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COMPUTER MODELING OF CUSTOMER SERVICE: CASES OF BUYER QUEUES IN PHARMACIES

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Abstract

The article deals with the maintenance of retail buyers of drugs and medical products in pharmacies. In particular, possible buyer queues in pharmacies are considered. The aim of the work is to reduce such queues and optimize the work of the attendants at the pharmacy while selling medicines and other pharmaceutical products. To this end, it is proposed to consider and simulate queues such as queuing systems with appropriate parameters. In the work, possible variants of such queues in pharmacies were preliminarily analyzed and a cortege approach for their formalized description has been developed. According to the results of field observations in pharmacies in Kharkiv, statistically substantiated distributions of the main parameters of the system were obtained, such as the intervals of the appearance of customers, their time in queue, the duration of service by the pharmacist, the amount of purchases. Then computer queue models were developed for different options for customer service in pharmacies using a specialized simulation package ExtendSim. Numerical experiments were carried out with these models and their results are presented. Based on the analysis of the results of simulation modeling, practical recommendations for improving the servicing of visitors and for optimizing the work of the pharmacy attendants themselves in various practical situations have been developed and proposed.

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Key words: computer simulation, queue modeling, information systems for improving consumer service, queuing in drugstores, ExtendSim software.

1 Indroduction

In modern conditions, mathematical and computer modeling of the components of the production and commercial activities of pharmaceutical enterprises,

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as well as the processes of interaction between the subjects of distribution of drugs and medical products, are an important tool in making their personal justified management decisions [3, 7, 13, 17].

Such decisions are aimed both at strengthening the position of the enterprises themselves in the competitive pharmaceutical market and at fulfilling the important social tasks of improving the provision of the population with medicines and improving the pharmaceutical service for consumers [4, 9, 11]. One of the effective directions of such modeling in the pharmaceutical industry and in the retail drug market is simulation modeling.

When imitating modeling of the processes of retail drug sales in the pharmacy's sales area, the main input parameters are the appearance rate and other statistical characteristics dealing with customers, the number and type of servicing devices (pharmacists, consulting doctors etc.), the distribution of service times and working intervals, financial indicators of purchases and the like.

The results of the simulation are the definition of workload and other parameters of the work of pharmacy staff, predicting the behavior of visitors in various situations and the following determination of the appropriateness of certain managerial and organizational solutions.

2 Research objectives

The issues of optimizing the activity of retail pharmaceutical enterprises in Ukraine and other countries constantly occupy an important place in scientific developments and relevant publications [1, 8, 14, 15]. Studies can be divided into two main areas.

Firstly, these are actual pharmaceutical solutions - marketing, logistics, recruiting and so on [2, 6]. Secondly, there are studies of queuing systems, the experience which can be applied in the simulation of the work of pharmacies [5, 10, 12, 16]. Unfortunately, not enough attention is paid to the possibilities of simulation modeling in this subject area.

The functioning of the pharmacy's trading floor (in particular, the process of purchasing of medicines and medical products by buyers) from the point of view of modeling is expedient to be considered as a queuing system. Such a system is inherent in both common components and elements, and in specific ones (which reflect the specific features of this process).

The development and research of a model of such a system for a pharmacy will allow us to identify and optimize such important common characteristics as the time of servicing requirements in the system, the availability and parameters of queues, the loading of servicing devices and the like.Therefore, the main purpose of this study is to simulate the process of customer service in a pharmacy.

During the first stage, a logical model (a process tree) is formed, and statistical data collected during field observations are processed.

The next step is the development of an appropriate computer model in the ExtendSim package with subsequent analysis of the results obtained, and then developing recommendations for practical improvement of the pharmacies working.

3 The functioning of the pharmacy's trading hall, as a queuing system

During the observations directly in the pharmacy trading hall (about way visitors show up, their interaction with pharmacists and a consultant, the shopping service, the purchase of medicines) was discovered that often there are queues to the service windows (to the pharmacists).

Visitors also sometimes leave the pharmacy as a result of an unacceptably long (in their opinion) queue, or excessive waiting in it.

It should be noted that this phenomenon was observed at different time intervals (pharmacy work) and on all days of the week.

Further questioning of visitors (about the importance for them of waiting time in the queue, as a component of service quality and evaluation of the level of service in the pharmacy, attachment to it) confirmed the important place of this component of service in the integrated assessment of the pharmaceutical service and the atmosphere of service in the pharmacy as a whole.

The analysis of scientific sources also confirmed the importance of working out this issue (both in the general context of improving the systems of mass customer service, and in relation to pharmaceutical services to the population in pharmacies, in particular).

Therefore, the following studies were in this direction.

In order to study the organization of customer service from the point of view of the organization of the pharmacy's sales premises as a queuing system, we examined several retail pharmacies in the city of Kharkiv.

Corresponding observations are given in Table 1.

It should be noted that buyer queues (of various lengths) were observed in almost every pharmacy.

We fixed the address, the name of a pharmacy, the number of general and specialized service windows, their features, the availability of personnel at the points of service at the time of the survey, the possibility of an additional consultation of the pharmacist (or doctor) directly in the trading floor.

The study and analysis of information, practical observations on the pharmacy premises showed that the most typical is the simultaneous operation of two or three service windows (in which the customers are fully serviced).

In this case, almost always there are minor queues to one or several windows.

It can be reasonably assumed that a large number of windows are only additional (reserve) workplaces.

They begin to be used in various force majeure cases.

That is (with rare exceptions - in pharmacy supermarkets, during an extreme flow of customers, during peak hours), simultaneously more than three pharmacists in the service windows do not work.

Table 1.
Data on pharmacies that were surveyed (all are located in the center of Kharkiv)

№	Name of the pharmacy	Number of service windows	Active service windows	Special service windows	Consultants
1	“Good Day” pharmacy network, pharmacy №10	2	1	-	-
2	“9-1-1” pharmacy network, pharmacy №12	5	3	1	1
3	“Mega-Health” pharmacy network, pharmacy №1	6	2	2	1
4	“Mega-Health” pharmacy network, pharmacy №33	3	2	-	-
5	“9-1-1” pharmacy network, central pharmacy №35	4	1	1	1
6	“9-1-1” pharmacy network, central pharmacy №4	2	1	-	-
7	“Slavutych” pharmacy network, pharmacy №12	2	2	-	-
8	“Gulliver” pharmacy network, pharmacy №1	1	1	-	-
9	“Health” national pharmacy network, pharmacy №1	4	2	-	-
10	“Kharkiv-Apteka” pharmacy network, pharmacy №2	5	3	1	1
11	“The First Pharmacy” pharmacy network, pharmacy №308	6	5	2	2
12	“Pharmacy Of Low Prices” pharmacy network, pharmacy №1	4	2	-	1
13	“Pharmacy Of Low Prices” pharmacy network, pharmacy №11	3	2	-	-
14	“Gamma 55” pharmacy network, pharmacy №21	4	2	-	1
15	“Pharmacy of Medicinal Plants”	1	1	-	-
16	“Homeopathic Pharmacy”	2	2	-	1
17	“9-1-1” pharmacy network, pharmacy №14	3	2	-	-

In about half the cases, a consultant (pharmacist or doctor) works directly in the hall (or in a separate room equipped for this place). That is, the case of the availability of advisory services takes place and is relevant for modeling the customer service system in the pharmacy as a whole.

But the existence of a separate cash window (where only payment is accepted and checks are issued, and then the buyer repeatedly returns to the pharmacist window to receive a check purchase) is an exception, an atypical phenomenon (unlike the situation five to ten years earlier). This service organization was observed only in two highly specialized pharmacies (medicinal herbs and homeopathic), so this is not the main case for modeling.

Thus, summing up the above, we can state, as the most common case, the organization of the pharmacy's trading hall in one, two or three working windows (pharmacists) and, possibly, a consultant working directly in the hall. Therefore, it is further that such models will be developed to study the performance characteristics of their elements and components in different conditions of the appearance of customers (buyers), and the work of staff (personnel).

4 The conceptual model of the queuing system in the pharmacy and its formalized representation

In our case, the queuing system is a pharmacy sales room, in which consumers purchase medicines. The main components of this system are transacts, service devices and queues for service (Fig.1).

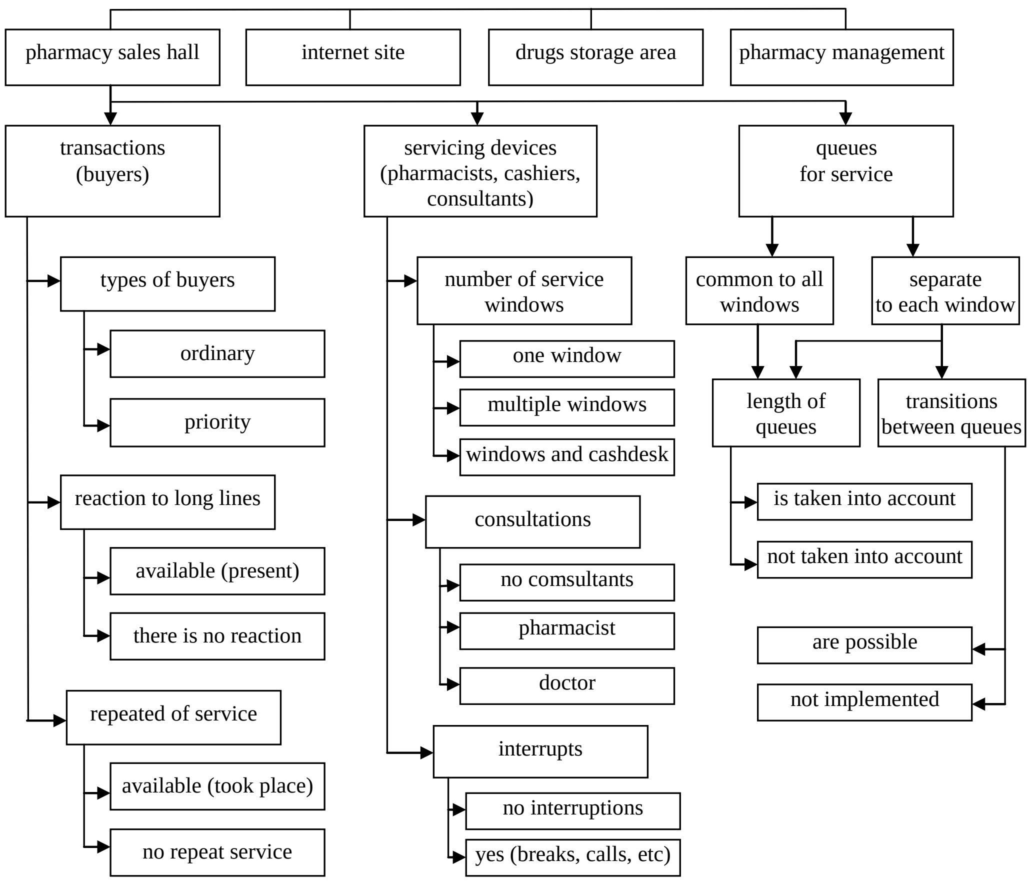

Figure 1. Composition and elements of buyer queuing systems in the pharmacy

Transacts are customers who form discrete service requirements (in the process of purchasing drugs and medical products). When modeling, it is necessary to take into account the priority of a particular transact, the possible abandonment of the pharmacy by the buyer because of the unacceptably long queue length, the possibility of buyer returning for repeated maintenance.

Serving devices are drug sellers (pharmacists) and medical consultants. Here it is necessary to consider how many devices serve the requests of the flow of customers, the presence of diversification of the roles of maintenance personnel.

For example, medical advice can be provided to the buyer either directly by the pharmacist or by a separate doctor. Also it is necessary to consider how often the staff is distracted by interruption (telephone consultation, lunch break, toilet).

Queues in the system consist of customers who expect to be serviced in pharmacy windows, at the cash desk, and getting consultations (Fig. 2).

In a simplified model, one queue to several windows is allowed. Buyers can move from one queue to another as a result of changes in their length. Depending on the circumstances, the queue length itself may have some maximum value.

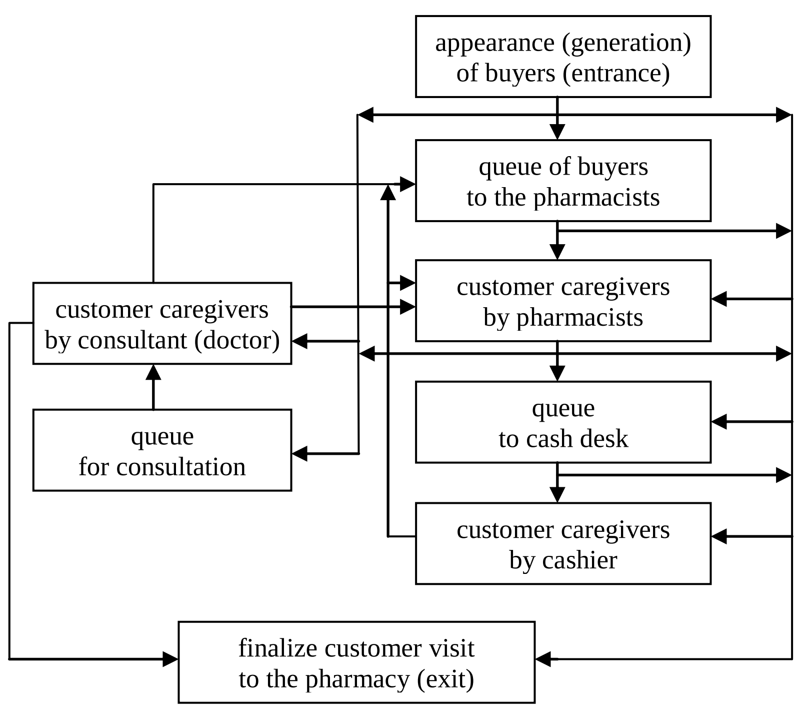

Figure 2. Sequence of customer service in the pharmacy's sales area (if cash desk and consultants are present)

To unify the models, we propose to apply the cortege approach for their formalized presentation. It comes from various options for organizing services, selling drugs and medical supplies to customers in pharmacies.

The corresponding service models can be described by the following cortege: $(A; B; ...; K)$, where:

A is number of serving devices (pharmacists): $A \in [1; N]$;

B is type of queue to pharmacists (0 if one common, 1 if separate to each of the pharmacists);

C is the opportunity of buyers return for re-servicing (0 if no, 1 if yes);

D is the possibility of the buyer leaving because of the unacceptable queue length for him (0 if no, 1 if yes);

E is the possibility of the buyer leaving the queue when the allowed timeout is exceeded (0 if no, 1 if yes);

F is the availability of cash register system (0 if no, 1 if as in the supermarket: leaving the buyer after service at the cash desk; 2 if return with a check to the pharmacist for a purchase);

G is the number of cash desks: $G \in [0; N]$;

H is the number of buyers' priorities (for example, the number of preferential categories that are served out of turn): $H \in [1; N]$;

I is the availability and number of auxiliary service devices (doctors, advertising consultants, etc.): $I \in [0; N]$;

J is the number of pharmacists serving customers only in cases of long queues appearance: $J \in [0; A - 1]$;

K the possibility of interrupting the operation of service devices (pharmacists, consultants, etc.), for example, a stoppage, phone call, accepting, preparation, issuance of an Internet orders (0 if no, 1 if yes).

The proposed cortege does not take into account the possibility of several customer priorities (more than two) and the priority of the buyer with a paid check in the queue to the pharmacist, since such models are extended subtypes of the main models.

Inclusion of these parameters in the cortege makes it too complicated and redundant.

The sequence of building queuing models in the pharmacy's sales area, which we realize, is shown in Fig. 3., and their representation by the corresponding cortege is presented in Table 2.

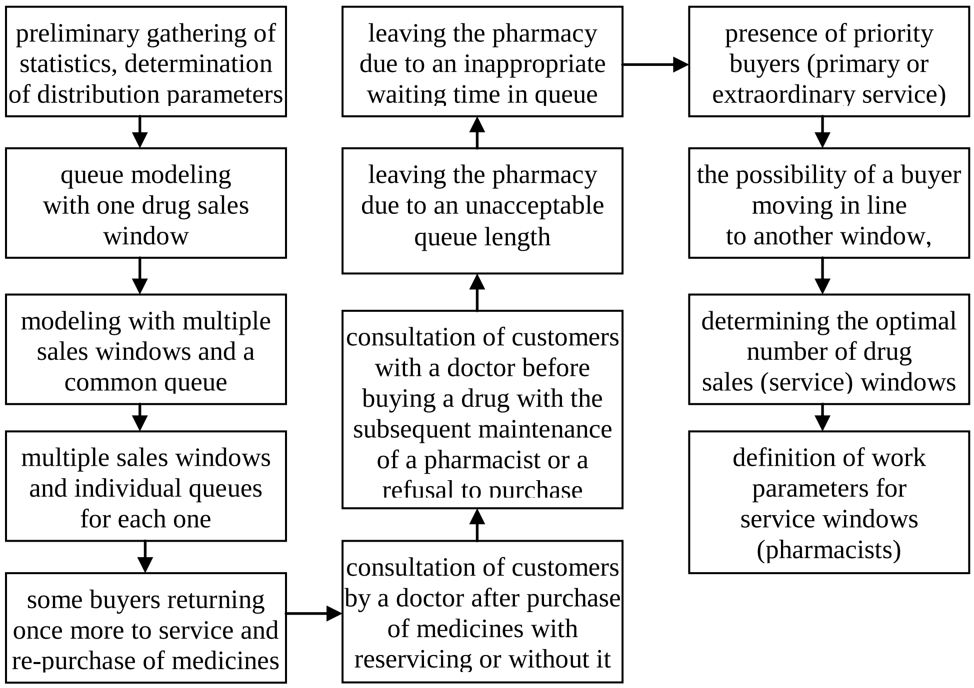

Figure 3. The sequence of development of queue models in the pharmacy

Table 2.
Cortege representations for different variants of buyer queues models in the pharmacy

№	Model description	Cortege
1	one pharmacist and one queue	(1;0;0;0;0;0;0;1;0;0;0)
2	two pharmacists and one common queue	(2;0;0;0;0;0;0;1;0;0;0)
3	two pharmacists and separate queues for each of them	(2;1;0;0;0;0;0;1;0;0;0)
4	two pharmacists and two queues for each of them, with the possibility of re-service	(2;1;1;0;0;0;0;1;0;0;0)
5	two pharmacists and two queues, with the possibility of re-service, the buyer can leave because of the unacceptable length of the queue (the number of people in it).	(2;1;1;1;0;0;0;1;0;0;0)
6	two pharmacists and separate queues for each of them, After visiting pharmacists, buyers pay for purchases at the check desk and leave the pharmacy	(2;1;0;0;0;1;1;1;0;0;0)
7	two pharmacists and two separate queues, after determining the list of purchases with pharmacies buyers pay in a single check desk, go back to pharmacists for take the drugs and then leave a pharmacy	(2;1;0;0;0;2;1;1;0;0;0)
8	two pharmacists and two separate queues, there is a preferential category of buyers	(2;1;0;0;0;0;0;2;0;0;0)
9	two pharmacists and two queues, buyers can leave queues due to long waiting times	(2;1;0;0;1;0;0;1;0;0;0)
10	three pharmacists and separate queues for each of them, the third window starts to work at large queues to the first and second	(3;1;0;0;0;0;0;1;0;1;0)
11	model №7 with the ability to set and read the priorities of customers	(2;1;0;0;0;2;0;1;0;0;0)
12	model №11 with one pharmacist and one check desk	(1;0;0;0;0;2;1;1;0;0;0)
13	two pharmacists and two queues, there is a preferential category of buyers, buyers can visit a consultant before visiting a pharmacist	(2;1;0;0;0;0;0;2;1;0;0)
14	one pharmacist, the pharmacist also serves telephone calls with a higher priority	(1;0;0;0;0;0;0;1;0;0;1)

5 The components of the ExtendSim software which are used for modeling of service at a pharmacy

The ExtendSim modeling package is quite convenient for modeling queuing systems. The ExtendSim working environment contains the main window for creating the actual model (Fig. 4) and various libraries (sets) of tools for building it.

Elementary components for building models are contained in the standard libraries of the program. For queuing models in the pharmacy's sales area, elements from libraries DiscreteEvent.lix, Generic.lix and Plotter.lix were used (Fig. 5).

The first contains conceptual components of queuing systems, the second - a mathematical device for processing events in them, and the third - tools for graphical analysis of simulation results.

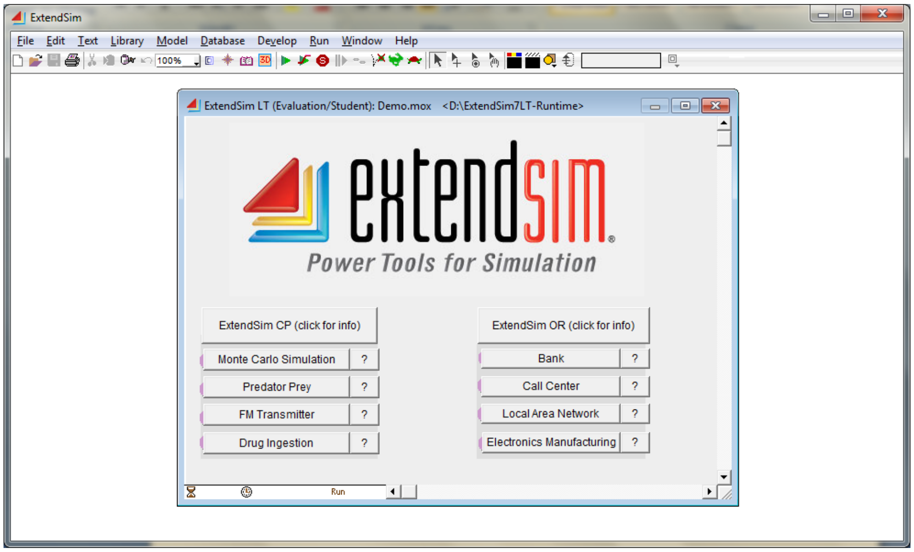

Figure 4. The ExtendSim modeling window on startup

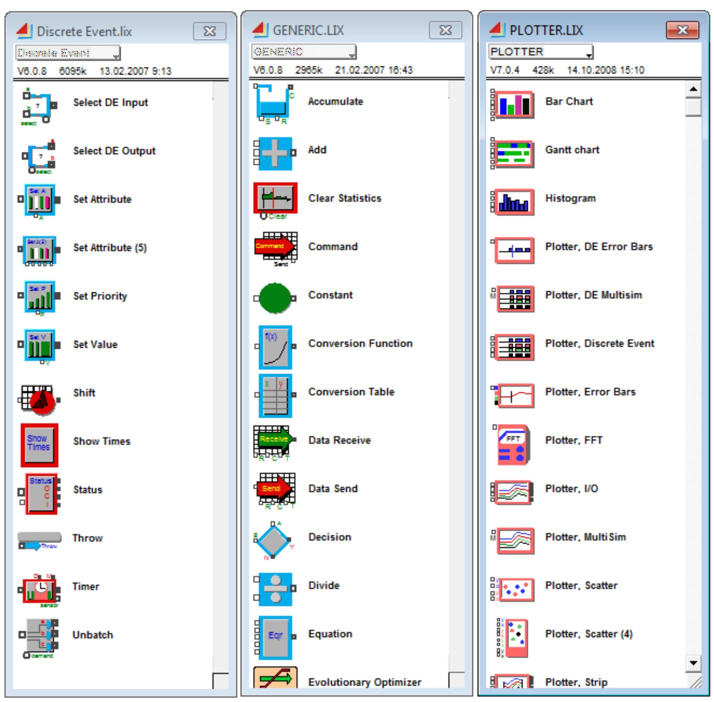

Figure 5. Main components of DiscreteEvent.lix, Generic.lix and Plotter.lix libraries

The standard initial queue model in ExtendSim is shown in Fig.6. Here are the following components (blocks): 1 - Executive time or event generator; 2 - Generator transacts appearance generator; 3 - transacts route lines; 4 - auxiliary information lines; 5 - queue components; 6 - serving device; 7 - mark the output of the transact from the system; 8- analyzer. Each block has inputs and outputs for transacts traffic (processing) (dark squares) and information inputs and outputs (light squares).

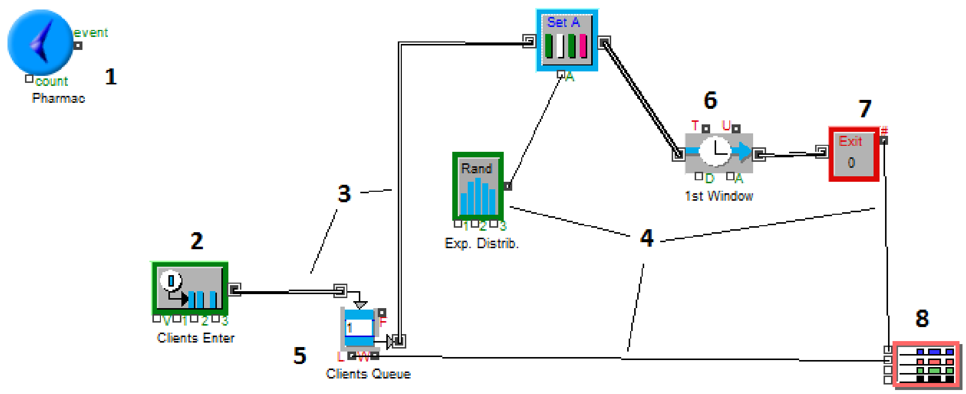

Figure 6. The simplest model of the queue in ExtendSim

Let us consider in detail each of these and other blocks that will be used in further modeling.

Block 1 Executive is a timer. It is usually located in the upper left corner of the model and specifies the conditions for stopping the simulation (by time or after the occurrence of a certain number of discrete events).

Block Executive has an information input Count (the time the model is running or the number of discrete events) and output Event (system status code).

Block 2 Generator serves for the generation of transacts. At the output Item it appears transact, as a result of generation (Fig. 7). Via the entrances Value and Argument1,2,3 you can specify the parameters of the generation function. Among these parameters, the type of time distribution of transact generation and its arguments, the cost estimate for each transact, the type of transact animation, and others.

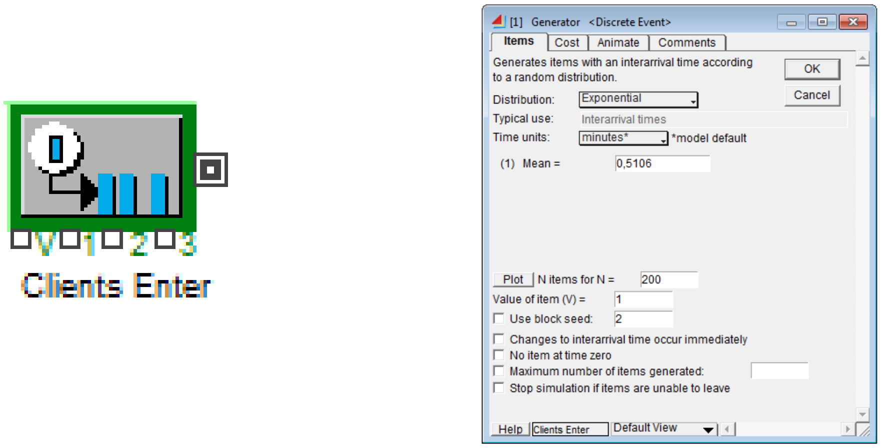

Figure 7. Block Generator and the setting of its parameters

Block 5 Queue is an ordinary queue of FIFO type (first came in - first out) or QueuePriority for the queue with priority of transacts. It has a maximum queue length parameter and information outputs: QueueLength (queue length), WaitingTime (average waiting time for the transact in the queue), Full (indicator of queue overflow) and Priority (priority indicator for the transact in the priority queue).

Block 6 ActivityDelay simulates the delay of the transact for service (Fig. 8). The delay parameter can be specified as a concrete time (numeric) value or as a random value generated by the specified distribution (coming through the input DelayTime).

Also, the block has an input AttributeModifier to change the attributes of the served transact (if it has them) and outputs TimeInUse, Utilization (the average transact service time and the load of the serving device). In the block, you can set the resource costs per unit of device operating time and the revenue from servicing one transact.

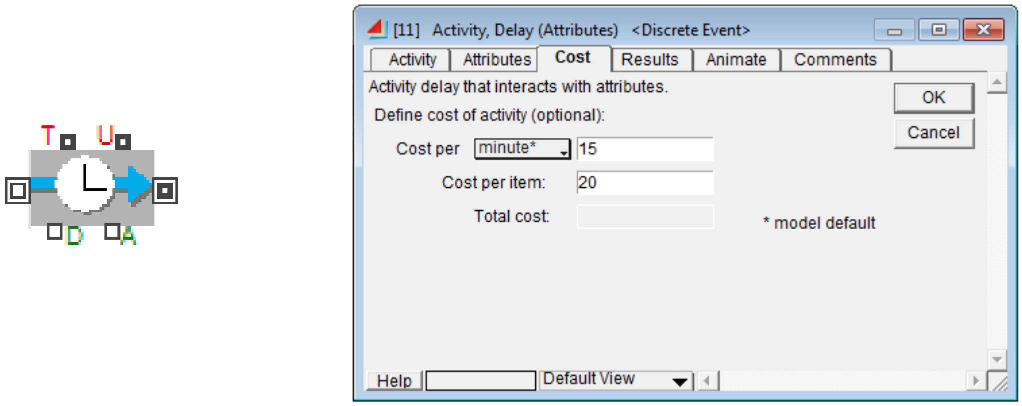

Figure 8. Block ActivityDelay and the determination of the material parameters of the transact service

Block 7 Exit indicates the end of the transact service and its exit from the system. The block can have up to 4 separate inputs (collectors). The information outputs contain the number of transactions that have passed through each of the collectors of the block.

Block SetAttribute ensures the determination and GetAttribute reading of attributes to a transact. The attributes move together with the transact. They contain accompanying transact information. For example, the delay time in the serving device (it can be specified by a certain distribution of a random variable), transact image variables at different stages of its processing in the system for animation, and the like. Block has an input (output) AttributeValue (attribute values) and Delta (logical parameter equal to unit if in block GetAttribute the value of at least one transact attribute has been changed).

Blocks (not shown in figure) SetPriority and GetPriority act like blocks SetAttribute and GetAttribute. As a transact attribute, the value of its priority is given (read out). It is used to form queues with priorities. Block SetPriority has output Priority, where priority can be set both manually and with usage external parameters.

Block GetPriority through the output Delta informs about the change in the priority of the transact. Blocks SelectOutput and Combine serve to form parallel routes for the movement of transacts. Fig. 9 shows the logical structure of the blocks and a dialogue box that specifies the logic of the block SelectOutput operation. One of the two outputs for the transact is selected depending on the value of the information input Select.

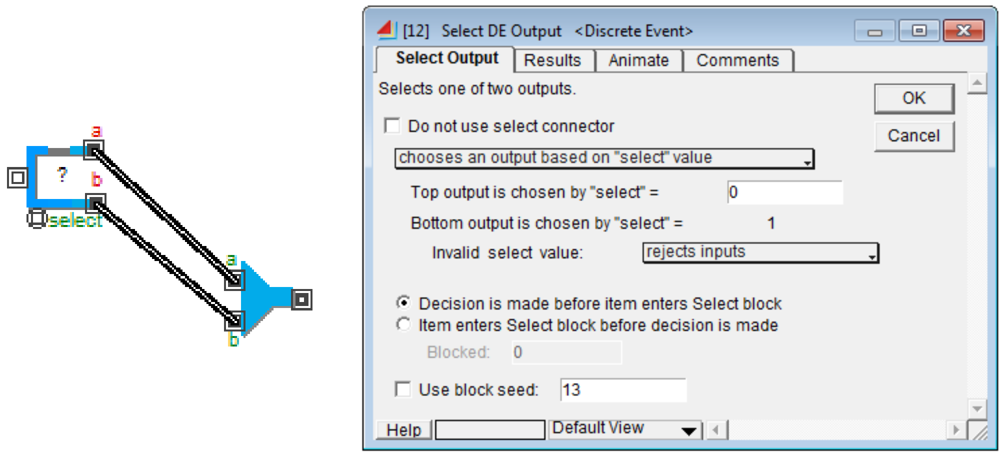

Figure 9. Interaction of blocks SelectOutput and Combine
and choosing an exit for the transact in the dialogue

Block InputRandomNumber is used to generate random values or their arrays, which can be input parameters for functions of other blocks, for example input for block SetAttribute, which specifies the transact delay time in the servicing device.

The block has three information inputs for parameters of the random variable distribution function and one output RandomValue, which returns the value of this value. Fig. 10 showns, how a random parameter having an exponential distribution with a given mathematical expectation is formed using this block.

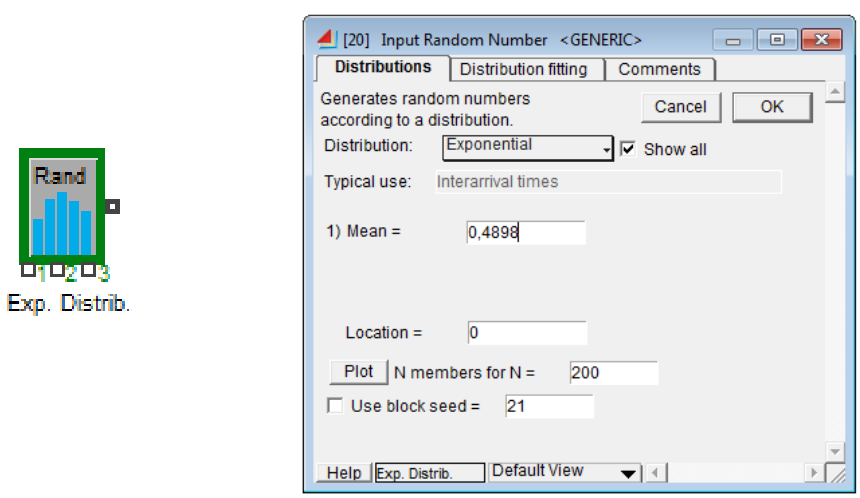

Figure 10. Block InputRandomNumber and the formation of a random variable in it

Block Decision is analogous to the logical comparison operator in high-level programming languages. The inputs of the block are parameters A and B, which are compared. Output Y forms a logical one (1) if the result of comparing the input parameters corresponds to the specified conditions. Respectively, output N is the output Y inversion. The comparison rule is given in the dialogue (Fig. 11).

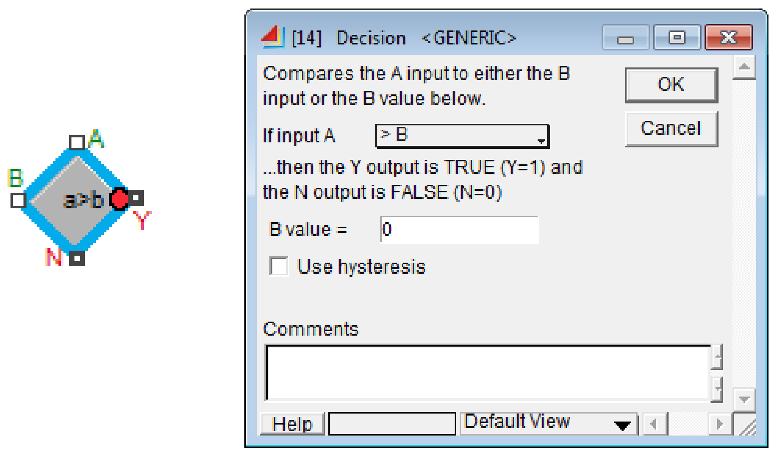

Figure 11. Block Decision and the formation of a rule for comparing the input parameters

Block PlotterDiscreteEvent is necessary to construct graphs for changing input parameters that are initial for certain blocks of discrete events. The value for each of the four inputs is shown on the resulting graphs in different colors (Fig. 12).

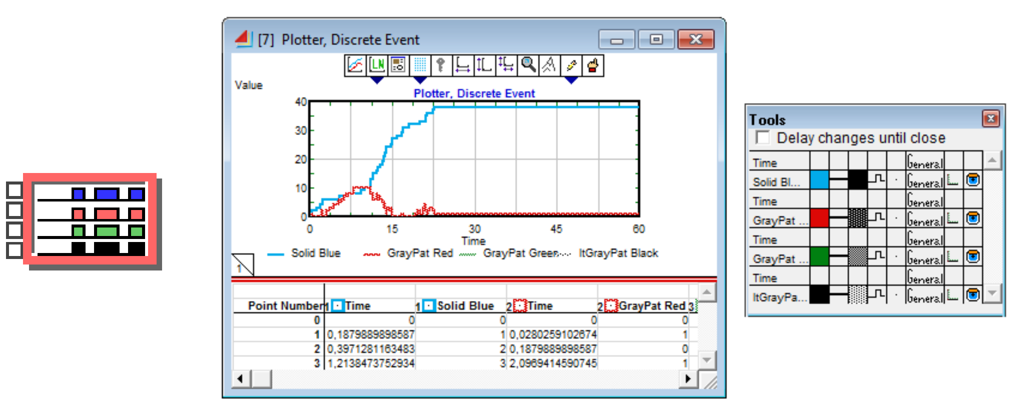

Figure 12. Block PlotterDiscreteEvent and an example of graphs in it

The list of components (blocks) described from different ExtendSim libraries is used in this study. A complete set, full of libraries components allows you to design models of fairly complex queuing systems, in particular - with elements of three-dimensional visualization.

6 Development of a number of queuing models in the pharmacies in ExtendSim

Using the above elementary functional and auxiliary blocks, according to the described approaches and the proposed classification of the existing schemes for organizing and servicing buyers and visitors in pharmacies, a number of computer queuing models were constructed (Fig. 13-19).

All these models were developed using standard logical, statistical and operational elementary blocks that are available in the specialized ExtendSim simulation environment.

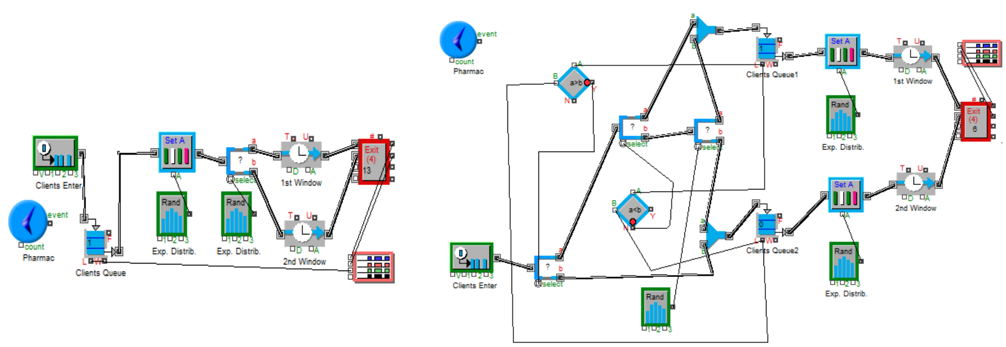

Figure 13. Two pharmacists with one common queue and separate queues for everyone

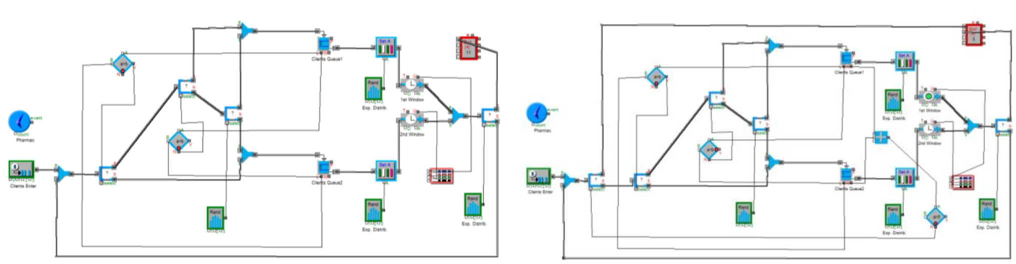

Figure 14. Two pharmacists and two separate queues with repeated service and leaving a long queue

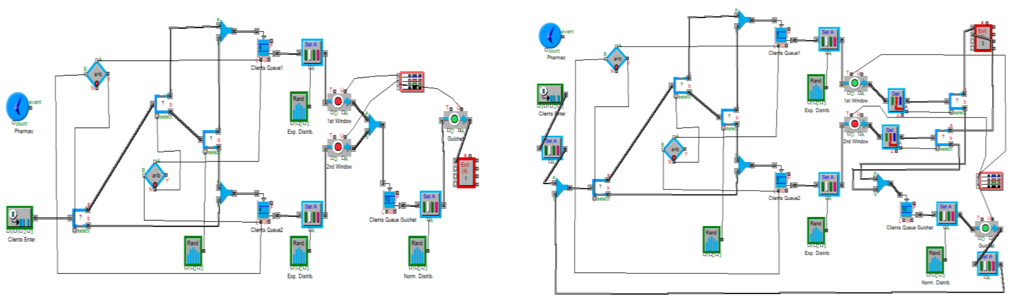

Figure 15. Two pharmacists and two separate queues (after visiting the pharmacist, buyers pay purchases at the check desk and leave the pharmacy or go back to the pharmacist to take the drugs and leave the pharmacy)

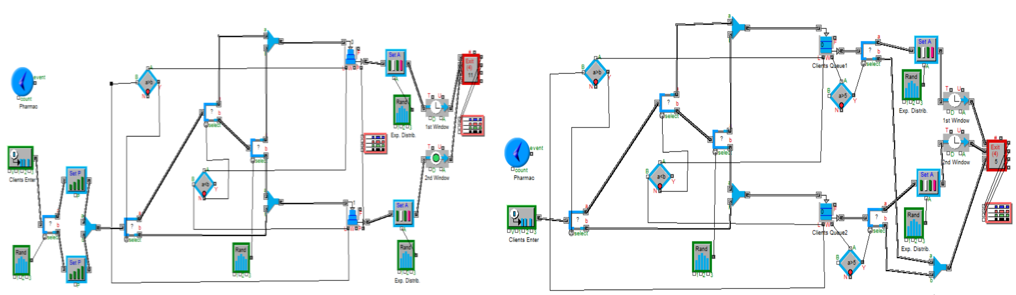

Figure 16. Two pharmacists and two queues (with priority buyers and buyers leave the queue in case of a long waiting)

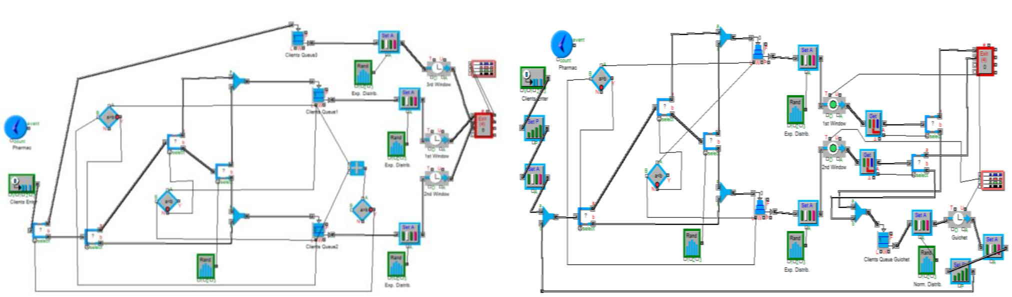

Figure 17. Three pharmacists and separate queues (the third work if a large queue length to the first two and model 7 with priority buyers)

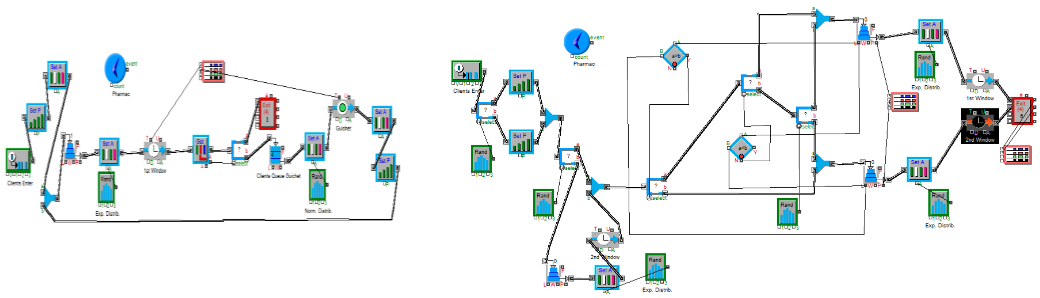

Figure 18. One pharmacist and one cashier; two pharmacists and two queues, with priority buyers and a consultant

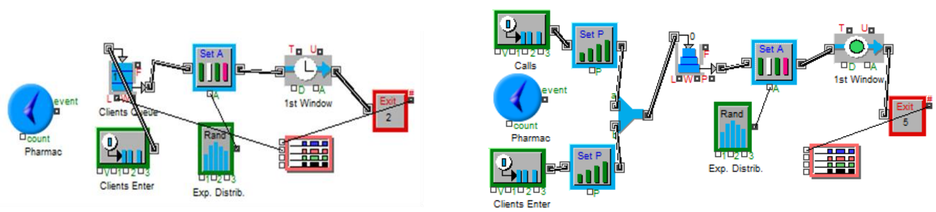

Figure 19. One pharmacist (1;0;0;0;0;0;0;1;0;0;0) and the service of telephone calls with a higher priority

To explain the operation and interaction of the elements in the models, let us consider (as an example) the selection of a queue with a minimum length by the transact (visitor, buyer) (Fig. 20).

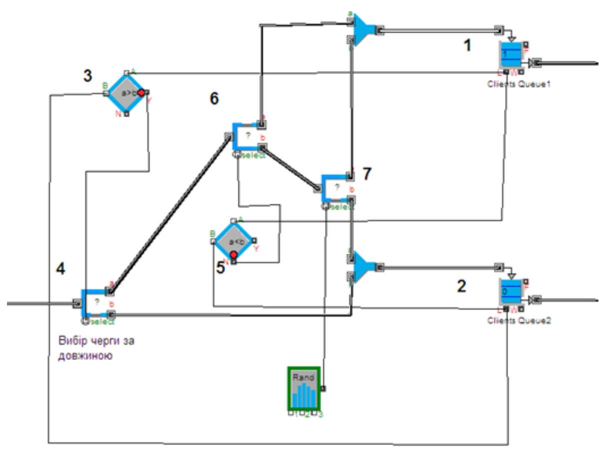

Figure 20. The buyer's choice of a queue with a minimum length

It functions as follows. In the comparison block (3), it is checked that the queue length 1 is greater than the queue length 2. If this is the case, the transaction by the branching unit 4 is immediately sent to queue 2. If queue 1 is not longer than queue 2, the assertion is verified that 2 is longer than 1 (the comparison block 5).

If this is the case, then transact by branching unit 6 is sent to 1. If this inequality is also not fulfilled, then the queues are equal in length, and transact arbitrarily chooses one of them (choice 7). The fragment of the service checker for the transaction in the cash desk (if it is in the model) works according to the following scheme (Fig. 21).

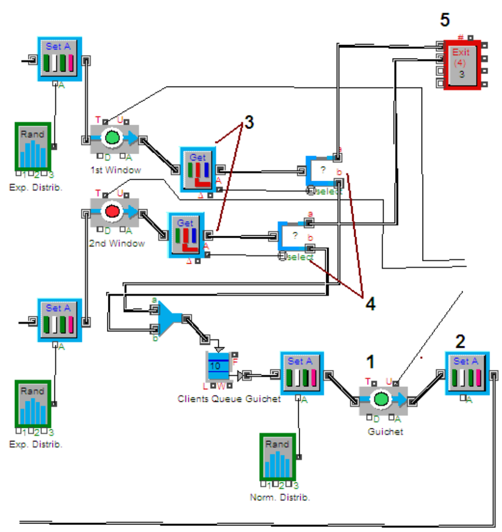

Figure 21. Check customer service at the check desk

The transact, having paid the purchase at the cash desk (1), receives the corresponding attribute in block 2. When re-visiting the window, the "payment" attribute (3) is read from it. If the visitor has already visited the cash desk (branch 4), he goes to the exit (5).

7 Preparation of input data for modeling

For practical implementation of further modeling, it is necessary to determine the basic input parameters. For this, a field observation was conducted. Statistics were collected in a pharmacy in the central part of the city of Kharkiv during 10.00-12.30.

There are 3 windows in the pharmacy, but 2 pharmacists work. If the flow of visitors is insignificant, one of the pharmacists is engaged in work not related to the direct sale of drugs to customers.

The following parameters were fixed: the time of arrival of the buyer to the pharmacy; number of the window approached by the buyer; time of the buyer's stay in the queue; time of customer service by a pharmacist; amount of purchase (if possible).

Cases of return of the buyer to re-service (for example, when buyer, having made a purchase, decided to buy other drugs) and the exit of some buyers from the queue due to its length were also taken into account.

For 150 minutes of observation the pharmacy was visited by 72 clients. The distribution of customers between two pharmacy windows was approximately 50% and 50%.

Two clients returned to re-service. Therefore, the probability of a buyer returning to re-service is: $P_{return} = \frac{n_{return}}{N} = 0,028$, where n_{return} is the number of customers who have been serviced repeatedly, N is the total number of buyers .

The probability that the buyer will leave the pharmacy in the presence of the queue is: $P_{leave} = \frac{n_{leave}}{N} = 0,185$, where n_{leave} is the number of buyers queued and left it, N is the total number of buyers.

The analysis of the initial data was carried out in the Statistica program (Fig. 22). For the values of the intervals of arrival of customers, the time of their stay in the queue, the service time, the amount of purchases, the hypotheses of normal and exponential distributions were tested (Tab. 3).

According to Pearson's criterion χ^2 for the first and third parameters, the hypothesis of the exponential distribution is accepted (Tab. 4); for the second and fourth - the normal (Fig. 23, 24).

	1 Int_Enter	2 Int_Queue	3 Servicing	4 /in_Numb	5 Return	6 Sum	7 Exiting
1	5	0	5	2	Ні	101,25	Ні
2	5	0	0	1	Ні	0	Ні
3	6	0	1	2	Ні	14,8	Ні
4	2	0	1	2	Ні	0	Ні
5	4	0	2	2	Ні	6,25	Ні
6	1	1	1	2	Ні	0	Ні
7	4	0	2	2	Ні	10,5	Ні
8	3	0	1	2	Ні	6,9	Ні
9	3	0	1	2	Ні	13,27	Ні
10	1	0	1	2	Так	13,27	Ні
11	0	1	2	2	Ні	0	Ні
12	1	1	2	1	Ні	Не визна	Ні
13	0	0	1	1	Ні	Не визна	Ні
14	2	0	1	2	Ні	19,4	Ні
15	7	0	1	1	Ні	2,55	Ні
16	0	0	3	2	Ні	10,5	Ні
17	7	0	1	1	Ні	Не визна	Ні
18	1	0	5	1	Ні	25,17	Ні
19	4	0	1	2	Ні	14,3	Ні
20	3	0	1	1	Ні	4,8	Ні
21	0	0	2	2	Ні	131	Ні
22	0	1	5	1	Ні	124,26	Ні
23	1	1	2	2	Ні	49,15	Ні
24	3	0	2	2	Ні	18	Ні
25	3	0	4	1	Ні	90,06	Ні
26	3	1	5	1	Так	17,84	Ні
27	0	1	0	1	Ні	0	Так
28	0	1	0	1	Ні	0	Так
29	2	4	1	1	Ні	127,3	Ні
30	3	0	1	1	Ні	12	Ні
31	0	2	1	1	Ні	Не визна	Ні
32	2	1	1	1	Ні	28,3	Ні
33	3	0	3	2	Ні	127,8	Ні
34	0	0	4	1	Ні	Не визна	Ні
35	3	0	11	2	Ні	372,64	Ні
36	0	1	1	1	Ні	Не визна	Ні

	1 Int_Enter	2 Int_Queue	3 Servicing	4 /in_Numb	5 Return	6 Sum	7 Exiting
37	1	1	1	1	Ні	12	Ні
38	3	1	0	2	Ні	0	Ні
39	0	0	2	1	Ні	13,1	Ні
40	2	0	1	2	Ні	97,2	Ні
41	2	0	2	1	Ні	130,5	Ні
42	2	0	1	2	Ні	26,65	Ні
43	9	0	6	2	Ні	167,9	Ні
44	1	0	1	1	Ні	Не визна	Ні
45	2	0	1	1	Ні	0	Ні
46	0	3	2	2	Ні	161,82	Ні
47	0	1	0	2	Ні	0	Так
48	0	5	1	2	Ні	6,85	Ні
49	0	6	5	2	Ні	127,37	Ні
50	2	0	3	1	Ні	Не визна	Ні
51	5	0	1	1	Ні	0	Ні
52	0	1	1	1	Ні	Не визна	Ні
53	0	1	0	2	Ні	0	Так
54	9	0	8	2	Ні	227,94	Ні
55	4	0	1	1	Ні	Не визна	Ні
56	0	1	1	1	Ні	0	Ні
57	1	1	1	1	Ні	0	Ні
58	1	0	3	1	Ні	Не визна	Ні
59	1	1	0	2	Ні	0	Так
60	1	0	2	2	Ні	5,8	Ні
61	2	0	3	1	Ні	Не визна	Ні
62	0	0	1	2	Ні	Не визна	Ні
63	1	0	1	2	Ні	6,8	Ні
64	1	0	2	2	Ні	48,5	Ні
65	0	1	2	1	Ні	Не визна	Ні
66	0	2	1	2	Ні	0	Ні
67	2	0	0	1	Ні	0	Ні
68	1	0	5	1	Ні	Не визна	Ні
69	2	0	5	2	Ні	76,65	Ні
70	1	2	3	1	Ні	66,96	Ні
71	2	2	3	2	Ні	77,6	Ні
72	1	2	1	1	Ні	15	Ні

Figure 22. Input data (observation results)

Table 3.

Characteristics of distributions for model parameters

Variable	**Type of distribution**	**Distribution parameters**		
		Mathematical expectation (a)	**Mean square deviation (σ)**	**Lambda (λ)**
Arrival interval, min.	Exponential	-	-	0,5106
Time in queue, min	Normal / Extremal	0,6528 / 0,2393	1,1526 / 0,5755	-
Time of service, min	Exponential	-	-	0,4898
Purchase amount, UAH	Normal / Extremal	45,7886 / 19,3557	70,4737 / 36,8388	-

Table 4.

The value of the Pearson criterion for various hypotheses
for the distribution of model parameters

Variable	**The value of the criterion χ^2 for various distributions**		
	Exponential	**Normal**	**Extremal**
Arrival interval, min.	21,34	6,87	36,97
Time in queue, min	71,38	86,09	43,11
Time of service, min	38,27	27,65	69,35
Purchase amount, UAH	9,52	12,71	14,55

Fig. 23, 24 show the empirical and model distributions of the investigated parameters.

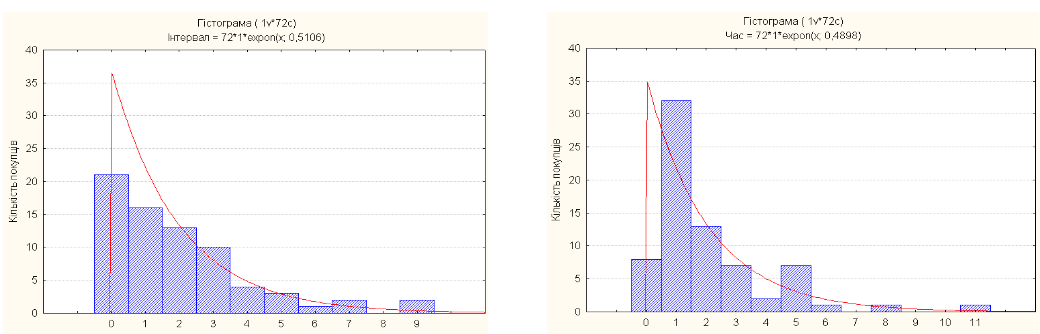

Figure 23. Distributions of the intervals of the arrival of drug buyers
and the time of their service

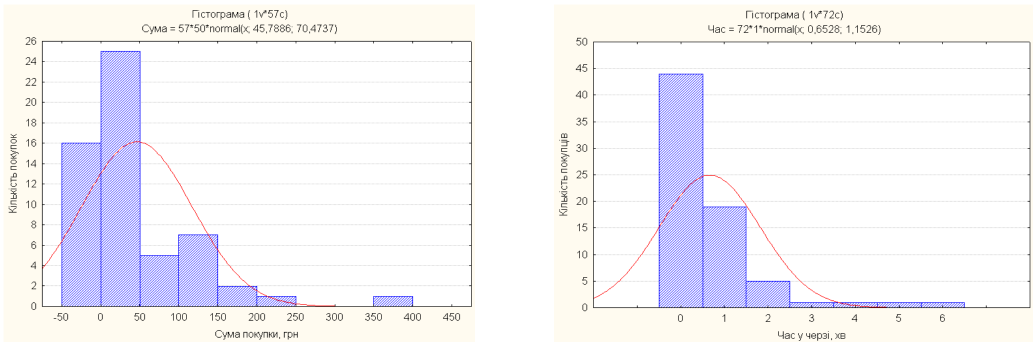

Figure 24. Distributions of the intervals of the purchase amount and the time the buyer is in the queue

During the analysis, the assumption about the existence of a correlation between the time of customer service by the pharmacist and the cost of medicines purchased was made (Fig. 25).

The corresponding regression equation has the form: $S = -9,159 + 26,769t$, $r^2_{tS} = 0,6463$, where S is amount of purchase (UA hryvna), t is customer service time in the window (minutes), r^2_{tS} is determination factor between customer service time and purchase amount.

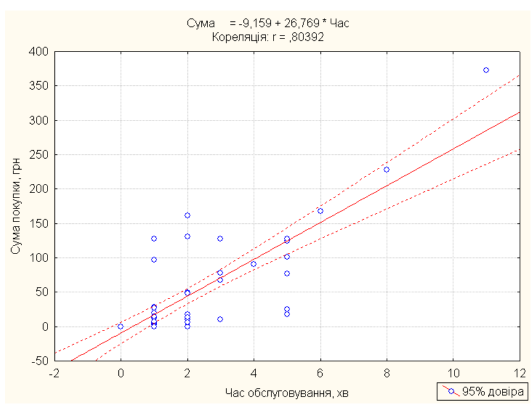

Figure 25. The relationship between service time and purchase amount

Thus, computer models of queues of drugs and medical products buyers in the pharmacy for various types of service organization are developed and presented.

They allow you to get the main characteristics of the service (the characteristics of queues, clients waiting time, the loading of pharmacists, etc.) and to develop measures to improve the service and work of pharmacies in general.

8 The numerical results of modeling

A number of experiments have been carried out with the models developed. Some of their results are presented in Table. 5-7. Input modeling parameters for this experiments was the next:

1: $\bar{\lambda}_{que}^{exp} = \lambda_{que}^{exp} = 0,51; \bar{\lambda}_{serv}^{exp} = \lambda_{serv}^{exp} = 0,49$

2: $\bar{\lambda}_{que}^{exp} = 0,7 * \lambda_{que}^{exp} = 0,36; \bar{\lambda}_{serv}^{exp} = \lambda_{serv}^{exp} = 0,49$

3: $\bar{\lambda}_{que}^{exp} = \lambda_{que}^{exp} = 0,51; \bar{\lambda}_{serv}^{exp} = 1,4 * \lambda_{serv}^{exp} = 0,68$

4: $\bar{\lambda}_{que}^{exp} = 0,8 * \lambda_{que}^{exp} = 0,41; \bar{\lambda}_{serv}^{exp} = \lambda_{serv}^{exp} = 0,49$

5: $\bar{\lambda}_{que}^{exp} = 0,65 * \lambda_{que}^{exp} = 0,31; \bar{\lambda}_{serv}^{exp} = \lambda_{serv}^{exp} = 0,49$

6: $\bar{\lambda}_{que}^{exp} = \lambda_{que}^{exp} = 0,51; \bar{\lambda}_{serv}^{exp} = \lambda_{serv}^{exp} = 0,49; \bar{\alpha}_{desk}^{norm} = 0,4; \bar{\sigma}_{desk}^{norm} = 0,25;$

7: $\bar{\lambda}_{que}^{exp} = 0,5 * \lambda_{que}^{exp} = 0,26; \bar{\lambda}_{serv}^{exp} = \lambda_{serv}^{exp} = 0,49$

8: $\bar{\lambda}_{que}^{exp} = \lambda_{que}^{exp} = 0,51; \bar{\lambda}_{serv}^{exp} = \lambda_{serv}^{exp} = 0,49;$

$\bar{\alpha}_{cons}^{norm} = 3,0; \bar{\sigma}_{cons}^{norm} = 1,0; P_{cons} = 0,2$

As already mentioned above, the primary (incoming) statistics have been obtained as a result of observations in the pharmacy of the city of Kharkiv and their processing.

Table 5.

Results for model 2

Number of experiment, parameters,comments	**№1 everyday situation**	**№2 30% intensity increase of buyers' arrival**	**№3 40% increase of service time**
Number of transacts	103	180	120
Average queue length, pers.	1,9313	8,0491	7,0073
Average waiting in queue, min	1,1579	2,4547	3,5036
Max queue length, pers.	11	26	17
Max waiting in queue, min	6,3943	9,8077	10,2605
Loading of a pharmacist №1	0,4151	0,6443	0,6071
Takings of a pharmacist №1, UAH	2564,16	3525,72	2701,52
Loading of a pharmacist №2	0,4091	0,5986	0,6318
Takings of a pharmacist №2, UAH	2014,69	3617,29	2793,10
Total takings, UAH	4578,85	7143,01	5494,62

Table 6.

Results for model 5

Number of experiment, parameters,comments	**№4 20% intensity increase of buyers' arrival**	**№5 35% intensity increase of buyers' arrival (for example, epidemiological situation)**
Number of transacts	139	184
Number of transacts out of turn	5	10
Average queue length №1, pers.	0,5480	0,7482
Average waiting in queue №1, min	0,5081	0,4894
Max queue length №1, pers.	3	3
Max waiting in queue №1, min	3,5197	2,5204
Average queue length №2, pers.	0,6005	0,7644
Average waiting in queue №2, min	0,4620	0,5039
Max queue length №2, pers.	3	3
Max waiting in queue №2, min	2,3953	3,8132
Loading of a pharmacist №1	0,5499	0,7099
Takings of a pharmacist №1, UAH	2747,31	4166,76
Loading of a pharmacist №2	0,6623	0,7282
Takings of a pharmacist №2, UAH	3571,51	4166,76
Total takings, UAH	6318,82	8333,52

Table 7.

Results for models 6, 10, 13

Number of experiment, parameters,comments	№6 model №6 with cash desk service	№7 model №10, 35% intensity increase of buyers' arrival (epidemy)	№8 model №13 (with consultant service)
Number of transacts	132	220	125
Average queue length №1, pers.	0,45081	1,1695	0,2263
Average waiting in queue №1, min	0,4326	0,7160	0,2263
Max queue length №1, pers.	3	3	2
Max waiting in queue №1, min	2,1103	3,9380	1,7826
Average queue length №2, pers.	0,2515	1,1498	0,1871
Average waiting in queue №2, min	0,2124	0,6944	0,1727
Max queue length №2, pers.	2	3	2
Max waiting in queue №2, min	1,7414	3,6779	1,7640
Loading of a pharmacist №1	0,6623	0,8433	0,5373
Loading of a pharmacist №2	0,4503	0,8009	0,5713
Takings of a pharmacist №1, UAH	no data	4487,28	2747,31
Takings of a pharmacist №2, UAH	no data	4395,70	2976,25
Average queue length №3, pers.	no service	0,2636	no service
Average waiting in queue №3, min	no service	0,6535	no service
Max queue length №3, pers.	no service	5	no service
Max waiting in queue №3, min	no service	2,5013	no service
Loading of a pharmacist №3	no service	0,1523	no service
Takings of a pharmacist №3, UAH	no service	1053,13	no service
Total takings (cash desk), UAH	5906,72	9946,11	5723,56
Average queue length to cash desk (to consultant), pers.	1,5190	no service	0,4475
Average waiting in queue to cash desk (to consultant), min	0,7221	no service	0,4197
Max queue length to cash desk (to consultant), pers.	8	no service	4
Max waiting in queue to cash desk (to consultant), min	2,7980	no service	4,6040
Loading of cash desk (consultant)	0,7529	no service	0,6783

9 Directions of improving service in the pharmacy based on the results of modeling

The analysis of the numerical results of the simulation of the queues of the pharmacy's sales hall should be presented under the form of Table 8.

Table 8.

The proposals for improving the service of pharmacy visitors based on the results of experiments

№	Explanation of actual situation	Possible causes of situation	Recommended activities
1	Unsystematic increase of the number of buyers	Reasons not established	Organization of a workplace for a pharmacist-trainee who will work with the high intensity of the arrival of customers
2	Systematic increase of the number of buyers	The epidemiological situation, the work of the pharmacy at peak times or on free days	Organization of a workplace for a pharmacist-trainee who will work with the high intensity of the arrival of customers
3	Both pharmacists are trainees	Organization of a pharmacy in a new place, especially in a place with a small influx of buyers (for example, in the sleeping area)	Replacement of one of the trainees with a pharmacist with experience
4	Unsystematic increase of the number of buyers	Peak time visiting a pharmacy	Not defined
5	Intensity of buyers' arrival far exceeds the expectations	The epidemiological situation	Organization of additional workplace for a pharmacist who sells drugs for which there is a demand during the epidemy
6	Non-rational organization of cash desk's work	Reasons not established	Add a second cashier, since the load of one cashier is 1.5-2 times the load time of one pharmacist
7	Intensity of buyers' arrival far exceeds the expectations	The epidemiological situation	Organization of additional workplace for a pharmacist who sells drugs for which there is a demand during the epidemy; this workplace may be occupied by an intern
8	Promotion from free consultation of a doctor; the workload of the doctor (consultant) is constantly increasing	Orientation of the pharmacy to buyers with symptoms of one group of diseases	Redirect part of the consultant's load to pharmacists

It contains a brief explanation of the situation; possible causes of its occurrence; suggestions regarding the improvement of the work of the pharmacy's sales hall in this situation.

It should be noted that the measures proposed are somewhat abstracted from the activities of pharmacies.

Their practical implementation requires a more detailed consideration of many individual factors, circumstances and peculiarities of customer service organization in each concrete pharmacy.

An important feature of the experiments conducted is the failure to take into account the cost factor of the equipment or the organization and functioning of the workplace of pharmacists. Here a significant part is the salary, which is determined individually in each pharmacy, and the relevant information is closed or inaccessible.

According to the analysis given experiments 1, 2, 5, 6, 7 can be recommended when making decisions about changing the staff of pharmacists or cashiers to hire trainees on a probationary period.

This will allow us to calculate the effectiveness of measures based on the possible excess of the cost of a new workplace over the economic effect of its introduction.

Among the ways and directions of further development of the approach proposed, first of all, it is necessary to note the need to take into account the amount of the purchase for each client. This will allow us to objectively estimate and predict possible losses from customer refusal in service (due to the unexpected queue length or waiting time in it).

In this case, it is necessary to make a comparison with the additional expenses for the introduction of a new window of service or the involvement of a higher-rank pharmacist (to eliminate the queue, reduce the waiting time or accelerate customer care itself by the pharmacist).

10 Conclusions

Thus, a set of queuing models for customer service in pharmacies has been developed and described. This set of models allows you to explore and improve the various options for selling drugs, pharmaceutical products and other medical supplies in a retail pharmacies.

The use of modern software and features of object-oriented modeling allows you to simulate an existing system of mass service in pharmacies even in the case of an unprepared user, in real-time. This provides a detailed visualization of the results, taking into account the economic indicators and characteristics of the subjects of modeling, obtaining statistically reliable information on the parameters of service and personnel.

This, in turn, allows operatively, in real time, to accept reasonably well-founded managerial, production and organizational decisions aimed at improving the service of visitors and optimizing the work of the staff of pharmacies in general.

It should be noted that the approach proposed and described, selected and used modeling tools that can be successfully used to solve a large number of different tasks, such as various queues in supermarkets, catering establishments, health facilities, and other places where queues may arise when serving visitors, buyers and customers.

The models described are open to further development in the event of the emergence of appropriate practical requirements and changes in the organization of maintenance.

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