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OPTIMIZATION MODEL FOR UNLOADING IMPORT CONTAINERS

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ABSTRACT

Highlights: Brazil's economy is very dependent on ports, which serve as the entry and exit of goods via cargo imports and exports. The use of containers has made handling operations in ports easier, increasing the speed of transport and efficiency of the handling process. Because of this, containerization is an innovation in general cargo services, bringing increases in company sites and building large terminals specializing in container handling. However, the internal handling of import containers entails operational costs for the port terminals. To apply a mathematical model to optimize the unloading of import containers, to define the optimal fleet for the process of the company under study. The purpose of the research is described as diagnostic research. As for the type of research, the study is classified as qualitative research. In terms of design, the research is a case study. The analysis technique consists of using in-process modelling and simulation. Modelling and simulation are used in a port logistics context. Through simulation, the number of trucks carrying out transportation was adjusted, demonstrating the ideal amount of vehicles for the terminal's demand. As a result, it was observed that operational research can help in the adjustment of the company's process. This study presents as a limitation the simulation with other equipment that involves the unloading process of import containers, limiting itself only to yard tractors. It is suggested to increase the number of pieces of equipment that involve the unloading process, such as gantry cranes, to verify if there is a decrease in the unloading process time of import containers. To demonstrate that simulation can serve as a tool that helps decision-makers, as well as, be applied in a port process.

Keywords: Simulation; Container Terminal; Scanner; Logistics.

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1. INTRODUCTION

Brazilian ports have been important since the country was a colony of Portugal. Because Brazil is characterized by its long coastline, it was gradually populated by the Portuguese and other people, who built ports to transport the riches present in the national territory. Brazil's economy is very dependent on the ports, which serve as an entry and exit of goods via cargo imports and exports. Brazil mainly imports goods for productive activity, such as industrial inputs, machinery for agriculture, and capital goods.

In 2019, according to the Statistical Yearbook of Performance of the Waterway Sector of the National Agency of Waterway Transport - ANTAQ, there was a movement of 1.104 billion tons of cargo in Brazilian ports, dividing the profile of the cargoes in 62% of solid bulk, 23% of liquid bulk, 10% of containers and 5% of loose general cargo. Regarding container handling in Brazilian ports, there was an increase of 3.5% compared to the year 2018, with the handling of 117 million tons of containers in the year 2019 (ANTAQ, 2019).

When analyzing container handling on a national scale, the port of Rio Grande ranks 5th as the largest container mover in Brazil. In the year 2019, the port of Rio Grande handled 488 thousand TEUs (Twenty-foot Equivalent Unit or TEU), representing 6.9% of the total full and empty container handling in Brazil (ANTAQ, 2019).

The use of containers has made handling operations in ports easier, increasing the speed of transport and efficiency of the handling process and thus making it possible to transport multiple cargo units simultaneously. In this sense, after the emergence of containers in the 1960s, port terminals changed the way they operate and it became necessary to introduce specialized equipment, allocate areas for storage, and define storage methods (Bandeira, 2005).

In this sense, there are specialized terminals for the operation of containers, called container terminal, which is an industrial enterprise that involves several activities. The main process of a container terminal is to load and unload ships, both import and export cargoes. To move these containers in the terminals, equipment such as pier cranes, yard cranes with wheels, forklifts and yard trucks are used.

However, this internal container handling process entails operational costs for the container terminals. In this study, we have as an example the unloading handling of import containers, in which the import container unloaded from the ship is later sent to a temporary position in a storage lot and, within 48 hours, it is sent to the scanner for inspection, and then forwarded to the destination at the terminal.

In this context, this paper aims to apply a mathematical model to optimize the unloading of import containers. Thus, the simulation is used in a port logistics context from a mathematical system, which will be intended to assist decision-makers in the process of optimizing the unloading of import containers from the ship to the terminal.

2. THEORETICAL REFERENCE

Containerization is an innovation in general cargo services, bringing about an increase in the areas of companies and building large terminals specialized in container movement. For Bowersox and Closs (2001), containers are fundamental tools for transport logistics, enabling the unitization of goods, bringing several advantages and, in general, reducing logistics costs such as, for example, the movement of loading and unloading containers.

Due to the increase in traffic volume, the container terminal has become an important interface between land and sea transport. In an increasingly competitive and global industry, ports need to ensure efficiency in managing various resources and decrease the response time of ships at the terminal (Chen et al., 2013).

Container terminals are responsible for a large part of the cargo export and import processes in Brazil. In this sense, importing and exporting companies need an increase in efficiency to maximize revenue, and for this it is important, among other things, that terminals seek ways to reduce the operation time of vessels, thus leading to an increase in the number of services (Fernandes, 2006).

Given this, the container unloading operation at the terminals begins with the prior receipt of a list containing data from the group of containers that will be loaded. The terminal, based on this information, makes a reservation of an area for the storage of the units, usually in the function of data such as place of destination, specific type (reefer and non-reefer), empty, full, tare weight and gross weight of the containers (Pereira, 2001).

In this sense, the loading and unloading process in a port occurs when a berth is designated, onshore gantry cranes (portainer) are allocated to unload incoming containers and load outgoing containers. At the terminal's storage lots, gantry cranes with wheels (RTG) or forklifts perform a series of operations that include transferring containers to and from terminal trucks, receiving outbound containers from shipping agents for stacking, and re-stacking containers when necessary. Yard trucks are used to transport containers between the dock and the yard, serving both container carriers and RTG's and stackers (Chen et al., 2013).

Studies such as by David and Collier (1979) use computer simulation techniques as a means of investigating the problems associated with minimizing the container handling time of a ship, involving the operation of container handling equipment (cranes and transports) in conjunction with the response time of a ship to study cargo optimization.

Given the use of a simulation model as a tool to solve the proposed problem, it is described that computational modelling and simulation are tools that allow various professionals to perform the activities that are proposed and, through them, they can acquire the ability to identify, formulate and solve problems linked to the activities of design, operation and management of work and production systems of goods and/or services (Carvalho, 2006).

Computer simulation provides a useful means of investigating problems since it allows great flexibility in choosing input parameters and testing alternative decision strategies, without the risks associated with direct experimentation on the real system (David and Collier, 1979). Thus, a mathematical model with its decision variables, function, objective, and constraints is used in management to maximize or minimize the performance index and performance rate, aiming to find a solution to the problem.

3. METHODOLOGY

According to Roesch (2013), this study can be classified as to its purpose, character, design, collection technique and analysis.

In this sense, the present study presents as purpose the diagnostic research, where it is desired to explore the organizational and market environment or to raise and define problems (Roesch, 2013).

Considering the type of research, the present work is classified as qualitative research, due to the information provided by the company being statistical data, to simulate the container unloading process.

As for the design, the research is classified as a case study, which allows the analysis of in-depth phenomena within their context.

As for the data collection technique, it was based on the observation of the unloading process of import containers. Data collection was based on observation and conversations with company employees (planners, analysts, marines, and coordinators). Thus, the population was the company where the research was carried out.

Data and information were acquired to generate a process modelling and simulation. The simulation was carried out through a mathematical equation, in which the fleet sizing for solving the research problem could be determined.

Case study

This case study took place at a company located in the city of Rio Grande, a municipality in the state of Rio Grande do Sul. The company is a bonded container terminal, an area of the Federal Revenue Service, which serves a large number of maritime shipowners, providing services of receiving and sending goods, loading and unloading containers. The company has been operating in the port area since 1997, has a storage capacity of 25,000 TEUs, and contains warehouses for goods and a warehouse for hazardous cargo. The port terminal has 900 meters of a pier and can operate with three ships at the same time. In the operational sector, the company has approximately 150 employees per shift and develops activities in three shifts of eight hours per day.

The company's technological park counts on nine containers, which have the purpose of removing and placing containers on the ship. Within the company's objectives, this equipment has to unload 30 containers per hour. The company has 56-yard tractors (trucks for transporting containers), each with a capacity of 40 tons.

In the unloading yard, the organization counts with 22 RTGs (rubber-tyred gantry cranes), which are gantry cranes on tires, used to unload and load containers onto trucks, and which bring great agility to the port movement. Finally, the company has seven Reach Stakers, large container handling equipment, and four Front Loaders for unloading empty containers.

Description of the unloading process for import containers

The import containers, planned to be unloaded at the port, are the first to come off the ship, due to the need to make room for the containers that will be shipped. As part of these logistics, the federal revenue requires that all containers that disembark have to undergo a non-invasive inspection, i.e., be scanned. This inspection has a deadline of 48 hours after the unloading of the ship that unloaded the container.

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The container comes off the ship through the container carrier and is placed on top of the yard tractor, where the mariner is inspected to verify the seal and that there are no damages. This container is then moved to a temporary position in the yard, where it is unloaded by a filling machine. Within 48 hours, the container is again placed on top of a conveyor, taken to the scanner, and then given the final unloading position of the container, which is usually in a row where the yard crane (RTG) operates. Finally, the container is removed from the yard tractor and placed in a final position to await its release to the customer.

Research problem

The research problem lies in the logistics of handling each import container that leaves the ship and needs to be moved to a temporary position, within 48 hours, after going through the scanner inspection process and finally, to its destination at the terminal. This process generates costs for the company because if at the moment the container is unloaded it is already inspected by the scanner and then sent to its final destination, the company could obtain savings in transportation and container handling.

To solve this problem, we will simulate the sizing of the yard tractor fleet for the unloading moment of the import containers, which at the moment the yard tractor unloads, the container is moved to the scanner and then to the final position at the terminal and back to the origin where it was loaded.

Simulation

Aiming to bring a solution to the research problem, a simulation of fleet sizing is proposed. However, it is necessary to meet some company requirements to maximize port operations. Given this, to optimize the operation, each portainer has to unload 30 containers per hour and the same crane cannot wait for transportation.

The proposed simulation is through a mathematical equation, in which the amount of transportation (yard tractors) necessary to meet the demand of 30 containers per hour will be defined and the entire circuit will be traversed without the pier crane waiting for transportation.

All information for the simulation was provided by the company through its employees. The time, distance and speed are averages taken from the company's data and control system. The mathematical equation was adapted from the study by Guerreiro (2017) apud Fabrício and Subramanian (2008) and presents the variables: demand, time to load and wait, time to wait and unload, rest time, distance from destination to the origin, distance from the origin to destination, the static capacity of the vehicle, days worked, hours worked per day, and average round trip speed.

$$Nt = \frac{D(Tc + \frac{Kmi}{Voi} + Tr + Td + \frac{Kmv}{Vov})}{Dm \times Hd \times CEV}$$

Where,

N_t: Transport number

D: Unloading or loading demand

T_c: Time to load and wait (h)

K_{mi}: Distance in kilometres from origin to destination (Km)

V_{oi}: Average travel speed to unloading point (Km/h)

T_r: Resting time (h)

T_d: Time to wait and unload (h)

K_{mv}: Distance in kilometres from destination to origin (Km)

V_{ov}: Average speed of return from unloading point to origin (Km/h)

D_m: Days worked

H_d: Hours worked

C_{EV}: Capacity of the vehicle

4. RESULTS

Table 1 shows the 9 simulations performed at 3 different container loading locations (Pier 1, Pier 2, and Pier 3) and 3 definite unloading locations in rows (F2, G1, and H1) where containers, after passing through the scanner, can be positioned. To determine accurate calculations, time units were worked out in hours, speed units in km/h, and distances were transformed into kilometres.

It can be observed that the demand (D) for unloading containers from the ship did not change, maintaining the 30 containers per hour determined for an ideal unloading operation. The portainer loading time (T_c) did not change. The round-trip speed (V_{oi}) and (V_{ov}) of the yard tractors average 30 km/h, for safety reasons. The rest time (T_r) for each transport is 1 hour in an 8-hour workday (H_d), and the unloading time (T_d) at the RTG is the same for all positions.

Days worked (D_m) is 1 due to the period being one day and an 8-hour shift, and the capacity of the yard tractors (C_{ev}) is 1 container unloaded.

Simulations Pier 1

Table 7 represents the simulation at Pier 1, the distance to go through the circuit passing the scanner is 1.24 km to the unloading queue F2. The calculations show that 4.44375 vehicles are needed to meet the operational demand (Table 8). Thus, it will be necessary to use 5 vehicles to cover the route.

The simulation starting from Pier 1 to unloading queue G1 travels 1.465km. The return from queue G1 to Pier 1 is 0.46km. From the result, we have the value of 4.440 vehicles to meet the demand of the operation (Table 9). We rounded the value to a whole number of 5 vehicles, necessary for the demand of unloaded import container.

Nesta simulação, o contêiner sai do cais 1 e percorre uma distância de 1,44km até o RTG. Desse modo, o recipiente faz sua descarga e o transporte percorrendo a distância de 0,5 quilômetros até o cais 1 para carregar novamente.

Para este percurso, precisa-se de 4,4425 veículos para fazer o transporte de 30 contêineres por hora (Tabela 10). Assim, são necessários 5 veículos para o processo de descarga de contêineres de importação.

Simulations Pier 2

The starting point has changed to Pier 2, in which the travel distance from the pier has shortened and the time and speed variables are the same. The distance between Pier 2 and the unloading endpoint is 1.45km and the return to Pier 2 is 0.47km or 470 meters.

From the simulation, it was concluded that 4.44 vehicles are needed to meet the established demand (Table 5). Thus, 5 vehicles will be needed to perform the route.

Table 6 shows the simulation of Pier 2 - G1, the container unloads at Pier 2 and travels 1.7 km to the yard crane located in row G1. Once it is unloaded, the transport travels 0.75 km to pier 2.

Table 1. General simulation of the sizing process

Simulation	D	Tc	Kmi	Voi	Tr	Td	Kmv	Vov	Dm	Hd	CEV	Result
Pier 3 - F2	30	0,07	1,73	30	1	0,05	0,75	30	1	8	1	4,51
Pier 3 - G1	30	0,07	2,02	30	1	0,05	0,98	30	1	8	1	4,575
Pier 3 - H1	30	0,07	2	30	1	0,05	1,05	30	1	8	1	4,58125
Pier 2 - F2	30	0,07	1,45	30	1	0,05	0,47	30	1	8	1	4,44
Pier 2 - G1	30	0,07	1,7	30	1	0,05	0,75	30	1	8	1	4,50625
Pier 2 - H1	30	0,07	1,65	30	1	0,05	0,81	30	1	8	1	4,5075
Pier 1 - F2	30	0,07	1,24	30	1	0,05	0,71	30	1	8	1	4,44375
Pier 1 - G1	30	0,07	1,465	30	1	0,05	0,46	30	1	8	1	4,440625
Pier 1 - H1	30	0,07	1,44	30	1	0,05	0,5	30	1	8	1	4,4425

Source: the authors (2018).

Table 2. Simulation Pier 1 - F2

Simulation	D	Tc	Kmi	Voi	Tr	Td	Kmv	Vov	Dm	Hd	CEV	Result
Pier 1 - F2	30	0,07	1,24	30	1	0,05	0,71	30	1	8	1	4,44375

Source: the authors (2018).

Table 3. Simulation Pier – G1

Simulation	D	Tc	Kmi	Voi	Tr	Td	Kmv	Vov	Dm	Hd	CEV	Result
Pier 1 - G1	30	0,07	1,465	30	1	0,05	0,46	30	1	8	1	4,440625

Source: the authors (2018).

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From the simulation, we obtained the value of 4.50625 vehicles needed to transport 30 containers per hour. Similarly, 5 vehicles are needed for the trip.

Containers cleared at Pier 2 destined for queue H1 travelled 165 km. To make the trip to the unloading queue H1, the trip from unloading to Pier 2 is 0.81 km; the other variables do not change. With the result of 4.5075, it is concluded that 5 vehicles are needed for the simulation to reach the goal of 30 containers unloaded per hour (Table 7).

Pier 3 Simulations

In the simulation Pier 3 - F2, the container disembarks from Pier 3 and the destination is unloading queue F2. The unit travels 1.730 km at a speed of 30km/h, passing through the scanner and arriving at the F2 queue. The RTG time to remove the container from the transport is 3 minutes or 0,05 of an hour, the transport from queue F2 to pier 3 covers a distance of 0,75 km and the capacity of each transport is 1 container at a time. In this simulation, 5 vehicles are needed to transport 30 containers per hour, covering the entire circuit and meeting the ship's operation target. The result of 4.51 was rounded up to 5 vehicles (Table 2).

The simulation Pier 3 - G1 presents the time to unload the container from the ship to the transport, the unloading time at the destination and the average speed as the other simulations. What makes it different is the distance travelled of 2.02 km to the unloading point and the distance from the final point to the initial point of 0.98 km.

It is observed that the distance between loading and unloading and return increased. Consequently, the number of vehicles to meet the demand is 4.575, in this case, 5 vehicles are needed to meet the unloading process (Table 3).

In the Pier 3 - H1 simulation, the distance from the departure of the container from Pier 3 to the unloading des-

Table 4. Simulation Pier 1 – H1

Simulation	D	Tc	Kmi	Voi	Tr	Td	Kmv	Vov	Dm	Hd	CEV	Result
Pier 1 - H1	30	0,07	1,44	30	1	0,05	0,5	30	1	8	1	4,4425

Source: the authors (2018).

Table 5. Simulation Pier 2 – F2

Simulation	D	Tc	Kmi	Voi	Tr	Td	Kmv	Vov	Dm	Hd	CEV	Result
Pier 2 - F2	30	0,07	1,45	30	1	0,05	0,47	30	1	8	1	4,44

Source: the authors (2018).

Table 6. Simulation Pier 2 – G1

Simulation	D	Tc	Kmi	Voi	Tr	Td	Kmv	Vov	Dm	Hd	CEV	Result
Pier 2 - G1	30	0,07	1,7	30	1	0,05	0,75	30	1	8	1	4,50625

Source: the authors (2018).

Table 7. Simulation Pier 2 – H1

Simulation	D	Tc	Kmi	Voi	Tr	Td	Kmv	Vov	Dm	Hd	CEV	Result
Pier 2 - H1	30	0,07	1,65	30	1	0,05	0,81	30	1	8	1	4,5075

Source: the authors (2018).

Table 8. Simulation Pier 3 - F2

Simulation	D	Tc	Kmi	Voi	Tr	Td	Kmv	Vov	Dm	Hd	CEV	Result
Pier 3 - F2	30	0,07	1,73	30	1	0,05	0,75	30	1	8	1	4,51

Source: the authors (2018).

tination at queue H1 is 2 km, and the return trip to Pier 3 is 1.05 km (Table 4). In this context, we obtained as a result of 4.58125 vehicles, being necessary 5 vehicles to perform the route.

5. FINAL CONSIDERATIONS

The objective of this study was to use a model to optimize the unloading of import containers from the ship to the terminal. This way, a mathematical equation was applied to find the number of vehicles necessary to perform the demand of 30 unloading containers per hour and meet the port legislation that determines that the container has a deadline of 48 hours to pass the scanner.

Given this, the study observed the problems in the current logistics process of unloading containers at a container terminal. Through simulation, the number of trucks to perform the transportation was adjusted, demonstrating the ideal amount of vehicles for the terminal's demand.

All information applied to the equation was provided by the company being studied, and the simulation was based on the definition of three loadings and three unloading locations. The distances, time, and speed are averages.

In the simulation, it was observed that the greatest distance, from the initial point to the unloading point, is in the simulation from Pier 3 to row G1 with 2.02 km and the shortest distance is from Pier 1 to row F2 1.24 km travelled. On the return from the unloading point to the starting position, the longest distance is 1.05km from row H1 to Pier 3 and the shortest distance is from row G1 to Pier 1, 0.46km. A range of 4.44 to 4.58 vehicles was found. With this, all were rounded up to 5 vehicles as the answer to the problem.

It is known that if one adjusts logistics, with planning and process studies, one has a better performance in organizations. In this sense, the work demonstrates that using operational research, in organizations that involve logistics, one can help the processes and, thus, improve the results.

However, this study presents some research gaps, such as modification in-process components and increase in RTGs. In this context, as suggestions for future studies, it is suggested to increase the number of RTGs in the unloading at the endpoint, to verify if there is a decrease in unloading time, as well as if it would increase the unloading of import containers.

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Table 9. Simulation Pier 3 – G1

Simulation	D	Tc	Kmi	Voi	Tr	Td	Kmv	Vov	Dm	Hd	CEV	Result
Pier 3 - G1	30	0,07	2,02	30	1	0,05	0,98	30	1	8	1	4,575

Source: the authors (2018).

Table 10. Simulation Pier 3 – H1

Simulation	D	Tc	Kmi	Voi	Tr	Td	Kmv	Vov	Dm	Hd	CEV	Result
Pier 3 - H1	30	0,07	2	30	1	0,05	1,05	30	1	8	1	4,58125

Source: the authors (2018).

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