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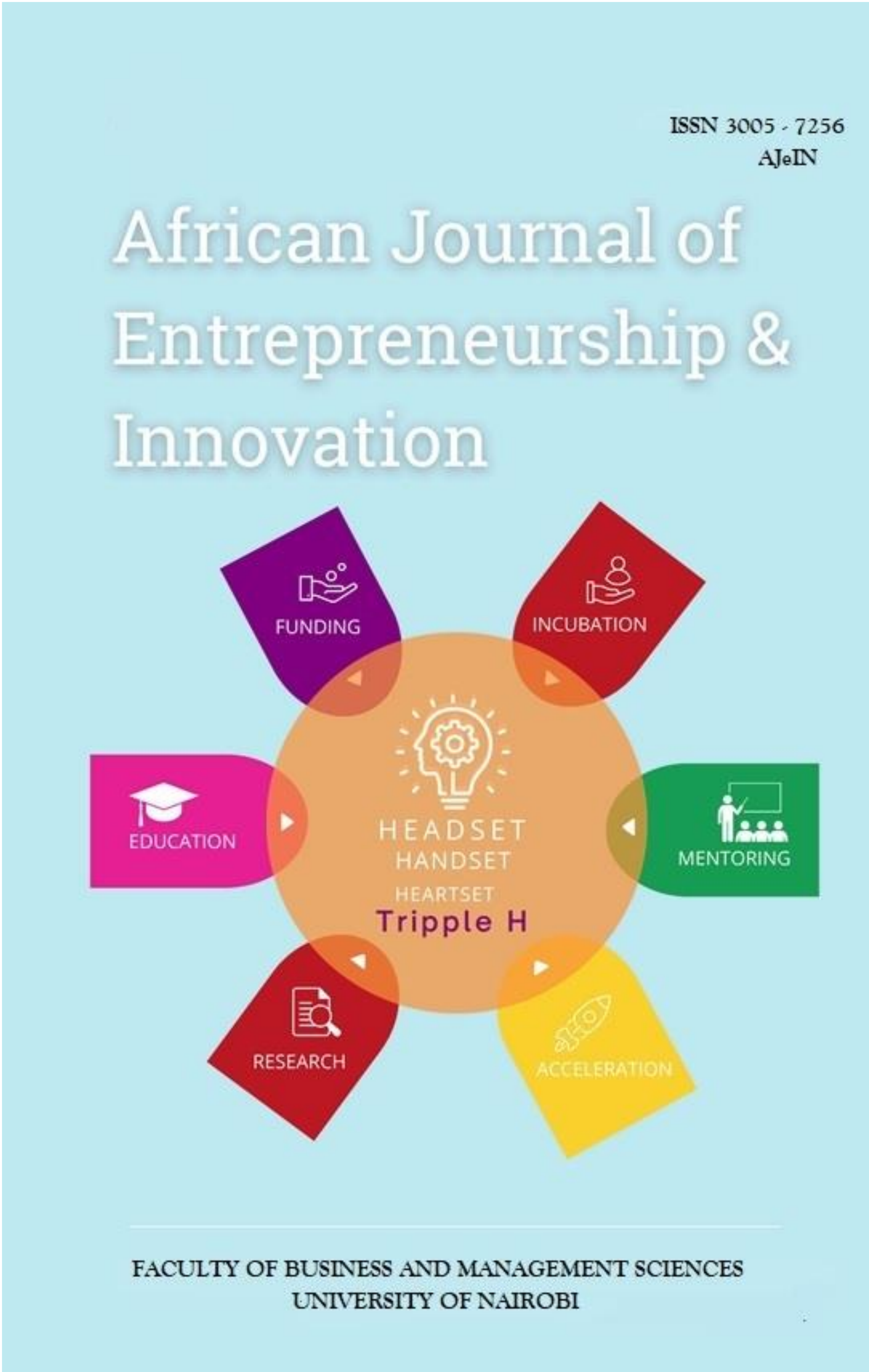

Nexus between Gang Productivity of Labour and Ship Turnaround Time in Tanzania Ports: A Case Study of Dar es Salaam Port

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Abstract

Ship turnaround time is one of the significant indicators used to measure port performance. It involves the total time spent by the vessel at the port from its arrival to departure. The aim of ship charterers/owners and shippers is to find a port with fast and efficient port calls in order to have a definite business profitability and commercial advantage. Dar es Salaam port has been experiencing higher ship turnaround time due to operational inefficiency that leads to vessel traffic at outer anchorage. Vessel traffic has been causing customer dissatisfaction such as shipment delays and increasing extra costs to shippers and ship charterers/owners and some shipping companies have opted to use neighboring ports like Mombasa in order to escape the cost burden. Tanzania's government has been losing revenue due to port inefficiency. Therefore, this research problem is derived from customer complaints who are involved in the shipping business. Therefore, the study used a quantitative approach with secondary data from the year 2020 to 2022 that collected from Tanzania Ports Authority (TPA) and Tanzania Shipping Agencies Corporation (TASAC). The data to be collected includes ship turnaround time and gang productivity of labour. The analysis of the study used analysis of variance, correlation and regression analyses depending on study specific objective in particular. The data analysed through R-programming as well as Microsoft Excel. The study found that the labour gang productivity exhibited significant correlation with turnaround time specifically, labour gang productivity in general cargo operations was correlated significantly with shorter turnaround time. The findings suggested that any potential extension of bulk operations may lead to congestion and space limitations, further impeding turnaround time for bulk ships.

Key Words: *Gang Productivity of Labour, Ship Turnaround Time*

1. Introduction

The port becomes fast, efficient and effective in timely serving vessels and handling cargo if it possesses quality services to its customers such as having a good infrastructure, storage facilities, modern handling types of equipment, efficient customs clearance, and enough port terminals and direct berthing. Port stakeholders (Shippers and ship charterers) determine the port performance by selecting the port with high efficiency and productivity in fasting operation and having a shorter ship turnaround time in handling vessels with their shipments aiming at reducing trade cost (Mazibuko *et al.,* 2024). Port performance can significantly affect a country's trade competitiveness since the increase in the shipping business goes on hand with the timely accommodation of ships. It impacts directly the extent to which users located within its hinterland realize their competitive advantages against supply chain systems that utilize port systems. Port determinants system involve a crucial measurement that used to identify the areas of opportunity and the greatest setbacks and the results provide a benchmark by which the port can be assessed relative to others. Port efficiency provides the

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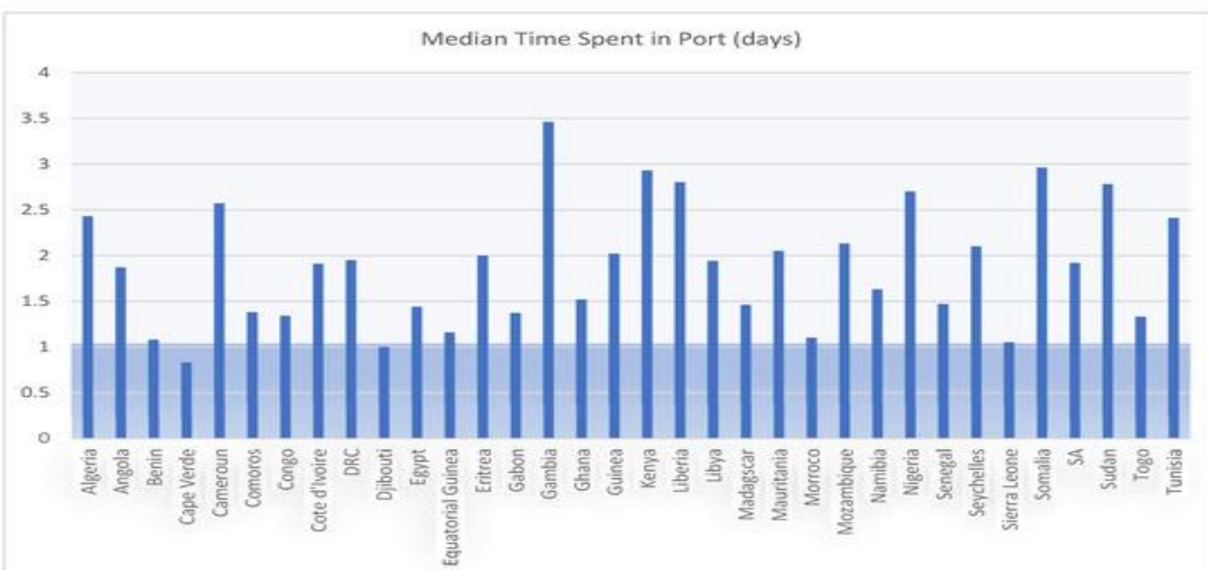
details of the port in multi-dimensional determinants such as total cargo throughput, port productivity, number of vessels, dwell time, waiting time at outer anchorage, ship turnaround time, berth occupancy ratio, and port productivity (Tampubolon, et al., 2025). These determinants are measured in operational and financial dimensions and they are normally quantified using mathematical models. Ship turnaround time is the total time taken by the ship to arrive and depart at the port. When the ship stays idle at the port, it spends more time and money. Turnaround time includes ship waiting time at outer anchorage, ship berthing time and unberthing time as well as berth services time. It can be used to determine profit and cost for all business partners in the shipping business indicated by the speed of the services offered at the port (Raj *et al.,* 2024).

During the period of the Corona virus diseases (COVID-19) pandemic, the market for bulk carriers and container ships globally dropped that weakening the demand for goods and the supply chain of freight transported by the sea that affected the global economy due to the restrictions kept by different countries in importing and exporting traded goods. Between 2019 and the first half of 2022, there was serious port congestion that result to increase of waiting time for vessels from 50 to 67 hours across 30 major dry bulk handling economies due to mandatory quarantine and negative Polymerase Chain Reaction (PCR) tests for seafarers (Gonzalez and Quesada, (2024). Høyer. Leivestad (2021), shows after the recovery from the pandemic in 2021, the global economy was projected to grow by 5.9% while the regional economy for Sub-Saharan Africa grew by 3.9%. In 2021, the global economy recorded 4.3 million vessel port calls whereby port calls in dry bulk carriers increased by 6.6%, and container ships increased by 1.1% corresponding to that of 2020. Container ships increased at a low ratio due to global container shortage and port congestion. However, in 2022 port calls have been reduced due to the impact of the COVID-19 pandemic and the Russia-Ukraine war that caused supply shock, an increase in energy and commodity prices, and importing countries that led to high inflation and an increase in shipping costs (Essel et al., 2022).

Looking at the history, the median time spent in container vessels was 0.7 days, and for bulk carriers was 2.05 days in 2021 in the world while the median time spent by vessels in discharging and loading cargo at the port was approximated to be 0.97 days. In 2020 the median time spent by the vessels increased to 1.5 days whereby Japanese and Norwegian ports handled vessels in loading and discharging cargo at the rate of 0.4 days (Justice *et al.,* 2025). The next best ports in the world were ranked from the Republic of Korea, Singapore, Malaysia, and the United States of America. Spain and

Netherlands in Europe, Panama and Colombia in Latin America and the Caribbean, Morocco and Egypt in Africa, and Sri Lanka and India in Southern Asia (Essel *et al.,* 2022). Shang *et al.,* (2024), The report showed some of the countries with the best economy possessed the busiest ports that are globally connected to liner shipping networks with high levels of port efficiency and trade competitiveness in the world. These ports operate faster with shorter time spent in handling vessels during the loading and discharging of cargo. Among the ranked container ports with the best performance was Japan with a rate of 0.36 days, Taiwan with a rate of 0.57 days, Turkey with a rate of 0.63 days, china had a rate of 0.73 days while the United States of America had 1.25 days, and Norway with 584,000 ships carrying cargo departing from Norwegian ports less than half a day just after arrival. The world shipping council through Liner Shipping Connectivity Index (LSCI) measured the busiest ports that carried large volumes of cargo throughput in the world from 2017 to 2021, the leading ports were found to be Shanghai, Ningbo Zhoushan from China, Singapor (Mezzadri and Majumder, 2022). Ship turnaround time in African countries has inevitable occurrence with the worst port efficiency due to having a longer average time spent by the to offload at the port except for Cape Verde which has an average of 0.83 days, Djibouti with an average of 1 day, Morocco with an average of 1.1 day and Sierra Leone with 1.05 day as shown in the figure below:

Figure 1.1: Median Ship turnaround Time for Various Ports in Africa States by UNTACD, 2019



These delays are caused by various factors such as poor port management and bureaucracy, weather condition, poor Labour productivity, Lack of information technology systems that integrate, Lack of poor customs procedures, lack of modern port infrastructures such as inefficient port terminals capacity, Lack of loading and unloading equipment's, such as crane's In recent years Tanzania ports have been experiencing vessels increase whereby in a year 2021 a total of 1290 vessel calls were recorded. These vessel calls included Bulk carriers (26%), Container ships (23%), General Cargo (8%), vehicle carriers (8%), and Oil/chemical Tankers (6%) (Marine Traffic, n.d.). Volume of international trade through Dar es Salaam port have increased by 21.3% in the last four years from 2017 to 2021 with a cargo throughput of 17 metric tonnes from 14 Metric tonnes (The Citizen, 2022). The global standard for ship turnaround time to discharge her bulk and containerized cargo is targeted to be one (1) day or less a day. The Benchmark kept by Tanzania Shipping Agencies Corporation (TASAC) as a port regulator, ship turnaround time to discharging bulk cargo should not exceed five (5) days while containerized cargo should not exceed three (3) days.

Despite vessel increase and cargo volume, the port of Dar es Salaam is seeming not the best wheel of the Tanzania economy since its operational efficiency to handle vessels and clearance of the freights can take even two weeks or a month to discharge cargo, leading to higher ship turnaround times.

In 2008, Dar es Salaam port experienced a bunching of vessels at the outer anchorage that led to a high ship turnaround time of over 20 days. The major causes of this congestion were mainly attributable to the unprecedented growth of containerized cargo, high container dwell times, and inadequate terminal capacity to handle container traffic. Furthermore, the container stacking space was eroded thus slackening the ship operation and causing a rise in ships' turn-around time. Ships had to queue outside the port waiting for berthing space. Delivery operations were slow because more time was used in shuffling containers in the yard. Consequently, trucks had to queue both in the terminal and outside the terminal waiting for their turn to take containers from the port. However, some of the improvement in optimizing ship turnaround time was made from 20 to 10 days, but still, 10 days were higher. In 2017, more efforts were made by TPA through the reconstruction and expansion of port facilities such as berths, storage facilities, and good infrastructures such as roads, and railways at Dar es Salaam port aiming at improving port operation efficiency in handling cargo and vessels but still, ship turnaround time was not satisfactory.

For the ship charterer and shippers, time means money, so they aim at finding a port with fast and efficient port calls to have a definite commercial advantage. Currently, Dar es Salaam port vessels are experiencing vessel traffic due to operational inefficiency whereby many vessels are queue for long time at outer anchorage resulting to various business problems such as customer's dissatisfaction and increase in operating costs to ship charterers such as port charges, bunker recovery charges, Equipment repositioning charges, etc., and costs to shipping companies (shippers) such as sea freight charges. Therefore, due to competitiveness advantages some shipping companies have opted to use neighboring ports like Mombasa port to escape the cost burden resulting in a country losing revenue that has a port not able to meet financial targets kept by the government for some years. In 2012, the economy of Tanzania and the neighboring country through Dar es Salaam port lost U$ 1.8 billion and 830 million U$ dollars (World Bank, 2013). Therefore, emanating from this gathering there is a need to discuss on how to determine the factors affecting ship turnaround time: A case of Dar es salaam Port in Tanzania in order to improve overall port efficiency that will lead to a competitive advantage in handling more ships movement per day compared to other ports in the regionmachines, inadequate vehicles to carry the cargo from the port (Zhang *et al.,* 2024).

2. Literature Review

Queuing theory involve queue mathematical model of waiting lines that are used to explain the quality of the services whereby the demand for the services offered is high compared to the capacity of services. The theory explains how the number of ships arrives randomly and independently at the port until any specific time (t) aiming at loading or discharging cargo but they're unable to dock because all berths (quay) are busy or occupied with operations therefore ships are supposed to wait at outer anchorage for free berth (quay) that leads to ships queuing process. The port management use queuing model to handle ships arriving at the port by assigning them to berths, ship loader, and unloader-like cranes through queuing discipline whereby the first ship to come, is the first ship to be served (Zhang *et al.,* 2024).

These Queuing models have random distribution characteristics whereby service time follows exponential distribution and the arrival rate follows poison distribution. Queuing theory modeling used in the analysis of optimization of ship turnaround times and vessels traffic at outer anchorage such as: determining the arrival rate of the ship and services time spent by the ship at berth, expected time spent by ships at the berths and queue (ship turnaround time) as well as the expected time spend on outer anchorage or Queue (Bolanle, Chinweze, Olanrewaju, & O, 2011), (Umaru, 2018).

The arrival rate of the ship

The arrival rate of the ship can be estimated by the following formula

$$P(X = x) = \frac{e^{-\lambda}\lambda^{x}}{x!}$$

Poisson Distribution

Where by $P(X)$ present probability of x arrivals, n represents the number of arrivals, t represents unit time and lambda (λ) represents mean arrival rate. The expected waiting time of the ship at outer anchorage. The expected waiting time of the ship at outer anchorage involves the average time that a ship spends in the queue only. It can be estimated by the following formula:

Let's assume: w_q represents the expected time spent on outer anchorage, represents l_w represents the average number of ships in outer anchorage and $\frac{1}{\lambda}$ represents inter-arrival time

$$w_q = \left(\frac{1}{\lambda}\right) l_w$$

$$= \frac{1}{\lambda}\frac{\lambda^2}{u(u-\lambda)}$$

$$w_q = \frac{\lambda}{u(u-\lambda)}$$

Services time involve the expected time to be spent by the ship during the loading and unloading of cargo.

The expected time spent by ships at the berths and queue

The expected time spent by ships at the berths and queue (ship turnaround time) can be estimated as follows:

Let's assume: T_{bq} is the expected time by ships at the berths and queue, λ represents the mean arrival rate of the ship, $\frac{1}{\lambda}$ represent the inter-arrival rate and N_s number of ships available at the queue and berths

$$T_{bq=}\frac{1}{\lambda}\ N_s$$

$$= \frac{1}{\lambda} \times \left(\frac{\lambda}{\mu-\lambda}\right)$$

$$T_{bq=} = \frac{1}{\mu-\lambda}$$

Generally, ship turnaround time will be obtained by taking departure time minus arrival time. (STT = Departure time - Arrival time).

Three Factor Theory was formulated by Professor Kano aiming at improving customer satisfaction. Customer satisfaction consists of three attributes known as three factors which are requirement, excitement, and performance factors. These factors have different impacts on customer satisfaction. Basic factors are the minimum requirements that make dissatisfaction if not met. Excitement factors include surprising customers by increasing satisfaction but it does not cause dissatisfaction if not met. Satisfaction occurs when there is high performance and dissatisfaction occurs when there is low performance resulting in Performance factors. Therefore, when there is good port performance, optimum ship turnaround time is met leading to customer (ship charterer and shippers) satisfaction, and when there are poor port performance results in higher ship turnaround time leading to customer dissatisfaction (Zhang et al., 2024).

The study used multiple regression to analyze time series data in investigating the quantitative relationship between turnaround time, cargo throughput, and revenue generated by the seaport and its effects on port performance in Nigeria. The study outcome found the established three variables which are revenue, cargo throughput, and vessel turnaround time had a strong positive correlation (R=0.998). This means cargo throughput and ship turnaround time affected port revenue performance since port revenue depends on throughput and ship turnaround time. From 1999 to 2013, the trend in cargo throughput and port revenue increased directly. This means as cargo throughput increased, annual port revenue increased. Furthermore, there was a positive correlation between (R=0.991) port revenue and vessel turnaround since annual port revenue is directly proportional to vessel turnaround time which means as annual port revenue increased, the vessel turnaround increased. The study recommended that port management policies should be made in such a way they attract shippers by increasing the volume of cargo throughput to increase revenue performance (Sucahyowati and Purnomo, 2024). The study aimed at investigating the consequences of port congestion on logistics and supply chains in the ports of Lagos, Durban, Mombasa, Doula, and the catchment ports of the Suez Canal (Port Said). The study identified various categories of port congestion including cargo congestion, ship congestion, and truck congestion within the port and terminal. The study results on the list of ports surveyed and investigated identified various categories of port congestion which were cargo congestion, ship congestion, and truck congestion within the port and terminal.

Durban Port and Port of Said are seen as the best in resisting port congestion in Africa port because they possess the best port strategies in cargo handling and managing storage systems also, port operations are arranged in a good manner. Durban port had a fast operational, transactional and storage dwell time of 4 days for import and export cargo followed by the port of Said with 5 days of dwelling time, Mombasa port with 11 days of dwelling time, the port of Lagos with 16 days dwelling and the least port was Douala with 19 days. The factors for port congestion in Africa were largely seen to be similar such as lack of enough storage facilities such as yards and sheds, improper planning, poor port investment leading to inadequate equipment, scarcity of port and landward route infrastructures, and bad weather conditions that can stop port operation. Therefore, port congestion negatively impacted port efficiency, leading to cargo delays and higher ship turnaround time, an increase in unnecessary expenses and extra costs to the economy, decreased port revenue, and trade disruption. Therefore, to optimize port congestion and reduce dwell time in terms of operational, transactional, and storage in African ports, the study recommended the following; Proper port planning, increasing port capacity, and expansion of the width of channels through dredging to ease access of entry and entry of ships calling at ports. Constructing and improving port infrastructures such as roads and railway networks, purchasing and installation of modern port equipment and facilities such as upgrading berths, storage yards, sheds, and warehouses as well as enhancement of regulatory mechanisms should be kept into consideration. Adoption of good port strategies in terms of cargo storage and management systems (Sucahyowati and Purnomo, 2024).

The studies aimed at identifying the factors that are responsible for the turnaround time of vessels (TRTV) at New Mangalore port in India that can be used in decision-making by various port authorities to improve port productivity and efficiency resulting in high port performance that benefits port users. According to the study turnaround time of vessels is categorized into the following components: waiting time, inward movement time, services time, and outward movement time. The factors affecting the turnaround time of vessels were categorized into the following; pre-berthing delay factors such as the absence of berths, tugs/crafts, mooring gangs, pilots, draft restriction, ship/shippers accounts, documents not prepared, etc. Pre and post-commencement factors included customs formalities inward and outward, documentation inward and outward, survey inward and outward, immigration documentation, sealing and inspection, and departure formalities. Port constraints and non-port constraints factors include holiday recess, shifting time, equipment breakdown, non-availability of labour gangs, shed congestion, lack of storage, lab testing, sampling, immigration, bunkering, hatch arrangement, opening, and closing, etc. Idle time at berth factors includes holiday recess, power problems, labour breakup, breaks during shifts, etc. Environment factors include weather/rain, tide, night navigation, etc., and lastly, vessel constraints factors involved engine failure, delay in sailing vessel repair, tank value problems, etc. TRTV was analysed in two ways which are year-wise and seasonal-wise. The outcome of the study in terms year wise analysis was observed that components of pre-berthing time during the non-monsoon period and service time had a maximum percentage of vessel turnaround time. Also, the study observed that the turnaround of the vessels during outward movement time was more compared to inward movement time. The seasonal analysis outcome observed was that service time was higher during the monsoon period and pre-berthing was higher during the non-monsoon period while the outward movement time was higher compared to the inward movement time of vessels arriving at the port. Also, the study noticed that dry bulk vessels had a longer turnaround time in terms of service time compared to container vessels. Liquid bulk (tanker) vessels had a longer turnaround time compared to all other categories of cargo vessels (Shetty , Gurudev, & Dwarakish, 2021).

3. Research Methodology

A Quantitative research approach was used to analyse numerical data and determine the factors affecting ship turnaround time. this study used Retrospective Longitudinal Design since the researcher used the data that already collected by Tanzania Ports Authority and Tanzania (TPA) and Tanzania Shipping Agencies Corporation (TASAC) over a period of time from a year 2018 to 2022 and year 2020 to 2022 of ship turnaround time and gang productivity of labour in order to provide insights and implications of the current status in terms of operational performance aiming at the improvement of Dar es Salaam port efficiency. The employed secondary data were collected direct from TPA and TASAC specifically for Dar es Salaam port. (Shukla, 2020). The target population of the study involved data on ship turnaround time and port handling equipment's of a year 2020 to 2022 with a total of 36 Months as well ship turnaround time and gang productivity of labour of a year 2018 to 2022 with a total of 60 Months. The selected sample consisted panel data that comprised ship turnaround time, port handling equipment's, and gang productivity of labour for Dar es Salaam port. The data for objective one spanned from a year 2018 to 2022 with 60 observations while objective two ranged from a year 2020 to 2020 with 36 observations.

The study employed non-probability sampling specifically purposive where, the researcher relied on his own judgment in selecting the sample since the data collected were limited in nature. The study used secondary data for Dar es salaam Port in the analysis of determining the factors affecting ship turnaround time. The collected panel data comprised ship turnaround time, port handling equipment and gang productivity of labour. The sample obtained after paying visit to these organizations were small in size but provided valuable insight into the factors affecting ship turnaround time at Dar es Salaam port and provided an implication for improving Dar es Salaam port efficiency. The panel data collected for both study objectives one and two were processed and statistically analysed using R programming software version 4.2.3. Correlation analysis, and mixed effects panel model were employed to analyse the data and addressing the research objectives.

3.1 Data analysis Techniques

To address the first and second objectives, a mixed effect model was sufficed for the analysis. The general equation of mixed effects panel model representing its mathematically relationship is given as follows:

$$\boldsymbol{y_{it} = \alpha + \sum_{i=1}^{p} B_i X_{it} + (\lambda_i + u_i) + \varepsilon_{it}}$$

where by:

yt_{it} is the dependent variable for unit i at time t

X_{it} represent the independent variable

$B_o, B_1 \ldots\ldots, B_p$ are the fixed effect coefficients

α intercept that is constant

λ_i represent a random effect for unit i of an unobserved heterogeneity across units.

u_i is an individual specific effect

ε_{it} is overall an error term Furthermore, Mixed Effects Panel Model was used in the second objective to determine the effects of gang productivity of labor on ship turnaround time at Dar es Salaam Port. Its mathematically illustrated as follows;

$$f\ (ship\ turnaround\ time)\ = f\ (gang\ productivity\ of\ labour\ )$$

Therefore:

$$\boldsymbol{STT_{it} = B_0 + B_1 * GPL_{it} + (\lambda_i + u_i) + \varepsilon_{it}}$$

where by:

STT_{it} is denoted as Ship turnaround time,

PGL_{it} is denoted as gang productivity of labour (Independent Variables)

B_o is an intercept representing the expected ship turnaround time when the port handling equipment is zero,

B_1 is the coefficient representing the estimated impact of port handling equipment on ship turnaround time,

λ_i represent a random effect for unit i of an unobserved heterogeneity across units.

u_i represent individual specific effect that capture fixed effect specific to each unit

ε_{it} is an error term representing the random variation or an unobserved factor that affect ship turnaround time

t ranges from year 2020 to 2022

Additionally, the first and second objective used correlational analysis specifically the Pearson Correlation coefficient (r) to examine the relationship sought to be studied.

4 Results and Discussion

4.1 Effects of labour gang productivity specialized in handling general cargo (break-bulk, bags and minerals) on the turnaround time for general cargo ships

In this analysis the dependent variable is the turnaround time for general cargo ships which encompasses all ships carrying break-bulk, bags and minerals. The independent variable includes labour gang productivity for general cargo specifically for those handling break-bulk, bags and minerals cargo. The correlation matrix presented in Table 4.3.3 (1a) shows the relationships between year (PTY), labour gang productivity for general cargo (LGP-GC) measured in tons per labour gang-shift and turnaround time for general cargo ships (TT-GC) from a year 2020 to 2022 together with a Pearson correlation coefficients revealed significant associations.

Firstly, there was a moderate negative correlation (-0.572) between the PTY and LGP-GC, indicating that as PTY increased by one unit, LGP-GC measured in tons per gang-shift tended to decrease by 0.572 units. Conversely, there was a moderate positive correlation (0.656) between the PTY and TT-GC, suggesting that as PTY increased, TT-GC tended to increase. Additionally, a moderate negative correlation (-0.522) was observed between LGP-GC and TT-GC, which means the increase in LGP-GC measured in tonnes per gang-shift was associated with reducing TT-GC. These correlations below provide initial insights into how these variables might be interconnected.

Table 1. Correlation matrix between PTY, LGP-GC and TT- GC from year 2020 to 2022.

Variable		PTY	LGP-GC (Tons/Gang-Shift)	TT- GC
PTY	Pearson Correlation	1	-0.572	0.656
	Sig. (2-tailed)		0.000	0.000
	N	60	60	60
LGP-GC (Tons/Gang-Shift)	Pearson Correlation	-0.572	1	-0.522
	Sig. (2-tailed)	0.000		0.000
	N	60	60	60
TT- GC	Pearson Correlation	0.656	-0.522	1
	Sig. (2-tailed)	0.000	0.000	
	N	60	60	60

NOTE: TT- GC: Ship Turnaround Time for General Cargo, LGP-GC – Labour Gang Productivity for General Cargo

The mixed-effect model in Table 4.3.3(1b) delves deeper into these relationships, particularly focusing on the effect of LGP-GC on TT-GC. The model includes pooled, fixed, and random effects. The pooled effect (-0.013, p=0.000) indicated a statistically significant negative relationship between LGP-GC and TT-GC, suggesting that an increase in LGP-GC by one unit was associated with a decrease in TT-GC by 0.013 unit. However, the fixed effect (-0.004, p=0.148) and random effect (-0.005, p=0.067) for LGP-GC were not statistically significant at the 95% confidence level. This implies that while there was an overall trend of LGP-GC affecting STT-GC.The constant terms in the model were significant (p=0.000), indicating their importance in predicting TT-GC

Table 2. Effects of TT-GC on LGP-GC (tons/Gang-Shift) from year 2020 to 2022.

	TT- GC		
	Pooled (1)	**Fixed (2)**	**Random (3)**
LGP- GC (Tons/Gang-Shift)	-0.013*	-0.004	-0.005
	(P=0.000)	(P=0.148)	(P=0.067)
Constant	10.717*		7.253*
	(P=0.000)		(P=0.000)
R^2	0.272	0.038	0.055
Adjusted R^2	0.26	-0.051	0.047

**Indicates significance at 95% (p<0.05)*

Moving on to the diagnostic tests in Table 4.3.3 (1c), several criteria were evaluated inorder to assess the validity and reliability of the mixed-effect model. The Lagrange Multiplier Test (Honda) had a significant statistic (6.6522, p<0.000), indicating the presence of significant effects (individual specific-effect or time-specific effect) in the model. However, Hausman Test shown a non-significant statistic (1.9199, p=0.1659), suggesting that both fixed and random effects models were consistent. Both model were appropriate for the data and there was no substantial difference between them. The Chow test (0.9870, p=0.4225) indicated that there was no significant differences in the coefficient and Wooldridge's test (1.3098, p=0.1903) also indicated no significant issues such as structural changes or unobserved effects in the model.

Table 3 Tests for individual and time effects (Mixed Effect Panel Model Diagnostic)

Diagonistic criteria	Statistics	P-Value
1. Lagrange Multiplier Test - (Honda)	6.6522	<0.000
2. Hausman Test	1.9199	0.1659
3. Chow test	0.9870	0.4225
4. Wooldridge's test	1.3098	0.1903

***1.alternative hypothesis**: significant effects* , ***2. alternative hypothesis**: one model is inconsistent,*
***3.alternative hypothesis:** significant effects,* ***4. alternative hypothesis:** unobserved effect*

In summary, the correlation matrix and mixed-effect model provided a valuable insights into the relationships between PTY, LGP-GC, and TT-GC. The negative correlation between LGP-GC and TT-GC suggested a potential efficiency gain in TT-GC with lower LGP-GC tones per gang-shift. However, the model's diverse level of significance for LGP-GC effects highlighted the need for further exploration, considering potential contextual factors or variability that may influence these relationships. The diagnostic tests affirmed the model's overall validity while pointing towards areas for potential refinement or deeper investigation, contributing to a more nuanced understanding of the dynamics between these variables in the shipping industry.

4.2 To determine the effect of labour gang productivity specialized in handling dry bulk cargo (including dry bulk fertilizer, dry bagged cargo and other form of dry bulk cargo) on turnaround time for dry bulk ships.

In this analysis the dependent variable is the turnaround time for dry bulk ships which encompasses all ships carrying dry bulk fertilizer, dry bagged cargo and other dry bulk cargo. The independent variable consists of labour gang productivity data measured in tons per gang-shift specifically for handling dry bulk cargo including dry bulk fertilizer, dry bagged cargo and other form of dry bulk cargo.

The correlation analysis revealed various relationships among the variables studied. Year (PTY) exhibited a significant weak positive correlation with labour gang productivity for other form of dry bulk cargo (LGP -ODB) ($r = 0.375$, $p = 0.003$) and a weak positive correlation with labour gang productivity for dry bulk fertilizer cargo (LGP -DBF) ($r = 0.096$, $p = 0.464$). LGP-ODB indicated a significant positive correlation with PTY ($r = 0.375$, $p = 0.003$) but no significant correlation with LGP -DBF ($r = -0.003$, $p = 0.979$). LGP-DBF exhibited a weak positive correlation with Year ($r = 0.096$, $p = 0.464$) and no significant correlation with LGP-DBF ($r = -0.003$, $p = 0.979$).

Table 4 Correlation between PTY, LGP-ODB, LGP-DBF, LGP-DCB and TT-DBS from a year 2020 to 2022.

Variables		PTY	LGP-ODB	LGP-DBF
PTY	Pearson Correlation	1	0.375	0.096
	Sig. (2-tailed)		0.003	0.464
	N	60	60	60
LGP-ODB	Pearson Correlation	0.375	1	-0.003
	Sig. (2-tailed)	0.003		0.979
	N	60	60	60
LGP-DBF	Pearson Correlation	0.096	-0.003	1
	Sig. (2-tailed)	0.464	0.979	
	N	60	60	60
LGP-DCB	Pearson Correlation	0.168	0.081	0.235
	Sig. (2-tailed)	0.2	0.538	0.071
	N	60	60	60
TT-DBS	Pearson Correlation	0.443	-0.002	0.064
	Sig. (2-tailed)	0.00	0.991	0.629
	N	60	60	60

*Note: *Indicates significance at 95% (p<0.05)*

Additionally, labour gang productivity for dry cargo bagged (LGP-DCB) demonstrated a moderate positive correlation with LGP-DBF ($r = 0.235$, $p = 0.071$) but no significant correlations with other variables. Turnaround time for dry bulk cargo (TT-DBS) indicated a significant positive correlation with PTY ($r = 0.443$, $p < 0.001$) but no significant correlations with LGP-ODB, LGP-DBF or LGP-DCB. These findings suggested various degrees of associations among the studied variables, with some significant correlations observed, particularly between PTY and LGP-ODB related variables, while others remained weak or non-significant as illustrated on table 4.3.3 (2a).

The correlation analysis present in Table 4.3.3 (2b) revealed relationships among the variables studied. PTY demonstrated a weak positive correlation with LGP-DCB ($r = 0.168$, $p = 0.2$) and a significant positive correlation with TT-DBS ($r = 0.443$, $p < 0.001$). LGP-ODB and LGP-DBF exhibited weak positive correlations with LGP-DCB and TT-DBS, but these correlations were not statistically significant. LGP-DCB and TT-DBS displayed a weak positive correlation with each other ($r = 0.135$, $p = 0.304$), which was not statistically significant. These findings suggested limited or weak associations among the variables, with PTY showing a significant correlation only with TT-DBS as illustrated on table 4.3.3 (2b).

Table 5: Correlation between PTY, LGP-ODB, LGP-DBF, LGP-DCB and TT-DBS from a year 2020 to 2022.

Variables		LGP-DCB	TT-DBS
PTY	Pearson Correlation	0.168	0.443
	Sig. (2-tailed)	0.200	0.000
	N	60	60
LGP-ODB	Pearson Correlation	0.081	-0.002
	Sig. (2-tailed)	0.538	0.991
	N	60	60
LGP-DBF	Pearson Correlation	0.235	0.064
	Sig. (2-tailed)	0.071	0.629
	N	60	60
LGP-DCB	Pearson Correlation	1	0.135
	Sig. (2-tailed)		0.304
	N	60	60
TT-DBS	Pearson Correlation	0.135	1
	Sig. (2-tailed)	0.304	
	N	60	60

The mixed-effect model in Table 4.4.2 (c) examined the relationships between TT-DBS and LGP-ODB, LGP-DBF and GPL-DCB using pooled, fixed, and random effects. Notably, the coefficients for LGP-ODB demonstrated a significant negative effect in both the fixed (-0.006, $p=0.019$) and random (-0.005, $p=0.025$) effects, indicating that increase in one unit of LGP-ODB measured in terms of tones per gang-shift were associated with reducing TT-DBS by 0. 006 or 0.005 units. However, the pooled effect for LGP-ODB measured in tons/gang-shift was not significant (p=0.930). Similarly, the coefficients for LGP-DBF and GPL-DCB did not show significant effects across all three types of effects.

The constant terms in the model were significant, with values of 6.040 (p=0.009) and 10.061 (p=0.000) for the pooled and fixed effects, respectively. This suggested that these constants play a role in predicting TT-DBS, although the fixed effect model seems to place more emphasis on the constant term as illustrated by 4.3.3 (1c).

Table 6. Effect of LGP-ODB, LGP-DBF, LGP-DCB on TT-DBS from a year 2020 to 2022.

Variable	**TT-DBS**		
	Pooled (1)	**Fixed (2)**	**Random (3)**
LGP-ODB (Tons/Gang-Shift)`	-0.0003	-0.006*	-0.005*
	(P=0.930)	(P=0.019)	(P=0.025)
LGP-DBF (Tons/Gang-Shift)	0.001	-0.001	-0.001
	(P=0.870)	(P=0.546)	(P=0.606)
LGP-DCB (Tons/Gang-Shift)	0.007	-0.00001	0.001
	(P=0.353)	(P=1.000)	(P=0.943)
Constant	6.040*		10.061*
	(P=0.009)		(P=0.000)
R2	**0.019**	**0.108**	**0.085**
Adjusted R2	**-0.033**	**-0.012**	**0.036**

*Note: *Indicates significance at 95% (p<0.05), STT-DB means Ship Turnaround Time for Dry Bulk*

4.3 Model diagonistic test

Moving on to the model diagnostic tests in Table 4.4.2 (d), the Lagrange Multiplier Test (Honda) indicated significant effects (statistic of 5.9079, p<0.000), suggesting that the model captured important relationships which are individual or time specific effects. The Hausman Test (3.5609, p=0.3129) did not show inconsistency between the fixed and random effects models. The Chow test

(1.0949, p=0.3685) and Wooldridge's test (1.1905, p=0.2338) also indicated no significant issues such as structural changes or unobserved effects in the model.

Table 7: Tests for individual and time effects

Diagonistic criteria	Statistics	P-Value
1. Lagrange Multiplier Test - (Honda)	5.9079	<0.000
2. Hausman Test	3.5609	0.3129
3. Chow test	1.0949	0.3685
4. Wooldridge's test	1.1905	0.2338

***1.alternative hypothesis**: significant effects* , ***2. alternative hypothesis**: one model is inconsistent,*
***3.alternative hypothesis:** significant effects,* ***4. alternative hypothesis:** unobserved effect*

In summary, the results above suggested a more nuanced relationship for LGP-ODB, LGP-DBF, LGP-DCB with TT-DBS whereby LGP-ODB showed a significant negative association with TT-DBS in the fixed and random effects while LGP-DBF and LGP-DCB did not exhibited significant effects on TT-DBS. This observations indicates that different types of cargo may have varying impacts on ship turnaround time, necessitating tailored strategies for optimization.

4.4 To determine the effects of Labor gang productivity specialized in handling Ro-Ro units on Turnaround Time for Ro-Ro Ships

Table 4.3.3 (3a) presents the correlation matrix between Year (PTY), labour gang productivity for Ro-Ro (LGP-RoRo) which includes Roll-on/Roll-off measured in units per gang-shift, and turn around time for Ro-Ro ships (RoRo-TTS) from a year 2020 to 2022. The Pearson correlation coefficients revealed a significant associations between these variables. Firstly, a moderate positive correlation (0.545) between Year and LGP-RoRo was observed, indicating that as the PTY progressed, the number of RoRo units tended to increase. Similarly, a weak positive correlation (0.321) between PTY and RoRo-TTS, suggesting that as PTY increased, the RoRo-TTS tended to increase but slighlty. Additionally, there was a moderate positive correlation (0.278) between LGP-RoRo and RoRo-TTS, indicating that as LGP-RoRo increased, correspended to longer RoRo-STT.

Table 8 Correlation between Year, LGP-RoRo and RoRo-TTS from a year 2020 to 2022.

		PTY	LGP-RoRo	RoRo-TTS
PTY	Pearson Correlation	1	0.545	0.321
	Sig. (2-tailed)		0.000	0.012
	N	60	60	60
LGP-RoRo (units/ gang shift)	Pearson Correlation	0.545	1	0.278
	Sig. (2-tailed)	0.000		0.032
	N	60	60	60
RoRo-TTS	Pearson Correlation	0.321	0.278	1
	Sig. (2-tailed)	0.012	0.032	
	N	60	60	60

Note:Ro-Ro TTS: Carrier Turnaround Time Car Carrier, LGP-Ro-Ro: Labour Gang Productivity of Ro-Ro (Roll-On/Roll-Off) Units

Moving on to Table 4.3.3 (3b), which focuses on the effect of LGP Ro-Ro on RoRo-TTS, the mixed-effect model includes pooled, fixed, and random effects. The pooled effect (0.001, p=0.032) and random effect (0.001, p=0.028) were statistical significant, suggesting an increase in LGP Ro-Ro was associated with a slight increase in RoRo-TTS but the fixed effect (0.001, p=0.282) were not statistically significant at the 95% confidence level.

Table 9 Effects of LGP-RoRo on RoRo-TTS from a year 2020 to 2022.

	` RoRo-TTS `		
	Pooled (1)	**Fixed (2)**	**Random (3)**
LGP-RoRo (units/ gang Shift)`	0.001*	0.001	0.001*
	(P = 0.032)	(P=0.282)	(P=0.028)
Constant	0.397		0.397
	(P=0.199)		(P=0.194)
R2	0.077	0.021	0.077
Adjusted R2	0.061	-0.069	0.061

Note: *p<0.05

The results above imply indicated that, during the time of this study, LGP Ro-Ro operations at Dar es Salaam port was sufficient for managing RoRo-TTS operations. However, there might be other factors beyond LGP Ro-Ro that may have also contritubuted significantly in determining RoRo-TTS, including operational efficiency, port infrastructure, and scheduling practices. Therefore, its advisable, to consider adding more labourers to accommodate the arrival of large Ro-Ro vessels while implementing measures to misuse of resources.

4.5 Model diagonistic test

The diagnostic tests outlined in Table 4.3.3 (3c) were conducted to assess and evaluate the validity and reliability of the mixed-effect model utilized in analysing the effect LGP-RoRo on RoRo-TTS from a year 2020 to 2022. Firstly, the Lagrange Multiplier Test (Honda) had a statistic of -2.0454 with a p-value of 0.581, indicating no linear significant effects detected in the model. The Hausman Test also showed a non-significant statistic (0.2021, p=0.653), suggesting there was no inconsistency between the fixed and random effects models. The Chow test (1.0949, p=0.369) and Wooldridge's test (-0.1898, p=0.849) further confirmed that there was no significant issues such as structural changes or unobserved effects in the model.

Table 10 Tests for Individual and Time Effects

Diagonistic criteria	Statistics	P-Value
1. Lagrange Multiplier Test - (Honda)	-2.0454	0.581
2. Hausman Test	0.2021	0.653
3. Chow test	1.0949	0.369
4. Wooldridge's test	-0.1898	0.849

1.alternative hypothesis: *significant effects* , ***2. alternative hypothesis***: *one model is inconsistent,*
3.alternative hypothesis: *significant effects,* ***4. alternative hypothesis:*** *unobserved effect*

In conclusion, the diagnostic tests above provided assurance regarding the reliability of the mixed-effect model in capturing the relationships between LGP-RoRo and RoRo-TTS. Collectively, these diagnostic results indicated that the mixed-effect model confirmed the absence of significant issues such as model inconsistency or unobserved effects.

Access to modern and well-maintained equipment is crucial for port operations to run smoothly and efficiently. Equipment such as cranes, forklifts, conveyor systems, reach stackers and automated handling technologies etc, play a vital role in cargo handling, storage, and transportation within the port premises. Studies by (Mwisila, 2018) and (Katera, 2021) highlighted the importance of equipment accessibility in enhancing port productivity and reducing turnaround times. This study is relevant to the mentioned above as it aims at demonstrating how inadequate and limited access to advanced and modern handling equipment at Dar es Salaam port significantly impact its operational efficiency. Furthermore, it explains how the absence of predictive maintenances and repairs to defective equipment may leads to delays and bottlenecks in cargo handling processes, causing longer ship turnaround time affecting overall efficiency and competitiveness.

The Research studies by He (2024), focused on equipment accessibility within African ports. The study shed light on the challenges such as limited availability of modern handling equipment, aging infrastructure, and inadequate investments in equipment maintenance. The findings of this study resonate with the situation at Dar es Salaam port, where absence of modern and advanced equipment and infrastructure have been identified as potential barriers to operational efficiency. Furthermore, a comparative analysis by Justice *et al.,* (2025). Examined equipment accessibility in major ports across Africa, including Dar es Salaam port. The study emphasized the need for ports to prioritize equipment upgrades, invest in technological innovations, and collaborate with private sector partners to improve equipment accessibility and enhance overall operational effectiveness. The findings from Table 4.2.2 (b) underscore the considerable variation in turnaround times for different types of containerized ships at Dar es Salaam port, ranging from 2.830 to 16 days, with an average of 5.438 days and median exceed its desired benchmark of less than 3 days. Therefore, these values indicate complexities in port operations that may be influenced by various factors such as in adequate equipment infrastructure, regulations, and managerial practices. Therefore, this variability necessity a continuous monitoring in order to optimize port operations and enhancing port efficiency and competitiveness.

Similarly, the analysis of container equipment quantities, ranged from 19 to 32 pieces with an average of approximately 24.44 pieces, reflects inherent fluctuations in demand or operational practices within the port, highlighting the importance of resource allocation and equipment management in optimizing terminal operations and service reliability (Shin *et al.,* 2025).

5. Conclusion and Recommendations

The study concluded that the presence of bulk equipment at grain and port terminal did not correlate directly with turnaround time for bulk ships, it is important to note that any potential extension of bulk operations could lead to congestion and space limitations, further impeding turnaround time for bulk ships. The TPA management should design the training programs and policies that are in alignment with port strategies and goals while addressing the specific skill and competency needs of labourers. Management should conduct a comprehensive analysis to identify the critical skill gaps among labourers and areas that needs improvement. These training programs should incorporate mult-skills operations and be flexible to accommodate changes that may happen in operational environment, including advancement in equipment and technology advancement that may occur in future. Port Authorities should prioritize investment in automated technology and digitalization in order to transform and modernize port operation. This involves replacing most of manual labourers and outdated equipment with computerized system and modern equipment that utilize the application of big data and Internet of things.

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