Development of a Simulation Model of a Marshalling Yard

S. A. Tsyganov*, and *P. B.* Romanova

Samara State Transport University, 1st Nameless lane, 18, 443066, Samara, Russia

Abstract. Object: The purpose of this article is about using simulation modeling, and the choice of the simulation environment in the study of marshalling yards. Predicting the approach of trains to marshalling yards for different time periods is an essential tool for detailed planning of its operation. Methods: To research the operation of sorting stations, the simulation method was chosen. The method includes: agent-based modeling, system dynamics, discrete-event modeling. The process of arrival, processing and departure of trains at the marshalling yard can be considered as a discrete-event model. Its functionality is determined by the main factors: the probabilistic distribution of the times of arrival of requests and the duration of service; configuration of the service system; the number and productivity of service channels; the discipline of the queue. Findings: The result of the research was the formalization of the simulation model of the marshalling yard. Conclusions: The simulation model allows to do: - build further work plans for all station resources; - establish dependencies and patterns; - predict the state of the sorting system to mitigate or eliminate operational difficulties.

1 Introduction

In the conditions of the current economic situation, the conjuncture of the transport services market has a great influence on the development and functioning of railway transport in the Russian Federation [1]. To ensure the competitiveness of the industry, it is necessary to use the best management technologies. The development of railway transport is directly related to the development and implementation of intelligent control systems built on the basis of simulation models of stations and sections. A marshalling yard is a critical unit of operational work. This is where the cars are located most of their turnaround [2].

Forecasting the approach of trains to marshalling yards for different periods of time is an essential tool for detailed planning of its work. For subsequent optimization, it is necessary to create an integrated simulation model. In the conditions of the current economic situation, the conjuncture of the transport services market has a great influence on the development and functioning of railway transport in the Russian Federation [1]. To ensure the competitiveness of the industry, it is necessary to use the best management technologies. The development of railway transport is directly related to the development and implementation of intelligent control systems built on the basis of simulation models of stations and sections. A

*Corresponding author: stepan_tcyganov@mail.ru

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2 Methodology

To develop a simulation model of the marshalling yard, the Anylogic simulation complex was used [3].

This tool for researching objects has a number of advantages:

- significantly saves time and money;
- simplifies editing and analysis;
- automatically detects errors during development.

The main advantage of this complex is the ability to combine several approaches in model design: agent-based modeling, system dynamics and discrete-event modeling.

Agent-based modeling can be defined as a kind of simulation. The object is, first of all, the behavior of decentralized agents, and also determines the state of the entire system as a whole. The individual behavior of each agent forms the global behavior of the modeled system.

System dynamics is a direction in the study of complex systems, which makes it possible to understand their structure and dynamics. As a modeling method, it is used to create accurate computer models of them.

Discrete-event modeling is used to simulate the interactions of system components and study its capabilities. In this case, all possible states of the system are determined and the factors influencing the transition from one of its states to another are described. In this case, simulation is a dynamically changing state over time. It can only change at the time of the event.

3 Literature Review

The issues of organizing the work of the marshalling yard, improving the interaction between them, as well as the problems of improving the organization of car flows on the basis of mathematical methods are reflected in the works of Professor V.M. Akulincheva

Mathematical methods for studying the operational work of marshalling yards are reflected in the scientific works of such scientists as V.A. Kudryavtseva

The problem of organizing the movement of trains and the operation of marshalling yards is given much attention in the works of the following scientists: doctors of technical sciences Dyakov Yu.V.

In the works of E.V. Arkhangelsk, a study of the interaction of the elements of the station, the study of the relationship between the loading of marshalling yards and their capacity is given.

The work presents a methodology for determining the load levels of the main station devices, taking into account the reserves necessary to ensure their stable operation in the conditions of in-line uneven train traffic, the time for the current maintenance and repair of devices at the marshalling yard. Also considered is the issue of calculating the required capacity of the humps, the required number of tracks of the receiving and departure parks and the parameters of their work.

The author defines the elements of the average time spent by a transit car at the station. The time spent by the train in the receiving park includes the element of waiting, the time of performing technological operations upon the arrival of the train, as well as the idle time of trains awaiting disbandment.

A.V. Bykadorov carried out a comprehensive study of the processing and throughput capacity of the station, technology, equipment and determined that the throughput of the complex's devices for disbandment significantly decreases due to changes in the processing time of trains in the receiving park and the time of their disbandment on the hill.

In work, the authors set out a technique for analytical modeling of the operation of marshalling yards operating under conditions of high loads of their devices. The calculated dependencies, which form the basis of the method, are presented. The influence of feedbacks and other forms of interaction of station subsystems on the operational performance of the station is shown and their mathematical description is given. An algorithm and a computer program for an analytical model of a marshalling yard, compiled using the above dependencies and taking into account the mutual influence of its subsystems, are proposed.

4 Results

The process of arrival, processing and departure of trains at a marshalling yard can be considered as a discrete event model. Its functionality is determined by the main factors:

- the probabilistic distribution of the times of arrival of requests and the duration of service;
- configuration of the service system;
- the number and productivity of service channels;
- the discipline of the queue.

The simulation begins by simulating the appearance of a train on the approach to a marshalling yard. The Source block (picture 1) creates orders (trains arriving for disbandment).

Fig. 1. Source block.

Further, applications are sent to the Seize block, in which the condition of the presence of free paths in the reception park is checked. For this, the following condition must be met:

$$X_1 \geq 1 \tag{1}$$

X_1 - is the number of free tracks in the reception park.

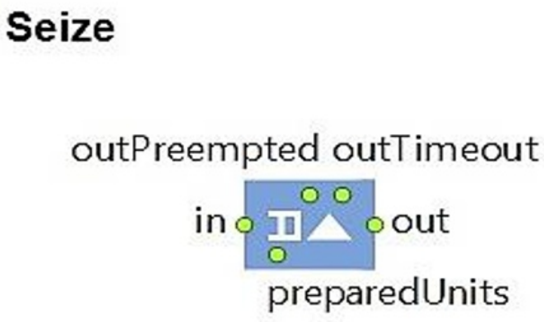

Fig. 2. Seize block.

If the condition is not met, then the applications are in the built-in queue in the Seize block until one of the paths of the sorted fleet is free. At this stage, the parking of trains at the entrance traffic light is simulated. This element is called "Reception Time".

When condition (1) is fulfilled, applications are sent to the Service block, which simulates operations for technical and commercial inspection on the way of the receiving park according to the technological process.

Fig. 3. Service block.

To perform this operation, it is necessary to have a free team of the technical inspection point of the reception park. Accordingly, the following condition is checked:

$$X_2 \geq 1, \quad (2)$$

X_2 - the number of free teams of the technical inspection point.

If the condition is not met, then the applications are in the built-in queue in the Service block until condition (2) is met. At this stage, the element "Idle pending technical inspection" is modeled.

If condition (2) is met, the request is delayed in the Service block for a time according to (3). At this stage, a technical inspection of the train is modeled.

The inspection time is modeled according to:

$$t_{\text{insp}} = \frac{\tau * m}{n}, \quad (3)$$

τ - inspection time of one car;

m - the number of cars in the train;

n - the number of groups in the teams of the technical inspection point of the reception park.

Further, the orders go to the Seize block in which the fulfillment of the condition of the free hump is checked:

$$X_3 \geq 1, \tag{4}$$

X_3 - number of free hump devices.

The fact of stopping the hill due to the insufficient capacity of the tracks of the sorting yard is also checked. If the conditions are not met, the orders remain in the built-in queue of the Seize block. At this stage, the element "Inspection waiting time" is modeled.

If condition (4) is fulfilled, the orders are placed in the Delay block in which they are delayed for the time of the composition disbandment, which is calculated according to [3].

Fig. 4. Delay block.

At the next stage, the accumulation and completion of the formation of trains in the sorting yard is modeled.

When exiting the Delay block, the orders go to the Batch block, in which the accumulation of cars on the tracks of the sorting fleet is simulated in accordance with the established specialization. Delay of applications in the Batch block is made for a time equal to the time of composition accumulation to the required weight and length. The delay will continue until the condition is met:

$$N_j = N_i \tag{5}$$

N_j - the number of cars on the track of the j-destination sorting yard;

N_i - the number of cars in the i-th train being formed.

Fig. 5. Batch block.

When an order approaches the Batch block, the following condition is checked:

$$N_4 \geq C_j \quad , \tag{6}$$

N_4 - the number of cars in the group sent on the track of the sorting yard;

C_j - free capacity of the j-th track of the sorting yard.

If condition (6) is not met, the application is sent to the Batch block. At this stage, the location of cars on the screening track is simulated. When a group of cars approaches this block, the following condition is checked:

$$N_5 \geq C_o \quad , \tag{7}$$

N_5 - the number of cars in the group sent to the screening track of the sorting yard;

C_j - free capacity of the screening track of the sorting yard.

In the case when the condition (8) is not met, the operation of the Delay block is stopped in which the operation of the hill to disband the trains is simulated.

$$\begin{cases} N_4 \leq C_j; \\ N_5 \leq C_O. \end{cases} \tag{8}$$

When conditions (8) are met, the Delay block continues to work. At this stage, the process of re-sorting the train is modeled.

After the requests are delayed in the Batch block, they are sent to the Service block, which simulates the end of the formation of the composition. Before entering the Service block, the following condition is checked:

$N_{мл}$ - the number of free shunting locomotives operating at the tail of the yard;

$N_в$ - number of free forming hoods.

If condition (9) is not met, then the claims remain in the built-in queue of the Service block. At this stage, the element "Waiting for the end of formation" is modeled. If condition (9) is fulfilled, requests are delayed in the Service block for a time equal to the time required to complete the formation of the composition.

The technological time for the end of the formation is calculated according to [5].

Further, the request enters the Service block. Here the transfer of the train from the sorting yard to the departure yard is simulated. To perform this process, it is necessary to have a free shunting locomotive and a free track of the departure fleet. When entering the block, the condition is checked:

$$\begin{cases} N_{мл} \geq 1; \\ N_{no} \geq 1, \end{cases} \tag{9}$$

$N_{мл}$ - the number of free shunting locomotives operating at the tail of the yard;

$N_{по}$ - the number of free tracks of the departure park.

If condition (10) is not met, the request remains in the built-in queue in the Service block. At this stage, the element of waiting for the relocation from the sorting yard to the departure yard is modeled.

Further, applications go to the Service block, which simulates the technical inspection of trains in the departure fleet. This operation requires the fulfillment of the condition:

$$X_5 \geq 1 \ , \tag{10}$$

X_5 - the number of free teams of the technical inspection point.

If the condition is not met, then the applications are in the built-in queue in the Service block until condition (11) is met. At this stage, a stand element is modeled awaiting technical inspection.

If condition (11) is met, the application is delayed for a time equal to the time required to perform a technical inspection of the train. The inspection time tosm is modeled according to (12).

$$t_{insp} = \frac{\tau * m}{n} \quad (11)$$

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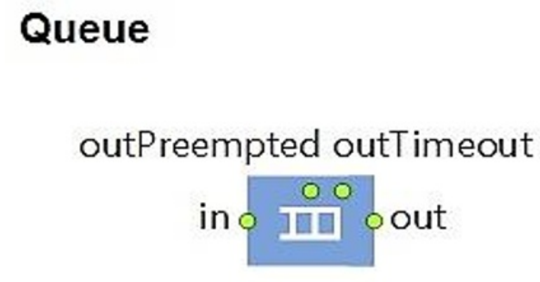

Fig. 6. Queue block.

Next, requests go to the Queue block in which the waiting for a train locomotive is simulated. As soon as a request (train locomotive) appears, the request (train), the Queue block combines them and sends them to the Sink block, which simulates the departure of the train for the haul.

5 Conclusion

The developed simulation model allows:

- to build further plans for the work of all station resources (PTO crews, locomotive crews, STC employees);
- to establish dependencies and patterns;
- predict the state of the sorting system to mitigate or eliminate operational difficulties.

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