Development and Analysis of Models for Handling the Refrigerated Containerized Cargoes

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Abstract. This paper considers the open multi-channel queuing system, which receives irregular homogeneous or heterogeneous applications with an unlimited flow of standby time. The system is regarded as an example of a container terminal, having conditionally functional sections with a certain duty cycle, which receives an irregular, non-uniform flow of vessels with the resultant intensity.

1. Introduction
Development of the Russian sea transport is determined not only by geography, but also by its economic advantages. Marine transportation remains the cheapest way of transport after the pipeline that leads to the demand and popularity of this mode of transport among others. Since the cost of water transport is very low, it is competitive, despite the low delivery rate.

Now the sea port is a large transport hub including a variety of transport modes. The port operation is one of the most important trends in development of the public sector of economy. It covers more than 50% of the total cargo turnover. The positive dynamics in increase of the cargo turnover of the Russian sea ports proves this fact. According to statistical data the cargo turnover in Russia increased for 4.4% for January-May 2015 as compared with the same period of 2014, and for 2014 it increased for 5.7% as compared with the previous year [1-7].

Container terminals become more common where large-tonnage refrigerating food containers are handled. Refrigerating containers as an achievement of modern technology is intended for transport of goods requiring the maintenance of special temperature and humidity conditions. Basically, these containers are used for shipping and storing perishable goods. Refrigerated containers can be used to transport virtually by all modes of transport and to store perishable goods both on the temporary basis, while transshipping in cargo terminals and for a long time. The use of refrigerated containers can deliver cargo "door-to-door" keeping the same temperature in transit and during loading and unloading when changing the modes of transport.

2. The status of the problem
While designing the complex systems for servicing the container terminals it is reasonable to apply complexes of coordinated and information-consistent and polynomial models, which are determined on the basis of the active identification methods. The current theory of complex systems identification is inextricably linked with the theory of optimal control theory and optimal experiment theory. Nowadays, there is a large number of papers devoted to optimal identification systems in various classes of models. At the same time, if at the initial stages of development of the identification theory,
methods of optimal control theory were used in general, now it is a trend towards a wider use of the optimal experimental design theory methods.

Development of a complex of polynomial and classical models of systems for servicing container terminals requires special plans for the computational experiment, which take into account specific features of the systems and processes of their designing. Planning of the computational experiment based on specific computational models and processing of the results, in accordance with the criterion of optimality, allows for the active identification of handling and storing the refrigerated containerized cargoes, i.e. getting a set of consistent models representing polynomial relationships of various indices of the process quality with the parameters of the systems under review.

To cut costs at the stage of the cargo transportation to the port and to reduce the provisional time of delivery, container transportation is widely used, as they have a very high degree of security. Modern containers are technically designed and manufactured in compliance with all the rules and standards in force, which ensure their strength and integrity. This is one of the most convenient and popular forms of transportation. In the world the popularity of using containers as a universal receptacle for transportation of goods is growing.

The technical equipment in the ports in respect of import and export, cannot always be ready for storage or handling the containerized cargo. In this regard, it is required to develop models optimizing and reducing the cost of equipment and resources [5-11]. Let us consider the mathematical model, by means of the queuing system, with which it is possible to reduce the error in the calculation of probability characteristics.

3. Scientific novelty

Reasoning from theoretical premises, the main consequence of nanopowder introduction into the melt should be refinement of the macro- and microstructure, as the powder particles must serve as nuclei of new grains.

When using the Markov’s model queueing system, the exponential service law is assumed. When calculating the QS probability characteristics, the use of the exponential law can lead to errors and lack of precision.

Deterministic approaches to describe the capacity of container terminals, in fact, do not reflect the specific features in processing and storing refrigerated goods, and in particular, do not take into account the time interval between the arrival of requirements in the service channel and release requirements of the channel, however, the delivery of batches of containerized cargo to the terminal is a random flow of events. Under real conditions the operation of the terminal infrastructure in terms of cargo handling processes is not adequate to the above mentioned assumptions [2]. Given the specificity of container terminals to meet the challenges of research and optimization, it is required to consider random processes in handling the vessels, describing these processes based on probability models [3]. Let us consider a different approach to the calculation of the characteristics of the QS probability model.

A mathematical model of the storage process allows for the irregular arrival of consignments and the random time of their finding in the stock within refrigerated container terminals. That leads in some cases to the demurrage and excess storage spaces in warehouses, in other cases it leads to the formation of queues.

In order to solve the problem of research and to develop a probability model it is necessary to investigate random processes in cargo storage and make their probability analysis. To move from one state to another, data of the cargo storage processes in certain moments of time are used. Transition of the process takes place in moments of change in cargo handling state, i.e. when a new vessel is entering the terminal, one of the berths is becoming free. The number of vessels in the queue for storing goods changes as well.

To reflect the major events of the system let us plot the process of functioning of an open multi-channel queuing system graphically. Fig.1. shows Multichannel queuing structure. Fig. 2 shows the basic processes of the multi-channel open QS.
Describe every event in the system under modelling:
1. Arrival of vessels in the terminal.
2. Entering the vessels to the roadsteads (queue / loading area).
3. Determination of the conventionally-functional section for servicing the vessel.
4. Waiting for emptying one of the conventionally-functional sections.
5. Leaving the loading area by the vessel.
6. Time of servicing the vessels in the conventionally-functional section.
7. Emptying the conventionally-functional section.

Figure 1. The Multichannel queuing structure.

Leaving the terminal by the vessel.

Let us introduce the notation of the refrigerated container terminal with F conventionally functional sections with the same duty cycle φ, which receives the irregular flow of the vessels m (a number of vessels) with the resultant intensity λ. The resultant intensity of the vessels’ arrival in the terminal is determined by the intensity and a number of vessels in the queue.

If the vessels are similar in terms of their service, it is believed that a uniform flow of applications or claims (vessels) enters the QS, i.e. all applications for discharging are the same [4]. In previous papers queuing systems based on probability models were considered in relation to the uniform flow of applications, namely all incoming vessels have the same specification, i.e. the same capacity and size of container consignments (number of containers on board the vessel).

However, there may be certain non-uniformity of the vessels’ flow, namely vessels may have different characteristics: the number of containers on the vessel, and capacity of containers, etc.

Assuming that the flow of consignments (vessels) coming into the port obeys the Poisson distribution law, it may be considered the simplest one (stationary Poisson law), which has three following properties: ordinariness, lack of aftereffect and stationarity.
4. Results and development of algorithm

Using polynomial and mathematical models schemes of the functioning processes and conditions of multi-channel open QS described above, the probability characteristics were calculated by the software.

The choice to use this tool as a software development, allows us to solve all of the above tasks, and provides a simple and convenient programming, and the possibility of future upgrades. The developed software is a set of libraries of functions and the dynamic content aimed at calculating the probability characteristics of the storage and handling reefer container terminals. The program provides the capability to input a parameter with no quantitative restrictions such as the type of vessel. The size of consignments, the size (capacity) of the container, the fill rate and other characteristics for a particular type of vessels are taken into account for every type of vessel.

In the course of development the following tasks have been set and solved:

- implementation of initial data input: $F$ is the number of conventional functional sections; $ms$ are vessels of s-type, where $s$ is the number of "non-uniform" vessels;
- $\phi_s$ - the duty cycle (Figure 3);
- entries must comply with the conditions and they should be checked for correctness;
- calculation of the average number of consignments in the queue for storage;
- the intensity of the arrival of batches of containers;
- the average time waiting for the container batches to be stored.

According to the results of calculations it may be stated that the average waiting time by increasing the duty cycle significantly increases and decreases by increasing the number of quasi-functional sections in the refrigerated terminal. Calculations have shown that by using $rs$ and $rcp$ indices differ slightly. It proves that it is possible to use average value $rcp$ in further calculations.

Figure 2. The process of functioning of the multi-channel open queueing system.
Figure 3. Block diagram of the calculation of the probability characteristics of the storage and handling of reefer containerized cargoes.
With the development of the terminal a new organizational structure was implemented, at the same time methods and tools for assessing the transshipment terminal and other parts of the multimodal transport were improved [5].

In order to simulate a model of loading-unloading terminal operation the queueing system tools are used. Open Q5 queuing systems are the basis of classical and polynomial modeling of cargo handling [6]. To determine the characteristics of the processes in handling the container cargoes, it is not always appropriate to apply the available queuing model, as these models do not correctly describe the processes of the port operation [7-8].

The deterministic methods to describe the capacity of container terminals, in fact, do not reflect the specific features in handling and storing refrigerated cargoes, in particular, such as the time of delivery of the container consignments to the terminal is considered as a random flow of events [15-20].

5. Conclusion

Thus, the resulting probability model allows us to analyze the storage processes in the refrigerated container cargo terminals, taking into account the specific features of cargo handling. While calculating the mathematical model, we can find the following parameters: the average number of container consignments in a queue for storage; average reduced expectation time, the intensity of the arrival of every batch of containers in the terminal and the fill factor of the conventionally functional sections. The results are more accurate than using the "standard" deterministic method, which does not fully reflects the specific features of handling the reefer container cargo due to the fact that using this method does not take into account such important aspects as the irregular flow of events, a random time of stay of vessels in the terminal (in the conventionally functional section) and a random variable handling time.

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