USING THE ANYLOGIC SOFTWARE PRODUCT IN MODELING THE PASSENGER TRAFFIC OF A RAILWAY STATION

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The article is devoted to the search for optimal solutions for organizing passenger service at a railway station using simulation. The AnyLogic software system was used to build a discrete-event model and implement the procedure for modeling passenger traffic. To implement the task, a uniform distribution of passenger traffic was chosen. Many stages of passenger service have been implemented, such as entering the railway station, checking passengers through a metal detector, purchasing a ticket, using storage cells, as well as a café. As an additional service for passengers, a system of X-ray television introscopes has been used. All of these structures were used to distribute people around the railway station and to assess passenger traffic at the station. The study included tests to detect "bottlenecks" in the system of departure and arrival of passengers.

ИСПОЛЬЗОВАНИЕ ПРОГРАММНОГО ПРОДУКТА ANYLOGIC ПРИ МОДЕЛИРОВАНИИ ПАССАЖИРОПОТОКА ЖЕЛЕЗНОДОРОЖНОГО ВОКЗАЛА

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Статья посвящена поиску оптимальных решений организации обслуживания пассажиров на железнодорожном вокзале с применением имитационного моделирования. Для построения дискретно-событийной модели и реализации процедуры моделирования пасссажиропотока использована программная система AnyLogic. Для реализации задачи выбрано равномерное распределение пассажиропотока. Реализованы многие этапы обслуживания пассажиров, такие как вход в железнодорожный вокзал, проверка пассажиров через металлоискатель, приобретение билета, использование камер хранения, а также кафе. В качестве дополнительного сервиса обслуживания и ожидания пассажиров использована система рентгенотелевизионных интроскопов. Все эти структуры использованы для распределения людей по железнодорожному вокзалу и возможности оценки пассажиропотока на вокзале. Проведено тестирование на наличие «узких мест» в системе отправки и прибытия пассажиров.

Introduction

Railway and air transport are the main competitors in the market for services that provide mass passenger transportation over long distances. The duration and cost of the trip, as well as the quality of the range of services provided, determine the choice in favor of one or another type of transport. Taking into account these conditions, the level of service of railway transport as a whole does not fully meet the requirements of passengers. This is due to the fact that the quality of passenger service at railway stations was not given due attention. As you know, modern airports are trying to attract passengers with the best conditions of transportation and transit, a high level of various services, the presence of new amenities and infrastructure, while railway stations are developing in this area with a lower intensity. This article is devoted to the critical problem of finding optimal solutions for organizing passenger service at a railway station using simulation modeling [1, 2]. To achieve the goal, the following tasks have been set:
  • Investigate the peculiarities of the functioning of a railway station when serving passengers.
  • Determine the modeling method corresponding to the passenger service technology.

Methods

The key concept of the problem under consideration is passenger traffic. The management of passenger traffic is based on the following principle: it is necessary to organize the movement of a passenger in such a way that his path runs from point "A" to point "B", taking into account the fact that while passing this route, the passenger will perform a number of related actions. With regard to the railway station, the passenger can carry out the following incidental actions: visiting shops, receiving information about the arrival of transport on the scoreboard, moving from one platform to another (when transferring), etc.

Such features that arise during the formation of passenger traffic at a railway station make it necessary to introduce a number of special commands. It should be noted that the modeling of the system reflecting the specified passenger traffic depends on the time of day due to the instability and dynamics of the ongoing processes. In this regard, the concept of "time" must be formalized.

The stages of the study of passenger traffic are:
  • research of available passenger traffic on routes by time of day and days of the week;
  • research of the route congestion factor by time of day and days of the week;
  • analysis of research results;
  • new proposals for optimizing the service system.

The construction of a relevant model makes it possible to assess the effectiveness of the management decisions made and promptly respond to changes of various kinds, as well as to determine the development strategy of the railway station, taking into account the expected passenger traffic.

To build the specified model and implement the modeling procedure, the well-known software system AnyLogic was used, which allows using various types of simulation modeling: discrete-event modeling, system dynamics, or agent-based modeling. AnyLogic uses the Java programming language and the graphical model building language, allowing the researcher to supplement and extend the constructed models [3].

Taking into account the above-described features, a discrete-event simulation model has been developed in the AnyLogic software environment, which will allow identifying bottlenecks in passenger service processes at a railway station.

Results

Since the goal is to identify problem areas in the services provided by railway stations, it is necessary to have knowledge of the calibration of the simulated system. For this it is necessary to choose the appropriate probability distribution.

To implement the model of a railway station in the case under consideration, a uniform distribution is chosen. The model has five entry points: three on the front and two on the opposite side. The choice of this value is due to the intention to create asymmetry in order to determine the difference in the behavior of passenger flows entering the station from different directions. The number of arched metal detectors for entrance control, used by the security service of the railway station, was calculated from the ratio: for each entrance, the number of frames is set equal to the number of entry points. This approach provides an opportunity to increase passenger traffic without creating crowds at the first stages of model operation. Ticket offices are considered in conjunction with ticket terminals. In the model under consideration, the number of checkouts is less than the number of terminals. This was done in order to analyze the efficiency of ticket vending machines and assess the degree of reduction in the load on the box office. Thus, the model presents two cash desks concentrated in one place and eleven terminals distributed across the territory of the railway station in groups. Since the waiting area in train stations has no specific boundaries, the model uses one abstract waiting area, which is a defined rectangular area. The number of escalator groups delivering passengers to trains corresponds to the number of railway tracks (platforms). The experience of the operation of the largest railway stations in the world, in which there were on average fourteen tracks, shows that two platforms correspond to one group of escalators. Consequently, the model has seven escalator groups. The group consists of two escalators going in opposite directions [4, 5, 7].

Consider the process of forming a model of a railway station. The incoming passenger traffic at the start of the simulation is 300 people per hour. The initial 2D model of the railway station in the AnyLogic GUI is shown in Fig. 1.

An hour of operation of the model under the specified conditions showed that there were no difficulties with servicing that would entail long queues, which makes it possible to expand the model by adding new
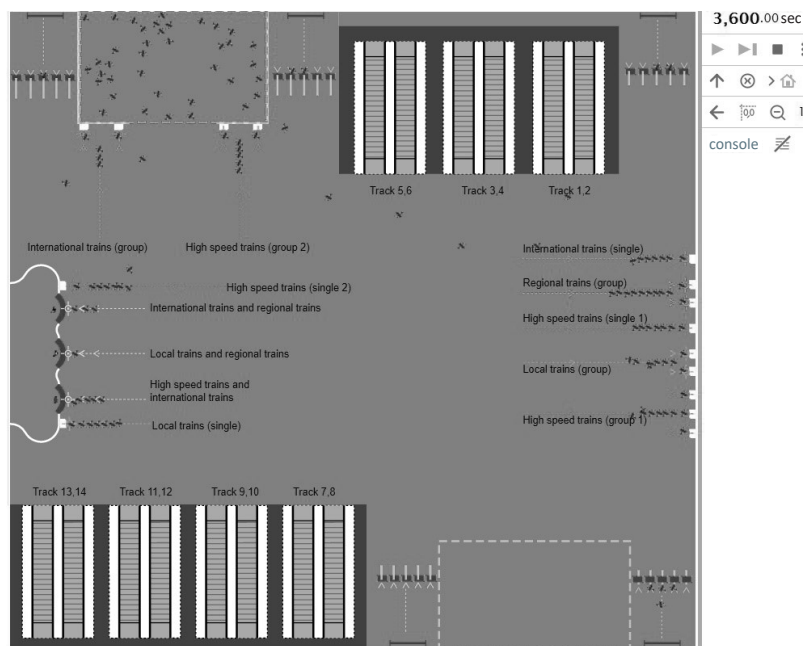

Fig. 1. Initial 2D model of a railway station in the AnyLogic GUI

elements to it. To remain competitive, a modern railway station must be able to provide various kinds of services, including such traditional ones as placing things in lockers.

There are two main types of storage rooms:

• Manual. The station employee accepts the baggage, determines the size of the baggage and allocates the appropriate cell for it, giving in return a receipt, with which the passenger later claims the baggage from the cell.

• Automatic. Mechanical: the cells are accessed using a lock. Electronic: a plastic smart card is used to open this type of cells.

There are two ways to use the service of automatic lockers:

• With the help of the station operator. The employee checks the passenger's passport, accepts payment and selects a cell, based on the size of the baggage, in return, issues a receipt.

• Independently. Terminals are used, with the help of which the passengers pay for the service themselves. Then a plastic smart card and receipt are issued. Using a smart card, the passenger opens the desired cell, independently choosing its size.

Practical experience shows that automatic lockers are actively spreading at large railway stations, which are used as an element of the process of self-service of passengers through the terminal. Based on this, it was decided to implement this service in the model in such a way that lockers are located in the current place of the waiting area, and the waiting area is located in the central part of the station [6].

The model with the specified advanced functionality is shown in Fig. 2.

Since, after the introduction of the new service, some of the passengers will use it, the load on the ticket offices will decrease, and, therefore, the model will need to be updated. It is necessary to increase the flow of passengers entering the model, assuming that in one hour of the model time, 1/6 of all passengers will use the storage services. Accordingly, given that initially the system includes a flow of 300 passengers per hour, it is necessary to increase it to 350 and distribute it among five PedSource blocks.

The territory of the station reserved for storage rooms is divided into 2 parts: a waiting line (Queue Baggage room) and a place for receiving services (Baggage room). To pay for the service, 2 terminals have been identified. If the terminals are occupied, the passengers wait, pay for the service and go to the lockers.
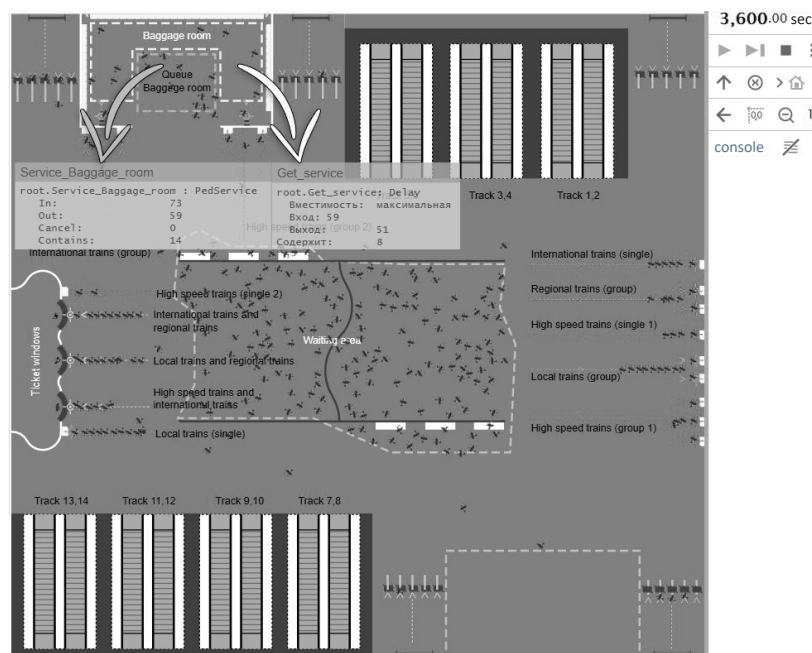

Fig. 2. 2D model of a train station enhanced by the introduction of automatic lockers

It is considered that passengers need 1 to 2 min. to receive a token. The terminal recovery delay time is 3-5 sec. The service itself takes 5-10 min.

Consider the new state of the model. For 1 hour of operation of the model, the queue was not formed, however, it should be noted that the risk of its occurrence appeared. Comparing the number of passengers waiting in line and the number of passengers using the baggage storage service, we can determine the following: with 51 people served, the queue is 14 people, and 8 people are currently in the process of receiving the service (see Fig. 2). The above estimate indicates that the model can cope with the current load, but it is recommended to improve it, otherwise, with an increase in passenger traffic, there is a risk of queues at this stage.

The analysis of the largest railway stations in the world also showed that in addition to the main activity related to passenger transportation, they have a number of additional services at their disposal, among them the main ones: shopping malls and various cafes [8, 9, 12]. Passengers should be able to wait for the train not only in a designated area, but also in other places, depending on their various interests. Let us add a service related to the provision of catering services to the model under consideration.

To implement a service providing catering services in AnyLogic, you need to use an element from the "Attractor" process modeling library. An attractor is a component that sets the exact position of an agent inside an area, as well as its orientation in space. There is an estimate that only 20 % of the total number of passengers visit cafes at railway stations. In this regard, it was decided to create 2 service points with one queue in the model. This addition paid off and did not lead to a large crowd of people.

It is known that at railway stations, special attention is paid to the safety of passengers, while taking into account the presence of people both on the territory of the station and outside, as well as on the platforms themselves. If arched metal detectors are installed at the entry points, which were mentioned earlier, then X-ray television introscopes are located at the exit points to the platforms. Such introscopes are of various types, the application of each of which depends on the specific field of activity. In the model under consideration, it is required to introduce introscopes that detect explosive, flammable substances and weapons in baggage [10, 11].

The implementation of baggage check using introscopes in the model is performed using services with queues. For paths with numbers 1–6, 4 services have been introduced, for each of which a queue is built. The same was done for paths numbered 7–14. To reduce the length of queues, security control is carried out selectively, following the instruction: "At least 50 % of the departing passengers must undergo the baggage screening process".

The following factor is important for the model: the process of servicing passengers at a railway station is not one-way, i.e., the passengers not only depart using the services provided, but also arrive. Using the features of AnyLogic software, it is possible to combine different types of models, implementing more complex processes. The process of passenger arrival is organized with the simultaneous use of 3 libraries: railway, pedestrian and process modeling [13].

Let's show how these libraries are used.

First of all, using the "Train_arrival_A" block from the railway library, a train is created on the railway at point "A". Then, the train stops for 1 minute and waits for passengers to board (blocks "Stop_A" and "Boarding_Back"), after which it goes to point "B", which is the simulated railway station. Passengers leave the cars by using the "Leave_train" block in the scheme, then the train waits at the station for another 1 minute and leaves. Within the developed model, this cycle is repeated every 8 min.

The second component of the scheme is the pedestrian library. The first block "Ped_from_A_to_B" creates pedestrians who move to the waiting area for the train. The "Retention" block is used to temporarily remove passengers from the system. Control is then passed to the process modeling library, which is the third major element in the arrival process and allows you to link different processes when developing the model.

Waiting for a train at point "A" is modeled by the "Stop_A" block, in the additional settings of which, in the "On entry" and "On exit" parameters, the freeAll () method of the "Waiting_for_train" and "Go_to_the_train" blocks of the pedestrian library is called. The ccl-port of the "Go_to_the_train" element must be bound to the input port "Waiting_for_train". This algorithm allows, after one minute, to put all the passengers in the waiting area on the train. In this case, passengers who were heading to the car, but did not have time to board, will be returned back to the waiting area until the next arrival of the train. We should also highlight the "Queue_for_boarding" block, which simulates the buffer of agents waiting for processing by the next block, thus creating a "queue". "Queue_for_boarding" connects to the inPickup port of the previously mentioned "Boarding_Back" block in order to "pick up" the agents (passengers) for their further movement to point "B" (to the train station). After the train reaches its destination, agents temporarily removed by the "Retention" element are restored by connecting the outDropoff port of the "Leave_train" block with the in-port of the "Recovery" block. Taken together, the presented elements simulate the process of passengers arriving at a railway station.

After arrival, each passenger with equal probability rises to the station building using one of the escalators. Then, 24 % of arriving passengers prefer to check in their baggage using the service of automatic electronic lockers, the rest leaves the railway station building [14, 15].

Fig. 3 shows a 2D model of a railway station with the adjustments outlined above.

In Fig. 3, one can observe the congestion of people in the area of lost baggage offices, since now not only departing passengers want to use the services of baggage offices, but also the arriving ones. Previously, it was noted that there is a risk of queuing at this stage of service. Consequently, the model needs to be adjusted again. Since with two terminals installed to pay for baggage lockers, there was already a possibility of large queues, doubling the terminals would lead to a similar result, since the number of people also doubled. Accordingly, in addition to two terminals that compensate the load, it is necessary to install an additional one that will reduce it. The result of the model adjustment is shown in Fig. 4.
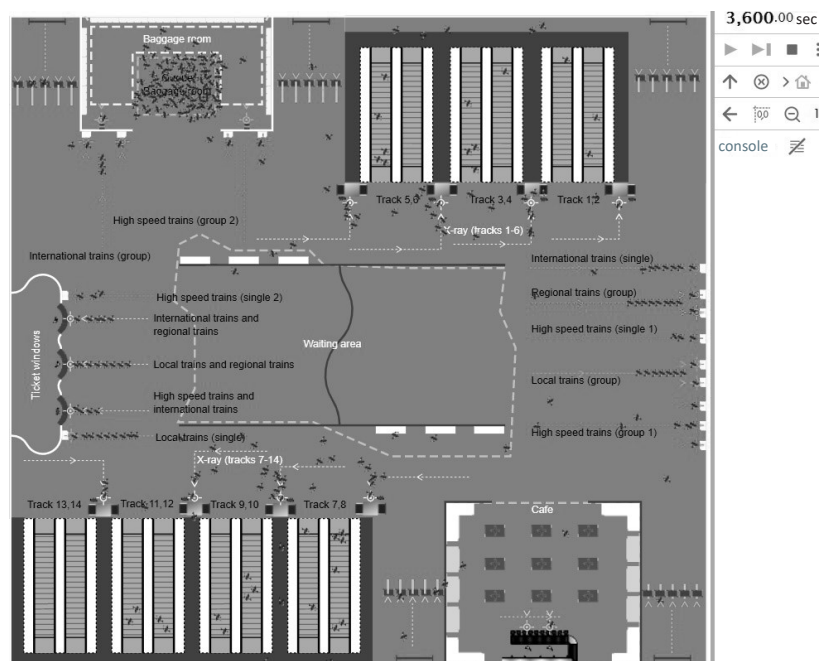

Fig. 3. 2D model of a train station with departing and arriving passengers,
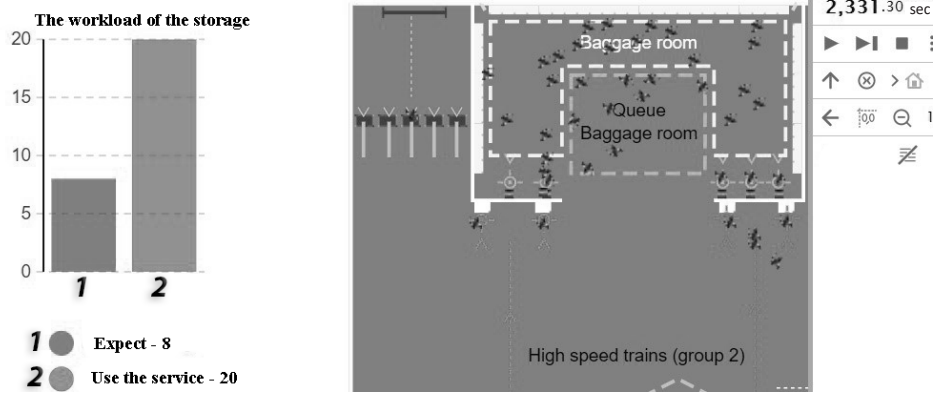with introscopes and cafes introduced

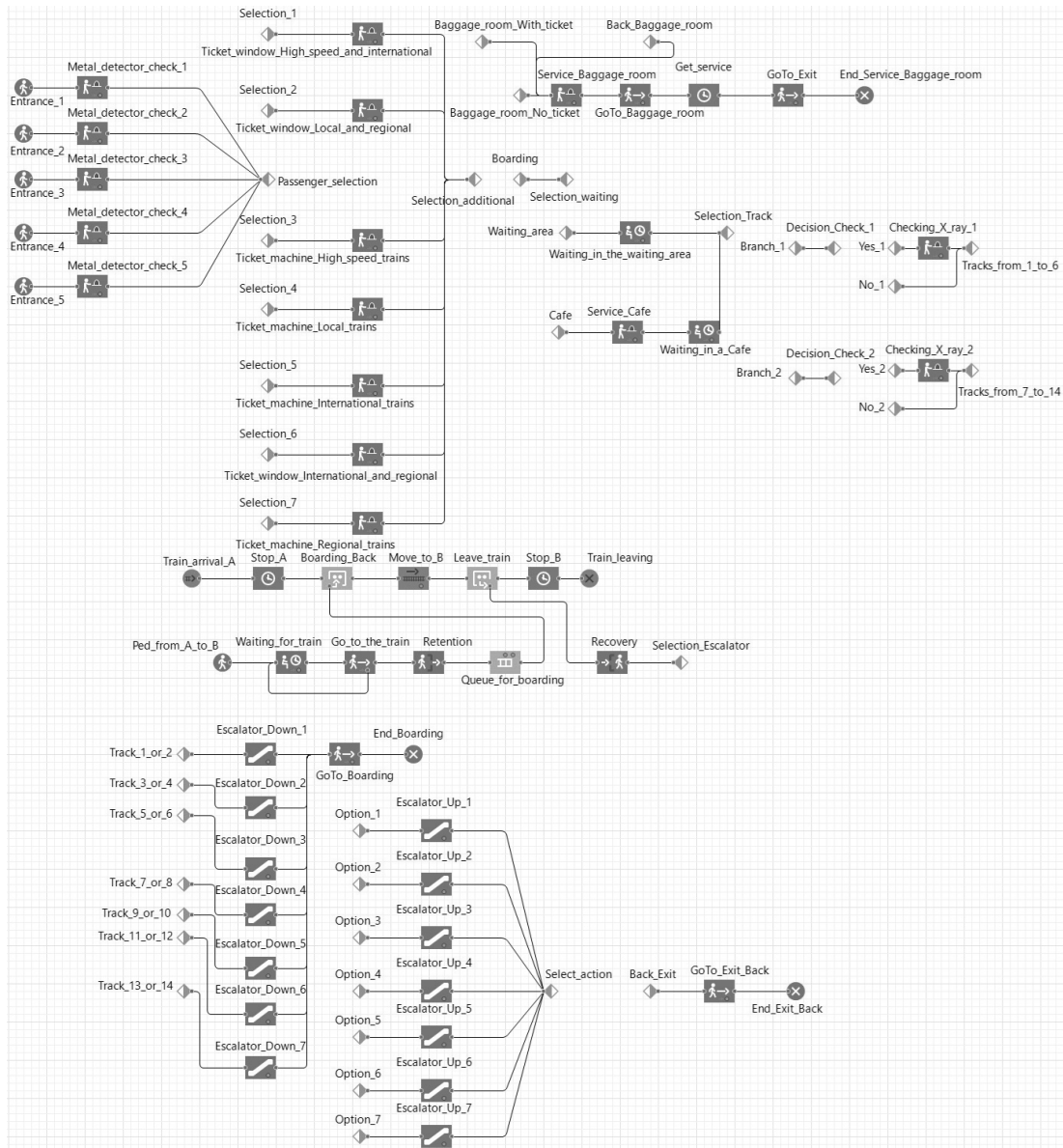Fig. 4. 2D model of storage rooms with a graph of their load

Fig. 5. Schematic of a model of a railway station

The time interval most at risk of queuing was selected for the assessment. In Fig. 4, the bar chart shows that out of 28 passengers present 20 are using the service and 8 are waiting for their turn, which indicates the correct decision [16, 17, 20].

Thus, a railway station was modeled, which includes the main modern services, the model diagram of which is shown in Fig. 5.

Discussions

After the formation of the model, it was tested with different amounts of passenger traffic, and the corresponding results were obtained based on the lengths of queues at each stage of service [18, 19, 29]. We also estimated the waiting time of passengers at each stage. It should be noted that in order to speed up the process of identifying bottlenecks, a passenger flow of 700 people per hour was set. The search results are shown in Table 1.

Table 1

Research results

	Queue length, person	Average waiting time in the queue, min
Incoming inspection	0	0
Ticket office (high-speed and international trains)	6	35.4
Ticket office (commuter and regional trains)	9	28.98
Ticket office (international and regional trains)	8	33.46
Ticket purchase Terminals (high-speed trains)	7	7.67
Ticket purchase Terminals (international trains)	20	44.34
Ticket purchase Terminals (suburban trains)	9	17.52
Ticket purchase Terminals (regional trains)	6	24.66
Cloakroom	4	7.43
Cafe	2	5.09
Inspection of baggage	19	2.35

The first thing you need to pay attention to is the workload of the baggage inspection service. In this case, the total queue for this service is 19 people, while the waiting time is less than three minutes, namely 2.35 min. The result is extremely optimal. Further, paying attention to the terminals selling tickets for international trains, you can see that the load was 20 people with a waiting time of 44.34 min. Considering the rather large workload of 700 people per hour, this figure is acceptable [21−23, 28]. If the load is reduced, the indicators will decrease proportionally, respectively, the model corresponds to an even distribution. With a given passenger traffic, the queue distribution schedule becomes uneven. This happens because all services, excluding the same type, have different specifics, differ in the principle of operation, and, as a result, the time spent by a passenger in each of the services also differs. Accordingly, in the aggregate visual presentation, the diagram reflects a system with a reduced level of abstraction, which has a positive effect on further decision making.

Conclusion

Thus, this article presents a workable model of a railway station, operating in a stable load of 700 passengers per hour, which is about 6,000,000 people annually. This simulated station, with a high probability, will be able to serve 3,000,000 arriving and 3,000,000 departing passengers without significant problems.

Simulation of passenger traffic in the AnyLogic environment allows solving several problems at once [24, 25]. In particular, it is possible to simulate the passenger traffic in the railway station as a whole, and to study the capacity in its individual parts.

It should be noted that those areas of the railway station territory where the service time was the highest or there was not a sufficient number of services were found to be the most exposed to the load [26, 27].

Further development of the model, in the interests of increasing the accuracy of the description of real processes, can be aimed at including knowledge about the train schedule.

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