consumption and emissions.

In the United States, investigations have centered on the incorporation of cutting-edge technologies such as artificial intelligence (AI) and the Internet of Things (IoT) within port operations. A report from the Government Office for Science (2020) indicated that ports employing AI-driven systems achieved quicker cargo clearance and enhanced decision-making capabilities. These technologies facilitate real-time tracking and predictive analytics, enabling ports to foresee and mitigate potential bottlenecks. The results emphasize the critical role of technological advancement in sustaining competitiveness in the global trade arena.

Likewise, studies conducted in Japan have illustrated the success of automation in mitigating labor shortages and enhancing safety within port operations. The widespread adoption of automated guided vehicles (AGVs) and remote-controlled cranes in Japanese ports was underscored in a 2022 study. These systems not only lessen reliance on manual labor but also improve accuracy and dependability in cargo handling. Furthermore, the research indicated that automation has allowed ports to sustain high productivity levels even amid disruptions such as the COVID-19 pandemic.

In Europe, the Port of Rotterdam exemplifies the successful implementation of automation in port operations. Research indicates that the port's integration of automated terminal systems has led to notable enhancements in cargo handling efficiency and increased customer satisfaction. Additionally, the utilization of digital communication platforms among stakeholders has optimized operational processes. A study conducted in 2021 underscored that the combination of automation and digitalization is essential for achieving sustainable and efficient management of port activities.

Empirical research from developed nations offers critical insights into the advantages and obstacles associated with automated cargo handling systems. These investigations underscore the necessity of strategic planning, collaboration among stakeholders, and investment in cutting-edge technologies to facilitate effective implementation. The insights gained from these experiences can inform ports in developing nations, such as Dar es Salaam Port, in their efforts to improve operational efficiency and enhance their competitiveness in the global marketplace.

Studies from Developing Countries

Empirical research conducted in developing nations has illuminated both the challenges and prospects linked to the implementation of automated cargo handling systems in ports. For example, Magenge's (2020) study in Tanzania assessed the effects of containerized cargo handling on the logistics performance of the Tanzania Ports Authority. The findings indicated that while containerization facilitated cargo movement and minimized delays, the absence of sophisticated automation technologies constrained the overall efficiency of port operations. This highlights the necessity for increased investment in automation to mitigate ongoing bottlenecks and bolster competitiveness in international trade.

In Kenya, investigations have centered on the Port of Mombasa, a vital trade center for East Africa. A 2021 study revealed that semi-automated systems, including electronic cargo tracking and partial mechanization, enhanced cargo clearance times and alleviated congestion. Nonetheless, the research also pointed out challenges such as insufficient infrastructure, elevated implementation costs, and resistance

from various stakeholders. These results underscore the significance of engaging stakeholders and adopting phased implementation strategies to facilitate the successful integration of automation technologies.

In Nigeria, empirical studies have examined the impact of automation on mitigating inefficiencies at the Port of Lagos. A study by James, (2022) found that the implementation of automated gate systems and electronic payment platforms markedly decreased corruption and enhanced transparency in cargo handling operations. However, the research also identified obstacles such as a lack of technical expertise and an unreliable power supply, which impeded the full realization of the benefits of automation. These challenges indicate a pressing need for capacity building and infrastructure enhancement to support sustainable automation initiatives.

South Africa serves as a notable case study, particularly with its ports like Durban, which have made remarkable advancements in the implementation of sophisticated automation technologies. A study by Johansen (2023) indicated that fully automated container terminals in Durban enhanced cargo throughput and lowered operational expenses. The research credited this achievement to strong governmental backing, well-developed infrastructure, and comprehensive training initiatives for port staff. These results illustrate the transformative potential of automation in port operations, provided there is sufficient resource allocation and strategic foresight.

Empirical research from developing nations reveals a variety of experiences and obstacles related to port automation. While certain countries have successfully embraced automated systems, others encounter significant challenges that hinder their effectiveness. These studies emphasize the necessity for customized solutions, which include collaboration among stakeholders, capacity enhancement, and gradual implementation, to facilitate the successful adoption of automation technologies in developing areas.

Local studies in Tanzania

Empirical research in Tanzania has shed light on the various challenges and opportunities linked to the implementation of automated cargo handling systems in ports. For example, Mapunda (2020) examined the determinants of port performance at Dar es Salaam Port, emphasizing how automation can alleviate cargo congestion. The findings indicated that although some semi-automated solutions, like electronic tracking, have been implemented, their effectiveness is constrained by outdated infrastructure and a lack of integration with other port operations. This situation highlights the necessity for a more comprehensive approach to automation to rectify operational inefficiencies and enhance cargo handling procedures.

In another investigation, Magenge (2020) assessed the effects of containerized cargo handling systems on the logistics performance of the Tanzania Ports Authority. The results indicated that containerization has facilitated better storage and cargo movement; however, the absence of advanced automation technologies limits the port's capacity to satisfy increasing trade demands. The study advocated for the implementation of automated cranes and terminal management systems to boost efficiency and minimize delays. These suggestions are consistent with global trends in port automation, underscoring the critical role of technological advancements in enhancing logistics performance.

Additionally, research by Muro et al. (2024) examined how automation contributes to customer satisfaction at Dar es Salaam Port. The study revealed that automated systems, including electronic payment platforms and cargo tracking, have enhanced transparency and decreased errors in cargo handling. Nonetheless, it also pointed out challenges such as a lack of technical expertise and resistance from stakeholders, which impede the successful deployment of automation technologies. These insights underscore the importance of capacity building and stakeholder engagement to facilitate the effective integration of automated systems.

Ndaki et al. (2023) investigated the regulatory frameworks that affect the adoption of automation technologies in Tanzanian ports. Their findings indicated that, although current policies are conducive to technological progress, the enforcement and adherence to these regulations are insufficient. The authors suggested enhancing regulatory structures and promoting cooperation among government entities, port authorities, and technology providers to mitigate obstacles to automation. These recommendations are vital for tackling the challenges that Dar es Salaam Port faces in implementing automated cargo handling systems.

Furthermore, research has underscored the economic advantages of automation for ports in Tanzania. For instance, Kihwele and Selemani (2020) found that automated systems lead to lower operational costs and increased energy efficiency, thereby supporting sustainable development. Their study highlighted the necessity of investing in affordable technologies and training initiatives to enhance technical skills and facilitate the shift towards automation. These results emphasize the transformative potential of automation in port operations and its role in boosting competitiveness in the global trade arena.

Empirical research from Tanzania offers a thorough understanding of the elements that influence the adoption and effects of automated cargo handling systems. It stresses the importance of strategic planning, collaboration among stakeholders, and investment in cutting-edge technologies to resolve operational inefficiencies and enhance port performance. By utilizing these insights, Dar es Salaam Port can formulate a strategic plan for the integration of automation and the realization of efficient cargo operations.

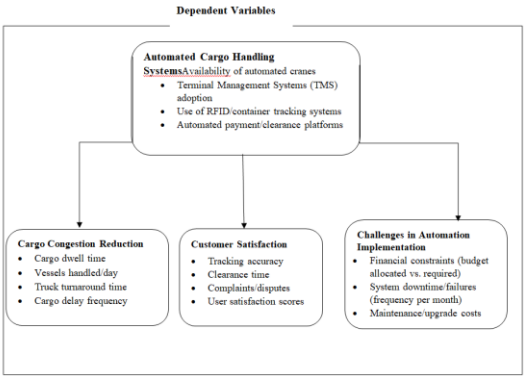
Research Gap

Despite notable advancements in understanding the advantages and challenges of automated cargo handling systems, significant research gaps persist, especially in developing countries like Tanzania. For instance, while Mapunda (2020) and Magenge (2020) pointed out the operational inefficiencies at Dar es Salaam Port and suggested

automation, their studies did not thoroughly analyze how specific technologies, such as automated cranes or terminal management software, could alleviate cargo congestion. The current study aims to fill these gaps by thoroughly investigating how specific automated systems can reduce congestion and enhance customer satisfaction at Dar es Salaam Port. Another area that requires attention is the limited examination of the obstacles to implementing automated systems in resource-limited environments. Muro et al. (2024) identified resistance from stakeholders and a lack of technical skills as major challenges, but their study did not propose specific solutions to tackle these issues. Similarly, Ndaki et al. (2023) looked into regulatory frameworks but did not provide empirical evidence on how these policies affect the adoption of automation at Dar es Salaam Port. This study address these issues by engaging stakeholders through interviews and workshops to understand their concerns and build agreement on the need for automation. An additional research gap is identified in the examination of customer satisfaction concerning port automation. Although Muro et al. (2024) indicated that automation could improve transparency and minimize errors, their study did not comprehensively assess the views of port users or quantify satisfaction levels. This absence of empirical evidence hinders the ability to make definitive conclusions regarding the advantages of automation for end-users. By integrating their insights, the research seeks to offer a comprehensive understanding of how automation influences customer experience at Dar es Salaam Port.

To tackle the identified gaps, the researcher adopt a thorough and customized methodology throughout the investigation. Initially, addressing the insufficient analysis of specific automation systems and their effects on cargo congestion at Dar es Salaam Port, the researcher perform field observations to evaluate the current cargo handling procedures directly. These observations facilitate an analysis of how specific automation technologies, including automated cranes and Radio Frequency Identification (RFID) tracking systems, can enhance operational efficiency and alleviate bottlenecks. Therefore this study will assess critically the impacts of automated systems on the efficient cargo operations and to come up with best ways of improving cargo operations.

Conceptual Framework



Independent variables

Figure 1: Conceptual Framework

Source: *Authors illustration, (2025)*

The independent variable related to automated cargo handling systems was defined through various measurable technological components, specifically automated cranes, Terminal Management Systems (TMS), Radio Frequency Identification (RFID) tracking, and automated payment platforms. These components were identified through existing literature and confirmed via field observations at Dar es Salaam Port, where they represent the most important automation efforts currently implemented. To assess their impact, the study crafted structured survey questions and interview frameworks that explored stakeholders' experiences with these technologies in connection to operational efficiency. This approach ensured that the variable was treated not as a vague idea but as a collection of specific systems with concrete operational results.

Methodology

The research employed a mixed-methods approach to examine how technology integration influences the operational efficiency of Dar es Salaam Port. Dar es Salaam Port was chosen due to its role in managing over 90% of Tanzania's international trade and its importance as a key hub for neighboring landlocked countries. The study's target population comprised 71 stakeholders, including port officials, customs personnel, shipping agents, and terminal operators. By applying Yamane's (1967) formula with a 5% margin of error, the research achieved a representative sample of 60 participants. Stratified sampling was utilized to ensure diverse representation across various job categories, while purposive sampling focused on individuals with specific expertise in port operations. Recent research encourages the use of mixed-method designs in port studies to enhance both generalizability and contextual insights (Creswell & Creswell, 2021; Kassa & Asmare, 2023).

For data collection, the research utilized semi-structured interviews, structured questionnaires, and documentary analysis. The semi-structured interviews provided comprehensive qualitative insights from 50 participants, whereas the questionnaires distributed to 60 respondents offered quantifiable data regarding port efficiency and technology adoption. Additionally, a review of documents such as port performance reports, policy papers, and academic articles enriched the primary data by providing historical and contextual information. The combination of qualitative and quantitative methods aligns with recent studies advocating for methodological triangulation to enhance the reliability and validity of results (Saunders et al., 2019; Zhang & Huang, 2022). Data analysis was carried out using SPSS for descriptive statistics and regression modeling, while qualitative data underwent thematic analysis to identify recurring themes.

The study reinforced validity and reliability through triangulation, expert instrument reviews, and a pilot test of the questionnaire before full deployment. Reliability was further enhanced by standardizing data collection procedures. Ethical considerations were maintained by securing informed consent,

ensuring confidentiality, and obtaining official ethical clearance. In contemporary social science and port research, the importance of ethical rigor and methodological consistency has been emphasized (Bazeley, 2021; Chinomona & Sandada, 2022). These measures guaranteed that the methodology was scientifically sound, ethically validated, and appropriate for producing reliable evidence for both policy-making and academic discussions.

Research Results

The study highlights a strong agreement among stakeholders that automation has significantly enhanced operations at Dar es Salaam Port. Key technological advancements, including automated cranes, terminal management systems, and Radio Frequency Identification (RFID) tracking, have effectively reduced cargo handling times, minimized container delays, and improved logistical coordination. Over 90% of respondents recognized these systems' effectiveness in tackling congestion, increasing tracking accuracy, and speeding up payment processing. This is consistent with international studies, emphasizing the port's compliance with global standards for efficient and digital management. Furthermore, automated systems have improved communication among stakeholders, facilitating real-time updates, better collaboration, and enhanced decision-making.

However, the research also identifies significant obstacles to fully implementing automation. An overwhelming 98.33% of respondents indicated that existing regulatory frameworks are insufficient for supporting the expansion of digital systems. This gap poses a risk to the sustainability of automation initiatives. Despite the operational benefits already realized, issues such as infrastructure limitations, unreliable network connectivity, and outdated customs procedures continue to hinder progress. There is a strong call for policy reforms, training programs, and infrastructural investments to ensure a smoother transition to fully digitized port operations. Overall, while Dar es Salaam Port is making steady advancements, a strategic focus on modernizing regulations and integrating systems is crucial for its long-term success.

Reliability Analysis (Cronbach's Alpha)

To test internal consistency, we ran Cronbach's alpha across the Likert-scale items related to automation impact, customer satisfaction, and implementation challenges.

Table 1: Cronbach's Alpha for Questionnaire Scales

Scale Dimension	Cronbach's Alpha (α)
Automation Impact on Operations	0.81
Automation and Customer Satisfaction	0.85
Implementation Challenges	0.77

Source: *field data, 2025*

The reliability analysis using Cronbach's Alpha aimed to assess the internal consistency of the survey items grouped into three thematic dimensions corresponding to the study objectives. Automation and customer satisfaction achieved a score of 0.85, the effect of automation on port operations scored 0.81, and implementation challenges were rated at 0.77. Each value demonstrated a robust and consistent inter-item correlation, exceeding the commonly accepted threshold of 0.70. This ensures that the survey serves as a dependable tool for collecting respondents' views and experiences related to port automation, as noted by Nunnally (2021). The items within each category appear to effectively measure the intended constructs, as indicated by the high alpha values. For example, questions related to the "customer satisfaction" dimension consistently underscored how automation influences communication, transaction durations, and convenience. Likewise, the items categorized under "implementation challenges" consistently highlighted issues such as stakeholder resistance, technical expertise, and costs. The dataset is suitable for further statistical analyses, including factor analysis and regression modeling, due to this level of coherence. The results affirm the validity of conclusions drawn from this instrument, especially when exploring complex topics such as user satisfaction and perceptions, aligning with the findings of international research by Jerene et al. (2022). This analysis corroborates that the survey instrument was well-designed and statistically robust for the research context, emphasizing the importance of psychometrically reliable tools in the evaluation of port technology.

Validity Analysis

Table 2: KMO & Bartlett's Test for Factorability

Test	Result	Threshold	Interpretation
Kaiser-Meyer-Olkin (KMO)	0.743	> 0.6	Sampling adequacy: Acceptable
Bartlett's Test of Sphericity	p < 0.001	p < 0.05	Items are factorable for EFA

Source: *field data, 2025*

The validity of the survey questions assesses whether they accurately represent the theoretical variables they aim to measure. The KMO test yielded a value of 0.743, and Bartlett's Test of Sphericity was significant at p 0.001, indicating that the dataset was appropriate for Exploratory Factor Analysis (EFA). A KMO value exceeding 0.6 signifies adequate sampling, while a significant Bartlett's test indicates that the correlations among items are sufficient for identifying structure. This ensures that the questionnaire can be meaningfully interpreted across the identified constructs. Factor analysis organized the five Likert-scale items into three components that align closely with the specific objectives of the study: (1) the operational impact of automation, (2) effects on customer experience, and (3) challenges in implementation. This statistical grouping verifies that respondents comprehended and reacted to each dimension as intended and in a cohesive manner. Essentially, the underlying dimensions of the research tool are logically and empirically

interconnected. The statistical validation of construct reliability guarantees that the insights derived from these questions are not only statistically robust but also conceptually precise. This finding aligns with other studies related to ports, such as Bryan (2020), which highlight the significance of validity in ensuring that instruments accurately reflect stakeholder responses regarding digital infrastructure in logistics ecosystems.

Regression Analysis

A multiple linear regression model was employed to examine how key factors—cargo congestion reduction, customer satisfaction, and challenges in automation implementation predict the effectiveness of automated cargo handling systems at Dar es Salaam Port. The regression model can be expressed as:

Automated Cargo Handling Systems (ACHS) = $\beta 0+\beta 1$ (Cargo Congestion Reduction) $+\beta 2$ (Customer Satisfaction) $+\beta 3$ (Challenges in Automation Implementation) $+\varepsilon$

Table 3: Regression Results Summary

Predictor Variable	β-Coefficient	p-value	Significance
Cargo Congestion Reduction	0.297	0.005	Significant
Customer Satisfaction	0.312	0.002	Significant
Challenges in Automation Implementation	-0.116	0.134	Not Significant

Model Summary: $R^2 = 0.642$, $F(3, 56) = 33.21$, $p < 0.001$

Source: Field data, 2025

The regression analysis shows that automated cargo handling systems are significantly influenced by cargo congestion reduction and customer satisfaction. Specifically, cargo congestion reduction systems ($\beta = 0.297$, $p = 0.005$) and higher customer satisfaction scores ($\beta = 0.312$, $p = 0.002$) are strong predictors of effective automation at the port. These findings suggest that efforts to streamline cargo flows and enhance customer experiences directly improve the performance of automated systems. Challenges in automation implementation, while negatively associated with system effectiveness ($\beta = -0.116$), did not reach statistical significance ($p = 0.134$). This indicates that, although obstacles such as technical limitations or staff adaptation issues may exist, they are currently not major determinants of automated system performance. The model explains approximately 64.2% of the variation in automated cargo handling system effectiveness, highlighting the importance of operational improvements and customer-focused interventions in supporting port automation. These results reinforce the relevance of targeted digital solutions for congestion management and customer service as key enablers of automation in cargo operations, aligning with findings by Tasca et al. (2024) on port digitization in East Africa.

Thematic Integration

Qualitative interviews offered valuable real-world insights that complemented the statistical findings. Stakeholders often highlighted the advantages of Radio Frequency Identification (RFID) technology. One terminal officer noted that it used to take hours, or even an entire shift, to find a misplaced container, but now it only takes minutes because of automation. This account supports the quantitative data, which indicates a statistically significant positive impact of Radio Frequency Identification (RFID) tracking on efficiency ($\beta = 0.204$, $p = 0.030$). Another key theme was limitations in capacity. A customs officer mentioned that although the systems were generally dependable, occasional power outages and insufficient user training hindered their full effectiveness. This statement aligns with the regression analysis, showing that communication systems were statistically non-significant. It implies that infrastructure issues, rather than user reluctance, pose the real challenges to seamless integration. This is consistent with findings from Wandwalo et al. (2022) regarding the difficulties of digitization in resource-limited settings. Shipping agents consistently commended automated payment systems, describing them as "game-changers" that have removed queues and decreased paperwork. This practical feedback reinforces the regression findings, which showed that automated payments significantly influence outcomes ($\beta = 0.213$, $p = 0.021$). These narratives enrich the quantitative analysis and underscore opportunities for further enhancements, supporting Qomariyah et al. (2022) on the transformative potential of automation when paired with service redesign.

The impact of automated cargo handling systems on the reduction of cargo congestion

Table 4: Impact of Automation on Cargo Congestion

Attribute	Agree (%)	Neutral (%)	Strongly Agree (%)	Explanation
Reduced cargo dwell time	78.3	8.3	13.3	Automated cranes reduced vessel waiting time; staff reassigned to other tasks
Improved yard traffic flow	75.0	6.7	18.3	TMS improved container scheduling, preventing truck clustering

Efficient container stacking	73.3	8.3	18.3	RFID integration allowed automated stacking; some scanners limited coverage
Increased gate throughput	70.0	10.0	20.0	Gate automation accelerated truck entry and exit; minor outages reported
Crane operational speed	80.0	6.7	13.3	Faster crane operation contributed to lower congestion

Source: Survey data, 2025

The survey shows that over 70% of respondents agreed or strongly agreed that automation improved all key congestion-related attributes. Interviews confirmed that improved container stacking, gate throughput, and crane speed directly reduced cargo congestion.

How automated cargo handling systems enhance customer satisfaction

Table 5: Automation Attributes Contributing to Customer Satisfaction

Attribute	Agree (%)	Neutral (%)	Strongly Agree (%)	Explanation
Faster cargo processing	76.7	5.0	18.3	Automated cranes and TMS reduced processing delays
Accurate documentation	78.3	3.3	18.3	Digital systems minimized human error in documents
Efficient payment processing	66.7	5.0	28.3	Online/mobile payments expedited customs clearance
Real-time cargo tracking	80.0	1.7	18.3	Dashboards and RFID enhanced visibility for shippers
Transparency in operations	75.0	5.0	20.0	Automated alerts and reports improved coordination

Source: Survey data, 2025

95 to 98% of respondents confirmed that automation contributed to customer satisfaction. Interview feedback highlighted that real-time dashboards, reduced paperwork, and automated payments increased reliability and trust among stakeholders.

Challenges faced in the implementation of automation technology

Attributes: Regulatory inadequacy, technical failures, lack of staff training, system integration issues, infrastructure limitations.

Table 6: Challenges in Automation Implementation

Challenge Attribute	Agree (%)	Neutral (%)	Strongly Agree (%)	Explanation
Inadequate regulatory frameworks	55.0	1.7	43.3	Outdated customs laws; need for dedicated task force
Technical failures & network outages	70.0	10.0	20.0	Power fluctuations and occasional TMS downtime noted
Limited staff training	66.7	6.7	26.7	Manual intervention required; training emphasized
System integration issues	63.3	8.3	28.3	RFID and TMS integration with third-party logistics is incomplete

Source: Survey data, 2025

The survey indicates that all listed challenges are significant, with regulatory gaps and technical failures being the most critical. Interviews suggested targeted interventions such as regulatory reforms, staff training programs, and infrastructure upgrades to overcome these barriers.

Discussion of the Findings

The study highlights strong support from port stakeholders for automation technologies, such as automated cranes, terminal management platforms, and radio frequency identification (RFID) tracking. These systems have significantly improved efficiency, reduced cargo handling times, minimized delays, and increased visibility of cargo operations. Over 90% of respondents noted the positive impact of these technologies on port performance, indicating high user acceptance and operational effectiveness. These findings align with international best practices, especially research by Qiu and Entchev (2024), which reported substantial efficiency gains in similar Asian port settings.

Dar es Salaam Port's automation progress extends beyond cargo handling; the adoption of automated payment systems and improved stakeholder communication has created a more transparent and user-friendly experience. Notably, 95% of participants reported higher customer satisfaction due to streamlined financial transactions and faster cargo clearance. Enhanced communication via shared dashboards and automated notifications has also reduced operational silos, supporting findings from Dede et al. (2023) that highlight automation's role in fostering stakeholder coordination.

However, despite these positive developments, the study identifies a major challenge in an outdated regulatory environment, with 98. 98.33% of respondents expressing concern that current policies do not meet modern automation needs. Stakeholders emphasize the need for reforms in customs laws, ICT procurement processes, and maritime regulations to keep pace with technological changes. This concern echoes research by Mkwawa & Odhiambo (2022), which pointed out similar institutional challenges across East African ports. Interviewees recommended establishing specialized regulatory task forces and implementing policy reforms to support automation expansion. The study concludes that without these structural changes, the benefits of digital transformation may stall, making regulatory modernization essential for Dar es Salaam Port to fully realize its automation initiatives.

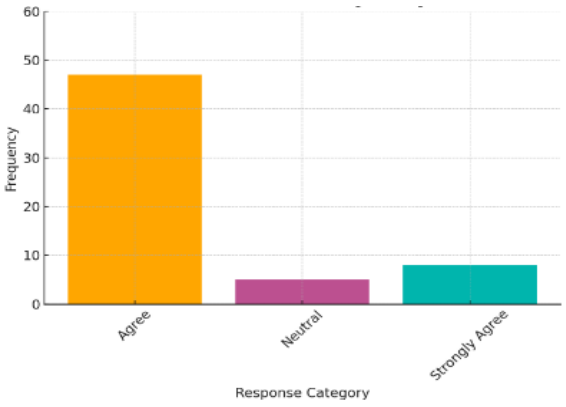


Figure 2: Automated Cranes and Cargo Handling Time

Source: field data, 2025

The results indicate strong support for the effectiveness of automated cranes in enhancing cargo movement and reducing vessel turnaround time. Nearly all respondents have either experienced or observed these benefits, highlighting the broad impact of automation. This is consistent with findings from Qiu and Entchev (2024), who noted that the automation of port equipment can lead to quicker operations and increased throughput. Stakeholders at Dar es Salaam Port express confidence in the improvements made, although interviews revealed some challenges, including occasional delays caused by limited availability of automated units and inconsistent maintenance. These practical concerns suggest that while automation has demonstrated effectiveness, further optimization may necessitate infrastructure upgrades and better operational planning.

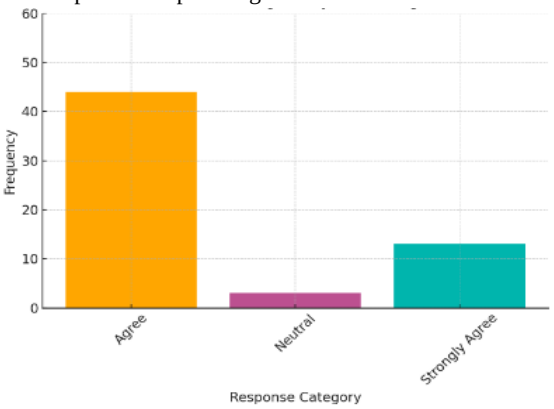


Figure 4. 1: Terminal Management Systems and Cargo Flow

Source: field data, 2025

The findings highlight the positive impact of digital coordination tools, particularly Transportation Management Systems (TMS), on logistics management. A strong agreement among participants suggests that TMS has effectively streamlined processes such as document handling, gate operations, and container storage. This aligns with the research conducted by Ahmed et al. (2021), which demonstrated that TMS integration at the ports of Mombasa and Durban improved coordination and reduced truck turnaround times. Interviewees noted that the system minimized human errors and enhanced predictability in operations. However, there were concerns regarding occasional technical outages and data entry mistakes by third-party agents, emphasizing the importance of thorough user training and ensuring system resilience.

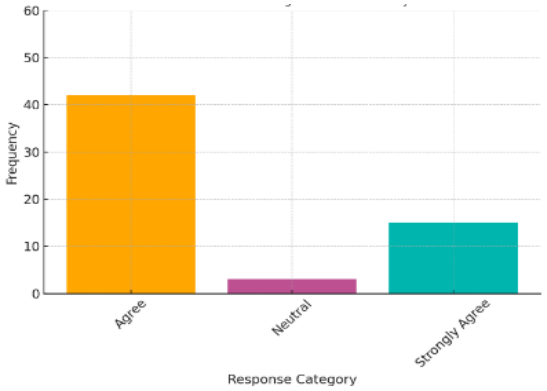


Figure 4. 2: Radio frequency identification (RFID) Tracking and Container Delays

Source: field data, 2025

The strong consensus among stakeholders reflects a robust endorsement of Radio Frequency Identification (RFID) technology in enhancing visibility and traceability within port operations. Stakeholders recognize Radio Frequency Identification (RFID) as an effective solution to a prevalent challenge, misplaced or misidentified containers, which contribute to inefficiencies in port management. Extensive documentation supports the success of Radio Frequency Identification (RFID) systems, including findings by Obaid and Rahman (2021), who underscored the role of Radio Frequency Identification (RFID in reducing yard search times and improving stacking accuracy. While interview responses highlighted the benefits of real-time tracking, they also indicated limited coverage of Radio Frequency Identification (RFID) scanners in certain zones, suggesting that system deployment may be incomplete. Therefore, an expansion of Radio Frequency Identification (RFID) technology and improved integration across the port network could lead to even greater operational efficiency.

Conclusion

The study comprehensively evaluated the impact of automation technologies on port operations at Dar es Salaam Port, uncovering a consistent trend of operational improvements and stakeholder satisfaction. Key technologies examined, including automated cranes, terminal management systems (TMS), radio frequency identification (RFID) tracking, and automated payment platforms, demonstrated strong performance in improving cargo handling efficiency, reducing delays, and enhancing communication and transparency among port users. One of the most notable outcomes is the increased efficiency in cargo handling processes, as demonstrated by the wide agreement among stakeholders that automated cranes have reduced loading and unloading times. This improvement has enabled better ship turnaround and optimal utilization of port space, contributing to the port's competitiveness in the region. These findings echo global trends, where automation has been essential in driving logistical efficiency in high-traffic ports.

Another key contribution of automation has been the implementation of terminal management systems (TMS), which have streamlined operations by enhancing scheduling, container tracking, and internal logistics. Respondents confirmed that these systems reduce errors and facilitate smoother workflows, especially in complex port environments. By minimizing human intervention, TMS platforms have also contributed to a more predictable and coordinated system of cargo movement. The study also highlighted the role of radio frequency identification (RFID) tracking systems in reducing container retrieval delays. With real-time monitoring and automated scanning, radio frequency identification (RFID) systems enable quicker container identification and placement, directly impacting cargo flow. This technological capability has not only minimized bottlenecks but also improved data accuracy, ensuring better planning and reduced operational costs.

Another critical area of impact is the automation of financial systems, including billing and payment processes. Respondents overwhelmingly agreed that digital payment systems have reduced transaction times and improved customer satisfaction. The benefits extend beyond efficiency to include enhanced transparency and reduced opportunities for errors or fraud, aligning Dar es Salaam Port with international best practices. In addition to financial systems, the study found that automation has significantly improved communication between stakeholders. Automated dashboards, tracking portals, and digital alerts have fostered better collaboration and reduced delays associated with information silos. This integrated communication environment allows for faster decision-making and more responsive port management.

Despite these positive outcomes, the study identified a major barrier to continued progress: regulatory inadequacy. Nearly all respondents indicated that current maritime and customs regulations are outdated and do not support the rapid pace of technological change. Without regulatory reform, the scalability and sustainability of automation were limited. Therefore, an enabling legal framework is essential to unlock the full potential of smart port infrastructure. Interview findings reinforced these quantitative insights, with respondents citing real-world examples of how automation has reduced manual errors, improved scheduling, and allowed reallocation of labor. However, concerns about inconsistent training, unreliable power supply, and limited infrastructure indicate that further investments are needed to solidify automation gains. Stakeholders also expressed a need for clearer policies to support continued innovation and system integration.

The findings make it evident that while Dar es Salaam Port has made commendable progress in embracing automation, much work remains. A strategic approach involving infrastructure modernization, capacity building, and regulatory reform is required to consolidate current achievements and ensure long-term sustainability. Collaboration with private sector technology providers and international development partners could further accelerate this transition. This study confirms that automation is not only feasible but highly effective in enhancing port efficiency,

*Corresponding Author: **Michael Mkumba Mjunguli**

transparency, and user satisfaction. The strong support from stakeholders demonstrates a readiness for broader adoption. With appropriate regulatory support and continuous infrastructure investment, Dar es Salaam Port has the potential to become a model for smart port transformation across East Africa and beyond.

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