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Proposal Of Time Optimization Procedures at Port of Balboa, Panama

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ABSTRACT

This document is a proposal to reduce the waiting time for trucks entering the port of Balboa; a port located in the Panamanian coast of the Pacific Ocean. Its objective is to reduce in an organized manner, the vehicular congestion at the entrance of the port and its surroundings areas, and avoiding waiting lanes that cause many inconveniences and great delays. Also, this document presents the mathematical modeling of this optimization problem, as well as its resolution using the Python programming language. The problem tries to minimize the total time in which all the trucks are served, but at the same time it is intended to minimize the average travel time of the trucks. As each of the problems to be introduce are independent, we propose to use a mixed objective function which are combined by means of weighted parameters. Solving the problem allows us to establish an order to serve the carriers by giving them an appointment with date and time of arrival at the port. Once inside the port, as long as the carrier complies with all the necessary documentation for the requested process, its route should not be affected. Each carrier will be attended to with a pre-arranged time for loading and/or unloading. Furthermore, the specific equipment and space needed for this cargo, and the assistance of adequate personnel, will optimize port management. Consequently, waiting times and congestion are reduced.

1. Introduction.

The purpose of this article is focused on the discussion of truck traffic congestion inside the container terminals around the port of Balboa in Panama. Road traffic congestion, in the dense and populated urban areas is a huge mobility challenge. (Pérez, 2014) The flow of containerized goods is made up of a succession of transport legs between the different agents in the logistics chain (Ilie, Oprea, Olteanu, Dinu, & Ruscă, 2019) . Each of the legs can be carried out by different modes of transport, land (road or rail), sea or air. (Pérez, 2014)

Firstly, we must understand the context that the container shipping industry is going through. The new changes and their challenges, impact of new components, demand in ports, current global scenario, and the processes that govern and drive the functioning / operation of terminals. (Williamson Sepúlveda, 2017)

It is important to mention that in Panama there have been several restructurings in the handling of cargo, due to the need of improving and updating the logistics and port system. But also, keeping in mind, the effects of climate change which can affect the operations of the Panama Canal. (CanaldePanama, 2024)

There are studies on how to improve traffic caused by carriers. One such study is the study of 2015 in Valencia, on how to implement improvement initiatives. It is a study aimed at designing the implementation of "prior appointments", to answer the problem. This system was proposed as one of the initiatives aimed at responding to the increase and concentration of delivery operations and admission of containers as a result of increased traffic. (Valenciaport, 2015) Due to these problems, appointment systems have begun to be implemented in the world's main port terminals. Port of Algeciras is a good example of the implementation of the appointment system. (Taciana Pamela

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Pérez Osorio, Adrián Ramírez Nafarrate., 2014)

The factors that make the implementation of Gate Appointment Systems (GAS) successful or unsuccessful are diverse and are influenced by the commitment of different factors (port authorities, terminals, loading companies and carriers, among others), as well as the incentives offered to carriers willing to apply, (PierNext, 2018) as shown in Figure 1, these ports have implemented the quotation system. The first container port in Great Britain was a pioneer in Europe when it introduced the system in 2006. (PierNext, 2018).

Figure 1: Some of the international ports that have implemented this type of services.

Source: https://piernext.portdebarcelona.cat/logistica/por-que-los-puertos-insisten-en-implantar-los-sistemas-de-reserva-en-terminal/.

The problem that this study attempts to solve is to dissipate the concentration of truck arrivals (Li, Mou, Chen, Huang, & Chen, 2023). This problem does not only apply to this operator, but it is common that terminals consider when planning their daily operations, to define the resources and personnel available in a specific day. (Williamson Sepúlveda, 2017)

In the quest for more efficient ports, it is crucial to identify and understand the problems that affect the performance and profitability of ports and terminals. For example, the loading and unloading operations of each vessel's containers generate great complexities, which in turn are related to the positioning and routes within the terminal yard. These problems can be mitigated with the implementation of advanced technological systems that optimize the percentage of space utilization for port operations. (Decidesoluciones.es, 2021)

This study arises from the current traffic in the road infrastructure outside and around the port of Balboa (GeorgiaTechPanama, 2016), which is located on the Pacific side of the Panama Canal. This port is a part of a group that has the concession of the Pacific and Atlantic Ocean and a direct connection to the railroad. In the search to improve efficiency in port operations, it has not considered how to mitigate the congestion that is generated. (MIVIOT, 2015).

For this, we designed a mathematical model, representing a supply chain for a location (Vélez, J. G. D., & Otero, L. F. R., 2012), its functionality respecting the current development and the information data and arguments of how the whole process of loading and / or unloading is developing at the port.

There is a lot of research on how port congestion can be reduced, which in turn reduces waiting times and truck congestion ashore. This results in an increased throughput and environmental efficiency ashore. (La Hoz, Carrion López Lavalle, & Sebastian, 2023) There are several researches on how port congestion can be reduced, which in turn reduces CO2 emissions per transport job by 50% by 2030, which result in increased environmental performance onshore. (Rubio Portolés, 2024)

The implementation of this improvement allows us to have an integration strategy, improving the port's management level. This allows the interested parties; carriers, shipping lines, concessionaires and port, to better understand the port's operational status and promote its development. (Viera Marín , 2014. PhD Thesis.) In addition, this proposal seeks to enable the port to predict ingress and egress, reduce congestion and further improve throughput. (Fuentes Reyes , 2016)

In order to carry out this research, a questionnaire has been done in the port. The questionnaire analyzed how the arrivals and the entire route within the port are is done; at all points. The time it takes the carrier to arrive and wait in order to obtain the time it takes in each of the operations that are performed either loading, unloading or both at the same time. Knowing the variables that are going to affect the formula, a series of conditions, that must be fulfilled can provide the best route. In doing so, a greater number of trucks is attended in the minimum possible time. The goal is an efficient and expedited process for cargo loading / unloading.

This paper begins with an introduction, explaining the scenario in which the study has been made. In the second part, the methodology is explained for defining the model used to evaluate and improve the efficiency of the port cargo fluxes. Finalizing, with the results section and conclusions.

2. Methodology.

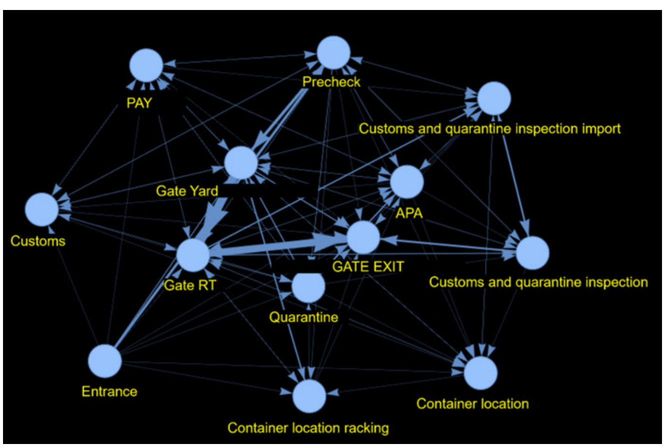
The methodology used for the selection of the sample, which was used to generate the proposal for the temporary optimization of the current procedure for loading and/or unloading trucks, is detailed below. This is achieved by a mixed approach study of surveys and interviews, with the objective of offering a more complete vision of the trucks' operational process. The sampled population were all trucks arriving at the port facilities, for a period of two weeks from 8:00 am to 5:00 pm.

The first step was to collect data by means of surveys, interviews and time spent waiting outside the port. Second, we analyzed the results presented by Georgia Tech, (Center, 2022) within the ports in each of the booths. The service times to code a combined transport network. This, establishing connections between the different modes of transport to ensure complementarity of each of the booths and thus achieve an optimal integrated solution. Then we proceeded to develop a tailor-made solution, knowing the needs and the current times by means of a formula. Finally, given the demand forecasts and the transport network, an optimization model was applied to determine the minimum time transport flows.

3. Descriptions Of the Assumptions, Notations and Model Settings.

In Figure 2, the partial graphical representation of the current transportation network model used in the study, shows aspects related to the movement of the trucks when they are inside the port in the loading and/or unloading process. There are waiting points that present greater congestion due to the fact that not all the documentation is available at the checkpoint or checkpoints, or the equipment is not available to receive or remove the cargo.

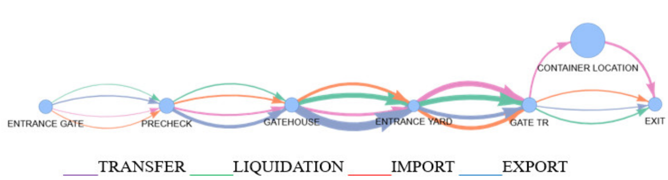
Figure 2: Partial graphical representation of the transport flow of the port of Balboa. Disorderly movements can be seen.



Source: Authors.

On the other hand, Figure 3 shows how the flow would be in an ideal way. In this figure the thickness of the edge represents the observed flow volume and the color represents the type of operation to be performed. The size of the nodes is a scaled representation of the delay times.

Figure 3: Ideal flow of traffic between the different port's sentry boxes.



Source: Authors.

4. Supply And Demand of The Port of Balboa.

With the combined transport network already characterized and with the estimated loading and/or unloading data, we proceeded to model the problem with the objective of obtaining the minimum transport times from the entrance to the port of to the exit.

5. Problem Statement.

There is a set of "I" trucks to perform "k" types of operations at the port. Each truck already has a pre-established type of operation to perform, and this does not change along the route. The trucks have to pass in line through a series of checkpoints. These checkpoints must always be passed in the same order by all trucks and these checkpoints only serve one truck at a time. The time each truck takes at each checkpoint will depend on the routing of the checkpoint and the type of truck operation. The transfer times from one checkpoint to another are given and do not depend on the type of operation; this time does not take into account the queuing time when entering the next node. It is desired to know in which order the trucks should pass in order to minimize the waiting time at the port.

6. Description Of Model.

6.1. Data.

Types of operations.

- K. Number of types of operations.
- I^k with $k = 1, 2, \ldots, K$. Number of trucks to perform each type of operation k.
- $I = \sum_{k=1}^{K} I_k$. Total number of trucks.
- J. Number of nodes to go through.
- P_j^k with $k = 1, 2, \ldots, K$ y $j = 1, 2, \ldots, J$. Operation processing time
- k at node j.
- T_j with $j = 1, 2, \ldots, J$. Node transit time j al $j + 1$, $(T_J = 0)$.

Variables.

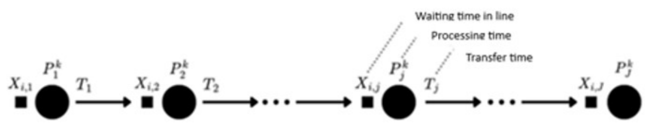
- $X_{i,j}$ with $i = 1, 2, \ldots, I$ y $j = 1, 2, \ldots, J$. Waiting time of ith truck to enter the node j. Positive real variable.
- δ_i^k with $k = 1, 2, \ldots, K$ y $i = 1, 2, \ldots, J$. Truck operation type indicator i. Binary variable.
-

$$\delta_i^k = \begin{cases} 1, & \text{if the } i\text{-th truck performs operation } k, \\ 0, & \text{otherwise.} \end{cases}$$

Schematic.

In Figure 4 below it is showed a representation of the truck flow, as well as the queuing times of each node's input, processing times and transfer times.

Figure 4: Flow diagram of trucks and time.



Source: Authors.

6.2. Objective Function.

In this problem we seek to minimize the total time in which all trucks are served, but we also seek to minimize the average travel time of the trucks. As each of the problems to be minimized are independent, we propose to use mixed objective function combining both objective functions by means of a weight w. That is, we define the objective function as follows:

$$\min\ f(X,\delta) = w\, f_1(X,\delta) + (1-w)\, f_2(X,\delta)$$
$$\text{with } w \in \mathbb{R},\ w \in [0,1].$$

In the function f_1 that corresponds to the total time in which all trucks are serviced, it designates the average time that trucks take from the time they enter the port to the time that they depart.

$$f_1(X,\delta) = \sum_{j=1}^{J} \left(X_{I,j} + T_j + \sum_{k=1}^{K} \delta_I^k P_j^k \right)$$

and f_2 is the function that responds to the average time that trucks take from the time they enter the port to the time they leave the part,

$$f_2(X,\delta) = \frac{1}{I} \left(\sum_{i=1}^{I} \sum_{j=2}^{J} X_{i,j} + I \sum_{j=1}^{J} T_j + \sum_{k=1}^{K} \sum_{j=1}^{J} I^k P_j^k \right)$$

Note, that f_2 does not take into account the waiting time at the entrance to the first checkpoint, since this time does not take place inside the port. Once inside the port at the first checkpoint; the goal is for a process that establishes ease of movement. Each truck should follow one another from one point to another without traffic backup or delays. Many trucks can flow through the port at the same time. It is imperative that each operator follow appropriate designated arrival time. This will reflect the total time in which all trucks have completed the process. In our case we set the value of $w = 0.5$ to prioritize both objectives equally.

6.3. Restrictions.

Each node can only serve one truck at a time. This results in a constraint for each consecutive pair of trucks passing through each node. That is, there are $(I-1)J$ restrictions of the following type.

$$\sum_{j=1}^{n} \left(X_{i,j} - X_{i-1,j} + \sum_{k=1}^{K} (\delta_i^k - \delta_{i-1}^k)\, p_j^k \right) \le \sum_{k=1}^{K} \delta_i^k\, p_n^k,$$
$$\forall\, i = 2,3,\ldots,I,\quad n = 1,2,\ldots,J.$$

Considering that the i-th truck can only do one type of operation, this results in the following I restrictions.

$$\sum_{k=1}^{K} \delta_i^k = 1$$
$$\forall \qquad i = 1,2,\ldots,I.$$

The number of trucks performing the different types of operations is given.

$$\sum_{i=1}^{I} \delta_i^k = I^k$$
$$\forall \qquad k = 1,2,\ldots,K.$$

Vector definition constraints X.

$$X_{i,j} \in R : X_{i,j} \ge 0$$
$$\forall \qquad i = 1,2,\ldots,I, \qquad j = 1,2,\ldots,J.$$

Vector definition restrictions δ.

$$\delta_i^k \in \{0,1\}$$
$$\forall \qquad i = 1,2,\ldots,I, \qquad k = 1,2,\ldots,K.$$

7. Results.

To solve this problem, we have used the Pulp library in Python. After entering all the constraints and the objective function in the program it identifies the optimal times in each transportation strategy. Through this tool, we also obtain a schedule to proceed to give appointments to the carriers, as well as a detailed breakdown of all the times of the route. See Table 1. This would be a proposal for an order of attention that would allow carriers, consignees, shipping lines, and all terminal users, to be able to access a request for delivery and/or pickup of cargo according to the type of cargo handled, without having to wait in a long line at the terminal entrance; arriving at the agreed time with all the necessary completed documentation.

These results were obtained for this particular use case but the program is versatile as it is parameterized. So, it can be adapted to different types and number of operations, different amounts of gateways and volume of trucks and/or vehicles in general. So, not only do you get a program that works well in one scenario, but one that can evolve and grow, adapting to changes and challenges along the way.

Table 2 is an example of a minor problem, with only 4 trucks per operation, for better visualization.

Table 1: Example of a matrix of estimated minimum times for each truck depending on the type of operation. Calculated for 50 trucks for each of the racking, settlement, import and export operations.

	i	k	X_i_0	P_0^k	T_0	X_i_1	P_1^k	T_1	X_i_2	P_2^k	T_2	X_i_3	P_3^k	T_3	X_i_4	P_4^k	T_4	X_i_5	P_5^k	T_5	X_i_6	P_6^k	T_6	Operacion	Hora_cita
0	0	2	0	1,6	0,2	0	1,5	1,02	0	2	2,38	0	0,7	3,33	0	3,9	1,07	0	26,9	1,115	0	1,6	0	LIQUIDACION	08:00:00
1	1	2	26,9	1,6	0,2	0	1,5	1,02	0	2	2,38	0	0,7	3,33	0	3,9	1,07	0	26,9	1,115	0	1,6	0	LIQUIDACION	08:26:54
50	2	0	50,3	1,9	0,2	0	3,2	1,02	0	1,1	2,38	0	0,8	3,33	0	2,3	1,07	3,9	0	1,115	1,6	1,6	0	EXPORTACION	08:50:18
2	3	2	53,8	1,6	0,2	0	1,5	1,02	0	2	2,38	0	0,7	3,33	0	3,9	1,07	0	26,9	1,115	0	1,6	0	LIQUIDACION	08:53:48
3	4	2	80,7	1,6	0,2	0	1,5	1,02	0	2	2,38	0	0,7	3,33	0	3,9	1,07	0	26,9	1,115	0	1,6	0	LIQUIDACION	09:20:42
100	5	1	104,5	1,3	0,2	0	2,6	1,02	0	2,3	2,38	0	0,5	3,33	0	1,5	1,07	4,6	0	1,115	1,6	1,6	0	IMPORTACION	09:44:30
4	6	2	107,6	1,6	0,2	0	1,5	1,02	0	2	2,38	0	0,7	3,33	0	3,9	1,07	0	26,9	1,115	0	1,6	0	LIQUIDACION	09:47:36
5	7	2	134,5	1,6	0,2	0	1,5	1,02	0	2	2,38	0	0,7	3,33	0	3,9	1,07	0	26,9	1,115	0	1,6	0	LIQUIDACION	10:14:30
6	8	2	161,4	1,6	0,2	0	1,5	1,02	0	2	2,38	0	0,7	3,33	0	3,9	1,07	0	26,9	1,115	0	1,6	0	LIQUIDACION	10:41:24
101	9	1	164,3	1,3	0,2	0	2,6	1,02	0	2,3	2,38	1,1	0,5	3,33	0	1,5	1,07	24,4	0	1,115	1,6	1,6	0	IMPORTACION	10:44:18
102	10	1	166,9	1,3	0,2	0	2,6	1,02	0	2,3	2,38	0	0,5	3,33	0	1,5	1,07	22,9	0	1,115	3,2	1,6	0	IMPORTACION	10:46:54
150	11	3	169,9	1,4	0,2	0	1,6	1,02	0,9	0,5	2,38	0	0,8	3,33	0	6,5	1,07	16,4	0	1,115	4,8	1,3	0	TRASIEGO	10:49:54
103	12	1	171,6	1,3	0,2	0	2,6	1,02	0,9	2,3	2,38	2,4	0,5	3,33	0	1,5	1,07	14,9	0	1,115	6,1	1,6	0	IMPORTACION	10:51:36
104	13	1	174,2	1,3	0,2	0	2,6	1,02	0,6	2,3	2,38	1,6	0,5	3,33	0	1,5	1,07	13,4	0	1,115	7,7	1,6	0	IMPORTACION	10:54:12
105	14	1	176,8	1,3	0,2	0	2,6	1,02	0,3	2,3	2,38	0,8	0,5	3,33	0	1,5	1,07	11,9	0	1,115	9,3	1,6	0	IMPORTACION	10:56:48
106	15	1	179,4	1,3	0,2	0	2,6	1,02	0	2,3	2,38	0	0,5	3,33	0	1,5	1,07	10,4	0	1,115	10,9	1,6	0	IMPORTACION	10:59:24
151	16	3	183,3	1,4	0,2	0	1,6	1,02	0	0,5	2,38	0	0,8	3,33	0	6,5	1,07	3,9	0	1,115	12,5	1,3	0	TRASIEGO	11:03:18
7	17	2	187,9	1,6	0,2	0	1,5	1,02	0,4	2	2,38	0	0,7	3,33	0	3,9	1,07	0	26,9	1,115	0	1,6	0	LIQUIDACION	11:07:54
107	18	1	189,7	1,3	0,2	0	2,6	1,02	1,6	2,3	2,38	0	0,5	3,33	0	1,5	1,07	25,4	0	1,115	1,6	1,6	0	IMPORTACION	11:09:42
152	19	3	192,2	1,4	0,2	0	1,6	1,02	2,4	0,5	2,38	0,6	0,8	3,33	0	6,5	1,07	18,9	0	1,115	3,2	1,3	0	TRASIEGO	11:12:12
108	20	1	193,9	1,3	0,2	0	2,6	1,02	0,3	2,3	2,38	7,4	0,5	3,33	0	1,5	1,07	15,1	0	1,115	4,5	1,6	0	IMPORTACION	11:13:54
109	21	1	196,5	1,3	0,2	0	2,6	1,02	0	2,3	2,38	6,6	0,5	3,33	0	1,5	1,07	13,6	0	1,115	6,1	1,6	0	IMPORTACION	11:16:30
110	22	1	199,1	1,3	0,2	0	2,6	1,02	0	2,3	2,38	5,5	0,5	3,33	0	1,5	1,07	12,1	0	1,115	7,7	1,6	0	IMPORTACION	11:19:06
111	23	1	201,7	1,3	0,2	0	2,6	1,02	0	2,3	2,38	4,4	0,5	3,33	0	1,5	1,07	10,6	0	1,115	9,3	1,6	0	IMPORTACION	11:21:42
112	24	1	204,3	1,3	0,2	0	2,6	1,02	0	2,3	2,38	3,3	0,5	3,33	0	1,5	1,07	9,1	0	1,115	10,9	1,6	0	IMPORTACION	11:24:18
113	25	1	206,9	1,3	0,2	0	2,6	1,02	0	2,3	2,38	2,2	0,5	3,33	0	1,5	1,07	7,6	0	1,115	12,5	1,6	0	IMPORTACION	11:26:54
114	26	1	209,5	1,3	0,2	0	2,6	1,02	0	2,3	2,38	1,1	0,5	3,33	0	1,5	1,07	6,1	0	1,115	14,1	1,6	0	IMPORTACION	11:29:30

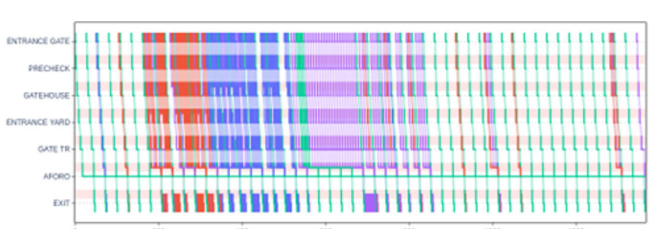
Source: Authors.

Table 2: Example of a time matrix for a minimum of 16 trucks.

	i	k	X_i_0	P_0^k	T_0	X_i_1	P_1^k	T_1	X_i_2	P_2^k	T_2	X_i_3	P_3^k	T_3	X_i_4	P_4^k	T_4	X_i_5	P_5^k	T_5	X_i_6	P_6^k	T_6	Operacion	Hora_cita
0	0	2	0	1,6	0,2	0	1,5	1,02	0	2	2,38	0	0,7	3,33	0	3,9	1,07	0	26,9	1,115	0	1,6	0	LIQUIDACION	09:00:00
4	1	3	11,6	1,4	0,2	0	1,6	1,02	0	0,5	2,38	0	0,8	3,33	0	6,5	1,07	14,2	0	1,115	1,6	1,3	0	TRASIEGO	09:11:36
5	2	3	18,1	1,4	0,2	0	1,6	1,02	0	0,5	2,38	0	0,8	3,33	0	6,5	1,07	7,7	0	1,115	2,9	1,3	0	TRASIEGO	09:18:06
8	3	1	21,4	1,3	0,2	0	2,6	1,02	0,8	2,3	2,38	0	0,5	3,33	0	1,5	1,07	6,2	0	1,115	4,2	1,6	0	IMPORTACION	09:21:24
12	4	0	23,4	1,9	0,2	0	3,2	1,02	0	1,1	2,38	0	0,8	3,33	0	2,3	1,07	3,9	0	1,115	5,8	1,6	0	EXPORTACION	09:23:24
1	5	2	26,9	1,6	0,2	0	1,5	1,02	0	2	2,38	0	0,7	3,33	0	3,9	1,07	0	26,9	1,115	0	1,6	0	LIQUIDACION	09:26:54
6	6	3	43,5	1,4	0,2	0	1,6	1,02	0	0,5	2,38	0	0,8	3,33	0	6,5	1,07	9,2	0	1,115	1,6	1,3	0	TRASIEGO	09:43:30
9	7	1	45,7	1,3	0,2	0	2,6	1,02	1,1	2,3	2,38	0,8	0,5	3,33	0	1,5	1,07	7,7	0	1,115	2,9	1,6	0	IMPORTACION	09:45:42
10	8	1	48,3	1,3	0,2	0	2,6	1,02	0,8	2,3	2,38	0	0,5	3,33	0	1,5	1,07	6,2	0	1,115	4,5	1,6	0	IMPORTACION	09:48:18
13	9	0	50,3	1,9	0,2	0	3,2	1,02	0	1,1	2,38	0	0,8	3,33	0	2,3	1,07	3,9	0	1,115	6,1	1,6	0	EXPORTACION	09:50:18
2	10	2	53,8	1,6	0,2	0	1,5	1,02	0	2	2,38	0	0,7	3,33	0	3,9	1,07	0	26,9	1,115	0	1,6	0	LIQUIDACION	09:53:48
7	11	3	69,6	1,4	0,2	0	1,6	1,02	0	0,5	2,38	0	0,8	3,33	0	6,5	1,07	10	0	1,115	1,6	1,3	0	TRASIEGO	10:09:36
14	12	0	71,4	1,9	0,2	0	3,2	1,02	2	1,1	2,38	0	0,8	3,33	0	2,3	1,07	7,7	0	1,115	2,9	1,6	0	EXPORTACION	10:11:24
11	13	1	75,2	1,3	0,2	0	2,6	1,02	0,8	2,3	2,38	0	0,5	3,33	0	1,5	1,07	6,2	0	1,115	4,8	1,6	0	IMPORTACION	10:15:12
15	14	0	77,2	1,9	0,2	0	3,2	1,02	0	1,1	2,38	0	0,8	3,33	0	2,3	1,07	3,9	0	1,115	5,4	1,6	0	EXPORTACION	10:17:12
3	15	2	80,7	1,6	0,2	0	1,5	1,02	0	2	2,38	0	0,7	3,33	0	3,9	1,07	0	26,9	1,115	0	1,6	0	LIQUIDACION	10:20:42

Source: Authors.

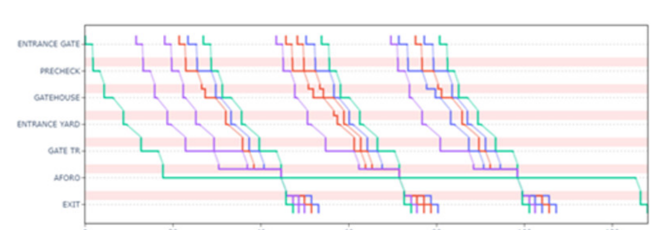
Figure 5: This figure shows the information in Table 1 in schematic form. The types of operations are represented in different colors to visualize how the algorithm interleaves the operations guaranteeing the optimal time. On the horizontal axis is represented the time and on the vertical axis the different control points of the port.



TRANSFER LIQUIDATION IMPORT EXPORT

Source: Authors.

Figure 6: Diagram corresponding to the example of 16 trucks, 4 per type of operation. This allows us to see graphically how the route is made through the different points in the course of time. The pink bands represent the waiting times before entering each point. The horizontal axis represents the time in minutes, and the vertical axis represents the different control points of the port. The colors represent the different operations.



TRANSFER LIQUIDATION IMPORT EXPORT

Source: Authors.

Table 3: Example of a summary table of how the citations would be organized.

	Appointment time	Operation
0	09:00:00	LIQUIDATION
4	09:11:36	TRANSIT
5	09:18:06	TRASINT
8	09:21:24	IMPORT
12	09:23:24	EXPORT
1	09:26:54	LIQUIDATION
6	09:43:30	TRANSIT
9	09:45:42	IMPORT
10	09:48:18	IMPORT
13	09:50:18	EXPORT
2	09:53:48	LIQUIDATION
7	10:09:36	TRANSIT
14	10:11:24	EXPORT
11	10:15:12	IMPORT
15	10:17:12	EXPORT
3	10:20:42	LIQUIDATION

Source: Authors.

Conclusions.

- The resolution of the problem allows establishing a flow to attend to the truckers by giving them an order through appointments to minimize waiting times. Through this process, both the average time to attend to trucks and the total time to attend to all trucks during the day are minimized.
- It is necessary to indicate that the time optimization management works as a gear, which allows a coordinated development of the appointment process.
- With this appointment system, the port also knows in advance the operations to be carried out. Thus, being able to dimension itself in terms of work equipment, goods and physical space.
- This optimizes port management and reduces truck congestion inside and outside the port.
- In order to solve the problem posed, a versatile optimization tool has been arrived at that can be applied to problems of different kinds.

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