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Level of Detail of the Simulation Model and its Influence on the Result Accuracy

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Abstract

This paper deals with the evaluation of the level of detail and depth of the simulation model on the resulting accuracy of the simulation and its time intensity. Using the import of infrastructure data, various models of the same regional line were created in variants according to the accuracy of the entered data. Based on a comparison with the movement of a real vehicle, a level of detail was determined that does not affect the results of the simulation from the perspective of the carrier or the customer. The results of this research will help in the preparation of simulation models of more complex parts of the network.

Keywords: railway infrastructure; simulation; OpenTrack;

1. Introduction

In addition to mathematical modeling (Vojtek, 2020) of (Bulíček, 2018), simulation of railway traffic has become an integral part of scientific research activities (Kornaszewski, 2019), project preparation of transport structures (Ricci, 2009) and the creation of models of state transport services (Abramović, 2020) or other territorial units. (Šipuš, 2020). The cornerstone of a correctly performed simulation is the preparation of the model. Each model is a picture of a real infrastructure and its preparation will take many hours of work. Of course, it is not always necessary to use the same depth (detail) of the model. In some cases, some simplification is possible. However, each simplification brings more or less distortion of the result compared to the real state. This article aims to present a model of a selected track in variants with different depths of detail and to show the effect of these simplifications on driving time compared to reality. The record of the vehicle's journey on the selected track was chosen as a basis for reality. One of the ways to enter the infrastructure into the model is the import of infrastructure data. This method

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allows you to import data in the highest amount of detail. However, the resulting model is then complex and places high demands on computing power. Another aim of this article is to present the dependence of the depth of detail of the model on the resulting driving time and to determine what simplification is still acceptable.

There are many simulation software (C. J. Goodman, 1998) and utilities (Ho, 2002) in the world, which are able to simulate various parts of a railway infrastructure or whole systems (Fernández, 2019). Scientific papers and research most often deal with optimization criteria, methods or operating conditions (Wei, 2015). A separate chapter is a set of articles, which deal with the timetable stability, and the impact of delays on the quality of transport services (Wales, 2015). However, it is not usual to focus the issue of the depth of detail of infrastructure input data. This parameter is not mentioned in the literature, although the complexity of the model is directly dependent on the length of its preparation and the complexity of the computational capacity. At the same time, the probability of error increases with a higher level of detail. In (Fernández, 2019) the many categories of modelling methods are mentioned, but no one deals with influence of infrastructure detail level on simulation results. Also neither (Altazin, et al., 2020) nor (Burdett, 2016) do not mention the influence of infrastructure level or infrastructure data quality used for simulation model.

This research was conducted in the simulation software OpenTrack, which is commonly used by authors and it is used worldwide for solving tasks in the field of railway transport, for example (Chen, 2014), (Tischer, 2020) or (Harrod, 2019).

1.1. Preparation of the model

Model preparation in OpenTrack software is a standard process and is the first step in every use of this software. In the case of this research, however, multiple data preparation for this simulation model was performed. For clarity, these models were marked as follows:

- Manual model 1 – this model takes into account the model situation that the simulation is performed by a civil servant without the possibility of access to information about the infrastructure,
- Manual model 2 – this version is a modification of the previous model with the addition of some parameters such as the height positions of other points on the track,
- Manual model 3 – again, this is a modification of the previous variant. Based on a video sequence from this track available on the Internet, a modified speed profile with restrictions was inserted into the model,
- Import of data – it is the import of data of the infrastructure manager in maximum detail directly into the simulation software. It is based on CAD or GIS data or on its combination.

1.2. Railway infrastructure

Based on the fact that this research was created as an output of the ITI project solution within the Hradec-Pardubice agglomeration, and since its partner is the Správa železnic, s.o. a regional railway from the Pardubice region, specifically Moravany - Holice - Borohrádek, was chosen as the model infrastructure. On this line, the transport is organized according to the SŽ regulation (CD) D3. To compare the data from the models, a test drive was performed in the section Moravany - Borohrádek and back in order to obtain the track tachograph of the real vehicle, which is shown in Figure 1.

Fig. 1. Railway vehicle ČD 810

Apart from infrastructure data, the model was provided with only a minimum number of other points. These include stops and stations and entry and exit signals at terminal stations (Borohádek and Moravany). Other parameters of the infrastructure were neglected due to the fact that the output should only be the travel time from the starting point to the destination stop in even and odd directions. The line speed was set to 60 km·h^{-1} for manual models, which is the highest allowed speed on the D3 line.

2. Manual model 1

The first variant of the manual model is based on the assumption that the model in the OpenTrack software is created by a government employee without the possibility of obtaining data on the transport infrastructure. His model will be based on publicly available map data, from which he will be able to read the kilometric position and altitude of individual stops. An example of data for this model is shown in Figure 2.

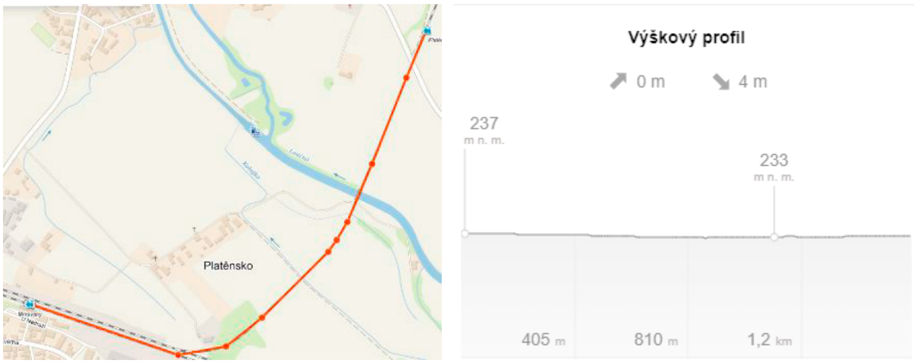

Fig. 2. Data collection for the Manual model 1 (Left – direction profile, Right – slope profile)

In this way, it is possible to obtain infrastructure data relatively quickly and efficiently and prepare the model for simulation. The disadvantage of this solution is the ignorance of terrain breaks between the stopping points and also the ignorance of the speed profile of the track.

3. Manual model 2

The second variant of the manual model is based on the assumption that longer time is used for the preparation of the model and that other double points are also included in the model in the form of terrain breaks between stopping points. An example of the data is shown in Figure 3.

Fig. 3. Data collection for the Manual model 2

In this way, the model can be improved by points that mean breaks on the track from the point of view of terrain height. Ignorance of the speed profile of the track also persists here.

4. Manual model 3

The last modification of the initial state added to the model the actual speed profile of the line with local restrictions. It is mainly a reduction of speed at crossings, in the village of Holice and also the long section in front of the station Borohrádek. Most of these restrictions are at 45 $km \cdot h^{-1}$ on a several hundred meters of track. Also in this case, a map base was used to calculate the length of the section with limited speed. However, the resulting model shows spatial inaccuracies, which are given by converting the position from the video sequence to the map.

5. Import of data

This method of preparing a simulation model is no longer in the power of public administration. This involves importing data directly into the simulation software, which requires access to this data from the infrastructure manager. The advantage of this import is the fact that the data of parameters of individual points on the infrastructure are very accurate and the distance of individual points is from meters up to tens of meters. The disadvantage of this import is the large number of points, which can reduce the computing power of the computer and for longer sections of double-track lines could cause a huge increase in the length of the simulation. At the same time, the clarity of such a model decreases. The model was built and uploaded into the OpenTrack software by importing data via the ivt format. In this way, more than 1,100 points were uploaded to the two files. All these points only represent the changes in inclinations. The model was not clear and in addition the Platěnice, Roveň and Holice stops were omitted. The total used time of model preparation was significantly longer than in previous variants. The disadvantage is also a homogeneous speed profile without changes in line speed. If the model were supplemented with these data, dozens of additional points in the model would be added.

6. Results

A simulation was performed for each of the models and a timetable was generated. The train in the direction of Borohrádek left at 8:00, in the opposite direction at 9:00. This timetable was compared with a real vehicle driving record. The first special ride took place in cooperation with ČD, a.s. on July 11, 2020. Unfortunately with the result in Figure 4.

Fig. 4. Deadlock of the first special train

The second ride on July 20, 2020 was already successful. All values for the direction Moravany - Borohrádek are presented in Table 1. The opposite direction is shown in Table 2.

Table 1. Time table of the train Moravany – Borohrádek.

Station	Manual model 1	Manual model 2	Manual model 3	Import of data	Real time table
Moravany	8:00:00	8:00:00	8:00:00	8:00:00	8:00:00
Platěnice	8:02:12	8:02:12	8:02:24		8:02:14
Roveň	8:05:14	8:05:14	8:05:24		8:04:54
Holice	8:11:06	8:11:06	8:11:31	08:11:19	8:10:22
Holice zastávka	8:15:35	8:15:35	8:16:11		8:15:10
Borohrádek	8:21:50	8:21:50	8:23:19	08:23:57	8:21:14
Total running time	0:21:50	0:21:50	0:23:19	0:23:57	0:21:14

The total driving time is the same for variants 1 and 2. It can therefore be seen that minor adjustments to the slope conditions do not affect the calculation of the driving time. For variant 3, the driving time has already been increased by 1.5 minutes. It is therefore clear that partial line speed restrictions have a significant effect on the resulting driving time and it is not possible to downplay it when preparing the model. The last variant offers the worst driving time, mainly because it does not have a real speed profile, but only a constant speed of 45 $km \cdot h^{-1}$.

Table 2. Running times of the train Borohrádek – Moravany.

Station	Manual model 1	Manual model 2	Manual model 3	Import of data	Real time data
Borohrádek	9:00:00	9:00:00	9:00:00	9:00:00	9:00:00
Holice zastávka	9:05:36	9:05:36	9:06:07		9:06:01
Holice	9:09:44	9:09:44	9:10:40	09:12:38	9:09:23
Roveň	9:15:33	9:15:33	9:16:44		9:15:12
Platěnice	9:18:36	9:18:36	9:19:47		9:18:13
Moravany	9:20:49	9:20:49	9:22:10	09:23:58	9:20:35
Total running time	0:20:49	0:20:49	0:22:10	0:23:58	0:20:35

Also in the opposite direction, the difference is only in the third variant, about 80 seconds. The variant with the maximum accuracy of inclinations is similar to that in Table 1. Interesting data are from the real time column where we can see that the real train is running a little bit faster than the manual models. That is because the real train was running thru the stops Roveň and Holice zastávka.

Figure 5 shows the output from the OpenTrack software, which captures a comparison of both approaches to entering data on inclination ratios. In the upper picture there is a reduced profile with breaks only at the stops and peaks of significant climbs and in the lower one there are absolute slope ratios.

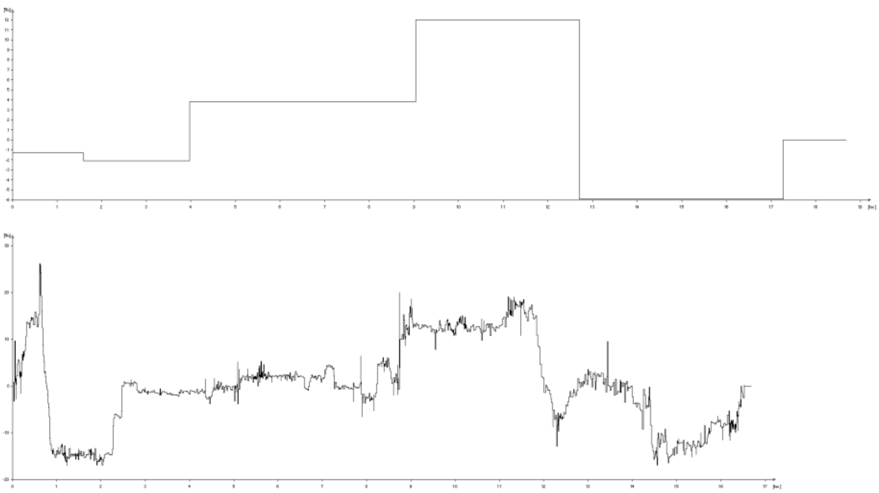

Fig. 5. Comparison of the reduced (upper) and full (lower) profile of line

7. Conclusion

Today, simulation models are a common part of the preparation of operational concepts and new transport structures. Their results can significantly affect the parameters of the future construction, including the price, and ensure optimal fulfillment of the timetable and its stability. In this paper, the effects of setting various parameters on the simulation accuracy were investigated. It was found that the most important parameter is the correct setting of the speed profile. In contrast, the precise setting of the slope ratios does not play such a role compared to a qualified estimate and observation. On the other hand, from the point of view of railway mechanics, it is clear that this fact will only apply to light passenger trains. For freight trains, this approach could be used to determine the maximum permissible train weight for a given line and engine.

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