Research Article

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Logistics of Trainsets Creation with the Use of Simulation Models

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Abstract: This paper focuses on rail transport in following the train formation operational processes problem using computer simulations. The problem has been solved using SIMUL8 and applied to specific train formation station in the Czech Republic. The paper describes a proposal simulation model of the train formation work. Experimental modeling with an assessment of achievements and design solution for optimizing of the train formation operational process is also presented.

Keywords: simulation models; Simul8; logistics problems; rail transports; train formation operational processes

1 Introduction

An important part of the technical base of railway transport and a significant position in the production process of rail transport have railway stations. These stations usually start and finalize traffic and transportation processes. The railway stations are involved in operating transit trains - called the station for the formation of trains. Solving technological problems in its technological structure is a need for a carrier structure of partial and complex decisions. Based on these decisions, it is possible to create enough situations and possible strategies to create the conditions for qualifying the optimal decisions. Besides the systemic methods for solving the problems of formation trainsets, the application of computer simulations in the form of construction of a simulation models are useful. Some methods, which uses simulation models in solving of logistic processes, were presented in [1–4].

2 Methods

For a description of the input wagons current of the system it is necessary to determine whether it is a deterministic or stochastic system. In stochastic systems, it is required to define the random number. Simulation models use random time intervals of entities processing.

2.1 Distribution function

When creating simulation models, especially in case of our application in train formation structures, there will be situations in which we need to reach a certain randomness processes such as demand, orders approaching, or the duration of a process [5, 6], what is called random number generation. Random numbers are independent values evenly distributed in the open interval (0, 1), which is denoted R (0, 1). Equitable distribution is the simplest continuous distribution, but it is used for generating values of other distributions. Basic features even distribution of the probability density, distribution function, mean and variance.

Distribution function [7–11] for a continuous distribution assigns to every real number \( x \) the probability that a random variable takes the value of less than or equal to \( x \),

\[
F(x) = P(X \leq x)
\]  

(1)

It is a non-decreasing function for which it is valid in interval \( 0 \leq F(x) \leq 1 \),

\[
F(x) = P(X \leq x)
\]  

(2)

The probability density is for continuous random variables expressed as a function

\[
f(x) = \frac{dF(x)}{dx}
\]  

(3)
for all real x, wherein

\[ f(x) \geq 0 \quad (4) \]

Normal, Poisson or Exponential probability distributions are mainly used to generate random numbers in trainsets process solutions. Such a random variable is reflected at random intervals that generate input entities, which in turn are fed into the simulation model. For the development of computer simulations arithmetic generators are primarily used. Because of a random number will finalize the calculation, we are talking about so-called pseudo-random numbers. There is a certain probability periodicity, but the current state of the art in computer technology, the period can seamlessly have length \(2^{64}\).

Random numbers have their place in simulation models to move closer to the real models. In this paper, we use the random variables in a way of affecting the execution time of various technological processes. These processes (in model) depends on human resources. Individual times of technological processes are derived from the average service times. These times are then affected by a random variable having a normal distribution with a suitably chosen times variance.

### 2.2 General plan of train systems

Moving wagons between deposition places, loading and unloading, is realized by inclusion of wagons to freight trains, which systematically displaces between railway stations. This process of inclusion of the wagons to trains, organization of freight trains on the railway network and related technological processes are a part of a broader conceptual activities in rail transport. Formation of train systems is the process of moving the organization of railway wagons - vehicle flows on the railway network for a certain period.

Tool-making train systems for specific and complex expression of the organization of vehicle current is a model of vehicle currents in organization – called general plan for train systems. The default groundwork for the train formation systems include a rail network carriage, currents of empty and loaded wagons, wagon routing streams and standards for utilization of a freight trains. The rail network needs to establish a plan of train formations and represent main stations, routing stations, border crossing stations and railway lines between these stations.

### 3 Solution

The project of the simulation model creation and working with this it can be divided into two basic parts. The first part is the design and creation (selection) of the simulation model, followed by the second part of experimenting with it.

#### 3.1 Designing and creation of the simulation model

In the process of designing and creating the simulation model, we follow in these steps:

- Formulation of the problem;
- Goals and desired model outcomes;
- Definition of a concept model;
- Input data obtaining;
- Model creation;
- Model validation;
- Model verification.

In terms of traffic management the train formation station and the dynamic system is complex. The aims of computer simulations, by using a simulation model of the planning operational processes in the train station Česká Třebová, are to investigate the following areas [11, 12]:

- The influence of changes in the number of target and starting operations of trains on train station operations;
- Scheduling service activities for the maintenance railway tracks;
- Reduction of operating costs by optimal use of all resources - optimizing operations in train station.

The subject of the model is a real system of the train station Česká Třebová. The monitored targets are entrance, departure and directional groups of wagons. When creating a model, it needs to be based on defined relationships between operational districts of the station, as a result of the technological processes. The finished model (final picture of the simulation model) is too big to be shown in this paper, but Figure 1 and 2 present the input and output sections of this model and gives an idea about the conception of the model.

The inputs of the simulation model are:

- Target train - number of trains on the level of differentiation according to the direction of travel and train session;
Transit train - number of trains on the level of differentiation according to the direction of travel (east, west direction) and the appropriate type;

Move the local loads of sidings - the number of attendants for the moving of railway wagons from the sidings.
Table 1: The results of the experimental modeling - basic characteristics monitoring (part 1).

<table>
<thead>
<tr>
<th>Monitored characteristics</th>
<th>Sim. Exp. 1</th>
<th>Sim. Exp. 2</th>
<th>Sim. Exp. 3</th>
<th>Sim. Exp. 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input current of transit trains type A</td>
<td>202 pcs</td>
<td>237 pcs</td>
<td>206 pcs</td>
<td>208 pcs</td>
</tr>
<tr>
<td>Input current of transit trains B, C, D</td>
<td>23 pcs</td>
<td>37 pcs</td>
<td>34 pcs</td>
<td>26 pcs</td>
</tr>
<tr>
<td>The no. of sets of trains – target trains</td>
<td>64 pcs</td>
<td>82 pcs</td>
<td>69 pcs</td>
<td>73 pcs</td>
</tr>
<tr>
<td>The no. of sets of trains – input trains</td>
<td>77 pcs</td>
<td>90 pcs</td>
<td>77 pcs</td>
<td>82 pcs</td>
</tr>
<tr>
<td>Number of railway wagons</td>
<td>2050 pcs</td>
<td>2610 pcs</td>
<td>2293 pcs</td>
<td>2361 pcs</td>
</tr>
</tbody>
</table>

Table 2: The results of the experimental modeling - basic characteristics monitoring (part 2).

<table>
<thead>
<tr>
<th>Monitored characteristics</th>
<th>Sim. Exp. 1</th>
<th>Sim. Exp. 2</th>
<th>Sim. Exp. 3</th>
<th>Sim. Exp. 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input current of transit trains type A</td>
<td>176 pcs</td>
<td>238 pcs</td>
<td>178 pcs</td>
<td>213 pcs</td>
</tr>
<tr>
<td>Input current of transit trains B, C, D</td>
<td>32 pcs</td>
<td>37 pcs</td>
<td>32 pcs</td>
<td>29 pcs</td>
</tr>
<tr>
<td>The no. of sets of trains – target trains</td>
<td>76 pcs</td>
<td>74 pcs</td>
<td>72 pcs</td>
<td>81 pcs</td>
</tr>
<tr>
<td>The no. of sets of trains – input trains</td>
<td>95 pcs</td>
<td>94 pcs</td>
<td>73 pcs</td>
<td>85 pcs</td>
</tr>
<tr>
<td>Number of railway wagons</td>
<td>2461 pcs</td>
<td>2398 pcs</td>
<td>2201 pcs</td>
<td>2721 pcs</td>
</tr>
</tbody>
</table>

Whereas the outputs of the simulation model are:

- Initial train - level of the resolution with direction and train session;
- Transit train - level of the resolution with direction and appropriate type;
- Supply of local loads on the siding - the number of operators for the supply of railway wagons on sidings.

The main simulation entity of the model is a railway wagon which is formed during the simulation. Railway wagon is formed during the transition entity called Target to feature directional group tracks. Entities, which moves through the simulation model, are routed and characterizes by the properties of the simulated model elements. To control the movement of the entities during the simulation, some attributes (descriptions) are assigned to those entities, so that they can be routed in different ways.

The total duration of a particular process depends on the sub-parameters, which are the length of the train, the number of empty and loaded vehicles included in the train, the number of disconnected units, which can be in various sessions. To ensure the needs of daily performing activities of the various sources in the model, a batching function is used, while a collect function is used for the waiting contingent processes. For proper execution of the assignment process to train, a certain target function is used like a batch type. Simulations run for experimental modeling is set in the period of 24 or 72 hours. Time simulation begins at 0:00 pm and ends at 24:00 pm on the first or third day. Experimental modeling is carried out with a set of interval entities entering the system, which are managed by an exponential probability distribution.

3.2 Simulation experiments

Roadmaps experimental modelling is in line with the aim of optimizing the design processes, including the examination of the impact of restrictions on the transport infrastructure in the event of accidental maintenance work on the formation trainset. In the experimental modeling the following operating situations are reviewed:

- Human Resource Management - assessment of options for optimizing the status of the operators at the maximum and minimum real workload;
- Technological procedures - considering the necessity of carrying out the technological processes in the group around the train entrance;
- Transport infrastructure - the possibility of limiting the number of station tracks in the entry and departure of the train station;
- Dynamics in a number of target trains in train station in the way of human resources needed for operations continuity.

4 Results

Based on the simulation experiments, a set of optimizations processes for rigs of various types of trains were formed in the way of human resources needs. The simu-
lution experiments also provided faster results that served as input data for the planning and evaluation of train formation work as well as the forecasts of the current relational wagon trains. Practical benefits of a simulation model include the possibility of doing simulation experiments and the gathering of data for optimization opportunities of train formation operational processes. Table 1 and 2 presents results of simulation experiments focuses on number of railway wagons and trainsets processed for a given time.

5 Conclusion

The creation of a simulation model is primarily used for the optimisation of the partial technology, the work of transport operators, the rolling stock roster and railway technology workflow. Outputs of the simulation experiments are shown in Tables 1 and 2. From the results of the simulation experiments it is possible to estimate the amount of the train system that can leave the railway station and the plurality of carriages needed for this purposes. However, results of simulation experiments depend on the random variables that are used for this purposes.

Train formation operational processes are closely related to the operations of the railway transports segment. For the management of the transport company engaged in the business processes, it is important a systematic evaluation of operational processes with a strong pressure on the continuous search for different ways to restructure processes. This contribution, to its content, focused on the application of computer simulation in rail transport systems by creating a simulation model of the train formation operational processes on the transport network in the Czech Republic. Moreover, the simulation model is used by professionals in the logistics business to successfully manage and positively regulate operational processes on traffic areas of business, especially in the Česká Třebová train station. The simulation experiments pointed to the possibility of train formations operational processes optimization steps, including verification of transport infrastructure capacity, for the case of solving different logistic situations in praxis. Simulation models are also a powerful tool for estimating the effects of interventions in train formation operational processes and changes in the load of trains in the use of managers and therefore as an instrument of the economical optimization processes and the success of the transport business.

References