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SIMULATION OF A QUEUING SYSTEM OF A POST OFFICE IN ANYLOGIC SOFTWARE

This paper displays the design and application of a model that simulates the queuing system of a fictional post office. Starting point for solving more complicated optimization tasks is to create a system model that consists of elements of reality and the relationships between these elements. The key part of the paper includes the model of a queuing system of a post office created in Anylogic simulation software. The model of the post office displays post office with 5 postal counters, a certain input flow and a certain service time with an exponential probability distribution. The model also includes statistics and cost calculation.

Keywords: *post office, simulation, Anylogic, costs, conceptual model*

1 Introduction

Digital technologies and to them related processes of automation and digitalization, are the driving force of the present. They affect the labour market, productivity and efficiency growth and ultimately are one of the key elements of transformation of functioning of society, businesses and economies. Digitalization and automation also affect the transport sector which includes the postal companies [1]. There are many applications in the field of digitalization and automation. From automated sorting systems and intelligent handling equipment in the processing of delivery items to innovative delivery methods through autonomous vehicles and smart mailboxes in the process of mail delivery [2]. In the process of collection of delivery items and within the points of the first contact, the queuing systems are commonly used. It is possible to design such systems through use of the computer simulation. Objectives of computer simulation are: elimination of the shortcomings of analytical methods and capturing of properties and elements of the real system that cannot be expressed in the analytical solution. In the system such as queuing system of a post office there are many random variables that cannot be captured in the analytical solution of optimization problems [3-9]. Therefore it is advisable to use a simulation method to get the system model closer to the real system, as much as possible. Contribution of the simulation method is in the ability of capturing the dynamic side of the system and complicated probabilistic relationships [10-15]. In Slovakia, the quality of postal services is monitored and the quality requirements for the universal postal service are regulated by the regulatory authority of the Slovak Republic [16-21]. Many of those quality requirements affect the Queuing systems of post offices. For example, one of the requirements is that a customer should not wait more than 12 minutes at the queue in the post office. Waiting and service times at post offices are directly related to customer satisfaction [1, 12].

Customer satisfaction, which co-creates a good image of the postal company and can significantly influence customer behaviour and preferences, is one of the factors of the of the postal services quality [22]. It is therefore necessary to shift focus to this area in order to retain customers and meet their needs.

The other factor of the postal services quality is location of the facility (post office). The success of each provider of high-quality services depends on the location of facilities of these businesses in relation to other facilities and its customers. The choice of the facility is primarily based on the availability, with customers choosing the closest (available) facility. Given that the availability provides an overall indicator of how a particular facility is accessible for other sources located in the analysed space, it is also necessary to determine the boundaries of this indicator [23].

2 Theoretical background

2.1 Queuing theory

The queuing theory is a mathematical discipline that analyses and solves processes in which request flows flow through certain devices from which they require service. The pioneer of queuing theory was Danish engineer Agner K. Erlang. At the beginning of the 20th century, he derived unique patterns for probabilities of states of a stabilized Markov system with losses. The queuing

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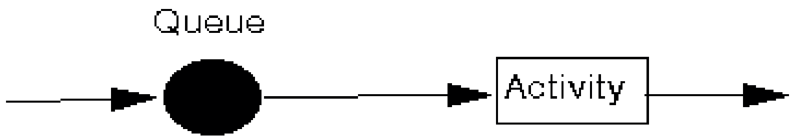

Figure 1 *General queuing system*

systems are systems (physical, social) serving to meet the needs of individuals, customers and requirements entering the system. The queuing service system is everything that is between the arrival of a request in the system and its departure from the system. A queuing system of a post office can be considered as a stochastic system with theoretically unlimited queue, a certain average service time, a customer arrival and a certain number of service lines [1, 7-9].

The queuing theory deals with problems, which involve queuing (or waiting) in the line. Typical examples might be:

- banks/supermarkets -waiting for service,
- computers - waiting for a response,
- public transport - waiting for a train or a bus.

Modelling of queuing systems requires introduction of notions originated by Kendall, which are also used to describe a queuing system [24-25]:

$$A/ B / m / K / n/ D, \quad (1)$$

where: A - distribution function of the inter arrival times,

B - distribution function of the service times, where m is a number of servers,

K - capacity of the system, the maximum number of customers in the system including the one being serviced, where n is the population size, which determines the number of sources of customers,

D - service discipline.

Exponentially distributed random variables are expressed by M, meaning Markovain or memoryless [22-23].

Generally, all the queuing systems can be divided into individual sub-systems consisting of entities, which are queuing for some activity (see Figure 1) [24-25].

2.2 System modelling

Simulation methods are methods that are often used in the queuing theory. Solving complicated optimization tasks using simulation often leads to a creation of model that contains elements of a real system and relationships between them. The dynamic elements of the system are handled by the time-slicing method. This method can model the progress of time when an event occurs. An event represents a change in the state of the system at a time. There are two event types in simpler event-based simulation models arrival of customer and an end of service [10-13].

3 Data and methods

The fundamental methods that are used in this paper are modelling and simulation method. In addition to the simulation model in the Anylogic program, the paper displays a conceptual model of the queuing system of a post office. The conceptual model of the system was created before the simulation model itself.

The model in Anylogic software displays five postal counters servicing customers. Three counters are universal and provide to customers all the postal services from the scope of universal service. There is also a financial counter and a service counter at the post office. For the public the opening hours (every work day) are from 7:00 to 19:00.

The queuing system of a fictional post office is characterized by the two main random variables, namely the average time of service and the average customer input at the post office. For this paper the average customer input is given:

$$\lambda = 2.20 \textit{ minutes}. \quad (2)$$

The given average service time is:

$$\mu = 4.20 \textit{ minutes}. \quad (3)$$

Input data of the model input are fictional. The simulation of a particular system requires a detailed system analysis that includes both an analysis of customer input flow and service time.

According to the Kendall's classification of queuing systems, the queuing system of a post office is classified as a system with an infinite queue, five independent parallel lines, exponential distribution of the arrivals of customers, service times and a waiting discipline FIFO.

3.1 Conceptual model of the post office queuing system

The model starts with an event - the arrival of the customer. The customer checks whether the counters are occupied. If they are not occupied, the customer enters counter. If they are currently occupied, he/she chooses a minimum queue. It is clear that the customer chooses a counter according to the service he/she requires. If the customer is waiting in the queue for more than 6.5 minutes, he/she leaves the post office without being served. This

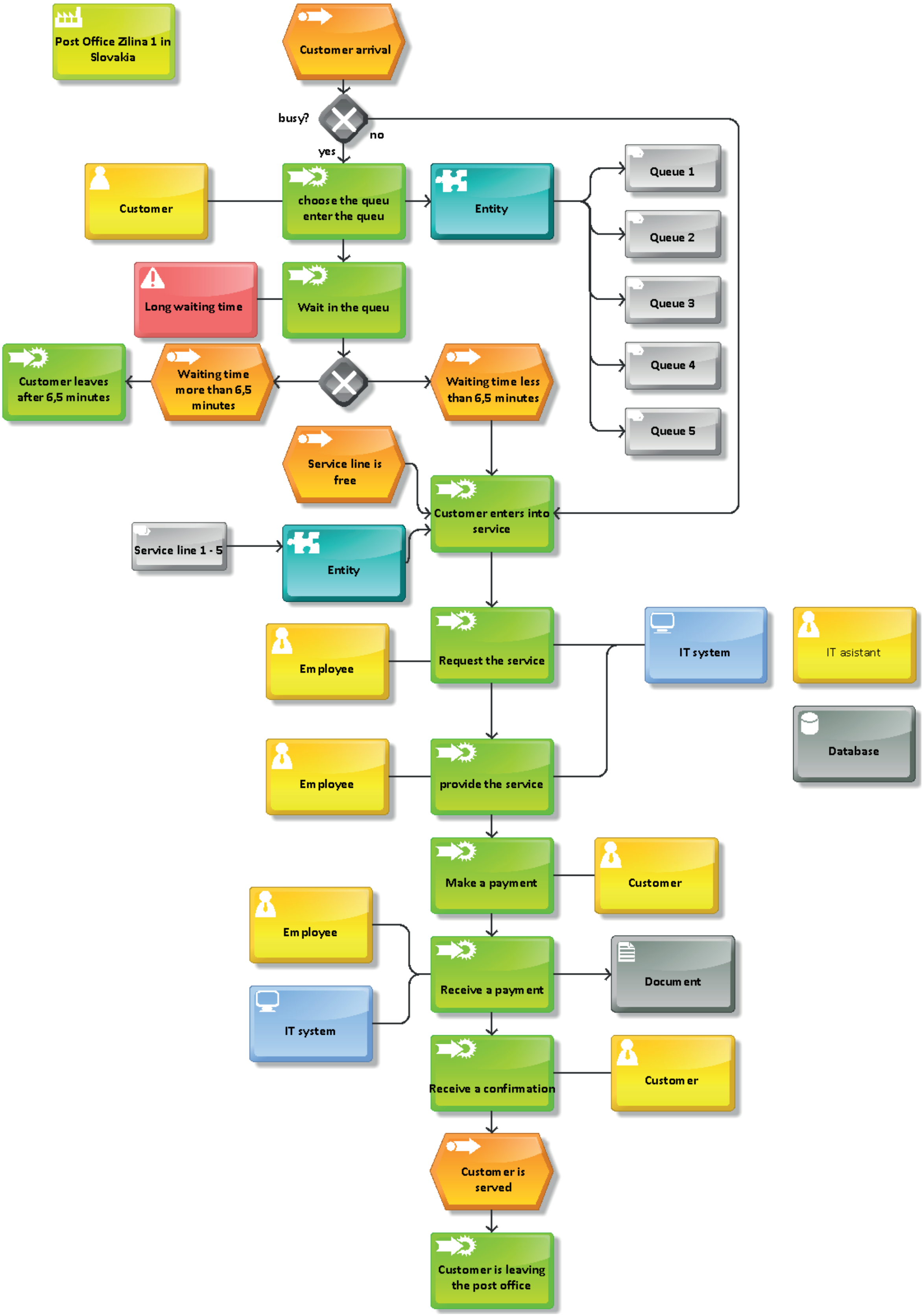

Figure 2 *Conceptual model of the post office queuing system*

condition is based on the results of a survey conducted in 2018 among postal customers. If a given counter is free, the customer enters the counter to be served. A post office employee works with an information system. With this system, employee is able to provide service to the customer. After the customer is served, he or she pays for the service.

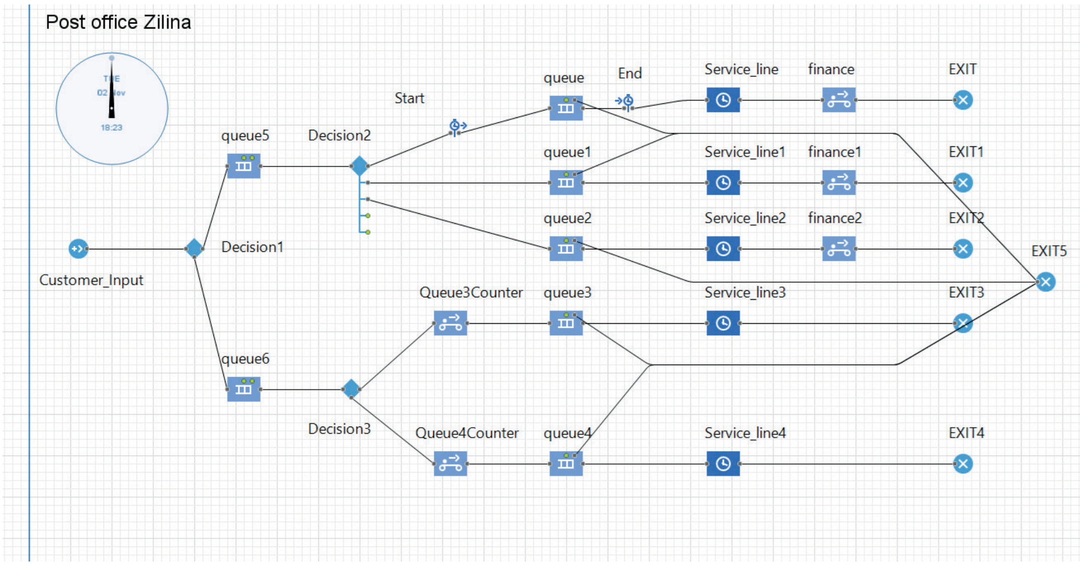

Figure 3 *The queuing model compiled in Anylogic simulation software*

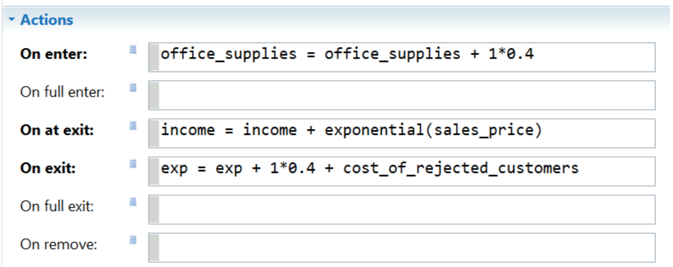

Figure 4 *Calculation of income and expenses in software Anylogic*

The customer is then served and the model ends with customer's activity - customer is leaving the post office. The whole process of functioning of the described model is presented in Figure 2.

4 Objective

The main objective of this paper is to design an application of a model simulating the queuing system of a fictional post office. Using the program, five simulation experiments were conducted. Based on the results of simulation experiments, it is possible to make further decisions about the system. Decisions are derived from the simulation experiments of a simulation model, which includes several variables and graphs.

5 Results

Design of the simulation model and results of five simulation experiments are presented in this section. The structure of the simulation model corresponds to structure of the conceptual model, which was defined in Figure 2.

5.1 Simulation model

The simulation model of a queuing system of a fictional post office, designed in Anylogic is graphically interpreted in Figure 3.

The simulation model (Figure 3) consists of following objects:

Customer_Input - which is defined by interval time. In this case it is exponential distribution with one parameter. The average customer input is λ = 2.20 minutes. Customer comes into the system (queuing model) for service. If they wait in the queue for more than 6.5 minutes, they leave the system without being served (refusal of service). This means the loss for the queuing system of the queuing model.

Decision 1 - customer has to decide if he wants to use service type number 1 provided by Service_line and Service_line2 or service type number 2 provided by Service_line3 and Service_line4. Probability for service type 1 is set up at 0.60. Probability of service type 2 is set up at 0.40.

Queue - after decision 1, customer chooses the queue. The logic is in always choosing the minimum queue. If queues are 0, the customer chooses the service line which is free.

Table 1 *Input data for simulation experiment 1*

	Time/minutes
Simulation Time	3600
Service Time	4.2
Customer Input	2.2

Table 2 *Input data for simulation experiment 2*

	Time/minutes
Simulation Time	3600
Service Time	4.2
Customer Input	4.4

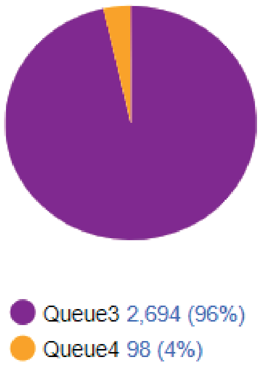

Figure 5 *Simulation 1 -utilization statistics*

Service lines - are defined by the delay time which is in this case the average service time with exponential distribution. In this case the average service time is μ = 4.20 minutes. Customers enter the counter providing the service from the queue (unless they decide to leave because of a long waiting time).

Finance - object Finance 5 is only for calculating expenses and revenue. Figure 4 displays calculation of income and expenses. The input data are fictional.

Model contains **exits 1-4.** There is also exit 5 for customers that decide to leave the queue after 6.5 minutes.

5.2 Simulation results

Several simulation experiments were performed in Anylogic simulation software. The first simulation experiment is based on input data from section 3. The rest of the simulation experiments are based on "what if" questions and are solved in the following parts of paper.

5.2.1 Simulation experiment 1

Simulation experiment 1 reflects current situation in terms of queueing in the service lines in a fictional post office. Table 1 display input data of the simulation experiment 1. Simulation time (3600 minutes) represents five business days. Opening hours in working days are 12 hours a day.

The simulation experiment 1 provided following statistics about the system:

- The final number of customers arriving at the post office within five business days is 7076 customers,
- The first three service lines were able to serve 4283 customers. According to customer numbers and individual service lines one can see that 74% of customers wanted the first type of services, which were served by Service_line and only 3.5% of customers were served by Service_line2,
- The similar situation happened in the case of Service_line3 and Service_line4. Only 2.69% of customers wanted the second type of services, which were served by Service_line4. Figure 5 displays percentage utilization of Service_line3 and Service_line4, respectively queue 3 and queue 4.

5.2.2 Simulation experiment 2

What if the customer input would be doubled? Solution to this problem provides the simulation experiment 2. Table 2 displays input data of the simulation experiment 2. In order to solve the problem the customer input is doubled.

The simulation experiment 2 provided following statistics about the system:

- The final number of customers arriving in the post office within 5 business days is 14 625,
- The first three service lines were able to serve 8744 customers. Only 8.5% customers were served by the Service_line2. It can be said that doubled customer input doesn´t have huge effect on the Service_line2,

Table 3 Input data for simulation experiment 3

	Time/minutes
Simulation Time	3600
Service Time	4.2
Customer Input	6.6

Table 4 Input data for simulation experiment 4

	Time/minutes
Simulation Time	3600
Service Time	4.2
Customer Input	2.2

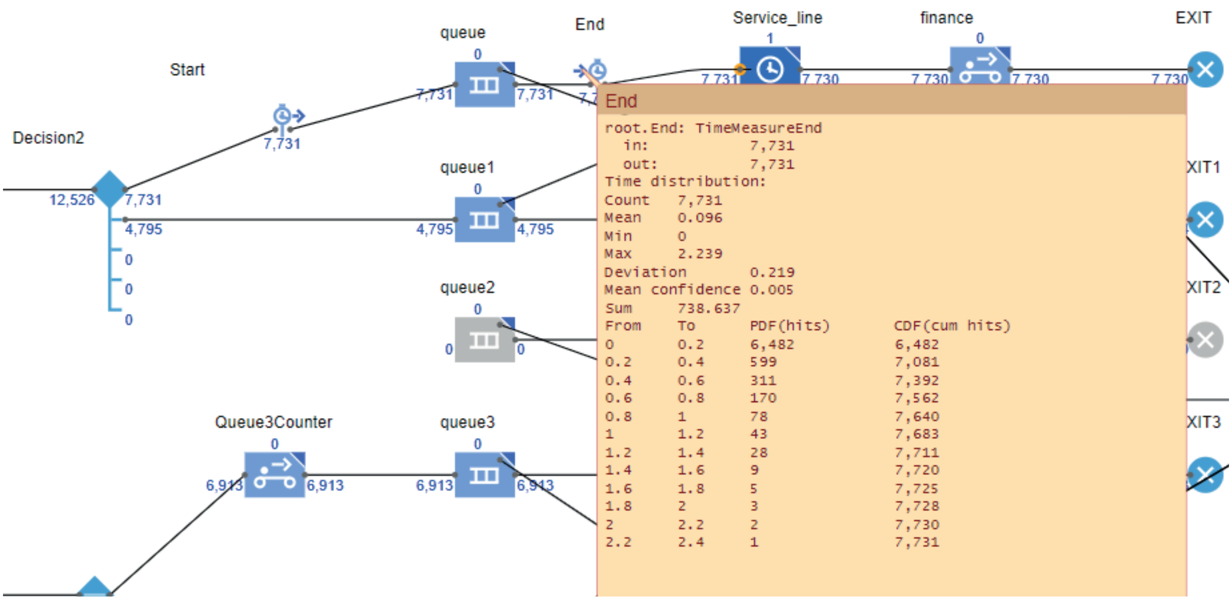

Figure 6 *Average waiting time statistics in simulation experiment 4*

- regarding theService_line4, the percentage change is even less, only 1.6%.

5.2.3 Simulation experiment 3

Simulation experiment 3 solves the following: what if the customer input would be tripled because of Christmas? Table 3 displays input data of the simulation experiment 3. The customer input data is tripled.

The simulation experiment 3 provided following statistics about the system:

- only 14.5% of customers were served by the Service_line2. It can be said that tripled customer input doesn´t have huge effect on the Service_line2,
- utilization of the Service_line2 doesn´t seem efficient; the same case is in the Service_line4, only 18% of customers were serviced by the Service_line4.

5.2.4 Simulation experiment 4

Another problem appears: What if Service_line 2 is closed? The simulation experiment 4 provides the solution to this problem. The Table 4 displays input data of the simulation experiment 4.

The simulation experiment 4 provided following statistics about the system:

- the waiting time for the service type 1 is no longer than 2.23 minutes even when Service_line2 is closed. System was able to serve these customers without any losses. Figure 6 displays statistics related to waiting time, for example the average waiting time or maximum or minimum waiting time in queue.

5.2.5 Simulation experiment 5

Last problem solved in this paper is bound to the question: What if the Service_line4 is closed? The input data of simulation experiment 5 are the same as in simulation experiment 4.

The simulation experiment 5 provided following statistics about the system:

- the waiting time for service type 2 is no longer than 3.10 minutes even when Service_line4 is closed. The system was able to serve these customers without any losses.

6 Conclusion and discussion

The paper examines the queuing system of fictional post office. Anylogic simulation software has proven to be a useful tool for modelling and simulating a queuing system. Using the program, five simulation experiments were conducted. These experiments were based on "what if" questions. "What if" questions were oriented to a change in customer input flow or a change in the number of postal counters. In both cases of a change in the customer input flow, the change does not have a huge effect on the system. The postal counters were able to serve doubled and tripled number of customers without any losses. The service_line2 productivity was low and only 3.5% of customers wanting service type 1 were served by this postal counter. Closing Service_line2 was done without any losses. Same situation can be seen in the case of Service_line4. Closing Service_line4 was done without any losses. The productivity of system can be increased by closing Service_lines2 and 4 and system will be still able to serve customers at a customer friendly waiting time. The major results obtained by the system provide the results that are helpful for making more decisions in the future.

The main objective of this paper was to design the application of the model simulating the queuing system of a fictional post office. The simulation model is functional and provides several statistics. This model also serves as a background for further research oriented to specific post office with specific input data. This kind of research requires a detailed analysis of a specific queuing system, identification of input parameters, their probability distribution, etc. An important phase in modelling the system is to build a model that matches the queuing system and creating it in simulation software. In the future, it is advisable to use Anylogic software for such research. Subject-oriented simulation experiments can result in optimization of the queuing system, new compilation of work schedules for post office employees, change in the number of postal counters or it can increase the system productivity.

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