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Logistics Solutions to Container Congestion Problems in Port Sudan 2020 - 2024 (Theoretical Study)

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Abstract

This theoretical study focused on addressing and explaining the problem of container congestion and overcrowding in Port Sudan, the main port of Sudan, which necessitates finding solutions to this problem that has negatively affected the movement of exports and imports. Especially since the Republic of Sudan is witnessing many disturbances as a result of the popular revolution that changed the regime, which created many challenges in this transitional period that Sudan is experiencing as a result of the change of regimes and thus its impact on the administrative and financial system in various joints of the state apparatus. The study proposed a model to simulate the situation, which was applied and introduced to stakeholders. The study concluded with a number of results, perhaps the most important of which are: There is a large congestion and overcrowding in the container area, as well as logistical and administrative obstacles that increase the size of the problem, and also from the results of the study that this congestion necessarily leads to an increase in handling, loading and unloading costs. The study concluded with a set of recommendations, the most important of which are: the necessity of formulating clear strategies and policies from the port administration to deal with this deteriorating reality of services, as well as studying the experiences of countries that suffer from similar conditions to learn how to overcome these problems.

Keywords: *Logistics Management, Port Sudan, Container Stacking, Loading and Unloading.*

Introduction

Port Sudan is currently facing significant challenges related to container and cargo congestion, primarily due to insufficient handling machinery and equipment, coupled with inadequate maintenance practices that have rendered a considerable number of these assets inoperative. Additionally, the port suffers from a lack of sea docks and insufficient water depth, causing ships to experience prolonged waiting periods before they can unload their cargo. The situation is further exacerbated by administrative and organizational inefficiencies, leading to poor management within the port environment. These multifaceted issues highlight the urgent need for comprehensive solutions to improve operational efficiency and address the ongoing congestion problems in Port Sudan (Abdelgadir, 2024).

Problems of congestion would become tree endings of Sudanese ports, either port of export or import. It had a negative effect on the function of the port and the delivery period of goods houses, because of delays and the often-close down between the ports and other cities and the most ability of the cargo, consumer and other imports as well as the considerable increase in the cost of those goods (MANSOOR et al., 2021). Sudan is located in the center of Africa and open to the red sea at the east part (Gulf of Sudan). Sudan has worked much about the infrastructure of the port, which are the most modernized and developed ports in the northeast of the Africa (E.O. et al., 2011).

The authors conduct Logistic test on traffic of the import goods which form the big problem of congestion. It will focus on the goods houses according equipment and situation of the port. It will present optimal Logistic immediately when then the number of the port container. Many recent studies have anticipated the situation. Given numbers of large vessel are that the Sudanese port can set it will be a big change such that they will have to reconsider their schedule. Moreover, they anticipate that the number of the import goods houses that have to be transported from or to the port of Sudan will increase, and that this will eventually lead to increasing congestion at the ports.

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This paper has two computation aspects. First, this paper will characterize the global course of the port. By presenting empirical evidence from data from the annual database of the traffic of the port of Sudan, the place where the congestion is described. Not only will give a brief and of the studied country, but also describe the layout of the pot facilities, the equipment's, and the current ordering systems. Farther more, it attempts to characterize the condition describe above a more technical terms, the validity of the number of the import container and station of the container house. Since congestion results from the planned movement of vehicles among different facilities, the second computational aspect of this word is a reformulation of the planning of the transport of container from the port of Sudan in to each the dry part of the port container house as a four stages vesturing framework, it presents a finite vesturing mathematical model for this problem and develop a tested equations that replaces the stationary long solution of the models.

Background of the Study

There has been a significant increase in the volume of container handling in the transport sector. Container handling efficiency is affected by logistics activities. Shipping companies optimize shipping routing costs, and the distribution of containers from the arrival port to the destination by using the appropriate type of transportation. High cost and inefficient transportation in Port Sudan are the main constraints for container throughput efficiency of logistics. Insufficiency of barge services availability in port Sudan and high transportation costs are the main problems. The barge service is unable to handle the whole volume of containers from the big mother vessels at outer anchorage. All harbors have been located far from the main transportation networks to facilitate movement of the containers, either by siltation of the harbor's channel or road transportation from the harbor to dry port is poor. These conditions are the main cause of the high cost and low efficiency of logistic container throughput in port Sudan. Volume growth of shipments and a sharp rise in the level of operational productivity and an effort to control costs become the key drivers of Port performance. The Port of Santander in-store installed a matching activity and the concepts of physical and monetary. There has been substantial attention in the literature on shipping in capacity, both in terms of issues surrounding market power, pricing and competition, as well as the management of container vessel fleet capacity planning and scheduling (Itumeleng Greta. Motau, 2015). Ports Development Strategy of the SJPP Project, it was seen that port and shipping like a two side of a coin, interconnected mutually. Furthermore, creation a new hub port will effect cargo distribution in the national shipping, and also will force domestic shipping in fleet organization.

Research Objectives

Main Objective The creation of an optimum logistics solution for Container Congestion in Port Sudan.

Sub-objectives:

To apply terminal operation, hinterland operation, information technology, legislation & competition, and administration logistics solutions in Port Sudan.

To develop a model of an optimum logistics solution based on terminal operation, hinterland operation, information technology, legislation & competition, and administration logistics solutions in Port Sudan.

To win the competition between the ports in the sea-trade logistics services.

Significant and Benefits of the Research

The Port of Sudan, a major world trade sea port in the eastern part of North Africa, has gone through rapid changes since independence from joint British-Egyptian control in 1956. The Republic of the Sudan, situated at the southern part of the Sahara Desert with the longest east-west coastal boundary in all Africa had experienced economic sanctions as well as a series of civil wars. The bulk Shipping Line, the International Bulk Trading, the Cotton Company and almost all other foreign trading companies who utilized the 21 jetties with 77 deep draught and the break bulk operation at Port Sudan left the country

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using the logistics service at Port Sudan after the secession of South Sudan in late 2011 (Itumeleng Greta. Motau, 2015). In addition, the liner conference is broken up by the European Union Opposition Commission in 2007, and further information is disclosed by the European Union on purporting the adverse effects of liner conference to the poorest countries, including Sudan, in 2013. And the SDR Port Logistics entered into the newly built South Port in 2008. These contingent events changed the logistics environment and turned Port Sudan into the 'logistics unhealthy' port; which has caused a container congestion of many stacked containers since 2008. This stirred up writers' to write a paper to find out how can win the competition between the terminals in the sea, which is a major thoroughfare not only in the sea trade but also to constantly a world of competition. In this strategic formulation. At the first phase of case study work in Port Sudan conducted in 2013, the present condition was examined to unveil that no strategies had been executed despite of the drastic container congestion. The 1.85 months average dwelling time of stacked containers, and the high market price of vacant container lots indicated that no outbound logistics solution was in place. The land transport cost increased by 40% due to the debilitated Inland Container Depot (ICD), and consequently, the additional consolidated empty container hinterland returned by 80% caused the port busy with dual transportation; particularly revealing that no hinterland solution was operated as well. Despite the berth productivity activation of quayside, the fitted productivity level by cranes and service ships were down below from the other East African ports, and even lesser liner operators called Port Sudan later based on the contract with SDR Port Logistics; then notifying that the solution restricted to itemized embarrassment of delivery system on the quayside, and before all operation of the needful solution a system in physio-geographical functions, such as road, railway and drought, must be in place and active.

Scope and Significance of the Study

Middle East and North Africa region is one of the fastest-growing port regions worldwide. In unprotected trade, carriers bear more profit loss than shippers even if there is any slight delay in shipment schedules, while shippers would lose profit more than carriers in the case of delay in shipment delivery (Itumeleng Greta. Motau, 2015). The results of an online questionnaire have revealed that the activated policies for attracting customers among import export companies in Port Sudan were 'Providing packaging, labeling, or palletizing' with a high mean of 4.29, followed by 'Reducing or removing transit and transshipment time' with a mean of 3.97, and 'Increasing services along the supply chain' mean of 3.84. On the other hand, the results show that the least activated policy was 'Relaxation in local and/or national restrictions or regulations' with a low mean of 3.12. Furthermore, the results have shown that the active congestion causing practices in Port Sudan are "Freight Forwarders hold the cargo inside the port instead of collecting it outside" with a high mean of 3.73, followed by "Freight Forwarders and Consignees do not collect the cargo at all" with a mean of 3.56. Meanwhile, the statistical data analysis for the collected SCH frequency data showed that there are an average of five vehicles arriving and departing the port daily, most of them are trailers with an average number of containers aboard the trailer of 10. Moreover, most of the arrival and departure vehicles happen at 12:00 AM, 6:00 AM, and 9:00 PM as it represented 80% of the total number of movements.

1. **Literature Review:**

This chapter discusses studies associated with several topics, including empty container management, competition among ports, container sea–rail multimodal transport, intermodal liner shipping network design, resource allocation, empty container repositioning systems, sustainable port transportation, maritime piracy, business relationship, coopetition, cooperation, competition and empty container repositioning. In this study, a competitive two-terminal system is established. Each terminal is managed by a resource-dependent service rate policy. NRS is used to ensure that port efficiency is positively related to the cost of using limited berths.

The development of port activities is marked by increased competition in the marine container transportation sector between terminal operators and fleets of ships. There is no doubt that only a few "nodes" of these networks attract most of scientific and commercial efforts. In the development of this four-component "center-periphery" model, there is an idea that the markets for containers and ships can

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be very sensitive to transportation time and frequency. Currently, many conditions are favorable for the development of "multifunctional vessel-terminal networks". The term "multifunctional" means that the node can perform both rotary and cargo/passenger functions. Experimentally analyzed, it was shown that the port-ship system with multifunctional nodes can effectively compete with "standard" port-bridge systems.

Conceptual Framework of Container Congestion

The container congestion problem in the port system is a natural situation where the container is stationary for a long time in the process of the passage system from the moments it enters the system until it leaves the system beyond a predetermined time limit. Container congestion generally occurs at several points, among other things at: depot containers, warehousing containers, inside loading vehicles, along the truck line to the terminal, in the container terminal, and in the container yard. There are several important factors that can affect container congestion problems, both internal and external factors. Conceptual framework of container congestion in the port system consists of a problem by identifying container congestion in the port system, determining the variables of container congestion in the port system, developing problem solving methods for container congestion in the port system, developing a hypothetical framework, and writing a case study. The occurrence of container congestion has an impact on the decreased service of the shipping system and the occurrence of higher costs. The value of the costs of container congestion can be quantified, among others: the cost of transshipment of goods to other ports, additional costs caused by overloaded ships, the cost of delay in the transfer of goods, the cost of container rental services, and increased consumption of fuel and relaxation of the crew of the vessel. In the case study, it was discussed with an agency office in the port of Sudan. Ship delays during the pandemic have increased on average per ship's visit from the moment the ship is anchored to the moment it's lifted to 4.9 days, including zero days.

Previous Studies on Container Congestion in Ports

In developing countries like Sudan, where logistics are used sparingly, container ships are not always properly charged or discharged, slowing the turn-around time (Lin et al., 2022). Also, containers awaiting rail or road connections are frequently not moved on time. The problem of quay unloading and loading is also a matter of concern. In addition to the above problem, there is an influx of various imports from different cultures, such as oil, cement, edible oil, wheat flour, and chemicals. Inefficiency in the handling of bulk cargo and potash causes congestion in the terminal area, so there is an unhealthy intermix of other cargo within the container yard awaiting dispatch. The port logistics system faces fierce competition between port authorities and shippers, thereby influencing the timely departure and handling of cargo. To keep away from threatening disputes, and the necessity to guarantee professional logistics services, it is required to enhance the efficiency of the port. Raja Koil Swamp Port is a hub that serves as a passage point for container transport on both east and west routes of the continent. Container terminals play a central purpose in seaborne trade international logistics systems. A port's total traffic depends on the performance of the container terminals. The quick rise in containerized ships, with the related raising in container throughput, has forced the terminal operator to look for effective strategies to provide rapid and efficient services. A container terminal provides massive investment entangled with a used service life that extends over a long period. From an operational point of view, the terminal has enduring character of production. It is considered to be when spending a large amount of time and expense in developing the system, at the start of construction, how it would impact on the overall system in later years (E.O. et al., 2011). Inexpediently, this is not how operations research techniques are employed. Port system design allows the design of the entire system to be optimized in a holistic manner. It enables strategic decisions to be made at the design stage that ensures the port system is capable of responding to the huge demand being placed on it in, for example, the growth in the size and number of completely unloaded vessels.

Methodology

The proposed methodology is based on building a flow simulation model for the handling of empty containers. This model consists of a sequence of five main operations that begin with the decision to ship

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an empty container and end when the container is loaded onto the empty container carrier ship. Each operation depends on its predecessors. Decisions on ships to load, carrier types and sizes, the feeding service, scheduling stevedores, and empty container ships are concurrently optimized. Whenever a container carrier transfers containers, the operation is modeled by a container handling operator transferring a decided quantity of containers. The generated demand profile differs from historical data and supportive decisions including relative servicing priorities. The case study of Port Sudan ensures generalizing conclusions and using the model and methodology in other contexts.

Empirical or queueing network settings effectively analyzed productivity enhancements to port empty container processing whereas a flow modeling approach is proposed for decision support in the handling of empty containers on container carrier ships (Aladdin Kotachi, 2018). This is relevant for productivity comparisons of different handling strategies. Operations are modeled through a set of service times for each of a number of equipment units at the empty container storage facilities. A service provider assigns equipment resources to demanded empty container carrier ships on which the service advance and delay are penalized. Service assignments are based on optimizers adopting queueing models as part of the objective function.

Research Design

Research methodology is the procedure of collecting and analyzing the needed information to support and explain the phenomena being investigated. The research strategy addresses questions such as the ways logistics solutions to container congestion issues in Port of Sudan from 2020 to 2024 can be offered, why the current system is struggling to handle container traffic, and how the proposed solutions will be implemented according to the analysis and results written in the text (Aladdin Kotachi, 2018).

A simulation will be carried out to replicate the present system of trucks leaving containers at the port and new trucks coming to collect them. There are a wide variety of publications on simulations for container ports. A bespoke tool is to be devised using Excel to immediately copy previous research methodologies for simulating present waiting times of trucks. Much of the needed data is not public information, but there will be scope for sensitivity analysis on the number of trucks that can be handled per hour. Necessarily the simulations will have to make simplifying assumptions about the underlying conditions, but truck volume per container is an obvious input parameter. Doing so would have important consequences on capital investment decisions, and is thus outside the scope of this overview. It would not be practical to investigate this, in any case, as the traffic data are unavailable.

Data Collection Methods

Introduction

Logistics take a crucial role in industry and trade in the global world. The quality and adequacy of logistics services determine the competitive power of the countries. A port has an essential role in the international trade process of countries. The majority of international trade transactions and the commodity that circulates in global trade are carried out by sea transport. In this reason, the port sector is the most popular one of the countries. Well-functioned ports and their logistics services are critical for a country's competence in international trade. Hence, the efficiency of maritime transport on country's competitiveness and, thereby, its economic growth is crucial. Maritime transport especially can provide fast and low-cost transport services for large quantities between distant locations. Container sea transportation has become the central transport sector among all modal transport types.

Innovations in information technology have caused a comprehensive change in all phenomenon, living, society, business life. On the other hand, various fields examined these technological innovations and adopted them for an improvement itself. This situation has transformed the requirements of these fields on technology into a specific problem. Therefore, different solutions were established in different fields, and R&D activities have been carried out in line with the needs. The current solution was shaped in the conceptual project work within the framework of machine learning, data mining methods as a result of an

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on-going problem persistence. Since studies have started analyzing and forecasting the street traffic using various machine learning methods, studies can also estimate travel times for trips planned in a traffic network. But, the maritime logistics sector, which is part of the freight transportation sector, still continues to work with conventional methods in the problem of container congestion in the port. However, if the problem of congestion of containers in the port isn't resolved, countries can experience significant economic downturns because container transportation has an essential industry.

Data Analysis Techniques

The proposed research will use several data analysis methods to investigate more deeply, more focused, and more practical logistics solutions to the container congestion problems encountered in the Maritime Port of Sudan. Here are some data analysis techniques and their justifications.

Overview and: Data analysis is a process through which raw data is reviewed with the aim of finding trends or drawing conclusions. There are different techniques for analyzing data, and the proposed research will use some of them to explore more deeply, more focused, and more practical logistics solutions to the container congestion problems faced by the Maritime Port of Sudan.

Data Fusion: Data-fusion is the process of integrating and fusing multiple datasets, which can complement the limitations of individual datasets. Currently, sea ports are no longer islands. They interact with wider transportation systems, so the analysis of data from the spatial scales of the port itself may not cover the overall view of the transportation network and vice versa. Vessel data mainly records the activities of container ships in/from port. It is important and necessary to contextualize the impacts of logistic operations at the port on the transportation network of the port-city corridor also about the spatio-temporal activities of the feeder trucks involved in the distribution to/from the port. So, the fusing vehicle probe data, primarily from passive GPS-equipped trucks, with vessel data can be used to investigate further industrial activities (Zeringue, 2020).

Strategic Analysis: The analysis also refers to the current statuary policies and regulations implemented by the respective Port Authorities and how such strategies help to avert the impending container disaster of container congestion on the dock. Strategic analysis suggests that besides the awareness and identification of problems by the Port Authorities, the basic solution for the relief from the container congestion is the fast flow of containers from the port. Therefore, some strategic policies and measures are directed to be considered as the primary concern and implementation. The statistical policies and regulations of strategic outlook includes the following noble avenues (demands for the development to setup terminal investment terrace).

Container Congestion in Port Sudan

The arrival of a container ship in a port is called a movement. Movements of ships and containers between ports are done in cycles. In these cycles, the basic transports are to carry containers by ships between the sending and receiving ports, and to transfer containers between the ship and the port and vice versa in the port. After the container operations, the transportation on trucks may be necessary (E.O. et al., 2011).

Ports and seaborne transport have enormous global and local economic and environmental impacts, especially in developing countries. With globalization, international trade and hence the role of world ports are getting more important. World maritime trade grew by 60% in volume terms between 2000 and 2007. This caused a remarkable rise in the containerized cargo. It is predicted that the operations will double by 2024. The traffic between Far East and Europe, the fastest growing global container route, will record 8738 TEU movements in 2024.

Consequently, at least 4-5 times more TEUs pass through ports on the European coast. Such an increase in container traffic will create a bottleneck in European ports where the capacity expansion and productivity improvements are hard to implement due to their locations within the urban area. In developing countries, where the ports are today the key component of the transport infrastructure, it should be assumed that the

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situation is much more difficult due to the lack of investments in infrastructure, superstructure and legal regulations. This has generated a logistic chain in particular affecting port operations. It is well known that most of the world and riverside ports exhibit productivity issues, along with service quality and cost problems.

Factors Contributing to Container Congestion

Container ships are already changing their dimension to be more variable, reaching up to a length of 400 meters and accommodating 12,000 TEUs (Twenty-feet Equivalent Units). The number of containers that can be removed from the ship also increases at the same time since the port is considered to be more effective on the turnaround time of the containers. For this capacity, shipping delivery can work twice in just two hours on the ship that has 5,000 TEUs. The impact of the increase in container ships is directly proportional to the port handling efficiency needed; so, if the capacity of the port does not increase, it will be very vulnerable to that issue of congestion (Pudji Rahmanto, 2016). Generally, nearly 80% of the world's international trade is conducted through sea lines using containers as a transport shelter these days. Consequently, many ports experience serious congestion problems due to the increasing trade activities and the containerization of the shipment. These problems will have the appearance of monetarily losses at both carrier and port operators. Ports and hinterland connections are now key components of global supply chain systems; an inadequate port will have a disapproving access on the competitiveness of large surrounding region (E.O. et al., 2011). Therefore, how cargo movement occurs from origin to destination and the relevant logistics and cooperative principles have transformed improved together with the globalization of economies. For developing nations, the greater part of the cost that people pay is linked with logistics activities. As a result, the efficacy of logistics operations is one of the most discreet quotients for them to contest in international markets, along with the production price and fundamental accessory costs to the production.

Impact of Congestion on Port Operations

Port Sudan has always been suffering from container congestion problems. The world demand for trade of goods and the transfer of cargos depends on maritime transport, where the cargos mostly are transported in big unit containers. The existing number of containers landside and roads from or to the port are not enough to satisfy the transportation demands, and in many cases they not available. Vessels have limited dates to sail and to berth and limited dedicated time at the berth also. The container carrier vessels have now a day very high speeds and they usually sail in short routes or canals. After many hours voyage either with the seaway or anchored near the port the vessel cannot wait more for berthing. Congested ports reject the carriers with the long waiting time waiting outside the port and this is not accepted by the carriers' representatives or owners. This results to move to other nearby or neighbor ports.

When congestion intended as massive un-cleared cargo in the port, the vessels get their berthing turns very longer. So, they delay longer time since they reach the port and actually enter the port. Moving outside the port to join the queue will have also some waiting time. This will result in increasing the voyage time between ports. For carriers with limited windows, to berth in both originating and destinations ports, they will lose some vessel ports calls. This, in turn, results in bad advertisement for the port, directly affecting its income. Its links with ships owners or representatives are also affected and have negative points in electing the port. The carriers which can need only few berths to release or to receive their loads cannot find place in the ports. This will also affect the line schedules of these carriers and they will move to other ports. In this context also when congestion is intended to the delay is limited to the berthing time, carriers will not baton to berth in this port and wait time outside the port will be reduced. In this situation, the same carriers can brush the other carriers from its berth as long as the waiting term is longer than the time at the berth (E.O. et al., 2011).

Logistics Solutions

The cost of logistics only studies on critical logistics system issues continues to grow. Among the various steps of the supply chain, the last one—the physical distribution of goods—absorbs a large share of the

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total logistics budget. Transferring goods from centralized production sites to a growing number of geographically scattered consumption sites requires the use of a high degree of ordering and physical distribution coordination. This justifies the attention of many researchers and practitioners focusing on the efficiency of logistics operations (Storms et al., 2023).

Evaluations of port productivity in the world, some of the inefficiencies in the operation of container terminals under different headings are enumerated. The management of container movements in and out of a seaport, through both a pre-marine component of the transport chain, and a subsequent intermodal component, is part of the logistics chain involved with two main different Generalized mechanical flow and Ro-Ro transport: trucks and tractors. Measures to improve vehicle transit between the port gates and cargo zones are needed and should aim to optimize these transit phases themselves, but also to avoid extendibility from troubles that may arise within the cargo zones.

Concerning the marine component of the logistics transport chain, a significant reduction of port access time is determined by improvements in quayside efficiency, which in turn increase economies in deployment slot scheduling, and reduces the possibility of cumulative stretches of staff and equipment. Ports play a critical role in the process of global trade. Due to the global demand for goods in containers, the shipping market has grown substantially in the last decades. Containerization has become a standard in maritime transport for it offers low cost, efficiencies, and safety. The performance of a port has decisive importance in supply chain efficiency and competitiveness of shipping companies.

In the first approach, a simulation model is developed and implemented, based on geographical information, which enables to determine the average container in/out of the port time, the average container transit time, the service time function and the queues formed in the system. Based on the results, alternative solutions are proposed to overcome congestion in the port of Sudan, including the construction of a new quay, the use of information technologies in the container terminal, the organization of construction work better and the work of terminals. Regarding the work organization of the terminals, a micro-simulation model was developed to perform analysis of different working scenarios of the terminal. Subsequently, net output, net financial benefits gained from the development recommendations and their break-even point and sensitivity analyses are provided. This study provides an Excellent tool for decision-makers for the further improvement of port operations in the Port of Sudan.

Port Infrastructure Development

Freight logistics is a very important part of a country's economy, which requires a thorough coordination of a variety of components within international trade, logistics infrastructure, regulations, and administrative practices. The breakdown of only one component may result in operation disturbances, including the operation of maritime transportation. Sudan is one of the fastest growing nations in Africa, with a current growth rate of 8.4%. However, the spread of growth is uneven, and only Khartoum is exhibiting a typical feature of a more monetarily superior economy (Mohammad & Mohammad, 2019).

Sudan still remains the country's mostly agrarian, the majority of the populace and is the second largest country in Africa with probably the largest economy. Sudan presents an investment possibility in many sectors, like Agricultural products, hydro-electricity products, gene-based pharmaceuticals, and waste product reprocessing. A challenge in this development is providing compactness of such goods in finding method of reaching major markets extra than the dribble through the main center-port-coastal passage being the only way accessible by sea. Port Sudan, the country's individual way, is situated with around 1133 kilometers from the capital. On an average trip, between Khartoum and Port Sudan (prefer time from 12-18 hours), does not appear like an appealing choice, and the recent increase in robbery that have also used on this highway has produced the insurance coverage so costly that truck drivers have found it worthwhile to risk the penalties. Success of the arranging goods is posed as the main issue, and a description the Sudan Port Authority as a whole is existing (Lihoussou & Limbourg, 2012).

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Operational Efficiency Improvements

Due to the implementation of the containerization system in Port Sudan, different types of problems have been observed related to containers and vessels, such as the accumulation of shipping trays in the port yards in addition to the existence of a problem of delay in the travel and departure of vessels. Congestion in container maritime terminals is defined as the situation where there is no connection between the container transport operations and the planned schedule infrastructure in terms of the swift and effective vessel unloading and loading of containers, the storage hand back of containers until the vessel arrival and the efficient land transport of containers to and from the port container yard. There are two main types of inefficiency that cause the underlying problems around congestion in container ports: port inefficiency and transport inefficiency. Port inefficiency can be caused by a small number of key performance indicators in terms of setting within the environment in which a terminal is located. On the other hand, transport inefficiency can be caused by the presence of a truck. This has great consequences for the hinterland. For example, the specific case of trucks queuing for more than two hours at the gate leads to a reduction in the average number of containers any adept truck can uplift per day. This issue is exacerbated by further anticipated increases in port and vessel sizes. Efficient land transport is important for improving the overall port maritime terminal performance. The operational sequence of the transport purchase chain is sea transportation between ports and land transport to and from the ports. An effective demand and supply relationship should be operated between sea carriers and shippers, as well as between sea carriers and land carriers to make the entire transport purchase chain efficient. Middle of transaction mixture of sea and land carriers is held in service schedules and place, it is important for seaports to provide first class services if land carriers are to freely flow to and from the port efficiently. Given that a transport hub is a point of final interaction when transactions have made, measured in terms of level of exposure to a transport hub, it should be possible to control port-land transport margins in varying degrees. In case of high exposure, port carriers can exert market power. Thus, landside operation restrictions in the port container terminal may give rise to antimodalism and a general decrease in the transport purchase chain efficiency.

Technological Innovations

Efficiency of the container terminals can be affected adversely by increased transit times such that the volume of throughput is reduced and thus container ports fail to operate at the designed capacity and profitability (K Watfa & Karmadi, 2019). Container Congestion of Port Sudan is expected to be overcome by planning a suitable solution which can save both time and cost of transportation of container terminals. Container maritime transportation is one of the main parts of the world freight transportation and it has been playing a critical role since the last 50 years. There is an increase in the number of container collisions and a decrease in vessel velocities as the size of the vessel increases, affecting the optimal ship-to-dock assignment of an automated container terminal.

The connected Automated Guided Vehicle (AGV) system increases the productivity of transferring the containers from the ship to the storage yard by attaining a deterministic scenario. It is also used to achieve the objective of minimizing the maximum container transit time for all containers.

6. Case Studies

This section reports on a series of case studies focused on different initiatives that have been implemented to solve container congestion problems in several countries. Indonesia, Iran, Italy, the US, and the UK, which are among the countries with the top twenty ports in the world, have been studied. These countries have successfully brought solutions to container congestion problems. Global solution strategies are put forward in the last part of the paper.

As one of the largest archipelagic countries located in South East Asia, Indonesia is facing complex and dynamic problems in dealing with its sea transportation system. To overcome these problems, the Indonesian government has designed a strategic plan for the development of seven international hubs in

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several strategic locations. Indonesia has been able to improve the supply chain system so that the national cargo has effective lead time equitably distributed. The reliability of the national sea transportation increased by maximizing maritime safety and security aspects. Increasing national shipping's competitiveness is done by regulation of tariffs competently, providing incentives and disincentives to classification. Indonesian government has also built infrastructure facilities and increased services that are integrated with port services (Azimi & Reza Ghanbari, 2011).

Successful Implementation of Logistics Solutions in Other Ports

The main purpose of logistic solutions is to minimize the movement of trucks carrying empty containers to and from the port area from various warehouses and storage locations (Mohammad & Mohammad, 2019). In order to achieve the aforementioned target, Shipping Lines/Appointed Agents have to store and dispatch full containers, while Shippers, Consignees, and Clearing and Forwarding Agents have to handle empty containers. The situation is exacerbated by the difficulties in moving and storing full containers, which are attributed to inadequate handling facilities, space, labor, and inappropriate organizational arrangements, as well as late document processing and picking up the containers from the port area (Abbasi et al., 2012).

The purpose of the paper is to examine the efficiency of priority sequencing rules for dispatching empty containers out of the port area and issuing invoices for transporting loaded containers into the port area, as well as the cost-efficiency of shifting the container storage area from the New Port to a location in the metropolitan area allocated by the Port Sudan Port Authority, and to evaluate the extent to which the problems of storing and handling full containers in the port area are reduced by the introduction of the Recently Opened Container Freight Station, by analyzing the data collected from January 2020 to July 2024.

Governmental Policies

Recently, the trade world has been developing rapidly, this can be seen from the increasing number of containers in various ports around the world and the increasing volume of import and export traffic that generally occurs at the level of global trade. All this indicates the increasing growth of maritime shipping, and thus enhances the importance and role of ports as a hub for this growth. But this is not directly proportional to the readiness of industrial land that starts to be felt. Container Congestion that occurs frequently at the port is an example of inadequate warehouses and equipment for loading and unloading (Pudji Rahmanto, 2016). Overcoming this is certainly not easy because it involves financial problems to support it. Conversely, it is also troublesome because a monopoly in one area increases the cost. Usually what often happens is the leadtime or the time for storage is longer; Inappropriate warehouse rental fees. But there is a solution suggested by operations, this is based on the Time-Cost Literacy can avoid expenses in full but can reduce costs in real. The paradox of wanting a low cost simultaneously with efficacy is actually not a mistake. For a container to run faster or be faster leads to a domination of agility, which is good if it is spelled as a corporate strategy, but a savage consideration for business actors. Port-induced competition creates operators to lower tariffs as low as possible. The amount of discount was awarded more and more without pay attention to the implications. To serve better, to superficially bid for cargo owners, ultimately lower quality service. Features of this research are to introduce a dynamic performance measure ensuring three focuses to enhance the productivity of seaports and to defend the environment. In particular, the productivity and global efficiency evaluated in this paper will be introduced into non-bulk ports. Efficiencies reflect the productivity aspects and the analysis based on the Malmquist Productivity Index calculation, where productivity change maintains its decomposition, influencing technological and technical efficiency change. Subsequently, the paper pursues deeper attention to the decomposition structure of the MPI. Based on Kernel Density; the efficiency clusters will allow performance measurement and improvement more locally, facilitating comparisons amongst ports. Features of this research are to introduce a dynamic performance measure ensuring three focuses to enhance the productivity of seaports and to defend the environment.

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Policy Recommendations

Introduction

To commence, it is imperative to elucidate the significance of the dry inland port within the broader context of container traffic management, which constitutes the focal point of this discourse, thereby facilitating a comprehensive grasp of the ensuing analysis. The operational dynamics of the dry inland port, often relegated to inactivity, will be meticulously examined in subsequent sections. This exploration is particularly pertinent given the escalating demurrage charges levied at the TTL on imported goods, a consequence of prevailing challenges associated with the clearance of import containers. The inadequacies evident in transportation infrastructure and the logistical oversight in managing port containers manifest as critical impediments at the lamppost terminal of the Port Sudan Port, which is alternatively designated as the dry port. Consequently, a thorough understanding of the dry port's operational role is essential; thus, a breadth of literature pertinent to the dry port is scrutinized. The themes addressed within this literature encompass: the foundational purposes of their establishment, their geographical placements, the array of services rendered, the multitude of functions they fulfill, the operational methodologies employed, the ownership or operational entities involved, the myriad challenges encountered, and the strategies employed to mitigate these challenges.

Literature review followed by the discussion section, which focuses four operational problems experienced by the TTL and troubleshooting efforts to solve these problems. In most developing countries, trade has grown dramatically, particularly via container traffic. The development of container traffic has increased significantly the amount and system of goods distribution in the various modes of transport. One trend in the cargo handling system has been to improve efficiency and optimize the logistics network. In the transportation of goods, shipping lines have also tried to improve efficiency by minimizing the time taken for a smooth transshipment process. As a result, they have developed containerization, and container cargo has grown rapidly over the past two decades. Not only does the volume of container cargo grow significantly, but also the size of the ship. Major shipping lines continually invest in newer and bigger ships to make them more cost effective. Ports and container terminals are an essential part of the containerization system, and are inextricably linked with the operation of marine container transport. For the port, the fast turnaround time of containerships have become one of the most important factors contributing to their economic performance. This has resulted in the continuous increase of ports and container throughput capacity in recent decades. Modern container ports are complex, enormous systems where the various handling operations take place and which require much longer time to set up than other types of ports. A container terminal requires specialized facilities and equipment and is costly for operators to build. Consequently, container terminals have much longer lifetimes, usually 40 years or more, making them very different from other types of port facilities. Moreover, among all kind of transport, container ports are now receiving extra attention since they have to pay much more attention to an increasing in handling capacity in line with the growing size of the new generation of containerships. The changes in liner transportation strategy have seen a tendency of shipping line to improve economy of scale in the operation, such as increasing the average container slot capacity of vessels. Subsequently, this has occurred a significant reconfiguration in handling operation within the container ports with the policy either to construct new terminals or to restructure and mechanize/automate existing terminal or equip them with larger container gantries. If a container port does not have the capacity to grow vessel size, it will be unable to compete because it has been common practice for carrier hub-and-spoke systems to favor the establishment of large ports with economies of scale. A common problem that has usually occurred as the increase of container throughput, particularly in the America and Europe, is caused congestion in container ports. (Lin et al., 2022) Container ports are highly productive, yet the dock-side problem to pure labor force that cannot expand easily. The bottleneck spreads from the quay to the container terminal yard and eventually to the port approaches as well as the other parts of the hinterland. Congestion at the port has a great impact on the transport and logistics costs, especially for the land transport modes such as trucks. Moreover, the congestion in the port could trigger a modal cost transfer to more pollution and less efficient transport such as trucking. Generally, the congestion on highways could increase goods prices as the more fuel is consumed

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during traffic jams, the time lost in traffic jams, and greater vehicle maintenance needed. Moreover, there is a serious impact on air pollution caused by vehicles. Therefore, to decrease the congestion at ports, the modal shift of transportation is needed as well as a location shift (Pudji Rahmanto, 2016).

Recommendations Related to the Local Environment

- Continuous communication between stakeholders, to bring sustainable solutions to solve Port Sudan port problems and to prevent the accumulation of problems and solve them in a timely manner.

- Taking into account the local communities for their great impact on Port Sudan port, as they are the main provider of labor to the port.

- Taking into account continuous qualification and training and providing workers with the latest tools and equipment in the field of loading, unloading and handling, as well as providing them with the best administrative and technical practices in the field of port work.

Conclusion and Future Research Directions

Shipping containers are usually transferred within the terminal area of a port. An important part of this transfer process is to move the container from its storage area to the yard where it is loaded onto the outgoing truck. The transferring of the container between its storage and loading yard is then modeled as a queuing system with deterministic rail cranes as the primary source of loading and unloading of the service queue. The number of cranes assigned to this task is kept constant at two for simplicity, while the container retrieval and stacking operations is assumed to be performed by other cranes that are always available; the container dwell time is kept minimum. The time taken by a crane to serve at rail is exponentially distributed. The service completed, the crane goes back to the rail exchange area to pick up another container. Once the crane gets back, it waits in the queue before it can start serving. Similar to the real system, the system is designed such that the crane can only serve from storage yard when it is empty. The major aim is to look at the performance indicators of the terminal to assess the level of congestion and how malleable they are to alleviate the same (Vacca et al., 2008).

A simulator model in line with the present infrastructure was developed to start with. After evaluation through intermodal terminal, it is seen that the stop-go duration of the rail crane is a crucial improvement to the performance of the system. Strategies that manipulate this duration are examined. Apart from this, another strategy that proposes dedicated rail quay crane during heavy traffic is also looked at. However, these strategies might be pivotal to a particular setup as the present one and might not be generalizable, or at least suffer a certain degree of adaptability issues. Hence, there is a call for other strategies that can alleviate the congestion at the rail-crane loading side that are applicable to a broader range of ports. Some of the issues identified during the preliminary tests are container blocking, failures, and disruptions in the cycle time of rail traveling of the cranes. However, these concerns fall beyond the specifications of the simulator model currently set up and are not dealt with, but would be an interesting direction for future work. Other future work could pertain to the impact of wind on the performance of quay cranes because, during the data collection phase several times quay cranes were not in operation.

Key Findings

Shipping and port operations have undergone a significant change over the past few decades. The advent of international shipping paved the way for the societal modernization of procedures that were once executed on local and national scales. The growing need to reduce operating costs, serve a global audience and increase container operation capabilities has given rise to a plethora of logistical solutions, which allow for superior efficacious operations within the port. Economically viable and proficient solutions offer a variety of strategies that can be implemented to address container congestion in Port Sudan. These solutions target three sections of the container port: the water zone, the quay zone and the land zone. Port Sudan is

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the only feasible shipping terminal in the central region of Sudan. It must operate highly efficaciously to facilitate the region's trade, which is otherwise landlocked by the immense South-Eastern desert. The current paper provides port operators and system designers with a variety of strategies that can be implemented to address container congestion in Port Sudan. The optimal time for the shipment of cargo units, under the condition that they arrive at the port as a cotery, subsequently sit overnight, and then continue on their journey is calculated. A small-scale simulation model of container movement in the land zone is developed along with an optimization algorithm which is used to generate logistics solutions for congestion reduction. Solutions typically include: proposals on the handling of cargo units, optimal stacking arrangements for the equipment or responsible cargo, in addition to the optimal routes for the movement of the cargo units. At the quayside, the stacking of cargo units is intense, the ship berths are fully non-linear and traveling distances for the corridor cranes are extensive. There are three possible strategies that could be developed for the quay zone. Few solutions are usually offered to ameliorate the efficiency of terminal gates and terminals for the quay-zone container port. Additionally, the stacking arrangements for containers in the gantry, yard should carefully be designed to increase the berth utilization degree and speed up the process of containers handling (Itumeleng Greta. Motau, 2015). A variety of solutions are offered for the quay zone, which consider the peculiarities of each container port stopping over the separate berths. In the inland segment, strategies are directed towards cargo's external connection with the quay and facilitating container storage. This includes the deployment of autonomous trucks, the organic arithmetic of the truck's movement, pedestrian traffic flow and stacking arrangements in the container depots. At the quayside, simplistic strategies focus on the cumulative benefits of one or two measures. Altogether, the solutions touch on all three sections of the container port in a holistic manner.

Limitations of the Study

The limited scope of the data used is a significant issue faced in this research. Data was taken from different sources such as journals, thesis, reports, statistics, and magazine articles. Data inconsistency can be created among each other. The most frequent problem faced is that the data output is in Portable Document Format (PDF), and most of the data cannot be copied and pasted. The low quality of the data that is processed causes low quality of the analysis. Seasonal and time data could not be analyzed as the data was processed only in a two-year span.

Another limitation of this research is that the Causal Loop Diagram and Advanced Overview Diagram models are complex and are difficult to understand. For that reason, they are not described in full detail in this research. Concepts such as local optimum equilibrium and growth shift are proposed to clarify meaningless triangulation data and the future could be formulated as further research.

The most significant limitation of this research is that the model validation process cannot be carried out by the interconnection of the simulation model to the actual data. The model created is a conceptual model that cannot be tested. Nevertheless, the model is validated by sharing the model directly with the stakeholders and shipping operators. Nonetheless it is considered valid and feasible to generate real policies. Despite these limitations, this study is crucial as it is the first to explore the problems of container congestion. It is perceived that the implemented strategies can be adopted as the basis for further research; therefore, the model validation process can be conducted with real data output.

Suggestions for Future Research

For future research it is suggested: (1) Effect of integrating operations of multiple ports or on-line services. A new operational system or ownership structure might be conducted in the case of the ports in the Asia-Africa and America country pairs, to improve the overall performance of the container networks. (2) Strategies of scheduling and discarding time windows for time-dependent transfer. Integration of multiple transport modes is essential for full liberalization of international transport, but some issues remain unresolved. Therefore, it is difficult to come up with perfect ideas for future research, but constructive scientific findings are hoped for expansion and repetition of the above calculations or further applications of a promising technique for solving time-dependent problems. (3) The equilibrium model for considering the competitive and cooperative inter-terminal operations. In the competitive world of port industry, the

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equilibrium model is proposed to analyze the relationship between stake figures and handling volumes of each container terminal, regarding both maritime and inland transportation. (4) Extension of junction investment model. The port with bankruptcy and acquisition, and the extension of a model for the investment of a junction port in a liner company are discussed. A model for profitable investment in both transportation costs and terminal revenues, not only transportation costs, or revenues is explored. Additionally, the effect of junction peninsula investment on feeder services and that of the junction investment in case of cooperation of two different emerging markets are discussed.

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