

Simulation model of processes of servicing refrigerated cargoes in the terminal

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Abstract. In the paper the simulation model of servicing processes of refrigerated cargoes in the terminal is described. The mathematical model of the storage process is constructed in view of irregular incoming of cargoes consignments and their casual time of arrival to the refrigerator terminals.

1. Introduction

Historically Russia by right is considered as one of the Great marine Powers due to its geographic location. During the epoch of developing and solidifying of the international connections the foreign trade takes an important place in the national economy. One of the convenient modes of goods shipping at long distances is the marine transport.

According to statistical data the international marine container cargo transportations take the first place in terms of distance and frequency of usage among all other types of cargo delivery. A reason for such great demand is that at present the container carriage is the most unified mode of cargo delivery all over the world.

The international marine container carriage has some indisputable advantages:

- it is the most economic method of cargo delivery. The cost of marine delivery is manifold cheaper than, for example, delivery by air. Such type of delivery will allow loading cargo of various dimensions into the cargo container and delivering it to the destination without problems;
- it is possible to supply cargo practically from any point of the world by means of maritime containers;
 - the transit time between ports of loading and discharging is fixed;
 - the channel capacity is high;
 - cargo safety in a maritime container is assured.

Container terminals for handling refrigerated containers are being developed now. Refrigerated containers can be used during transportations practically by all modes of transport. The use of refrigerated containers allows delivering cargo 'from door to door'.

With the development of the terminal a new organizational structure of control was realized, both methods and means of estimation of job performance standards of the reloading terminal and other sites of multimodal transportations were simultaneously improved [1-3].

Nowadays for exposition of valuation performance of the reloading terminal the determined methods are used. However, such methods, actually, do not reflect all specificity processing of container refrigerated cargoes. The delivery moments of consignment of cargo containers to the terminal present a casual flow of events.



The mathematical model of the storage process is constructed in view of irregular incoming of cargo consignments and their no regular arrival to the refrigerator terminals. In one case, that leads to trailer idle hours, idle and overflow of places in storage depots, in the other – to standing in line.

To analyze and estimate the process of terminals functioning, it is necessary to use both the mathematical models grounded on probabilistic methods and a simulation model, allowing the construction of the models of processes grounded on logical-mathematical description of an object.

The simulation model is a formal description of logic of the researched system functioning during a certain period of time, considering the most significant interactions of system elements and ensuring a possibility of carrying out of statistical experiments.

A suitable method for achieving the assigned tasks in view of the storage process is represented by the method of theory of queues, in the form of a queueing system.

The queueing system is an aggregate of sequentially connected entering streams of requirements (vessels) for servicing, turns of vessels, maintenance channels (conditional-functional sections) and exit streams of requirements after operation.

A simulation model of the queueing system is the model reflecting system behavior and a modification of its condition status when adjusting streams of requirements that introduce the inputs of the system. Parameters of input streams of requirements are exterior parameters of the queueing system. Exit parameters are the magnitudes describing properties of the system, the quality of its functioning, such as the time of the requirements expectance in queues and maintenance channels etc.

Simulation modeling allows the research of the queueing system with various types of entering streams and a different intensity of inflow of requirements in the system.

The cores stages of simulation for effective utilization of the system are:

- problem statement;
- detection of the basic singularities;
- solution of the problem using analytical methods;
- solution of the problem using an imitative method.

2. Problem statement

Let us suppose that the multi-channel broken queueing system with an unlimited latency period and with the inhomogeneous elementary (stationary Poisson) flow of requirements is set. The elementary flow is characterized by the following singularities:

- inflows of requirements (vessels) in the system for servicing arrive one after another, that is the probability of inflow of two or more requirements (vessels) in one instant is very small, and it can be neglected; □ a flow of requirements is ordinary;
- □ the probability of inflow of subsequent requirements (vessels) at any moment does not depend on probability of their inflow during the previous moments; □ a flow of requirements is without aftereffects;
- the flow of requirements does not depend on the disposition of a considered interval of time for the time axis; □ a flow of requirements is stationary.

As far as the requirements (requests) of the queueing system have already been analysed, we may consider incoming vessels. As servicing devices belong to a conditional-functional section, the process of cargo-handling is realised there.

Let us analyse the functioning of handling processes of refrigerator containerized cargoes in the reloading terminal, by a mathematical model grounded on probabilistic methods, and a simulation model grounded on logical-mathematical description of a project.

3. Detection of the basic singularities

To solve the research problem and to develop a probability model, it is necessary to research stochastic storage processes of vessels and to make their probability analysis. Functioning of the multi-channel broken queueing system may be described by its all possible condition statuses and by the intensity of passage from one condition status to another.

Main specifications of functioning of the queueing system are probabilities of a condition status of systems, i.e. each vessel can appear in a conditional-functional sector (event A) with the same probability of p . And movements of individual consignments may be considered as f of independent trials.

If probability p is a determination of a shipment in terminal $q = 1 - p$ there is a probability that the given shipment will be in other condition status (in other phases), i.e. no occurrence of event A .

We need to find probability (P_n) of shipment in the terminal, which will help to treat n shipments, i.e. event A in these f experiences will appear exactly n times as an event.

By using Bayes approach we shall consider event B_n , which shows that event A appears equally n times in f experiences. This event can be carried out by various modes. We shall spread out event B_n as the sum of product of the events consisting in occurrence or nonappearance of event A in separate experience. We shall designate A_i as an event corresponding to determination i of the consignment in the terminal, and \bar{A}_i – the event corresponding to determination i of the consignment outside of the terminal.

Really, each term of sum B_n (occurrence of event) should consist of n events A_i and $(f - n)$ events \bar{A}_j with various indexes. Then B_n will be described by the following formula:

$$B_n = A_1 A_2 \dots A_n \bar{A}_{n+1} \dots \bar{A}_f + \dots + A_1 \bar{A}_2 A_3 \dots \bar{A}_{f-1} A_m + \dots + \bar{A}_1 \bar{A}_2 \dots \bar{A}_{f-n} A_{f-n+1} \dots A_f \quad (1)$$

In the given expression the number of possible modes allows choosing n from f experiences containing an event. Let us designate this number as C_n^f .

Using the private theorem of recurring experiences, it is possible to discover probability $P_{n_1 n_2 \dots n_s}$.

$$P_{n_1 n_2 \dots n_s} = \prod_{i=1}^s C_{f_i}^{n_i} p^{n_i} q^{f_i - n_i}, \quad (2)$$

where $C_{f_i}^{n_i}$ – figure of modes, with which from f_i experiences it is possible to choose n_i , in which there was an event (the determination of a shipment of cargo containers in store).

The probability of shipments determination n_1, n_2, \dots, n_s of stored cargo containers corresponds to the terms of expansion of a binominal formula in a degree equal to a number of shipments of cargo containers.

Therefore, the specified probability distribution is called binomial. By the probability distribution we mean binomial allocating possible occurrences of events A (the determination of a shipment of cargo containers stored) at repeated independent trials, in each of some events A can be determined with the same probability.

For this purpose we shall present all possible condition statuses of the queueing system in the form of labelled columns of condition statuses (Figure1).

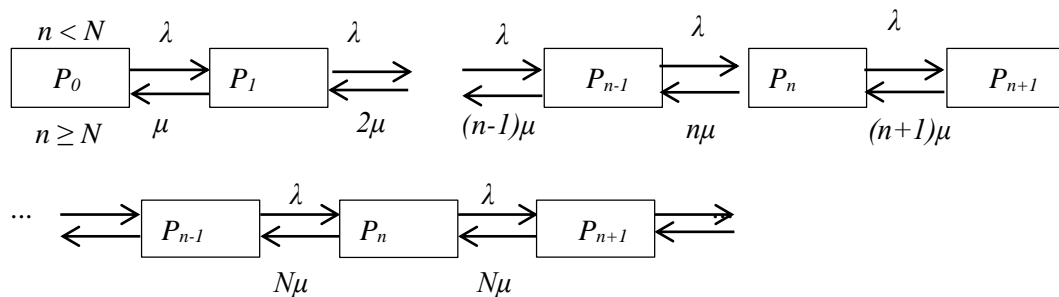


Figure1. Labelled columns of condition statuses of the open multi-channel of the queueing system.

Each rectangle of the column determines one of all possible condition statuses P_n denoting a possibility of presence n requirements (vessels) in the system. Arrows on the column specify in what condition status and with what intensity the system can transfer. Thus in the multi-channel of the queueing system it is necessary to distinguish two cases:

- number of vessels n , arrived in the system is less than the number of servicing channels N , that is, all of them are in service ($0 \leq n < N$);
- number of vessels n , arrived in the system is more or equal to the number of channels of servicing ($N \leq n$), i. e. N vessels are serviced, and remaining r are expected to be in turn ($r = 1, 2, \dots, n - N$).

Columns with probability P_0 determine a condition status of the system in which all channels of servicing stand idle because of lack of vessels. With intensity μ the system can transfer into condition status P_1 when one requirement appears in it, and also from condition status P_1 into condition status P_0 if the unique requirement that was in the system has been serviced earlier than a new one appeared, etc.

4. The solution of the problem using analytical methods

The important parameter of functioning of the queueing system is the average latency period in turn for storage $\bar{\tau}_{\text{wait}}$ and an average number of shipments of cargo containers in turn are on deposit \bar{r} . The initial parameters describing the queueing system, are:

- number of conditional-functional sections, $\square F$;
- intensity of inflow of one requirement for servicing we marked, λ'_i ;
- intensity of servicing of a vessel, μ .

Let us consider the system of the queueing system by the example of the refrigerator container terminal, introducing F for conditional-functional sections with duty cycle φ_i for each type of the vessel on which irregular inhomogeneous traffic flow m_i with resulting intensity λ_i acts. Duty cycle φ_i is directly proportional to the intensity of each incoming consignment λ_i .

Let us designate the magnitude of incoming shipments for all terminal ψ , by:

$$\psi = \frac{\lambda}{\mu}, \quad (3)$$

where λ is an intensity of a flow

$$\lambda = \lambda' m \quad (4)$$

The intensity of vessels servicing is determined as a magnitude in verse to the holding time of one requirement, T_{storage} :

$$\mu = \frac{1}{T_{\text{storage}}} \quad (5)$$

The magnitude of incoming shipments of all terminal (ψ) shall be designated as duty cycle (φ):

$$\psi = \sum_{i=1}^s \varphi_i \cdot F \quad (6)$$

The average dwell-time of consignment in terminal \bar{T}_{Σ} is an aleatory variable, however expectations of its components, such, as \bar{T}_{storage} and \bar{T}_{wait} , where \bar{T}_{wait} – an average latency period of consignment in queueing in the arrangement in the conditional-functional section is known. Thus the first one is considered to be known, and the last one is determined by a method of successive approximations. Expectations of the dwell-time of shipment in terminal \bar{T}_{Σ} and expectations of storage time of lot \bar{T}_{storage} will be identical for all vessels.

$$P_{\Sigma} = \lambda' (\bar{T}_{\text{wait}} + \bar{T}_{\text{storage}}) = \frac{\lambda}{m} (\bar{T}_{\text{wait}} + \bar{T}_{\text{storage}}) \quad (7)$$

In subsequent calculations storage time \bar{T}_{storage} will be accepted equal to 1. Then:

$$P_{\Sigma} = \lambda' (\bar{\tau}_{\text{wait}} + 1), \quad (8)$$

where P_{Σ} – probability of determination of a lot in the conditional-functional sector (we shall designate it as p).

Let us calculate the parameters of functioning of the queueing system, determination of an average number of cargo containers shipments in turn for storage:

$$\bar{r} = \begin{cases} \sum_{n_{\Sigma}=F+1}^{m_{\Sigma}} (n_{\Sigma} - F) P_{n_1 n_2 \dots n_s} & , n_{\Sigma} > F \\ 0 & , n_{\Sigma} \leq F \end{cases} \quad (9)$$

The average reduced latency period of the location for storage of cargo containers shipments is

$$\bar{\tau}_{\text{wait}} = \frac{\bar{r}}{\sum_{i=1}^s \lambda'_i m_i r_i} \quad (10)$$

The received probability model allows making the probability analysis of performances of storage of containerized cargoes in container refrigerator terminals.

5. The solution of the problem using an imitative method

To display the basic events of the system we shall represent a process in the form of the graph of functioning of the multi-channel broken queueing system. In Figure 2 the basic processes of the operating multi-channel open for the queueing system are presented [4-6].

Let us describe each event which arises in the modeled system:

- inflow of vessels to the terminal;
- vessels arrival to the roadstead (hoard);
- determining of the conditional-functional section for vessel servicing;
- expectation of the release of one vessel from the conditional-functional sections;
- the exit of the vessel from the accumulator;
- the time of servicing of vessels in the conditional-functional section;
- the release of the conditional-functional section;
- the exit of the vessel from the terminal.

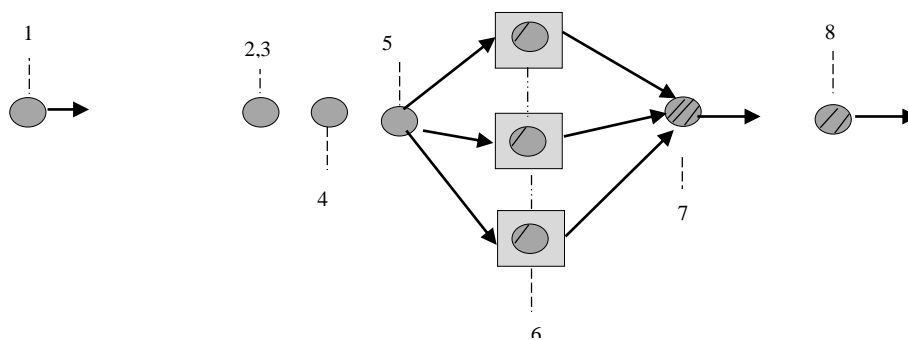


Figure 2. A process of functioning of the open multi-channel of the queueing system.

6. Conclusion

Making the analysis of the results of the work, we have come to a conclusion that the considered simulation model is grounded on logical-mathematical exposition of the plant.

However, the logic part of the system functioning shows the process of modification of condition statuses of work processes of the terminal, during the preset flows of the requirements arriving to inputs of the system.

The mathematical model, is presented by a probability model which allows the analysis of processes of storage of containerized cargoes in refrigerator terminals, considering the specificity of processes functioning of cargo handling. In calculation of the mathematical model, we can discover the following parameters: an average number of cargo containers shipments in turn for storage; the average reduced latency period, the intensity of income of the consignment containers to the terminal and a duty cycle of the conditional-functional sections. When using the ‘classical’ determined method, the following prominent aspects are not considered: an irregular flow of events, the casual time of vessels arrival to the terminal (in the conditional-functional section) and random time of cargo-handling. That leads to inaccuracies in calculations of probability performances of the queueing system.

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