



PORT AUTOMATION ON YARD OPERATION IN CALABAR SEAPORT OF NIGERIA: IMPLICATIONS FOR AFRICA'S REGIONAL DEVELOPMENT.

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Abstract

This study examines the relationship between Port Automation and Yard Operation in Calabar Sea Port. The study seeks to identify key factors that impact the efficiency of the seaport. This study collected data through a structured questionnaire and survey method, specifically employing a cross-sectional investigation approach. The study population consisted of the staff of NPA and Terminal Operators, which is 2800, with a sample size of 350. The Spearman Rank Correlation Coefficient was employed to evaluate the hypotheses of the empirical investigation. The results indicated that the Lack of automated cargo handling equipment will negatively affect Calabar Port operations and productivity. Well-maintained and up-to-date port infrastructure, such as berths and cargo handling facilities, has a substantial impact on minimising user time during the berthing process. The study recommends that port authorities and pertinent government agencies prioritise investments in contemporary cargo handling machinery, berths, quays, and yard facilities. This encompasses routine maintenance to ensure the highest level of functionality. Ports should contemplate the possibility of extending their operational hours to facilitate both daytime and nighttime activities. Nonetheless, it is imperative to tackle the security, customs, and workforce-related obstacles linked to night-time operations.

Key Words: Port Automation, Technology, Seaport, Yard Operation, Regional.

1.0 INTRODUCTION

Seaport development in Nigeria holds significant implications for Africa regional development, enhancing trade connectivity, economic growth, and infrastructural advancement across the continent. As one of the largest economies in Africa and a key player in the West Africa region development plan, ports in Nigeria serve as crucial gateways for international trade, not only for the nation but also for its neighbouring states. One of the primary advantages of seaport development is the facilitation of trade. With Nigeria's access to the Atlantic Ocean, well-developed ports can streamline import and export processes, reducing transportation costs and times for goods circulated throughout West Africa (Adedotun *et al.*, 2023). Improved port infrastructure, including modern cargo handling facilities and efficient customs systems, allows for increased trade volumes, thus positively impacting local industries and creating job opportunities. Furthermore, enhanced seaport facilities can attract foreign direct investment (FDI) into Nigeria and the region, stimulating economic growth. Investors are more inclined to establish operations in regions where logistical capabilities are efficient (Ugwuoke.,2020). This, in turn, act as a catalyst for technological transfer and skills development, creating a more competent workforce. Beyond Nigeria, these investments can uplift regional economies by fostering economic interdependence among African countries. In addition, seaport development can lead to improved regional infrastructure (Soumyajit, 2019). The construction of road and rail lines connecting ports to inland markets can bolster regional transportation networks, facilitating smoother movement of goods across borders. This interconnectedness promotes trade routes, reduces trade barriers, and supports a unified economic space. However, for these benefits to materialise, strategic planning and collaboration among African nations are crucial. Policymakers must focus on sustainable development practices, ensuring that seaport activities do not compromise environmental integrity or local communities (Mohammed, 2022). Therefore, an increase in port revenue is a function of the movement of effective and efficient cargo handling operations on time. An increase in world tonnage has positively changed the mode of operations of ports around the world. UNCTAD (2016) opined that as shipping services changed because of specialisation of vessels, that is, the design and employment of vessels changed, ports must improve their infrastructure, operating hours, and yard operations.

Port automation is changing the way cargoes are handled, increasing reliability, productivity and streamlining processes. Port automation is the use of advanced technology and robotics to automate various aspects of port operations. These technologies include robotic container handlers, automated cranes, and intelligent conveyor systems and discharge operations. Replacing manual labour with automated systems can significantly increase port efficiency and reduce the risk of accidents (**George** and Camille, 2023). One of the key elements of port automation is the use of automated guided vehicles (AGVs) Rubber Tyre Gantry cranes (RTG), and Automated Stacking Cranes (ASCs) to transport containers within the port. These AGVs, RTGs and ASCs are equipped with sensors and navigation systems, allowing them to navigate within ports without human interference. Also, drones are deployed to survey the port environment, monitor cargo conditions, and conduct equipment checks. We can transport containers from ships to storage sites and vice versa, ensuring that the entire process runs smoothly and efficiently.

Also, port automation is the implementation of intelligent systems that can monitor container movements in real time. These systems use sensors and data analyses to determine the location, condition, and status of containers, providing accurate and timely information to port operators and shippers. It also aids in inventory management, reducing theft and loss of cargo. This allows you to make informed decisions and optimise the flow of cargoes through the ports. (Lun *et al.*, 2021).

Contrary to popular belief, port automation does not eliminate the need for human involvement. Instead, a collaborative approach is encouraged, where humans and machines complement each other's strengths. Machines perform repetitive and physically demanding tasks, while humans provide the critical thinking, creativity, and adaptability necessary for complex decision-making and problem-solving. In automated ports, people play an important role in monitoring and controlling the operation of automated systems (Ogola, 2024). It is your responsibility to monitor the performance of your machine, ensure that it is functioning properly, and correct any problems that may arise. Additionally, port managers provide the expertise and knowledge needed to make strategic decisions and optimise the overall performance of their respective seaports. Port automation has a significant impact on the efficiency and productivity of port operations. By replacing manual labour with automated systems, ports can achieve higher throughput rates,

reduce operational costs, and improve overall performance. Additionally, port automation improves security (Malnatchi, 2023).

Shipping yards are specifically designated zone that comprises approximately 60-70% of the overall terminal area. Its purpose is to facilitate the efficient handling of cargo within the port. A container stacking area is utilised for the temporary storage of containers, which are awaiting further distribution to their ultimate destination. Containers are typically labelled and organised into blocks to facilitate easy identification and accessibility. These blocks are primarily designated for the import and export of containers, primarily located near the quayside. Empty containers are segregated and stored in dedicated yards or off-dock terminals to alleviate congestion throughout the terminal facility. Refrigerated containers, which contain perishable cargoes, are stacked separately due to the characteristics of their contents (Lun *et al.*, 2010).

Port automation also promotes environmental sustainability through the use of green technologies. Automated ports are at the forefront of implementing green practices and technologies that minimise carbon emissions and reduce environmental impact (Banomyong 2005). One of the most important environmentally friendly technologies in automated ports is the use of electric devices. By replacing diesel-powered machinery with alternative electrical equipment, ports can significantly reduce air pollution and noise levels. Electric cranes, AGVs and other equipment produce no emissions on site, making them a cleaner alternative. Another green technology in automated ports is the integration of renewable energy sources. The port is considering the use of solar panels, wind turbines and other renewable energy systems to power its operations. These energy sources can reduce dependence on fossil fuels, reduce greenhouse gas emissions and contribute to a more sustainable energy mix. Additionally, automated ports enable better energy management and optimisation (Nottebom *et al.*, 2022).

The impact of the coronavirus pandemic (COVID-19) and how it affected shipping operations despite borders being closed to the movement of people, movement of goods across borders, such as food and medicine, remains important. The pandemic had little impact on ports with automated cargo handling equipment in cargo operations around the world, and it is also a driving force for the use of autonomous computer controls in the maritime sector (Nwokedi *et al.*, 2019). In some ports, this technology allows crane operators to work from remote play stations, allowing

automated cranes to move containers at ports with minimal worker control or with workers controlling computers. Advances in telecommunications, originally developed for toy-scale models, enable remote control of ships in port areas, despite quarantine restrictions, a portion of the population essential workers who must report to work to provide services that keep the community functioning. Those at the forefront of automation can work from home with their colleagues to develop future autonomous transport technologies, including transport operations directly and indirectly involved in ports and ships (Magdiel *et al*, 2023).

Lack of adequate infrastructure, finance, government policies and no regional development plan in the implementation of a central regional development plan for seaports across the continent. Many Nigerian ports, such as Ports in Lagos and Port Harcourt, still rely on outdated technology and manual processes, leading to inefficiencies, congestion, and long turnaround times for vessels. Without substantial investments in modern infrastructure and technology, achieving seamless automation becomes difficult. Consequently, these inefficiencies hinder Nigeria's ability to serve as a regional trade hub, affecting neighbouring countries that rely on Nigerian ports for import and export activities. Another significant challenge is the workforce skill set. Automation requires a workforce proficient in technology and data management. However, Nigeria faces a skill gap, with many port workers lacking the necessary training and education to operate advanced automated systems effectively. These shortcomings not only limit operational efficiency and effectiveness but also raise concerns about job displacement, as labour-intensive roles diminish in automation settings. Moreover, port automation raises regulatory and governance challenges. There are issues surrounding policy frameworks, investment prospects, and collaboration between government agencies and private sector stakeholders. Without clear and cohesive policies promoting automation and cybersecurity practices, the integrity and security of automated systems may be compromised. The implications of these challenges extend beyond Nigeria. A lack of efficient automated systems in Nigerian ports can slow down regional trade, affecting supply chains across West Africa and Africa. It limits economic growth potential, as inefficient logistics systems deter foreign investment and inflate shipping costs for neighbouring countries reliant on these ports.

2.0 LITERATURE REVIEW

Port Automation

Port automation transforms how cargoes are handled, increasing productivity and streamlining processes. Port automation refers to applying advanced technologies and robotics to automate various aspects of port operations. These technologies include container handling robots, dry bulk loading and discharging, liquid bulk loading and discharging, automated cranes and smart conveyor systems. By replacing manual labour with automated systems, ports can significantly increase efficiency and reduce the risk of accidents (Domenico and Domenica 2023). One of the key elements of port automation is the use of AGVs, RTGs and ASCs to transport containers around the port. This automated equipment with sensors and navigation systems allows them to navigate ports without human intervention. They can transport cargoes from the ship to the storage yard or vice versa, ensuring the entire process runs smoothly and efficiently. Another important aspect of port automation is the implementation of smart systems to monitor cargo movements in real time. Below is a chart showing fully automated and semi-automated seaports in the world.

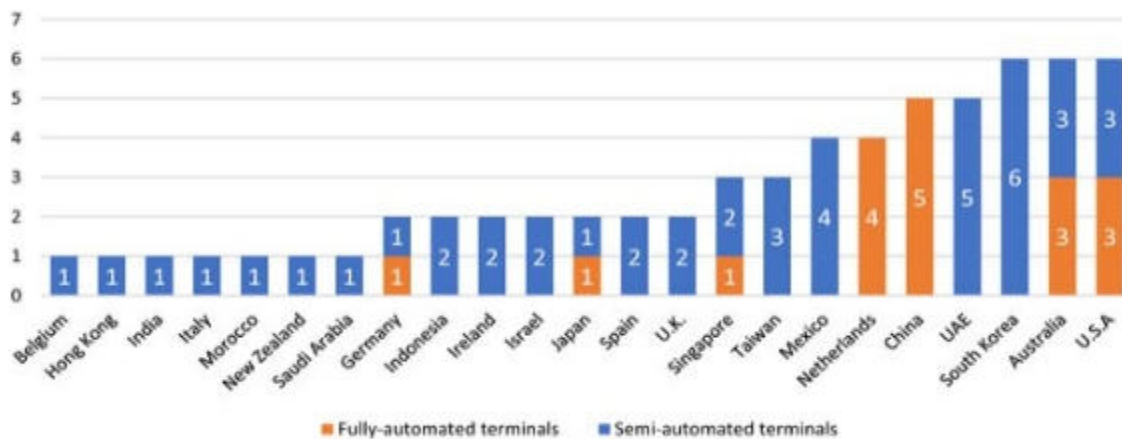


Plate 2.1: Knatz et al (2023) Distribution of automated sea port terminals in the world.

The port of Tanger Med 1 moved from 83rd position to 17th position in world ranking as a result of port automation, which represents an exceptional productivity and position, thereby becoming the

first African port, followed by Port Said in Egypt and the port of Durban in South Africa. (UNCTAD,2023).

Table 2.1: SEMI AUTOMATED PORTS IN NIGERIA

S/N	NAME OF PORT	LOCATION	TYPE OF AUTOMATION	AUTOMATION OF CARGO HANDLING EQUIPMENT
1	Onne Port ➤ West African Container Terminal (WACT) ➤ Onne Multipurpose Terminal (OMT) ➤ Intels	Rivers State	Truck Call Up Systems	NIL
2	Tincan Port	Lagos State	Truck Call Up Sytems	NIL
3	Apapa Port	Lagos State	Terminal Management	NIL
4	Warri Port	Delta State	NIL	NIL
5	Calabar Port	Cross Rivers State	NIL	NIL
6	Port Harcourt Port	Rivers State	NIL	NIL

Source: Ogola, (2024). Semi-Automated Sea Ports in Nigeria.

From Table 2.1 above, we can deduce that Warri port is not automated and which has a negative implication in seaport development in Nigeria.

Furthermore, automation has improved productivity and costs about 20% to 50% in the entire port operation process, while in warehousing, it has improved port operations by 30%. Also, cars, trucks and manufacturers have successfully automated the most difficult processes. Most equipment used for port automation includes material handling robots, automated guided vehicles, and all are relevant for port operations (Malnatchi, 2023). Also, the magnitude of automation differs from port to port and also her operations, locations, the amount of cargo throughput and economic value. Port

automation can be viewed from different perspectives. Port automation can be viewed from different points, i.e., cargo handling equipment, material handling, inventory management, assisting ship docking, building the necessary infrastructure, digitisation of ship records and maintenance.

Familiarity with data collection, activity monitoring, track and trace operations and automation systems is considered fundamental for port operations, developing new business models and strengthening the competitiveness of seaports. (Satta *et al.*, 2019). This will further strengthen the efforts of port operators. In an era marked by rapid technological advancements and the necessity for efficiency in global trade, smart ports are emerging as pivotal players in the maritime industry. These ports leverage technology to optimize operations, enhance safety, and minimise environmental impact. (Liu *et al.*, 2021)

Methodology

The study population consisted of the staff of NPA Calabar port and Terminal Operators, which is 2800, with a sample size of 350. A simple random technique was adopted using Taro Yamane to determine the sample size of 350. Primary data was adopted as the method of data collection. Spearman's rank correlation coefficient was used to analyse relationships between the variables. Port automation on yard operation in Calabar Seaport of Nigeria, implications for Africa's regional development where;

n= Sample size

N=Population of the study

e= Level of significance @ 5%.

$$\frac{2800}{1 + 2,800 (0.05)^2}$$

$$= 350$$

Sample size of = 350

Table 2.2: Population and Sample size

S/N	Actor/Operators	Population	Population%	Sample Size
1	Ecomarine Terminals (NIG) LTD	1960	70 (1960/2800*100)	245 (350/100*70)
2	INTELS NIG. LTD (INTELS)	260	9 (260/2800*100)	32 (350/100*9)
3	Shoreline (ADDAX) NIG.LTD (SLNL)	280	21 (280/2800*100)	73 (350/100*21)
		2800	100	350

Source: NPA, 2020 Annual Report

Result and Discussions

This chapter presents the data analysis results, interpretations and discussion of findings. It is organized as follows: First it presents the response rate then the background information of the respondents. Primary data was used as a method of data collection, and Spearman's rank correlation was used in analysing the data. The administration of the questionnaire among senior and middle management personnel was carried out personally.

Table 2.3 Gender of Respondents

Responses	Frequency	Percentage
Male	210	60.0
Female	140	40.0
Total	350	100.0

Source: Researchers' field report (2025).

Table 2.3 above indicates the gender distribution of the respondents. The information shows that out of 350 respondents, 210 were male, accounting for 60% of the total respondents, while the remaining 140 (40.0%) were female.

Table 2.4: Port Automation Improves Seaport Yard Operation.

S/N	Response	Frequency	Percent
1.	SA	206	58.9
2.	A	120	34.2
3.	D	14	4.0
4	SD	10	2.9
Total		350	100.0

Source: Researchers field report (2025)

The participants' responses regarding how port automation improves seaport yard operation were presented in Table 2.4. A significant majority of respondents, comprising 58.9 percent of the study's entire population, were in agreement with the statement that port automation improves seaport yard operation. Additionally, 34.2% of the people surveyed agreed with this notion. In addition, 10 individuals (2.9%) strongly expressed their disagreement with the notion that port automation improves seaport yard operation, while 4.0% which represents 14 of the population simply disagreed with this idea.

This indicates that a substantial segment of the entire population agrees with their perspective on the continuum. This discovery indicates that 93.1% of the individuals in the study area were included in the analysis. Furthermore, it is worth mentioning that only 6.9% of the population at large expressed disagreement with the statement that port automation improves seaport yard operation. Our analysis aligns with the findings of previous research in the maritime industry, such as UNCTAD (2020; and Ezeala-Harrison (2018). Ports that have invested in automation technologies such as automated cargo tracking systems, robotic cranes, and digital logistics platforms have experienced a notable increase in yard operations. Furthermore, effective yard management has been shown to reduce dwell times for cargo. Ports that implement advanced yard management systems, which provide real-time visibility and tracking of cargo, enable more efficient allocation of space and resources, thus minimising the time goods spend within the port premises (Onyekwelu, 2019).

Table 2.5: Port automation increases cargo transferring operations in the Yard

S/N	Response	Frequency	Percent
1.	SA	218	62.3
2.	A	100	28.6
3.	D	20	5.7
4	SD	12	3.4
	Total	350	100.0

Source: Researchers' field report (2025)

The opinions of the participants regarding port automation increase cargo transferring operations in the yard, were presented in Table 2.5. Out of the total study population, 218 respondents, which makes up 62.3%, strongly agreed with the assertion that "port automation increases cargo transferring operations in the yard." Additionally, 28.6% of those surveyed agreed with this notion. In addition, 20 individuals (5.7%) expressed disagreement regarding the notion that port automation increases cargo transferring operations in the yard, while the remaining 12 respondents (3.4%) strongly disagreed with this idea.

This indicates that more than half of the people surveyed are in agreement on the continuum. This discovery indicates that 90.9% of those surveyed in the study area agreed that the automation of ports enhances the efficiency of cargo transfer operations. Furthermore, it is worth mentioning that only 9.1% of the total population expressed disagreement with the claim that port automation increases cargo transferring operations in the yard. Also, it is essential to acknowledge that the successful implementation of port automation is contingent on various factors. The availability of reliable power sources and uninterrupted connectivity is critical, also, sufficient cargo handling equipment for transferring cargo is needed for a smooth cargo operation. Automation heavily relies on continuous electricity and data connectivity, and any disruptions can hinder her smooth operations (Achebe et al., 2022; Hang et al., 2022).

Table 2.6: Utilisation of electronic cargo handling devices enhances yard operations in the port

S/N	Response	Frequency	Percent
1.	SA	200	57.1
2.	A	136	38.9
3.	D	10	2.9
4.	SD	4	1.1
	Total	350	100

Source: Researchers' field report (2025)

The participants' responses regarding the utilisation of electronic cargo handling devices do enhance yard operations in the port, as presented in Table 2.6. Out of the total study population, 57.1% (200 respondents) strongly agreed via assertion three, which states that the use of utilization of electronic cargo handling devices enhances yard operations in the port. Additionally, 38.9% of those who participated agreed with this notion. In addition, 10 individuals, accounting for 2.9% of the total, expressed disagreement with the notion that the utilisation of electronic cargo handling devices enhances yard operations in the port. Furthermore, an additional 1.1% strongly disagreed with this statement.

This indicates that a considerable portion of the entire population agrees with the position stated on the continuum. This discovery indicates that 96% of the individuals involved in the study from the specified area were included. Furthermore, it is worth mentioning that only a small 4% of the general population expressed disagreement with the statement that the utilisation of electronic cargo handling devices enhances yard operations in the port. Furthermore, automation has been found to optimise the utilisation of existing port infrastructure, maximizing their capacity. Ports that have integrated automation with their infrastructure have demonstrated a greater ability to handle larger volumes of cargo and accommodate bigger vessels, attracting more traffic and trade, thereby reducing ship dwell time in port (Ajayi, 2016).

Table 2.7: Port Automation Reduces Vessel Dwell Time in Port

S/N	Response	Frequency	Percent
1.	SA	168	48.0
2.	A	150	42.9
3.	D	17	4.9
4.	SD	15	4.2
Total		350	100

Source: Researchers field report (2025)

The participants' responses regarding the port automation reduces vessel dwell time in port, were presented in table 2.7. Out of the total study population, 168 respondents, which makes up 48.0% of the participants, strongly agreed with assertion, "port automation reduces vessel dwell time in port," Additionally, 42.9% of the general public agreed with this notion. In addition, 4.9% of the participants expressed disagreement regarding port automation reduces vessel dwell time in port, while the remainder of 4.2% strongly disagreed with this notion.

This indicates that a substantial portion of the entire population agrees with the position relative to the continuum. This discovery indicates that 90.9% of the participants in the study area were included. Furthermore, it is worth mentioning that a significant proportion of the total population, specifically 9.1%, expressed their disagreement with the claim that port automation reduces vessel dwell time in port. Our analysis revealed a noteworthy relationship Port Automation Reduces Vessel Dwell Time in Port, corroborating the findings of earlier research (Budiprivanto et al., 2017; Baoli., et al., 2022). Ports with extended working hours, accommodating operations during both day and night shifts, exhibited reduced ship dwell times. This extended operation alleviates congestion and enables a more continuous flow of cargo, resulting in quicker ship turnaround times. Ports that invest in well-lit and secure facilities during extended hours experience more efficient operations (Ziaul and Hans, 2018; Guo, et al., 2016).

Table 2.8: Correlation between port automation and cargo transferring delays in the Eastern Sea Ports

Correlations			Port automation	Yard Operation
Spearman's rho	Port automation	Correlation	1.000	-.699**
		Coefficient		
		Sig. (2-tailed)	.	.020
	Yard Operation	N	353	353
		Correlation	-.699**	1.000
		Coefficient		
		Sig. (2-tailed)	.020	.
		N	350	350

****.** Correlation is significant at the 0.05 level (2-tailed).

Source: SPSS Ouput version 25

The Pearson correlation investigation output in table 2.8 displays the association between automated ports and yard operations. The results demonstrate a significant negative correlation ($r = -0.708$, $p = 0.020$) between the level of port automation and the occurrence of yard operations. This was demonstrated by the statistically significant level of the Pearson correlation coefficient. Based on this analysis, it can be deduced that implementing more port automation would lead to a decrease in of cargoes in the yard.

Conclusion

In automated ports, humans play an important role in monitoring and managing the operation of the automated system. They are responsible for monitoring the performance of machines, ensuring that they are operating properly, and resolving any problems that may arise. They also provide the expertise and knowledge needed to make strategic decisions and optimise the port's overall performance. Port automation has a significant impact on port operational efficiency and productivity. By replacing manual labour with automated systems, ports can achieve higher output, reduce operating costs and improve overall performance. In addition to efficiency and productivity benefits, port automation also promotes sustainability and environmental responsibility through the use of green technology. Automated ports are at the forefront of adopting environmentally

friendly measures and technologies to minimise carbon emissions and reduce environmental impact. One of the important green technologies in automated ports is the use of electrical equipment. By replacing diesel-powered machinery with electric alternatives, docks can significantly reduce air and noise pollution levels. Electric cranes, AGVs and other equipment produce no emissions at the time of use, making them a cleaner, quieter alternative. Another green technology in automated ports is the integration of renewable energy sources. Ports are exploring the use of solar panels, wind turbines and other renewable energy systems to power their operations. These energy sources can help reduce dependence on fossil fuels, reduce greenhouse gas emissions and contribute to more sustainable energy sources. While seaport automation holds tremendous potential for enhancing trade efficiency in Nigeria and Africa, addressing the infrastructural, educational, and regulatory challenges is crucial for maximising its benefits and fostering regional development in Africa. Solutions must be implemented collaboratively to unlock the continent's trade potential.

Recommendations

Port administrators should allocate resources towards implementing automated technologies, including computerised cargo management systems, computerised logistics platforms as well and immediate monitoring systems. This will optimise cargo operations, minimise dwell times, and improve overall port yard operations and efficiency.

Based on the findings and contributions to knowledge of this study, the following recommendations are put forth to improve the efficiency and competitiveness of Calabar Sea port operations.

Port authorities and relevant government agencies should prioritise investments in modern cargo handling equipment, berths, quays, and yard facilities. This includes regular maintenance to ensure optimal functionality. Also, Port authorities should invest in automation technologies such as automated cargo handling systems, digital logistics platforms, and real-time tracking systems. This will streamline cargo operations, reduce dwell times, and enhance overall efficiency.

Contribution to Knowledge

This study provides an overview of the important factors influencing maritime operations in Calabar seaport in Nigeria. Port Automation and Yard Operations do have a symbiotic relationship, and an increase in Port Automation variables will reduce cargo dwell time in port yards.

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