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SIMULATION MODEL FOR MARITIME CONTAINER TERMINAL

Summary. For logistic chains that have a maritime component, the ports transition involves a set of specific operations inside maritime container terminals. This can be cargo handling operations from the terrestrial vehicle in the storage area of ports, from port storage area in the maritime ships, as well as storage operations in the port area and other container terminal activities. Taking into consideration the multi-flow interactions and the non-uniform arrival of vessels and in-land vehicles, discrete event simulation stands as a feasible technique for investigating berthing capacity during the initial planning stage of the terminal or for operative planning of logistic processes at the terminal. If the storage area is analysed as a queuing system, the quality serving attributes could be evaluate. When different distributions for arrival flows of the containers in the maritime container terminal are taken into consideration, the quality serving attributes are difficult to estimate. In our paper, a discrete simulation model is developed in ARENA software for case of a maritime container terminal. The estimation of the general measures of performance for the container port terminals through simulation could provide data for the implementation in the management plans by port administrations.

1. INTRODUCTION

The maritime container terminal has an important role in the structure of logistics chains with maritime components. It has the role of connecting land and sea transport networks. At the same time, it must allow the collection of containers in the port through the storage area, so that the stationing of maritime vessels will be as short as possible. The transit through maritime container terminal involves a set of specific operations. [1,3] Some of them include the handling of containers inside the terminal between trucks or ships to storage area and vice versa. Moreover, for containers loaded with dangerous goods, the handling and storage operations must be conducted under security rules and be supervised by a specialized expert [13]. All these problems must be resolved by maritime terminal administration in accordance with the safety rules and a high level of quality serving attributes [6].

According to Steenken et al., for planning and controlling of maritime container terminals, three levels can be identified in decision-making process [14]:

- First is the design of maritime container terminal: terminal layout, interface with inland network, handling equipment, ITC systems, etc.
- Second is the operative planning: crane assignment, berth allocation, storage planning, and storage rules and policies.
- Last level is the real-time control: movements inside of the terminal, slot assignment inside of the storage area, crane scheduling, etc.

The transit capacity of maritime containers terminal has an influence over the capacity of whole logistic chain that includes it. It is, therefore, so important to develop an approach for evaluating the quality serving attributes.

A solution in this direction is to use a mathematic model. Using the theory of queuing system for different known mathematical distribution, the length of queue, probability of refuse, utilization ratio, etc. can be calculated.

In the case of the maritime container terminal, its complexity makes it quite difficult to achieve such a mathematical model. Solving this problem is accomplished by developing a discrete simulation model. This allow to take into consideration different distributions for arrival flows of the containers in the maritime container terminal, for processing time of the cranes, etc. in evaluate the quality serving attributes.

The results obtained through simulation help port administration to evaluate the activities in container terminal in all three levels of decision-making process. Moreover, these allow to test new improvements of the activity for maritime container terminal before implementation and evaluation of variation of the general measure of performance attributes.

2. LITERATURE REVIEW

The main objective of the research presented in this paper was to develop a good model for the case of the maritime container terminal, which can be used in the estimation of quality serving attributes. The approach used involves modeling the maritime container terminal as a queuing system. The queuing theory, developed for the first time by Agner Kraup Erlang, offers some approaches for the case of queuing system with particular mathematical distribution for entering flows and serving time (such as Exponential, Erlang, and Poison) [8].

The other discrete simulation models evaluated by the research team are adapted for all kinds of maritime terminals. So, for the case of maritime terminal for bulk cargo, in the paper of Campeanu et al, a simulation model is developed. An algorithm in pseudo code is presented, but a logical model is not developed for activity inside the maritime terminal [5]. In the literature, papers with developed models that use discrete event simulation for the case of RO-RO maritime terminals can be found. In this case, the maritime terminals have only a small storage area and inland vehicles arrival moment must be coordinated with the itinerary of the ships [7, 11]. The discrete event simulation models are also evaluated in other papers [2, 10 and 12].

The complexity, the number of operations, the multi-flows interaction and the non-uniform arrivals of vessels and in-land vehicles lead to the need of a discrete event simulation model. For this, it is necessary to have access to a software platform dedicated to a discrete simulation model. In our case, we used Arena Rockwell Software, which is not dedicated to study maritime terminals like in case of Microport [15], but with a high degree of adaptability. We find in the literature, a set of papers with discrete event simulation model developed in ARENA or in Planimate® adapted for maritime terminal: for containers, RO-RO or bulk cargo [3,6 -9, 16]. In some of these, the authors have mentioned the use of software in obtaining results but have not presented the logical structure of the model developed. For this reason, we chose ARENA software as a simulation instrument because the structure of simulation model in software platform reflects logical algorithm of discrete event simulation. It is expected that this study will contribute to make up for the deficiency in the literature and could present a logical model for discrete simulation developed for maritime container terminal which can be adapted for all kind of maritime terminals.

3. TOPOLOGY OF DISCRETE SIMULATION MODEL

The logical model used for simulation of the activities inside of maritime container terminal is developed on the basis of topology of real terminal. In that direction, the berths have an important role in the terminal. These must be properly equipped and sized for the container flows from maritime to inland network and opposite. Moreover, the transit of containers between ships through terminal has an important role in port activities. In figure 1, the transshipment from the berth, storage and landside dispatching are represented for a typical maritime container terminal.

From maritime ships (1) arrived at the berth, the containers (3) (import or inbound containers) are unload by quay cranes (2) and also are loaded with containers on them (export or outbound containers). The transit capacity through maritime container terminal depends on the quay cranes number and handling capacity. The quay cranes provide direct transshipment between vessels and landside vehicles (railcars – 8 and trucks – 9) and also from marine stacks on the landside vehicles. On the berth, there are operative container stacks (marine stacks – 4 and 4'). In storage area (5), containers wait before departure with another ship or for rail or truck transshipment. This area is served by rail-mounted gantry cranes (6). These cranes are useful also for load/unload trucks. A container may be stored in container terminal in one or more successive storage areas. Between marine stacks and landside stacks, containers are handled with straddle carriers, reach stacker or chassis (7).

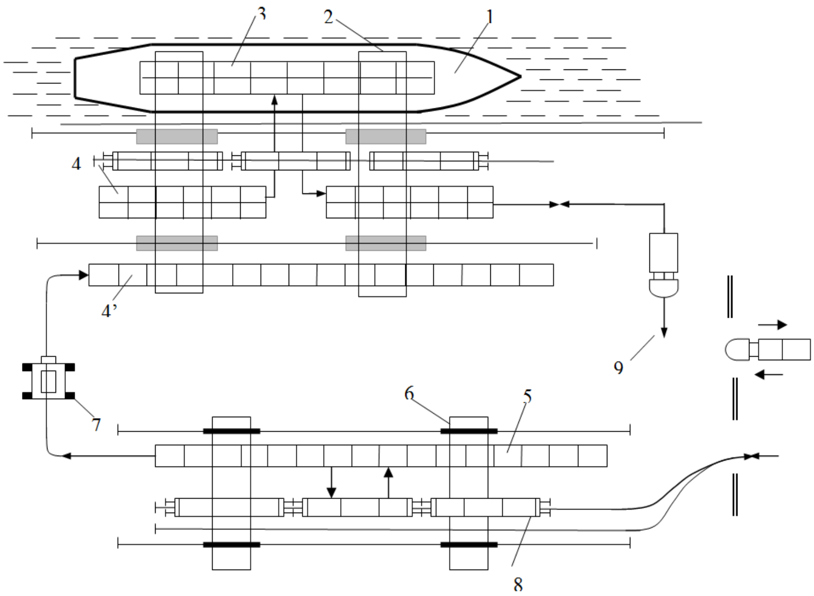

Fig. 1. Typical topology for maritime container terminal

4. SIMULATION MODEL FOR A MARITIME CONTAINER TERMINAL

For the case of SOCEP maritime container terminal, in ARENA 11 software, a simulation model was developed. The authors chose this simulation instrument because it allows a logic model development using logical blocks with specific functions. This allows for an easy understanding of the model by readers. This terminal is located in port of Constanta, in West part of Romania, at Black Sea. The load/unload of container to/from ships can be made with three Shore Panamax Cranes. In storage area, approximately 10.000 standard containers (1 TEU) can be stored. Inside the terminal, the containers are handled using two transtainers, and also 16 other equipment like reach stackers, empty handlers or forklifts. The logic model is structured in three sub-models as shown in Figure 2. In our case, we suppose a container terminal connected to the inland network by road. The containers are unloaded from maritime vessels and loaded in trucks if these are available or are stored inside of terminal and wait for a free truck.

A discrete simulation model is developed in ARENA 11 software for case of a maritime container terminal. This is structured in three sub-models as shown in Figure 2. The hypothetical container terminal used for simulation model is connected to the inland network by road. The containers are unloaded from maritime vessels and loaded in trucks if these are available or are stored inside of terminal and wait for a free truck.

The first submodel describes vessels arrival to port: waiting in queue or free berth, occupying the berth, waiting for containers unloading and in the end leaving the maritime terminal (Figure 3). In this sub-model, the different distributions for arrival flows of the vessels and number of containers in the maritime container terminal are introduced. The second sub-model contains the containers unloading process accomplished by two quay cranes directly on waiting truck or on storage area (Figure 4).

The handling activities inside of terminal, except loading/unloading process, are not taken into consideration in the simulation model. The identification process of these activities is difficult because it is dependent on the strategy of the terminal administration. We decide this because the large number of handling equipment's offer enough capacity, so it is not restrictive for transit flow of container through terminal. The distribution types of variables used to reflect the simulation model are summarized in scenarios (Sa.b) according to arrival of trucks (a) and vessels (b) as follows:

- the arrival's time between trucks is assumed to be constant (1, 2 or 5 minutes corresponding to a=1, a=2, a=3)
- the arrival time between vessels follows (1) a normal distribution with mean of 25 hours and standard deviation of 4 hours (b=1), respectively 30 hours and 5 hours (b=2); (2) an exponential distribution with mean 25 hours (b=3), respectively 30 hours (b=4).

The unloading time for quay cranes follows a triangular distribution with a minimum value of 2, mode of 3 and maximum value of 4 minutes. The number of containers for unloading from each vessel is 800. This number is consider for our hypothetic scenarios as a constant. In reality, this can vary depending on the commercial data. Taking into consideration these assumptions for the model, the calibration of input data was made only for duration of technological operation of handling. This was made using survey data obtained from the container terminal.

The other simulation variables are as follows:

- the number of statistically independent replications – 10;
- the replication length (simulation time) – 3 months; and
- the operating time of the terminal – 24 hours;
- The results are presented in Table 1.

Table 1

The simulation results

Scenarios	Time between arrivals of vessels	Average number of vessels	Occupancy ratio of berth	Occupancy ratio of cranes	Average waiting time for entering vessels to berth [h]	Average number of waiting vessels	Average time required for unloading vessels	Average waiting time of containers [hour/container]		Average number of waiting containers	
								Storage area	Vessels	Storage area	Vessels
S1.1	N(25,4)	85.5	0.97	0.94	6.78	0.27	20.6	210.00	9.99	811	158.00
S1.2	N(30,5)	73.5	0.83	0.84	0.73	0.03	20.6	19.30	9.97	63.80	135.00
S1.3	Expo(25)	80.2	0.95	0.88	96.6	4.03	20.6	175.00	10.00	670	148.00
S1.4	Expo(30)	73.1	0.83	0.83	50.8	1.75	20.6	116.00	10.00	378	135.00
S2.1	N(25,4)	85.8	0.97	0.88	9.6	0.4	20.6	808.00	10.00	6293	159.00
S2.2	N(30,5)	72.7	0.82	0.83	0.5	0.02	20.6	565.00	10.00	3666	134.00
S2.3	Expo(25)	80.8	0.92	0.86	109	4.7	20.6	710.00	10.00	5259	149.00
S2.4	Expo(30)	68.3	0.77	0.8	43.5	1.5	20.6	566.00	10.00	3420	126.00
S3.1	N(25,4)	86	0.97	0.85	8.5	0.34	20.55	970.00	9.98	10633	158.60
S3.2	N(30,5)	73.2	0.83	0.77	0.5	0	20.6	872.00	9.98	8126	135.00
S3.3	Expo(25)	79.8	0.9	0.8	83.3	5.4	20.6	920.00	9.97	9407	147.10
S3.4	Expo(30)	71	0.81	0.75	48	1.71	20.6	900.00	9.98	7984	131.00

The results obtained by simulation reflect the link between the size of the container's input flow in the terminal, the period required to handle the containers inside the terminal, and the size of the truck's arrival time in the terminal. When time between arrival of vessels decreases and time between trucks is at maximum value used for simulation (5 minutes), it is necessary to have enough capacity in storage area of maritime container terminal (Scenario 3.1). This is reflected by queue length of vessels waiting to start the unloading/loading process (Figure 6). If storage area is small, the handling process of container from maritime vessels to terminal is stopped, until the storage slots are released.

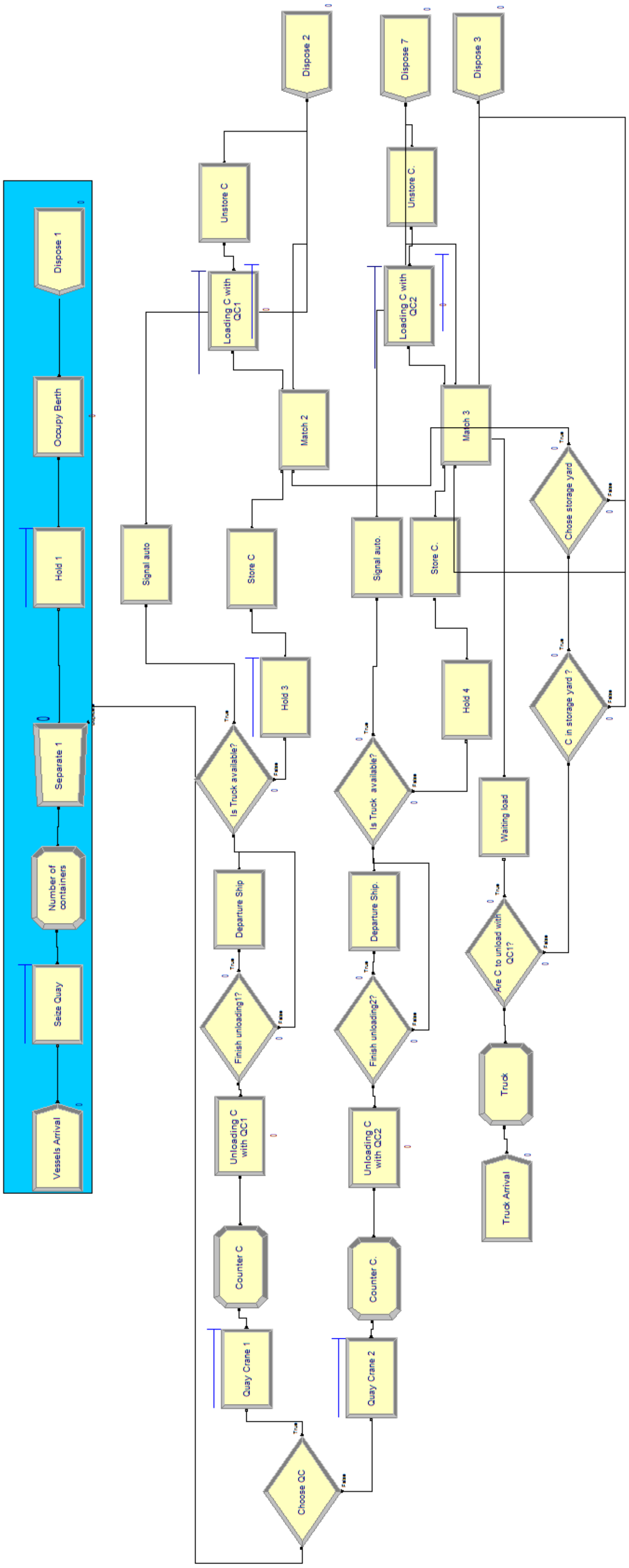

Fig. 2. The ARENA simulation model for maritime container terminal

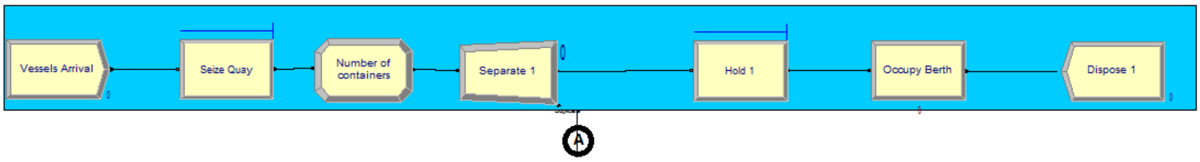

Fig. 3. The simulation model-vessels arrival process

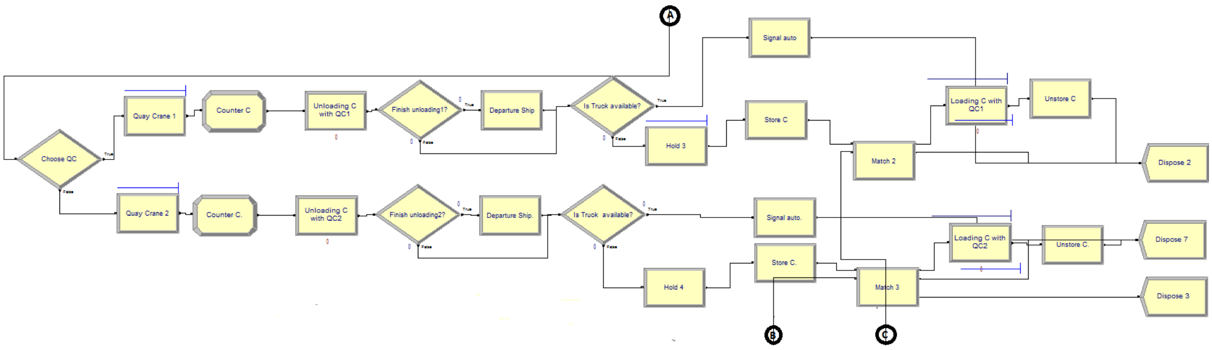

Fig. 4. The simulation model-containers handling process

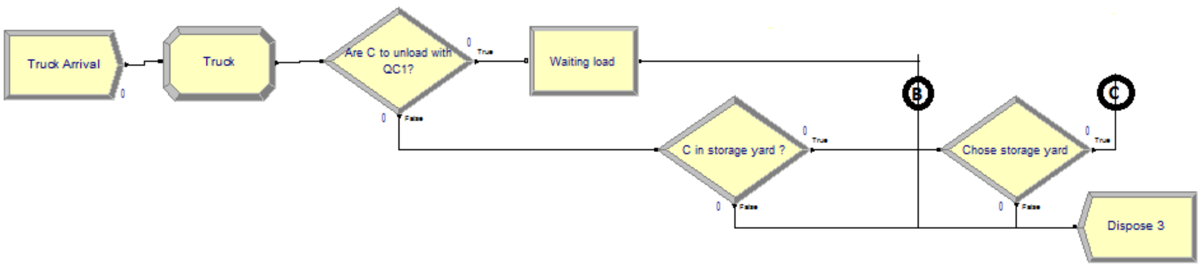

Fig. 5. The simulation model-trucks arrival

5. CONCLUSION

In case of maritime container terminals, it is important to have an estimation of berthing capacity during the initial planning stage of the terminal or for operative planning of logistic processes at the terminal. This is difficult because it must be taking into consideration the multi-flows interaction and the non-uniform arrivals of vessels and in-land vehicles. In that direction, the discrete event simulation with an analysis of storage area as a queuing system is a feasible technique. A simulation model allows to estimate the quality serving attributes when evaluated with different distributions for arrival flows of the containers in the maritime container terminal and for time of handling process inside of terminal.

In our paper, how to develop a discrete simulation model in ARENA software for case of a maritime container terminal is presented. The study case is made on a general structure of Romanian container terminal connected to the inland network by road. In reality, this terminal has also a railway connection, but with a low utilisation (2-5%). We want to include this aspect in our next simulation.

This model can also be adapted for other cases, like the transit of container loaded with dangerous goods and limitation of capacity of storage area. Moreover, for our next simulation model, we want to evaluate the handling activities inside the terminal in storage area. This is very important for terminal administration, but depends on commercial restriction (container with priorities rules, safety rules, etc). This kind of model is useful in evaluating also the necessary capacity for storage area, taking in consideration the characteristics of arrival flow for maritime vessels, the priority rules in handling containers inside the terminal, the duration of handling process, etc.

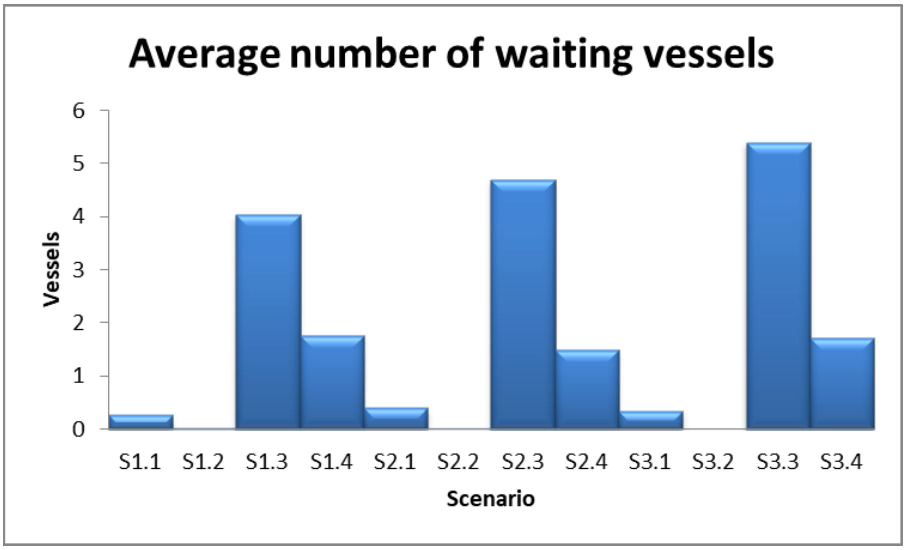

Fig. 6. The length of vessels waiting time in queue before berth

The results obtained through simulation for performance attributes are important in the development process of the management plans made by port administrations. The simulation models are useful in decision-making process. Using this, a design for new maritime container terminals can be tested. In this case, the input data are obtained from real terminal located in neighboring areas or from statistical forecasts. Moreover, for operative planning, using a simulation model allows to test new crane assignment or berth allocation plans.

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