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RESEARCH ON OPTIMIZING THE OPERATION OF SHIPS IN CONTAINER TERMINALS

Robert Alexandru DAINEANU[1], Dumitru DINU [1] , Mariana PANAITESCU[2] & Fanel Viorel PANAITESCU [2]

[1]Constanta Maritime University, Doctoral school of Electro-Mechanics Engineering, Romania, 104 Mircea cel Batran Street, 900663, Constanta, Romania, robertibanesto@yahoo.es; dumitru.dinu@cmu-edu.eu
[21]Constanta Maritime University,, Faculty of Naval Electro-Mechanics, 132, 104 Mircea cel Batran Street, 900663, Constanta, Romania, mariana.panaitescu@cmu-edu.eu; viorel.panaitescu@cmu-edu.eu

Abstract : The time allotted to a single ship at berth varies greatly depending on the characteristics of the ship, the volume of cargo and its specifications**.**. Taking into account the service time and the problem of terminals by overcrowding of waiting ships and available berths (which may vary in number, depending on the size of ships already berthed), the average waiting time is calculated and obtained. The operating process is usually sequential, ie each type of cargo is stacked separately from the other types. For this reason, the operating time was considered to consist of four other indicators, which correspond to the main types of cargo of Ro-Ro / Ro-Pax ships: complete trucks, semi-trailers, • passenger cars, vehicles as goods themselves. Also, the time of operation of the goods by the dockers can be formulated by two other different terms: the time related to the ship and the time in the terminal. In this context, we intend to analyze the capacity of the terminal in Constanța Port.. Two different scenarios are considered: a more "common" case for the studied terminal with 40 semi-trailers and 80 trucks to be unloaded and the same amount to be loaded and an "extreme" case in which all goods are composed of semi-trailers (160 plus 160 in total). By using simulation models, the values for the optimal quay time were obtained, in relation to the number of units for loading data in the specified scenarios. Using modeling algorithms, we obtain reports of situations that include tables and graphs that allow the optimization of terminal operation.

Key words : terminal, ship, scenarios, optimization, simulation, algorithm.

1. INTRODUCTION

When analyzing the operations of a container terminal, there are a large number of interrelated variables that must be taken into account, which makes it advisable to consider the terminals as continuous production systems, consisting of a succession of stages or separate subsystems where each of them must be optimized to increase overall performance and avoid any possible bottlenecks. This type of terminal operation approach allows focusing on each process and helps to understand, improve and ultimately determine the capacity of each subsystem and the terminal as a whole.

In general, the operation of a terminal can be divided into four main subsystems that correspond approximately to distinct physical areas of the terminal: Loading / unloading from / to the ship to / from the shore, transfer (from berth to storage area), storage and delivery and reception, all depending on the type of traffic / terminal.

With regard to Ro-Ro terminals, it was considered that a division into three subsystems instead of the common division with 4 subsystems would be sufficient, as the transfer time if loading / unloading is greatly affected by the storage configuration, which makes it difficult to approach the three subsystems on their own. In fact, RoRo terminals are characterized by, among other things, the shorter stay of the platforms in the terminal, as well as the unique feature through which the goods can move by their own means.

The operating process is usually sequential, ie each type of cargo is stacked separately from the other types. For this reason, the operating time was considered to consist of four other indicators, which correspond to the main types of cargo of Ro-Ro / Ro-Pax ships: complete trucks, semi-trailers, • passenger cars, vehicles as goods themselves. Also, the time of operation of the goods by the dockers can be formulated by two other different terms: the time related to the ship and the time in the terminal. In this context, we intend to analyze the capacity of the terminal in Constanța Port.

2. MATERIAL AND METHODS

In this context, we intend to analyze the capacity of the terminal in Constanța Port. By using simulation models, the values for the optimal quay time were

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2.1 *Simulation models:*

A model that uses Lanner's Witness software has been developed for terminal operating scenarios [1].

By entering parameters such as towing units, return / loading / unloading speed (a typical value would be 14 km / h), the distance between parallel and opposite parking rows and the load pick-up time, it is possible to obtain a graph showing values used to simulate quay operability (Figure 1) [2].

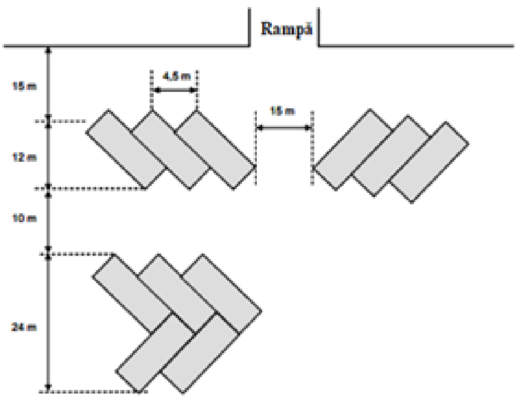

Figure 1 Values used for simulation

From the simulation it can be stated that the time on the quay depends on the chosen scenario [3].

The estimation of the values for the optimal time at the quay, in relation to the number of units for loading in the scenarios set for the study is done by graphs for time / units and different configurations and units of towing and loading (Figure 2).

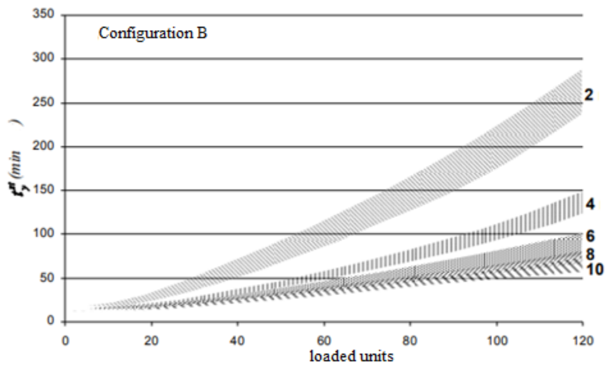

Figure 2 Estimating the values for the optimal time at the quay

Models are built in WITNESS using the elements displayed in the many tabs of the designer elements window (Figure 4) [3].

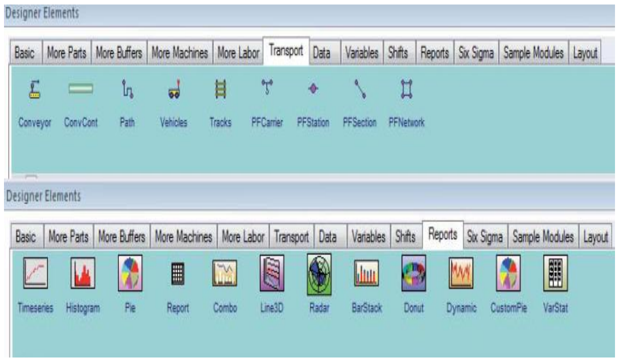

Figure 3 WITNESS designer elements

2.2 *Systemic analysis of the terminal:*

When analyzing the operations of a container terminal, there are a large number of interrelated variables that must be taken into account, which makes it advisable to consider the terminals as continuous production systems, consisting of a succession of stages or separate subsystems where each they need to be optimized to increase overall performance and avoid any possible bottlenecks. This type of terminal operation approach allows focusing on each process and helps to understand, improve and ultimately determine the capacity of each subsystem and the terminal as a whole.

In general, the operation of a terminal can be divided into four main subsystems that correspond approximately to distinct physical areas of the terminal: Loading / unloading from / to the ship to / from the shore, transfer (from berth to storage area), storage and delivery and reception, all depending on the type of traffic / terminal. With regard to Ro-Ro terminals, it was considered that a division into three subsystems instead of the common division with 4 subsystems would be sufficient, as the transfer time if loading / unloading is greatly affected by the storage configuration, which makes it difficult to approach the three subsystems on their own.

The three subsystems considered will be:

- anchoring,
- storage and
- delivery and receiving, as shown in Figure 4 [2]:

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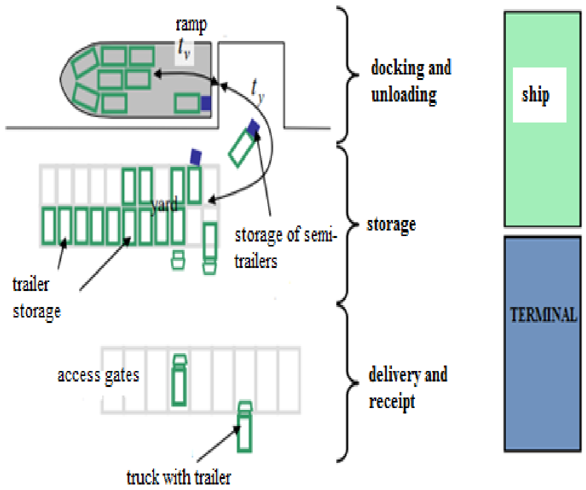

Figure 4 Ro-R terminal subdivisions

The methodology developed for obtaining the capacity and thus the level of service for a certain terminal and for a certain setting of operations is performed in four main stages, in which:

• the optimal value for the operating time is estimated;

• the waiting probability associated with the obtained operating time is calculated;

• the capacity graph for the current terminal is drawn and finally;

• the level of the service scale associated with the terminal is obtained.

Once the time of port operations is known, the analytical formula can be obtained to estimate the total stationary time.

It should be noted that the stowage time varies greatly depending on the characteristics of the ship, the volume of cargo and its specifications.

2.3 The operating process:

It is usually sequential, meaning that each type of cargo is stacked separately from the other types. For this reason, the operating time was considered to consist of four other indicators, which correspond to the main types of cargo of Ro-Ro / Ro-Pax ships:

- complete trucks- ^{t}
- semi-trailers- st
- passenger cars- ^{p}
- vehicles as actual goods- ^{cc} (Figure 5) [3].

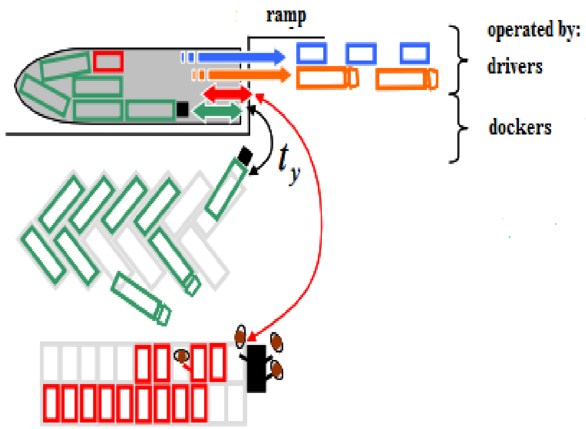

Figure 5 Types of goods and mode of operation

In RoRo terminals, the expected size of the ship (actual length) is not found in the equation, as the degree of berth occupancy is actually related to the number of access points, where a frame can be placed and not to the available berth length. In this type of terminal, the problem comes from elsewhere: the program [5]. However, Ro-Ro terminals usually operate by scheduling ships in advance and therefore arrival times are usually planned in advance and follow a strict schedule. But even so, the waiting time in the shed cannot be approximated and depends on many external factors [6]. So, once again, simulation is the usual choice to estimate the waiting time in the radar and the probability that it will occur [7].

3. APPLICABILITY PORT OF CONSTANTA

The proposed methodology is now applied to the data of a transport company, which operates with two independent ramps in a RoRo terminal in Constanța, Romania. Both the ramps and the systems on the quay are independent of each other and it is therefore possible to analyze them independently of each other, in foreseeable waiting terms, when ships arriving at the terminal follow a pre-established schedule.

3.1 Study hypotheses

• The load consists only of trucks and semi-trailers, being the second type of cargo that requires a lot of time for stacking;

• The unloaded goods are equal to the loaded goods;

• Two different scenarios are considered: a more "common" case for the studied terminal with 40 semi-trailers and 80 trucks to be unloaded and the same amount to be loaded and an "extreme" case in which all

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goods are composed of semi-trailers (160 plus 160 in total);

- the initial time and the total time are taken deterministically and thus no variation was taken into account;
- 8 mobile platforms and 2 ramps operate at the same time;
- The time for semi-trailer operation is considered to follow a normal distribution with the average obtained through a mix of analytical and simulated values with a purely analytical variation;
- the number of trucks that can be loaded 80 trucks / hour;
- the number of trucks that can be unloaded 140 trucks / hour;
- the number of trucks that can be parked 100 trucks / hour and there is room for 19 trucks on the inner lanes of the terminal;
- The typical ship has two ramps (R = 2), and the distance from the port entrance to the berth, d, is equal to 3.1 nautical miles;
- The standard deviation of the ship's arrival is 30 minutes.

3.2 Ship operating time

Includes all times allotted to a berth for the operation of a single ship. This is twice the time the ship spends in the dock and until the ramps go down the quay.

$$_{o}= 16\cdot d+ 3\cdot R+ 20 \quad (1)$$

where R represents the number of ramps (R = 2), and d the distance traveled from the road to the berth (3.1 nautical miles).

The calculation of the time of port operations t_{sv} is done with the equation

$$_{sv}=t^{t}+t^{p}+\max(t_{y}^{st}+t_{v}^{st},\ t_{y}^{cc}+\ t_{v}^{cc}) \quad (2)$$

where:

$_{v}$ is ship time; t_y is time in the terminal.

Equations (3) and (4) can be easily obtained to estimate $t^{t}$and t^{p}

$$^{t}= \frac{1}{\mu_{1}^{t}}\, n_{1}^{t}+\frac{1}{\mu_{u}^{t}}\,\mu_{u}^{t}+t_{af}^{t} \quad (3)$$

$$^{p}=\frac{1}{\mu_{u}^{p}}\, n_{u}^{p}+\frac{1}{\mu_{1}^{p}} \quad (4)$$

where:

$^{p}_{1}$, $^{t}_{1}$ represents the number of vehicles / trucks that can be loaded in a unit of time;μ_{u}^{p} , $^{t}_{u}$ -the sum of the vehicles that can be unloaded; n_{1}^{p}, n_{1}^{t}, n_{u}^{p}- number of vehicles for loading / unloading; t_{af}^{t} is damage due to congestion in the yard.The value of μ is directly proportional to the volume of the ship's ramps, their distribution inside the ship and the terminal facilities.

4. RESULTS

Specifically for the Ro-Ro terminal in Constanța Port the results are:

$^{t}_{1}$=0 .... 90 trucks / hour; μ_{u}^{t}= 120-150 trucks / hour; $^{p}_{1}$= 120... 180 trucks / hour; μ_{u}^{p}= 120... 180 trucks / hour. $^{t}_{af}$ is interpreted as overtime due to inadequate terminal capacity. This value can be obtained by equation 5

$$^{t}_{af}=\frac{1}{_{g}}(n_{u}^{t}\text{-L})\text{-}\ \frac{1}{^{t}_{u}}\, n_{u}^{t} \quad (5)$$

where:

$_{g}$ is the capacity represents the capacity of all the gates of the terminal (ta

L the capacity of the terminal (the number of trucks that can fit in the traffic system of the terminal).

Semi-trailers and vehicles are usually stacked simultaneously. When stacked, the main difference between these types of cargo and those defined above is that semi-trailers (as well as car loads) are not autonomous and thus the limiting factor is no longer the ship's ramp capacity, but the number of stacked units.

The time of the ship with semi-trailers t_{v}^{st} and its variability must be calculated for each type of ship in the terminal [8]. RoRo lines are usually operated on a regular basis, with the same ships over time; therefore, this amount of time can be obtained for the few ships working with the terminal in the Port of Constanța. It can be approximated by equation 6

$$^{st}_{v}=\text{N}\left(\frac{t_{v}^{m}(n_{u}^{st}+n_{l}^{st})}{n^{m}},\frac{\sigma_{v}^{m^{2}}(n_{u}^{st}+n_{l}^{st})}{(n^{m})^{2}}\right) \quad (6)$$

where:

n_{u}^{st}, n_{l}^{st} are the number of semi-trailers intended for loading and unloading; n^{m} represents the number of mobile loading platforms; $\sigma_{v}^{m^{2}}$ is the variation t_{v}^{m}(time spent by mobile platforms inside the ship). However, the use of equation 6 may not be sufficiently accurate. In such a case, the total time of the semi-trailer (t_{s}^{t}) can be obtained by simulation once t_{v}^{m} is known.

On the other hand, the time spent on the quay of semi-trailers (t_{y}^{st}), understood as the value of the operating time spent outside the ship, is obtained after simulating the operability of the terminal.

From the simulation it can be stated that the time on the quay depends on the chosen scenario, but only to a small degree (the total time varies only 2-3%)(Figure 6).

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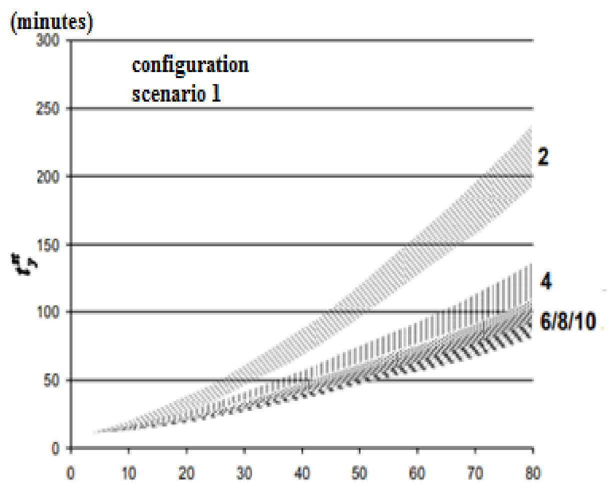

Figure 6 Estimation of values for the optimal quay time, in relation to the number of loading units in scenario 1

Knowing that the standard deviation for the arrival of ships is approximately 30 minutes, the following figures are obtained (Figure 7):

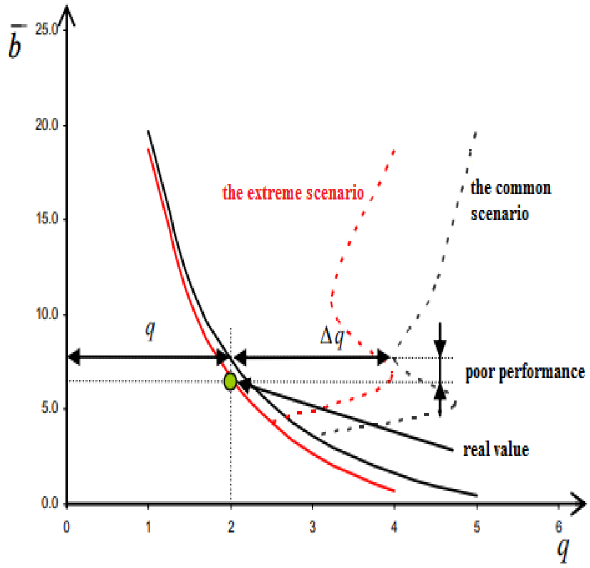

Figure 7 Ships operated for a given average distance and ships that could be served without changing scheduled arrivals at the Ro-Ro terminal in the Port of Constanța

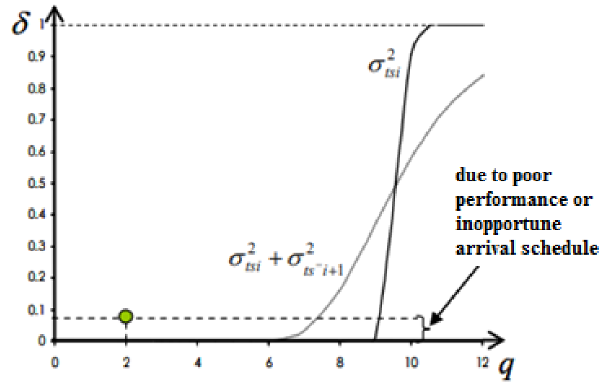

Figure 8 Relationship between the probability of waiting, the number of arrivals and the variability of arrival times and operating time

where on the ordinate- δ we have the waiting probability and on the abscissa- q, the flow.

Adding the actual values obtained, we can determine what could be the number of ships per day served for operation in optimal conditions (according to planning and operating times)(Table 1).

Table 1. The operational vessels on main line

No.	Berthed-Sailed	Vessel
1	7/11/21 12:00-7/13/21 5:10	COSCO SHIPPING PANAMA
2	7/14/21 0:50-7/16/21 3:15	CMA CGM TIGRIS
3	7/18/21 6:45-7/19/21 21:45	CMA CGM TANYA
4	7/26/21 4:40-7/27/21 23:45	COSCO SHIPPING SEINE

5. CONCLUSIONS

Ro-Ro traffic is likely to increase worldwide and therefore an increase in the capacity of Ro-Ro terminals is needed. The geography of the Black Sea is ideal for short sea shipping. It has an increased potential to support the development of a Ro-Ro / Ro-Pax transport network between neighboring countries.

The terminal in the Port of Constanța will undergo some modifications so that the Ro-Ro type ships can benefit from all the port operations necessary for a good development of the project. Piloting services (if applicable), storage, stacking, mooring, access to railways and highways, etc. will be provided.

It takes into account whether the arrival pattern is random or scheduled and the time of service provided by the terminal (average value and reliability). Also, the different types of goods and their distribution on the quay are identified and taken into account. A methodology for assessing the level of service provided by the terminal under certain operational constraints is also provided, in part, as a by-product of the methodology. This paper ends by applying the methodology of the terminal in the Port of Constanța.

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