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Optimization and Calculation of Probability Performances of Processes of Storage and Processing of Refrigerator Containerized Cargoes

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Abstract. In the work the queueing system of the disconnected multi-channel type to which irregular, uniform or not uniform flows of requests with a unlimited latency period arrive is considered. The system is considered on an example of the container terminal having conditional-functional sections with a definite mark-to-space ratio on which the irregular inhomogeneous traffic flow with resultant intensity acts.

1. Introduction

Historically the mankind is indissolubly linked with navigation and for this reason the water transport is considered one of the most ancient aspects. Developing of a maritime transport in Russia is determined not only by geographical position, but also by its economic advantages. Marine cargo transportation remains the cheapest mode of transportation after pipeline, that leads to a demand and popularity of this mode of transport among others. As the cost price of a water transport remains the lowest it is competitive, despite a low velocity of delivery.

At present the maritime port is a large transport junction which links various modes of transports: marine, railway, automobile, pipeline, etc. Port activity is strategic aspect of developing of economy of the state and covers more than 50 % of all world cargo turnover [9]. The evidence of this fact is positive dynamics of growth of a cargo turnover of maritime ports of Russia According to statistical data during the period of January-May 2015 the cargo turnover of Russia has increased for 4,4 % in comparison with similar period of 2014, and in 2014 - for 5,7 % in comparison with the previous year [1].

A container terminals are being developed where large-capacity refrigerated containers with food stuffs are handled. Refrigerated containers are achievements modern technology. They are intended for transportation of goods demanding maintaining of special temperature and humidity. Basically such cargo containers are used for ocean carriages and storage of perishable cargoes. A temperature range of ref containers which they can maintain is from - 25ºC up to + 25ºC degrees of Celsius. According to the size refrigerated containers are divided into 20 and 40-foot. Refrigerated containers can be used for transportations practically for all modes of transports, and also for temporary storage of perishable cargoes as temporary when reloading on freight terminals, and long-term. Using of Refrigerated containers allows to deliver cargo «from door to door », not breaking a temperature condition of storage an route and during loading-unloading when changing a mode of transports.

For a diminution of costs part at a stage of transporting of cargoes up to a docks area and reducing the time of preliminary delivery container carriages are widely used, they have a very high degree of safety. Modern cargo transporters are designed developed and manufactured with observance of all existing norms and standards that warrants their durability and watertightness. It is one of the most convenient and popular aspects of transporting of cargoes. Popularity of usage of cargo transporters as universal package for a shipping goods all over the world grows [2-3].

Theoretical channel capacity of the terminal does not always coincide with actual. As the technical equipment of port in a direction of import and export, can be not always ready to storage or handling of containerized cargoes. In this connection, development of mathematical models which allow to optimize and moderate expenditures for the equipment and resources is necessary.

Process of storing goods in the container refrigerator terminal can be presented in the form of a queueing system. A conditional functional sections in port are considered as servicing devices in which the cargo-handling is carried out. The arriving boats which are a subject of handling are accepted as of a queueing system requests. If all moorings are occupied, the arrived ship will stop at the roadstead and wait its turn for mooring. Each vessel has the schedule of arrival, but because of unexpected circumstances it may be broken. Therefore it is considered, that arrival of boats is casual event that entails idle time of servicing devices or formation of turns. According to a response time of requirements in turn prior to the beginning of a upkeep of system in a classical theory of queues there are: systems of the "pure" and "mixed" type.

In system with "pure" (unlimited) expectation the figure of places in turns of boats and a latency period is not limited, i.e. each vessel during any time will be necessarily handled and a consignment will be located for storage. In limited expectation a refusal of the terminal to handle a vessel is possible. In real conditions the number of shipments in turn is always limited. To have analytical probabilities of separate condition statuses in many cases it is expedient to consider the figure infinite. Situations when in separate phases of time the part of ships can be transmitted for handling to other terminal because of excess of an admissible latency period are possible.

When using a of a queueing system of Markov model, the exponential (demonstrative) law of a upkeep is supposed. In calculations of probability performances of a queueing system, application of the exponential law, can lead to errors and an insufficient exactitude.

But, for today for exposition of a channel capacity of container terminals the determined methods are used. Given methods, actually, do not reflect all specificity of processing and storage of refrigerated cargoes: the interval of time between the moment of inflow of the requirement to the channel of maintenance and the moment of an exit of the requirement from this channel has no casual character, however, the moment of delivery consignments of containerized cargoes to the terminal presents a casual flow of events. In real conditions functioning of an infrastructure of the terminal from the point of view of processes of cargo handling are not adequate to above specified assumptions. Considering specificity of functioning of container terminals it is necessary to research stochastic processes of handling of ships, describing these processes on the basis of probability models, for a solution of research problems and optimization.

Let's consider other approach to calculation of performances of probability model of a queueing system.

2. Statement of a problem

The mathematical model of process of storage is formulated in view of irregular incoming of cargo consignments and their casual response time at depot in refrigerator container terminals. That leads in one case to idle time and overflow of places on storage depots, in others it leads to formation of turns.

To solve the research problem and to develop probability model it is necessary to research stochastic processes of storage of ships and to make their probability analysis. The given processes of a storing goods in casual instants transfer from one condition status to another. Passage of process happens during the moments when the new vessel approaches the terminal, or one of moorings is free. Thus the amount of vessel in turn for storing cargoes varies. The process maintains calculating amount

of condition statuses, occurrences of figure of requests: E_1, E_2 ... E_n, where n figure of ships (requests) which are in conditional-functional sector (the channel of a upkeep) in turn, and stored, during an interval of time. Probabilities of passages of system from condition status E_n to condition status E_{n-1}, i.e. servicing of one request depends on number of working channels of a servicing.

Condition statuses of process of a storing goods:

E_0 - all channels of a upkeep are not occupied;

E_1 - one channel of a upkeep is occupied;

E_i - it is occupied i channels;

E_f - all is occupied;

E_{f+d} - channels of a upkeep are occupied all and d shipments stand in a queue.

Process of a storing goods can be described through the block – the scheme which shows a principle of passage from one condition status to another (Figure 1).

Let's introduce labels of the refrigerator container terminal having F of conditional-functional sections with an identical duty cycle, on which the irregular traffic flow m (an amount of vessels with resulting intensity acts. Resulting intensity of incoming ships in the terminal is determined by intensity and number of the ships which are being in turn.

If all boats are identical from the point of view of their servicing then it is considered, that of a queueing system receives a uniform flow of requests or requirements (ships), i.e. all requests for a unloading are identical. In the previous works the queueing systems based on probability models with reference to a uniform flow of requests have been considered: all arriving boats possess identical characteristics, i.e. identical containers capacity and cargo consignment (number of containers on board a ship).

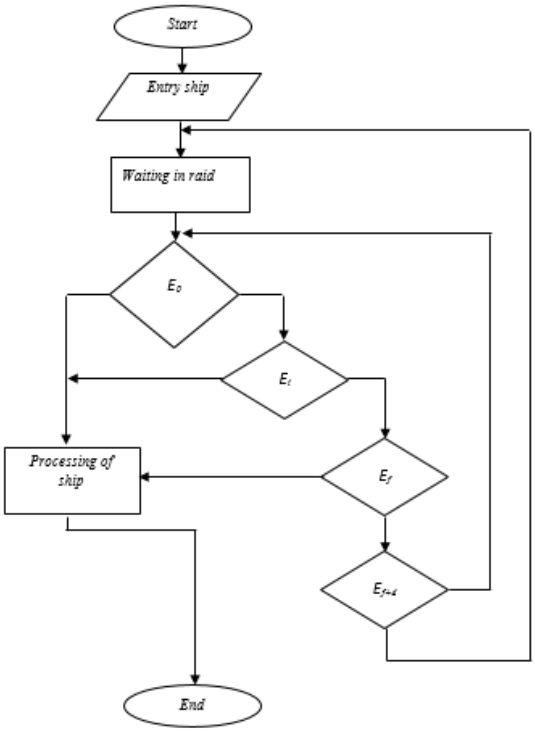

Figure 1. The chart of condition statuses of processes of a storing goods.

However, there may be specified heterogeneity of a traffic flow - boats can possess various performances: an amount of cargo containers on a vessel, capacity of cargo containers, etc.

Accepting, that the flow of consignments (ships) arriving to the port, submits to a Poisson distribution law, it is possible to consider it elementary (stationary Poisson), possessing three properties: absence of an aftereffect and a stationarity.

The system is characterized by following singularities:

- inflows of requirements (vessels) to the system for servicing happens one by one, 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 the subsequent requirements (vessels) at any moment does not depend on probability of their inflow during the previous moments - a flow of requirements without aftereffects;
- the flow of requirements does not depend on a disposition of a considered interval of time for axis of time - a flow of requirements stationary.

Let's admit suppose, the multi-channel disconnected queueing system with a unlimited latency period and with the inhomogeneous elementary (stationary Poisson) a flow of requirements is set.

The inhomogeneous traffic flow possesses various performances, i.e. miscellaneous types of ships m_1 - boats of 1-st type, m_2 - ships of 2-nd type, m_3 - ships of 3-rd type, m_s - ships of s-th type; and intensity of incoming of a shipment: λ_1 - for ships of 1-st type, λ_2 - for ships of 2-nd type, λ_3 - for ships of 3-rd type, λ_s - for ships of s-th type.

The total number of ships in turn for storage is determined by expression:

$$m = \sum_{i=1}^{s} m_i \tag{1}$$

Intensity of a traffic flow can be discovered under the formula:

$$\lambda = \sum_{i=1}^{s} \lambda_i \cdot m_i \tag{2}$$

The process proceeding while handling and storage of container refrigerated cargoes in terminals, is a process of discrete type with final (or calculating in general) set of condition statuses. Thus the amount of the lots which are in turn for handling varies. At the casual instant, researched processes of consignments transfer from one condition status to another. Transfer of process happens during the moments, when a new consignments arrives, or one of conditional-functional sections is free.

Let's consider one of enumerated above processes, namely calculation of a latency period of batches of cargo containers in turn for storage.

Each vessel can appear in is conditional-functional sector (event A) with the same probability p. And movements of individual consignments may be considered as f of independent trials.

If the probability p is a determination of a shipment in the terminal q=1-p it is probability of that the given shipment to be in other condition status (in other phases), i.e. not occurrence of event A.

It is required to discover probability P_n of that in the terminal will treat n shipments, i.e. event A in these f experiences to appear exactly n time, as event.

Under the Bayes approach we shall consider the event B_n, consisting that event A to appear in f experiences equally n time. 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 the event corresponding a determination i of lot in the terminal, and $\bar{A}_i$ - the event corresponding a determination i of lot outside of the terminal.

Really, each term of the 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 it will be described by the following formula:

$$B_n = A_1 A_2 \dots A_n \overline{A}_{n+1} \dots + \overline{A}_1 \overline{A}_2 \dots \overline{A}_{f-n} A_{f-n+1} \dots A_f \tag{3}$$

In the given expression the number of possible modes by which it is possible from f experiences to choose n in which there was an event, figure such C_f^n is described.

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

$$P_{n_1 n_2 \ldots n_s} = \prod_{i=1}^{s} C_{f_i}^{n_i} p^{n_i} q^{f_i - n_i} \tag{4}$$

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 a determination $n_1, n_2, \ldots, n_s$ batches of cargo transporters stored corresponds to terms of expansion of a binominal formula in a degree, equal to figure of batches of cargo transporters.

Therefore the specified probability distribution calls binomial. The probability distribution is meant binomial allocating possible occurrences of events A (the determination of a batch of cargo transporters 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 a queueing system in the form of graduated column of condition statuses (Figure 2). Each rectangle column determines one of all possible condition statuses. P_n is a possibility of presence in system n requirements of vessels. Arrows on the column specify, in what condition status the system can transfer and with what intensity. Thus in multi-channel of queueing system it is necessary to distinguish two cases:

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

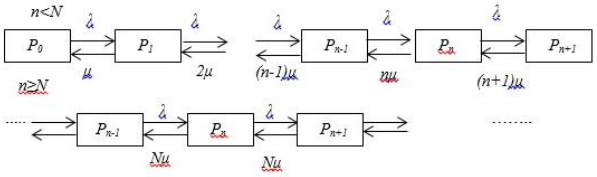

Figure 2. Labelled columns of condition statuses multi-channel broken of queueing system.

Columns with probability P_0 determines a condition status of system at which all channels of a upkeep stand because of lack of vessels. With intensity μ the system can transfer as in a condition status in P_1 when in it to appear one requirement, and also from condition status P_1 in condition status P_0 if the unique requirement was in system, has been serviced earlier, than has appeared new, etc.

Having specified probabilities of separate condition statuses of the terminal, it is possible to learn on the basis of the Bayes approach average value of a latency period of batches of cargo transporters in turn on the storage, corresponding defined values of number of ships m_s and figures is conditional-functional section F the researched specialized terminal.

Primal problem is determining average time expectations of lots in turn, i.e. a direct commitment - association of function on a duty cycle φ and is conditional-functional section F. And, the refrigerator terminal $\varphi_1, \varphi_2, \varphi_3 \ldots \varphi_i \ldots \varphi_s$, accordingly for each type of a vessel, and $r_1, r_2, \ldots r_i \ldots r_s$ a size of a batch of containers (an amount of cargo containers) for vessels of s-th type. In work a duty cycle φ of directly proportional intensity of incoming of each lot λ_i'

The average reduced latency period of a location on storage of a batch of containers:

$$\bar{\tau}_{o.ж} = \frac{\bar{r}}{\sum_{i=1}^{s} \lambda_i' m_i r_i} \tag{5}$$

$$\bar{\tau}_{ож.ср} = \frac{\bar{r}}{\sum_{i=1}^{s} \lambda_i' m_i r_{cp}} \quad (6)$$

r_{sr} - the averaged value of a size of a batch of the containers, calculated under the formula:

$$r_{sr} = \frac{m_1 \cdot r_1 + m_2 \cdot r_2 + \ldots + m_s \cdot r_s}{\sum m_i} \quad (7)$$

The received probability model allows to make the analysis of processes of storage of containerized cargoes in refrigerator terminals, namely determining of an average latency period of lots in turn stored a refrigerator container terminal.

3. Outcomes

Using a mathematical model described above, the average latency period of a location has been calculated for storage of batches of cargoes.

In the subsequent, for fast and effective calculation of the specified indexes, the software product has been developed. By development of the program studio NetBeans IDE 7.2 maintaining gears of such languages, as java which was chosen [8]. NetBeans IDE - the free integrated medium of development of applications (IDE) in programming languages Java, JavaFX, Python, PHP, JavaScript, C, C ++, and of some others. For development of programs in medium NetBeans and for successful installation and work of medium NetBeans should be installed beforehand Sun JDK or J2EE SDK suitable version. The medium of NetBeans development by default supported development for platforms J2SE and J2EE.

Java - the object-oriented programming language, is high-power and now very popular. Has set of advantages: steady and reliable, multicontinuous, is architecturally-independent, highly effective, it is equipped by high-power library of classes and the methods, allocated, etc.

Java applications are usually compiled in special byte-code, therefore they can work by any virtual Java-machine (JVM) without dependence from computer architecture. That in turn, is very actual in the heterogeneous world of PO.

The choice of usage of the given toolkit, as development of software product, allows to solve all above tasks, and also provides simplicity and convenience of programming, and possibility of the future updating [4-7].

During development of the software, following objectives have been put and solved:

- implementing input of input datas: F - an amount of conditionally-functional section; m_s - boats of s-th type, where s - figure of "inhomogeneous" ships, φ_s - a duty cycle;
- calculation of an average number of container consignments in turn for storage;
- intensity of cargo containers arriving [10];
- average time of waiting of storage rooms for containers keeping.

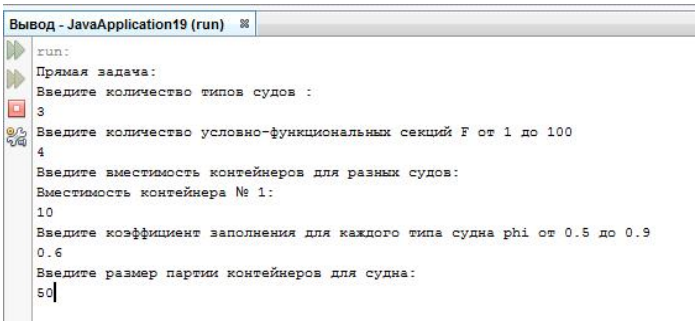

Figure 3. Input of input date's, for the first type of a vessel.

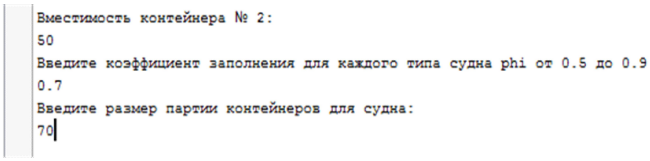

Figure 4. Input of input date's, for the second type of a vessel.

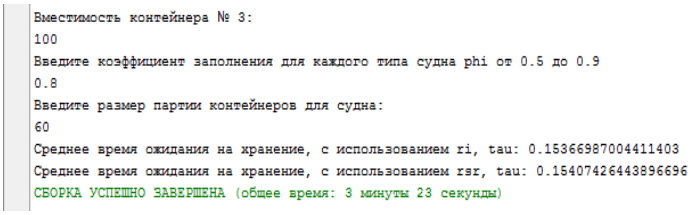

Figure 5. Input of input date's, for the third type of a vessel and a conclusion of outcome.

By results of calculations it is possible to tell, that the average time waiting significantly increases with magnification of a duty cycle and is moderated with magnification of number is conditional-functional section the refrigerator terminal. Calculations have shown, that at usage r_s and r_{sr} indexes slightly differ. That speaks that it is possible to use at the further calculations the averaged value r_{sr}.

4. Conclusion

With developing the terminal the new organizational structure of control was realized, both methods, and means of an estimation of job performance standards of the reloading terminal and other sites of multimodal transportations were simultaneously improved.

For simulation of work of the reloading terminal the means of a theory of queues is used. Thus in a basis of simulation of processes of cargo handling the broken queueing systems are supposed. Application of existing models of a queuing for determining performances of processes of processing of containerized cargoes not always is expedient as the specified models not correctly describe processes of functioning of work of port.

For today for describing a channel capacity of container terminals the determined methods are used. However these methods, actually, do not reflect all specificity of processing of container refrigerated cargoes. As the moments of delivery of cargo containers to the terminal are a casual flow of events.

Thus, the received probability model allows to manufacture the analysis of processes of storage of containerized cargoes in refrigerator terminals, considering specificity of functioning of processes of cargo handling. At calculation of a mathematical model, we can discover following parameters: an average number of cargo containers consignments in turn for storage; the average reduced latency period, intensity of incoming to the terminal of each cargo consignment and coefficient of filling of conditional-functional section. Outcomes are more precise, than when using of the "classical" determined method which does not completely reflects specificity of processing of refrigerator containerized cargoes. Because the usage of the given method some prominent aspects are not considered: an irregular flow of events, a casual response time of arriving of ships into the terminal (in is conditional-functional section) and casual period of cargo-handling time.

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