# COMPUTER SIMULATION OF A TRANSPORT RELOADING COMPLEX

**Mykola Dekhtyaruk**

***Abstract.*** *The article considers the reloading complex, in which the machines input flow is served by the rule of relative priorities. Algorithms functioning of a separate elements are constructed, on the basis of which its computer model developed, by means of object-oriented programming system - Embarcadero RAD Studio XE10 Seattle. Simulation of the reloading complex is performed, and the calculation of the main parameters of the complex – total and average waiting time of machines in the queue, total and average length of the queue, etc., depending on the intensity of the machines input flow and service channel performance, to analyze and select optimal modes work of the complex.*

***Keywords:*** *Reloading complex, Algorithm simulation model, Service channel, Object-oriented programming system.*

***ITHEA Keywords****: H. Information Systems; H.0 General; H.1 Models and Principles; H.4 Information Systems Applications.*

***DOI****: https://doi.org/10.54521/ijita29-03-p05*

## 1. Introduction

Transport is one of the most important sectors of the state's economy and belongs to the sphere of material services production. The main task of transport is timely, high-quality and full satisfaction of a national economy needs and the population in transportations. The most important element in the development of freight technology is the choice of transport and technological system. Each transport and technological system can be represented as a set of standard operations, the main of which are: cargo; transport network; rolling stock; cargo concentration points; loading and unloading means; participants in logistics processes; packaging materials [Christopher, 2016].

The main factors determining the choice of transport and technological systems are local technological processes that take place in all parts of the transport logistics system, which have a number of features and depend on the type of cargo, mode of transport and its structure, industry characteristics, state of logistics process elements [Shortle, 2018].

The main reserves for improving the transport and logistics process are in the rational organization of interaction of participants in the supply chain, in the coordination of their interests and the search for mutually beneficial and suitable solutions. Progress in the field of information technology makes it possible to significantly increase the efficiency of transport logistics, information and computer support has a proper place among the key logistics functions [Trivedi, 2016].

The purpose of this work is to develop a simulation model of the reloading complex, in which the input flow of machines is served by the rule of relative priorities, in the form of a computer software package. based on the use of the latest information technologies - Embarcadero RAD Studio XE10 Seattle - object-oriented programming system [RAD, 2019].

Using a computer model to simulate the operation of the reloading complex, and calculate the basic parameters of the complex – total and average waiting time of machines in the queue, the total and average length of the queue, as well as their variance, depending on the intensity of input flow and service channel performance, in order to analyze and optimal modes selection the operation of the reloading complex.

## 2. The Primary Research Materials

The theory and practice development of the freight transportation organization is given considerable attention in scientific publications. Thus, the articles [Khorshidian, 2019; Kumar, 2016; Escobar, 2020; Heidari, 2018] present the results of the study of routing optimization by the criterion of minimum delivery time. In [Nasiri, 2018; Soeanu, 2020; Lai, 2015] methods of route selection based on alternative sampling are considered.

Publications [Sun, 2020; Luisa, 2015] use routing modeling methods in transport systems based on fuzzy logic. The heuristic model of route selection is considered in articles [Tokgeoz, 2015; Manley, 2015]. In works [Yu, 2020; Rodado, 2017; Havelock, 2018] the statistical model of a routing choice in transport systems is considered. The method of cargo transportation using genetic algorithms is described in publications [Tintu, 2020; Mohammed, 2017; Chiappone, 2016; Lu, 2017; Yang, 2016].

The modeling results of the routes choice using data from the Global Positioning System (GPS), focused on trucks that perform long trips, are given in [Hess, 2015]. The publication [Nyrkov, 2015] describes a differential method for determining the location of land vehicles, using the GLONASS/GPS system, using special processing algorithms. Probabilistic methods of controlling the movement of ground objects, using satellite navigation systems, are considered in [Zhilenkov, 2015].

Analysis of the results of these studies shows that these works use various analytical methods for organizing the movement of cargo flows and modes of operation of individual elements and parts of logistics systems.

At the same time, the use of the latest information technologies and systems helps to increase the efficiency of transportation. Information systems of logistic processes automation allow to automate all information and technological activity of the transport enterprises participating in processes of the freight transportations organization. Automation of transport logistics is necessary to increase the efficiency and optimization of transport. Due to computer data processing, introduction of information systems of routing, accounting and planning at the transport enterprise, transport logistics reaches a qualitatively new level [Shortle, 2018; Trivedi, 2016].

Therefore, the development of a simulation model, by means of object-oriented programming, and modeling of the reloading complex, in order to analyze and select the optimal modes of its operation is relevant.

## 3. Development of a mathematical model and algorithmization of the reloading complex

The block diagram of the reloading complex is shown in fig. 1. The operation of the system is described as follows. Two types of machines come to the reloading complex: the first consists of machines arriving for unloading (service time of such machines is $\tau_1$; the second - of machines arriving for loading (service time of such machines is equal to $\tau_2$.

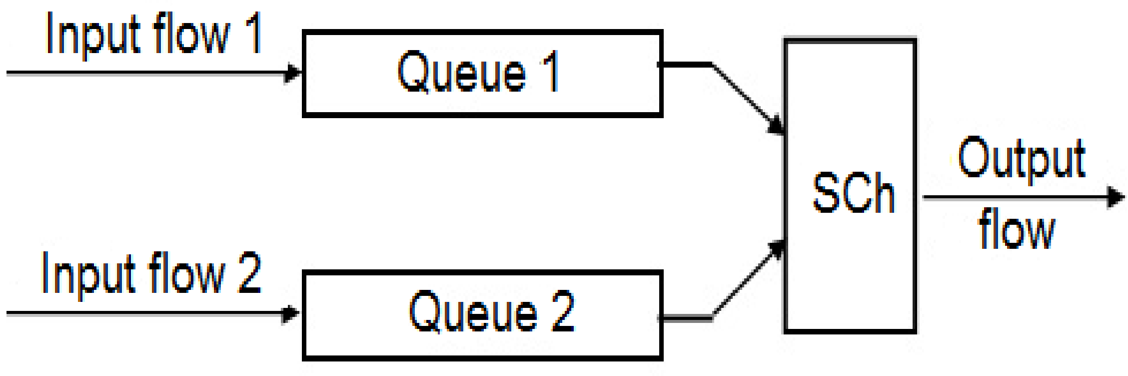


Fig. 1. Block diagram of the reloading complex

where SCh - servicing channel of machines input flows.

.

The reloading complex can serve only one machine at a time. If at the time of arrival of a new car the service channel is occupied, it becomes into one of two queues: one consists of cars arriving for unloading, the other - of cars arriving for loading. Let the service of the machines be carried out in the following order: at the moment of release of the service channel the service of the machine standing first in line for unloading begins. Only if this queue is empty, the first machine is serviced from the queue for load (expressed in the language of queue theory, we can say that the service of machines in the system are performed according to the rule of relative priorities). In this case, the reloading complex is considered as a queuing system (QS).

Because the moments of machines arrival for service are random variables, the length of the queue and the waiting time for service will also be random, so as a result of modeling it is necessary to determine their statistical characteristics - the average value and variance.

Consider the average waiting time of machines in the queue for streams 1 and 2. For each *i*-th machine, the waiting time in the queue is equal to the difference between the time when it began to be serviced and the time when it came into the system. The average waiting time is:

$$\omega_{1ave} = \frac{1}{n_1}\sum_{i=1}^{n_1}\omega_{1i}; \quad \omega_{2ave} = \frac{1}{n_2}\sum_{i=1}^{n_2}\omega_{2i} \tag{1}$$

where $n_1$ and $n_2$ are the number of machines, respectively, streams 1 and 2, which were serviced by the system during $T$.

Summarizing the number of machines in the queue at short intervals and dividing the amount by the number of summations, we obtain the average value of the queue length:

$$L_{1ave} = \frac{1}{N}\sum_{i=1}^{N} m_{1i}; \quad L_{2ave} = \frac{1}{N}\sum_{i=1}^{N} m_{2i} \tag{2}$$

where $m_{1i}$ and $m_{2i}$ is the number of machines in the first and second queues at the time of observation *i*;

*N* - the number of observation moments (moments of receiving statistics) for time *T*.

The variance of the values of *ω* and *L*:

$$D\omega_1 = \frac{1}{n_1 - 1}\sum_{i=1}^{n_1} (\omega_{1i} - \omega_{1ave})^2 \tag{3}$$

$$D\omega_2 = \frac{1}{n_2 - 1}\sum_{i=1}^{n_2} (\omega_{2i} - \omega_{2ave})^2 \tag{4}$$

$$DL_1 = \frac{1}{N - 1}\sum_{i=1}^{N} (m_{1i} - L_{1ave})^2 \tag{5}$$

$$DL_2 = \frac{1}{N - 1}\sum_{i=1}^{N} (m_{2i} - L_{2ave})^2 \tag{6}$$

To build a simulation model of the reloading complex, you must first be able to model the moments of machines arrival in the queue of each flow. Both streams of machines coming into the service channel can be described by the function of distribution *A*(*t*) of time intervals between the moments of their arrival in the queue (this function will be different for each stream), that is *A*(*t*)=*P*(*Q* <*t*).

The practice of queuing systems research shows that in many cases the approximation of the intervals distribution function between the moments of machines entry into system by exponential function appears satisfactory:

$$A(t) = \begin{cases} 1 - e^{-\lambda t} & for\, t \geq 0; \\ 0 & for\, t < 0, \end{cases} \tag{7}$$

where $\lambda$ is the intensity of the input flow (a value inverse to the average time interval between the arrival of two adjacent machines).

In this case, the requirements at the input of the system form the s-called Poisson flow. Poisson flows of requirements are often found in practice, because they are in a sense boundary for different flows. For most applications similar to logistics tasks, the replacement of non-Poisson flows by Poisson with the same intensities leads to a solution that differs little from the real one, and sometimes does not differ at all. In this case, the errors of the solution, as a rule, are within the accuracy of the original data, which are often known approximately [Kirpichnikov, 2018; Gnedenko, 2018].

For the first stream $Q_{1i+1} = t_{1i} + Q_{1i}$, where the values of $Q_{1i}$ are distributed by the law $A(t)$. It is easy to prove that if there is a random variable $R$ distributed evenly in the interval (0, 1), then to obtain a quantity $Q$ having a distribution function $A(t)$, we must solve the equation $A(Q)=R$ relatively to $Q$. In particular, for $A(t) = 1 - e^{-\lambda t}, t \geq 0$ , it is necessary to solve the equation $1 - e^{-\lambda Q} = R$.

From here:

$$Q = -(1/\lambda)\ln(1-R) \tag{8}$$

Therefore, obtaining $Q$ is reduced to finding $R$, which is subject to a uniform distribution, and calculating $Q$ by (7).

All programming systems have special standard programs that produce so-called pseudo-random numbers, the sequence of which is subject to a uniform distribution in the interval (0, 1). Obtaining one such number requires one reference to this standard program.

Thus, the algorithm for obtaining the arrival time of the next machine in the queue can be represented in the form of a diagram shown in Fig. 2 for stream 1, assuming that this stream is Poisson.

Next, you need to make an algorithm that describes the logic of the queue (it is clear that the algorithm will be identical for both queues). Assume that the queue has a maximum length of *LM* (number of waiting places). One-dimensional array *P*, consisting of elements (cells) $P_1$, $P_2$, .... $P_{LM}$, simulates the "places" of this queue. Each of these cells can be either free or occupied by a machine. As an equivalent of the car, it is convenient to take the moment of its arrival in the queue - this information will be needed to determine the waiting time of the car in the queue. Cell *X* is used as a working cell when writing the next machine in the queue or when selecting from the queue.

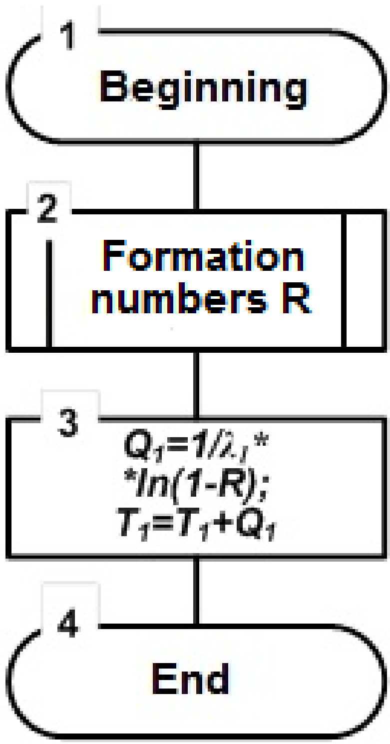


Fig. 2. Scheme of the algorithm for modeling the input stream 1

*PER* and *POS* cells contain information that allows you to determine the presence of the first and last machines in the queue, respectively. This information is the number (index) of the corresponding cell of the array *R*.

When the machine is selected from the queue, the contents of the *PER* cell are increased by one according to the queue selection rule in the order of arrival. The contents of the *POS* cell increase by one when writing to the queue of a new machine. The maximum value of the variables *PER* and *POS* is equal to *LM*, so their change occurs according to the formulas:

$$PER = \begin{cases} PER+1, & if\ PER < LM; \\ PER+1-LM, & if\ PER \geq LM. \end{cases} \quad (9)$$

$$POS = \begin{cases} POS+1, & if\ POS < LM; \\ POS+1-LM, & if\ POS \geq LM. \end{cases} \quad (10)$$

Variable *NP* - the number of machines in the queue; when selecting from the queue, the *NP* decreases by one, and when writing to the queue, it increases by one. The variable *PUST* is equal to one if there are no machines in the queue, and is equal to zero, in otherwise case. The *POLN* variable is equal to one if there are no free spaces in the queue (in which case the new machine cannot be written to the queue). The *WYB* variable must be set to 1, if the reference to the algorithm is performed for the purpose of sampling. If the reference to this algorithm is performed for writing, it is necessary to set *WYB*=0. The scheme of the algorithm modeling the work of queue 1 is shown in Fig. 3.

The operation of the service channel can be described by the sign "free - busy", which changes over time. As a sign, you can take the binary variable *KSW* (*KSW*=1 if the service channel is free and *KSW*=0 if the service channel is busy).

Let the previous releasing moment of the service channel be $T_3$. Then, according to the logic of the system, the request to queue 1 is executed, and if it is not empty, then the next releasing moment of the service channel will be:

$$T_3 = T_3 + \tau_1 \tag{11}$$

If queue 1 is empty, then there is an appeal to queue 2. There are two options:

1) if this queue is not empty then the next releasing moment of the service channel will be:

$$T_3 = T_3 + \tau_2 ; \tag{12}$$

2) if queue 2 is empty, the value *KSW*=1 is set.

At the time of machines selection from the queue for service, you can calculate the waiting time in the queue according to the formula:

$$W = T_3 + X \cdot \tag{13}$$

To determine the average waiting time and variance of this value, it is necessary to perform the accumulation (summation) of the waiting time and the square of this value:

$$SW = SW + W ; \tag{14}$$

$$SW2 = SW2 + W^2 , \tag{15}$$

while *N*=*N*+1.

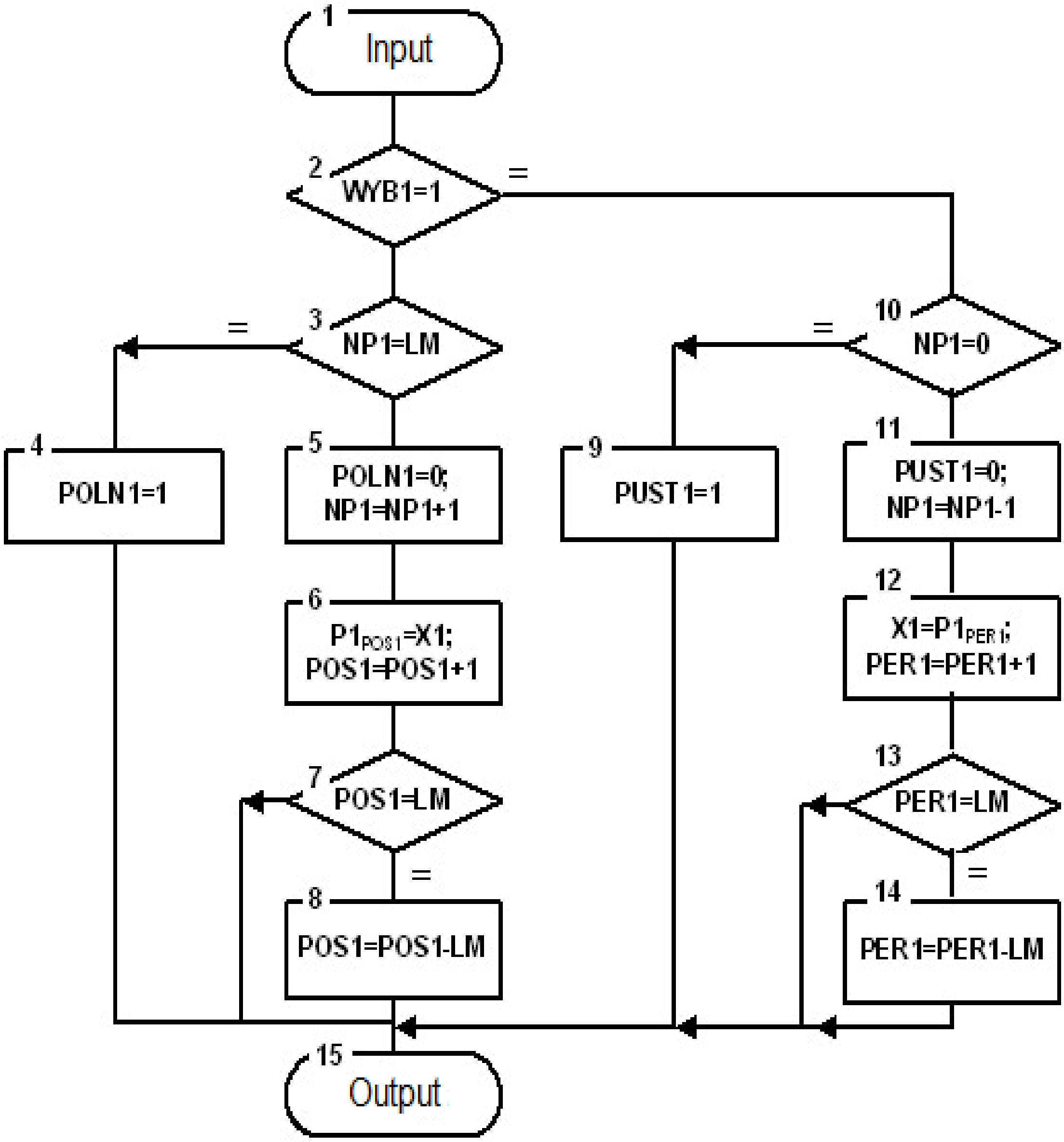


Fig. 3. Scheme of the algorithm for modeling the work of the queue 1

The scheme of the algorithm, which simulates the logic of the service channel and simultaneously performs the accumulation of statistical data, is shown in Fig. 4. At certain points in time (with a period of *DT*) it is necessary to calculate and print the following statistical characteristics:

$$SWR = SW / N \,, \tag{16}$$

$$DW = SW2/(N-1) - N/(N-1) \times WSR^2 \,. \tag{17}$$

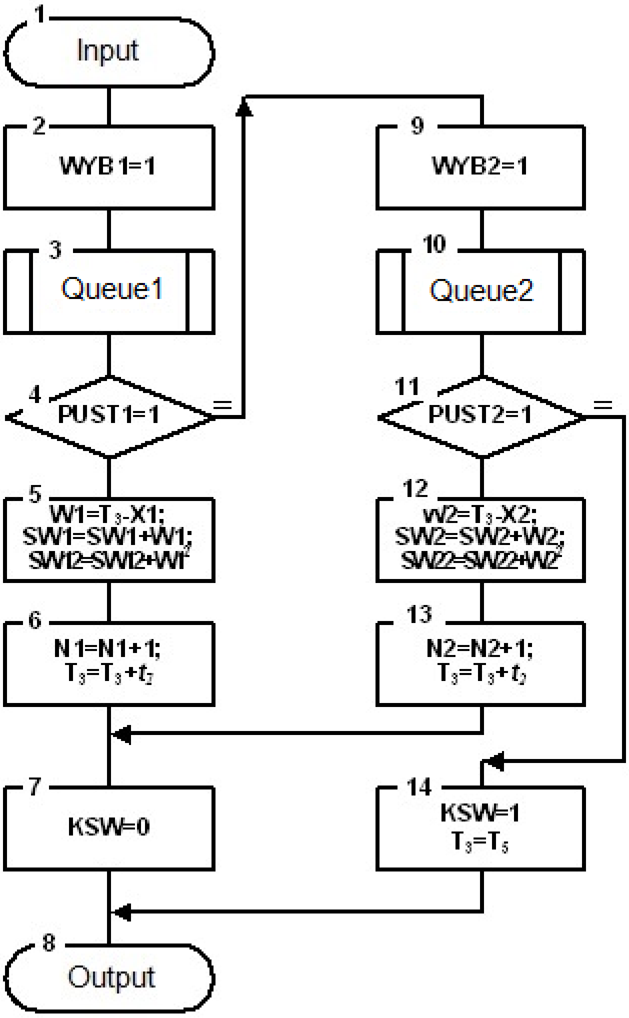


Fig. 4. Scheme of the algorithm for modeling the operation of the service channel

It remains to make an algorithm that provides the correct sequence of events in the system model. Such events are the arrival in the system of the machine of the first or second stream, the release of the service channel, the printing of statistical characteristics. The operation of this algorithm is based on the introduction of the system time concept, which is used to represent time-ordered events.

System time changes discretely, passing sequentially through all moments of events. The role of the algorithm, that controls the sequence of events, is now to determine the time of the next event and transfer control to those algorithms, that simulates this event. The moment of occurrence of the next event can be determined by finding the minimum element in the so-called list of future events, which represents the nearest moments of requirements arriving of the first or second streams, the nearest dismissal moment of the service channel, the nearest moment of printing statistical characteristics. This minimum element will determine the new value of the system time and what event should be performed at this time.

After this event is performed, the list of future events is restored by calculating a new point in time, that corresponds to the type of event, that occurred. For example, if the minimum list item is the arrival time of the first flow machine, you must refer to the subroutine, that implements the algorithm of queue 1, to write the machine in this queue, and then generate the value of the arrival time of the next first flow machine (new future event), according to the algorithm shown in Fig. 2.

The algorithm scheme of the whole system model is shown in Fig. 5. In this scheme, the list of future $T_{\mathrm{IKR}}$ events (block 3 in Fig. 5) also includes the end of the simulation.

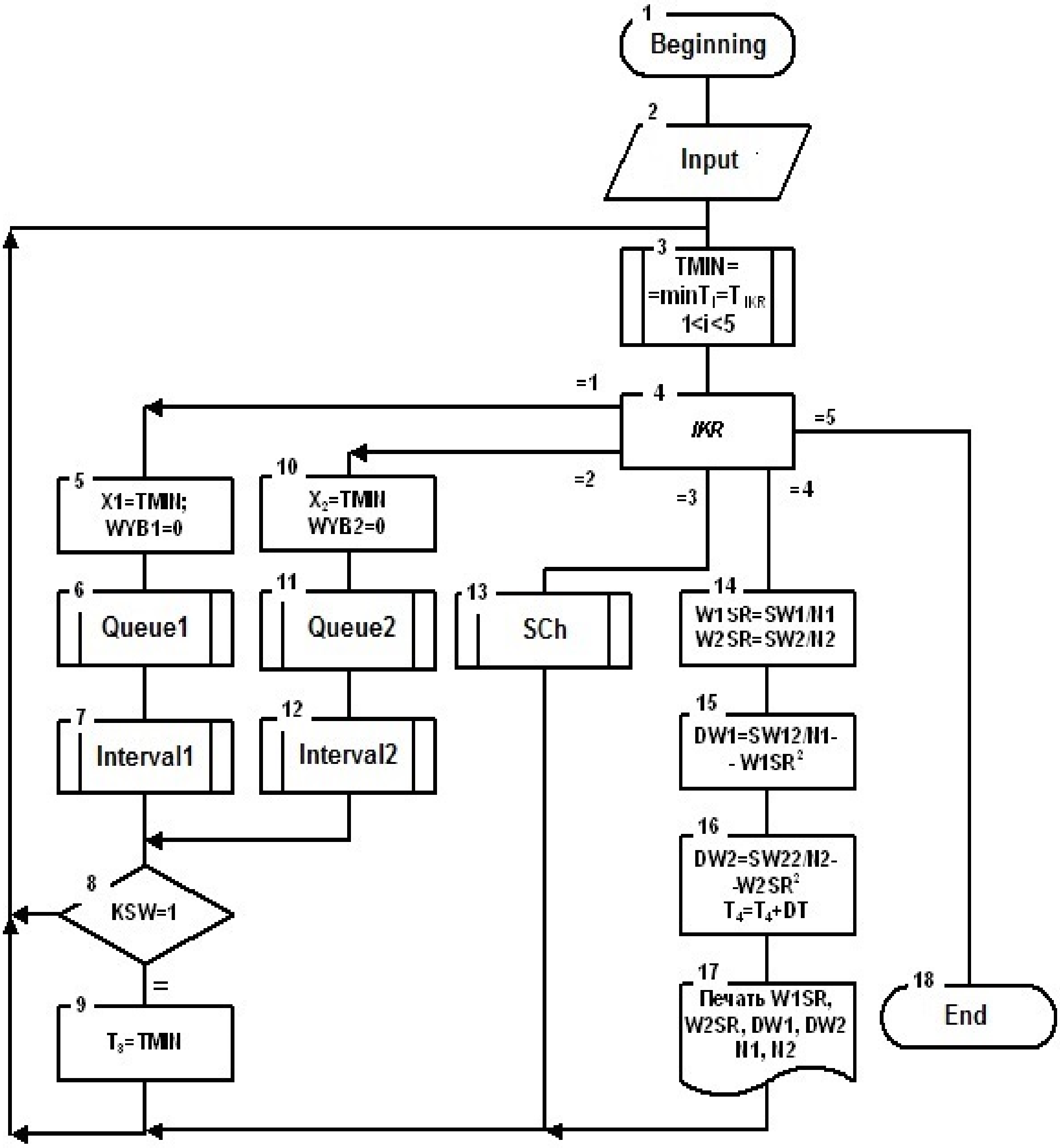


Fig. 5. Scheme of the general modeling algorithm reloading complex

## 4. Simulation model development of the reloading complex and conducting experimental research

Based on the developed structural scheme of the reloading complex (Fig. 1), built algorithms for modeling individual elements (Fig. 2 - Fig. 4) and the general algorithm of the complex (Fig. 5), developed a computer simulation model of the reloading complex.

The Embarcadero RAD Studio XE10 Seattle object-oriented programming system was used to develop a simulation model of the reloading complex, in which the input flow of machines is serviced according to the rule of relative priorities [RAD, 2019].

In Fig. 6 shows the main window of the computer simulation model of the reloading complex.

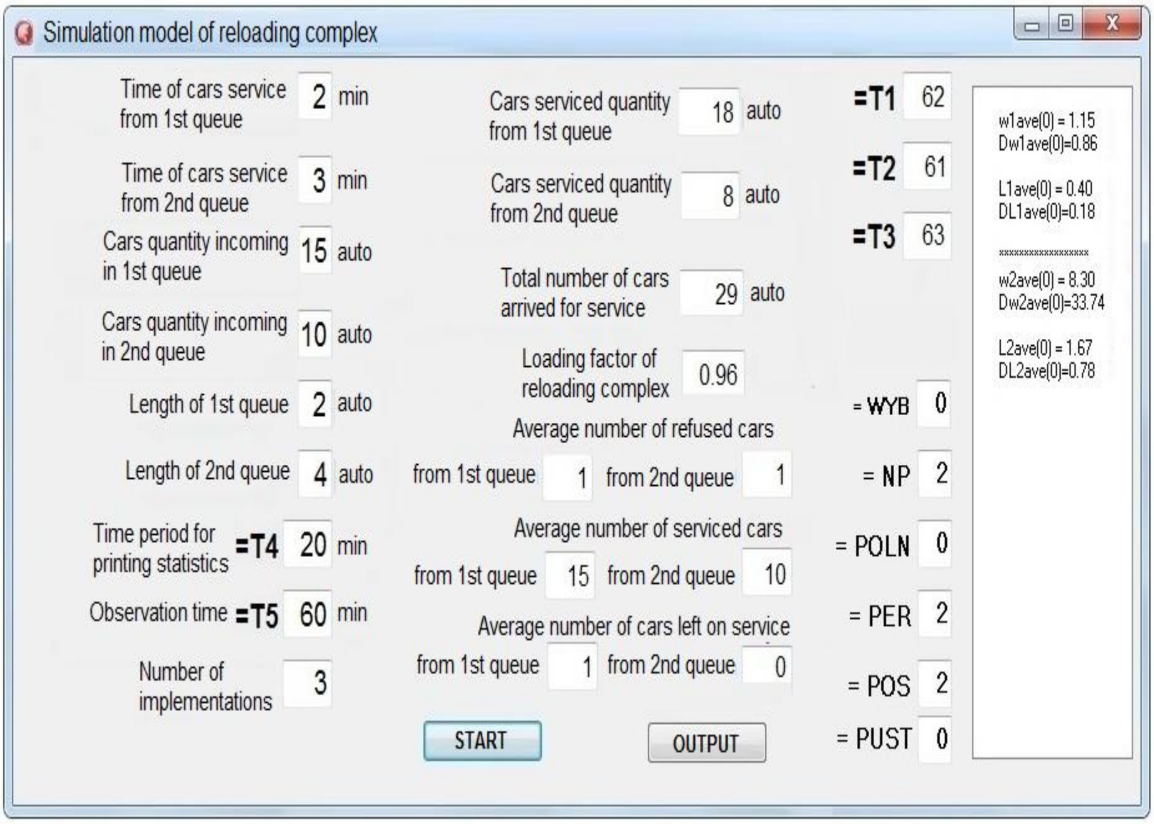


Fig. 6. Simulation model window of reloading complex.

.

The input parameters were:

• machine service time in the first and second queues - $\tau_1 = 2$, $\tau_2 = 3$;

• the number of machines arrival in the first and second queues for 1 hour of system operation - $\lambda_1 = 15$, $\lambda_2 = 10$;

• length of the first queue $L_1 = 2$ and the second queue $L_2 = 4$ (maximum = 5);

• period of printing statistics time $T_4 = 20$ min;

• observation time $T_5 = 60$ min;

• number of system implementations = 1, 2, 3, ... , $n$.

Simulation of the machines input flow was carried out in accordance with the scheme of the algorithm shown in Fig. 2.

The entry of machines into the system was carried out using the built-in Embarcadero RAD Studio XE10 Seattle standard program - a generator of pseudo-random numbers, the sequence of which is subject to uniform distribution in the interval (0,1).

Simulation of the first and second queues was performed according to the scheme of the algorithm shown in Fig. 3. The total number of machines entering the first and second queues for 1 hour of system operation was calculated:

$$\lambda_{tot} = \lambda_1 + \lambda_2 . \tag{18}$$

Simulation of the reloading complex service channel was performed in accordance with the scheme of the algorithm shown in Fig. 4. At the same time, the waiting time of machines in the queue and the square of this value were summed, for the subsequent determination of the average waiting time and the average value of the queue length, as well as the variance of the values $\omega$ and $L$. The following system parameters were also calculated:

• the number of serviced cars, received separately from the first and second queues for 1 hour of its operation:

$$\mu_{1ave} = 60/\tau_1 \times \frac{\lambda_1}{\lambda_1 + \lambda_2}; \tag{19}$$

$$\mu_{2ave} = 60/\tau_2 \times \frac{\lambda_2}{\lambda_1 + \lambda_2}; \tag{20}$$

• the total number of serviced machines received from the first and second queues for 1 hour of system operation:

$$\mu_{tot} = \mu_{1ave} + \mu_{2ave}. \tag{21}$$

In addition, the calculation of the following parameters was also performed:

- the average number of cars that were denied service from the first and second queues;

- the average number of serviced cars from the first and second queues;

- the average number of cars remaining in the first and second queues.

Simulation of the entire reloading complex was performed according to the scheme of the algorithm shown in Fig. 5, which provides the correct sequence of events in the system model. The following events are (block 3 in Fig. 5):

1. Work of the first queue;

2. Work of the second queue;

3. Operation of the service channel;

4. Calculation and printing of statistical characteristics;

5. End of system work.

## 5. Discussion and Outlook

The results of calculating the average waiting time in the first ($\omega_{1ave}$) and second ($\omega_{2ave}$) queues, the average length of the first ($L_{1ave}$) and second ($L_{2ave}$) queues and the variance of $\omega$ and $L$, which were calculated by formulas (1)-(6), were displayed in the window of the ListBox component (Fig. 6), and for each implementation of the system separately.

From the simulation results (Fig. 6) it is seen, that for the given of the input flow intensity, coming in the first and second queues $\tau_1$ = 2 and $\tau_2$ = 3, and the performance of the cars service channel, coming from the first and second queues $\lambda_1$ = 15, $\lambda_2$ = 10, give the following values of the main parameters reloading complex:

• average waiting time in the first queue $\omega_{1ave}$ = 1.15 min, and in the second queue $\omega_{2ave}$ = 8.3 min;

• the length average value of the first queue $L_{1ave}$ = 0.40 cars and the second queue $L_{2ave}$ = 1.67 cars;

• variance of the average waiting time in the first queue $D\omega_{1ave}$ = 0.86, and in the second queue $D\omega_{2ave}$ = 33.74;

• variance of the length average value of the first queue $DL_{1ave}$ = 0.18 and the second queue $DL_{2ave}$ = 0.78.

Thus, simulation and obtaining the basic parameters of the reloading complex, depending on the intensity of the machines input flow and performance of the service channel, makes it possible to analyze and select the optimal modes of the complex working – determine the optimal number of machines or service channels required for cargo delivery and execution reloading works, which ensures optimal use of vehicles and reloading machines.

In addition, the results of modeling the reloading complex show, that simulation models of transport logistics systems are convenient to build on a block basis, and each block is subject to its own logic, which simulates a particular process or element of the system being modeled. Some of these blocks can be implemented as standard, by including them in libraries of standard programs.

## 6. Conclusions

The article considers the reloading complex, in which the incoming flow of machines is served by the rule of relative priorities. In this case, the reloading complex is considered as a queuing system.

Modeling algorithms schemes of separate elements (input stream 1 and queue 1, service channel) and the scheme of the general modeling algorithm of a reloading complex are constructed, on the basis of which its computer model developed, by means of programming system - Embarcadero RAD Studio XE10.

The calculation of the main characteristics reloading complex, such as the total and average queue length, total and average waiting time in the queue, as well as their variance, depending on the intensity of the machines input flow and performance channel, which allows analysis and selection of optimal modes.

## Bibliography

[Christopher, 2016] Christopher M. Logistics & supply chain management, 5th ed, p. 328. Pearson UK (2016)

[Shortle, 2018] Shortle J., Thompson J., Gross D., Harris C. Fundamentals of queueing theory, 5th ed, p. 576. John Wiley & Sons (2018). https://doi.org/10.1002/9781119453765

[Trivedi, 2016] Trivedi K. Probability and Statistics with Reliability, Queueing, and Computer Science Applications, 2nd ed, p. 830. Hoboken, New York: John Wiley & Sons (2016)

[RAD, 2019] RAD Studio XE10 Seattle Product Reviewer’s Guide, (2019). http://docwiki.embarcadero.com/RADStudio/XE10.

[Khorshidian, 2019] Khorshidian H., Shirazi M., Ghomi S. An intelligent truck scheduling and transportation planning optimization model for product portfolio in a crossdock. Journal of Intelligent Manufacturing, vol. 30(1), pp. 163–184, (2019)

[Kumar, 2016] Kumar R., Kondapaneni K., Dixit V., Goswami A. Multi-objective modeling of production and pollution routing problem with time window: a self-learning particle swarm optimization approach. Computers & Industrial Engineering, vol. 99, pp. 29–40, (2016)

[Escobar, 2020] Escobar J., Marin A., Lince J. Multi-objective mathematical model for the redesign of supply chains considering financial criteria optimisation and scenarios. International Journal of Mathematics in Operational Research, vol. 16(2), pp. 238–256, (2020)

[Heidari, 2018] Heidari F., Zegordi S., Tavakkoli-Moghaddam R. Modeling truck scheduling problem at a cross-dock facility through a bi-objective bi-level optimization approach. Journal of Intelligent Manufacturing, vol. 29(5), pp. 1155–1170, 2018

[Nasiri, 2018] Nasiri M., Rahbari A., Werner F., Karimi R. Incorporating supplier selection and order allocation into the vehicle routing and multi-cross-dock scheduling problem. International Journal of Production Research, vol. 56(19), pp. 6527–6552, (2018)

[Soeanu, 2020] Soeanu A., Ray S., Berger J., Boukhtouta A., Debbabi M. Multi-depot vehicle routing problem with risk mitigation: model and solution algorithm. Expert Systems with Applications, vol. 145, pp. 135–147, (2020).

[Lai, 2015] Lai X., Bierlaire M. Specification of the cross-nested logist model with sampling of alternatives for route choice models. Transp. Res. Part B Methodol, vol. 80, pp. 220–234, (2015)

[Sun, 2020] Sun Y. Green and reliable freight routing problem in the road-rail intermodal transportation network with uncertain parameters: a fuzzy goal programming approach. Journal of Advanced Transportation, vol. 2020, pp. 1–21, (2020)

[Luisa, 2015] Luisa M., Vitetta A. Route choice on road transport system: a fuzzy approach. J. Intell. Fuzzy Syst, vol. 28(5), pp. 2015–2027, (2015)

[Tokgeoz, 2015] Tokgeoz E., Alwazzi S., Trafalis T. A heuristic algorithm to solve the single-facility location routing problem on Riemannian surfaces. Computational Management Science Journal, vol. 12(3), pp. 297–415, (2015)

[Manley, 2015] Manley E., Orr S., Cheng T. A heuristic model of bounded route choice in urban areas. Transp. Res. Part C Emerg. Technol, vol. 56, pp. 195–209, (2015)

[Yu, 2020] Yu Y., Zhou J., Xu W. Regret-based multi-objective route choice models and stochastic user equilibrium: a noncompensatory approach. Transportmetrica A: Transport Science, vol. 16(3), pp. 473–500, (2020)

[Rodado, 2017] Rodado D., Escobar J., Garcrıa-Crٰaceres R., Atencio F. A mathematical model for the product mixing and lot-sizing problem by considering stochastic demand. International Journal of Industrial Engineering Computations, vol. 8(2), pp. 237–250, (2017)

[Havelock, 2018] Havelock J., Ommen B., Granmo O. Novel distance estimation methods using “stochastic learning on the line” strategies. IEEE Access, vol. 6, pp. 48438–48454, (2018)

[Tintu, 2020] Tintu G., Amudha T. Genetic algorithm based multiobjective optimization framework to solve traveling salesman problem. Advances in

Computing and Intelligent Systems, pp. 141–151, Springer, Singapore, (2020)

[Mohammed, 2017] Mohammed M., Abd-Ghani M., Hamed R., Mostafa S. Solving vehicle routing problem by using improved genetic algorithm for optimal solution. Journal of Computational Science, vol. 21, pp. 255–262, (2017)

[Chiappone, 2016] Chiappone S., Giuffre O., Grana A., Mauro R. Traffic simulation models calibration using speed-density relationship: an automated procedure based on genetic algorithm. Expert Systems with Applications, vol. 44, pp. 147–155, (2016)

[Lu, 2017] Lu F., Bi H., Huang L., Bo W. Improved genetic algorithm based on delivery time control for Fourth Party Logistics. In Proceedings of the IEEE Conference on Automation Science and Engineering (CASE), pp. 390–393, Xinan, China, August (2017)

[Yang, 2016] Yang Y., Dong H., Qin Y., Zhang Q. Parameter calibration method of microscopic traffic flow simulation models based on orthogonal genetic algorithm. In Proceedings of the22nd International Conference on Distributed Multimedia Systems, Colchester, UK, November (2016)

[Hess, 2015] Hess S., Quddus M., Rieser-Schüssler N., Daly A. Developing advanced route choice models for heavy goods vehicles using GPS data. Transp. Res. Part E Logist. Transp. Rev, vol. 77, pp. 29–44, (2015)

[Nyrkov, 2015] Nyrkov A., Sokolov S., Belousov A. Algorithmic support of optimization of multicast data transission in networks with dynamic routing. J Modern Applied Science, vol. 9(5), pp. 162–176, (2015)

[Zhilenkov, 2015] Zhilenkov A., Nyrkov A., Cherniy S. Evaluation of reliability and efficiency of distributed systems rigs. Automation in the industry, vol. 6, pp. 50–52, (2015) [Kirpichnikov, 2018] Kirpichnikov A., Yelizarov A. Methods of Applied Queuing Theory, 2nd ed, p. 223. Moscow: LENAND, (2018)

[Gnedenko, 2018] Gnedenko B. Theory of probability, p. 520. Routledge, (2018). https://doi.org/10.1201/ 9780203718964

## Author's information

***Mykola T. Dekhtyaruk*** *– Ph.D. Phys.- Mat. Sciences, Associate Professor, Senior Researcher, Professor of the Information Technologies and Programming Department, University "Ukraine", st. Lvivska, 23, Kyiv, Ukraine, 03115; e-mail: dekh@ukr.net.*

*Major Fields of Scientific Research: Computer modeling, Transport logistics systems, Queuing systems.*