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COMPUTER MODELLING AND SIMULATION OF RAILWAY OPERATIONS ON THE LINE VARAŽDIN – DALJ

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Abstract
In this paper the application of OpenTrack software for computer modelling of the line from Varaždin to Dalj is presented. It is 249,839 km long single track line with 25 railway stations and 32 additional train stops. The created model was tested on trains running times calculation where the comparison of simulation results with the official timetable data planned by infrastructure manager proved the quality of the model. In addition, comparison of energy consumption between diesel multiple unit (HŽ series 7121) and the train powered by diesel electric locomotive (HŽ series 2044) with five wagons is carried out.

Keywords: Railway line Varaždin - Dalj, computer modelling, simulation of railway operation

Introduction

The railway line from Varaždin to Dalj is 249,839 kilometres long single track line. It is a non-electrified line with 25 railway stations and 32 additional train stops [3]. The line is equipped with mechanical, electro-mechanical and relay interlocking systems for local traffic control with a station distance train separation method. The railway line Varaždin - Dalj is dedicated for mixed train traffic of domestic and international transport. In this paper the main points in creation of microscopic model of the railway line from Varaždin to Dalj will be presented.
The application of simulation modelling on the line Varaždin - Dalj should allow the testing of the timetable stability and help to define possible measures in order to improve the railway operation. Regarding that the model will be tested on two example scenarios. First one is related to comparison of running times of the trains calculated during the simulation process with the official timetable data planned by the infrastructure manager. The second example is related to energy efficient train driving.

Modelling of railway line Varaždin - Dalj in OpenTrack Simulation Software

OpenTrack is software for modelling and simulation of railway systems. It was developed at the Swiss Federal Institute of Technology's Institute for Transportation Planning and Systems (ETH IVT) [1]. Today, this railway simulation tool is used by railways, the railway supply industry, consultancies and universities in different countries. In this paper OpenTrack is used for creation of microscopic model of railway line from Varaždin to Dalj and for simulation of rail operations based on the real data about the infrastructure, rolling stock and timetable which are necessary for modelling the railway system which can be used for simulation of real railway operations.
For simulation of a railway system in OpenTrack three groups of data are necessary (Figure 1):

- infrastructure,
- rolling stock and
- timetables [2]

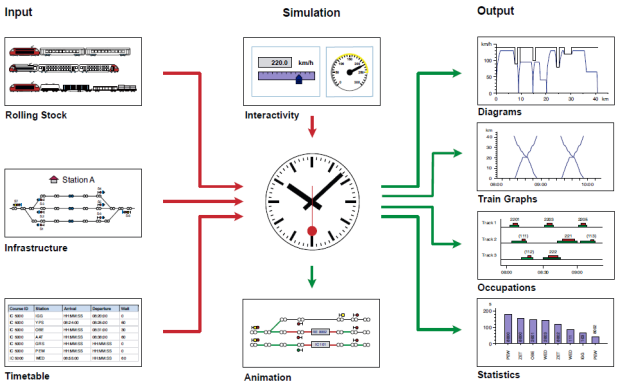

Fig. 1. Structure of the OpenTrack simulation software Source: [2]

This program can be used for testing of different variants of railway timetable, analysis about the influence of railway infrastructure modification or different rolling stock solutions on the rail operation. In this work, OpenTrack was used to define some possible traffic disturbances or take infrastructure out of service to evaluate alternative traffic scenarios on the line. It was also applied for testing and comparison in use of different types of rolling stock and to evaluate and test infrastructure plans and operating schedules to optimize the timetable on a defined railway line.

Infrastructure layout data consists of a description of the physical infrastructure that is being simulated. This includes actual infrastructure such as track segments like edges, signals, stations, vertices and routes.
Type of the railway line longitudinal profile document used for the modelling of railway line from Varaždin to Dalj is presented in Figure 2.

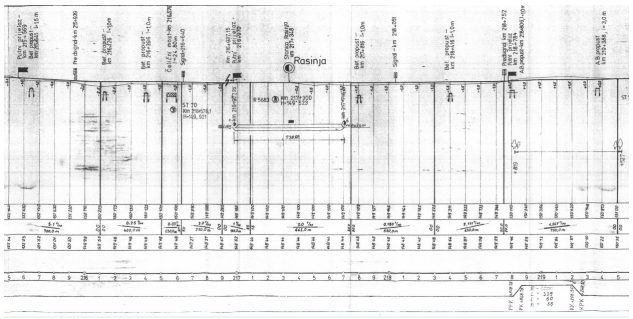

Fig. 2. Type of the longitudinal profile document Source: [4]

Based upon signalling maps given by the infrastructure manager the infrastructure layout was created. The provided maps start at Varaždin railway station and stop at station Dalj. The speed limits and the positions of all relevant signals were introduced in the model.
Rolling stock consists of locomotives and wagons which are combined to form models of trains. Every train composition model consists of one or more locomotives trailer loads. In the model the database of locomotives, DMUs and EMUs is created and it is available for use in the simulation process.
From this database the requested train can be chosen and extended by the length and the weight of the wagons. Thereby 100 % utilization of the tractive-effort-diagram is supposed to accelerate the model of train and deceleration of 0.6m/s² is supposed. The simulation model of the railway line from Varaždin to Dalj was made on two worksheets. On the first worksheet is the computer model of railway line from Varaždin to Koprivnica and on the second one is the line from Koprivnica to Dalj. After the infrastructure model was made the next step in development of the simulation model was defining of routes, paths and itineraries. During the simulation process, if a route is required by a train, it will be reserved for this train only if it is not reserved for another one and if an edge belonging to the route is not reserved or occupied.

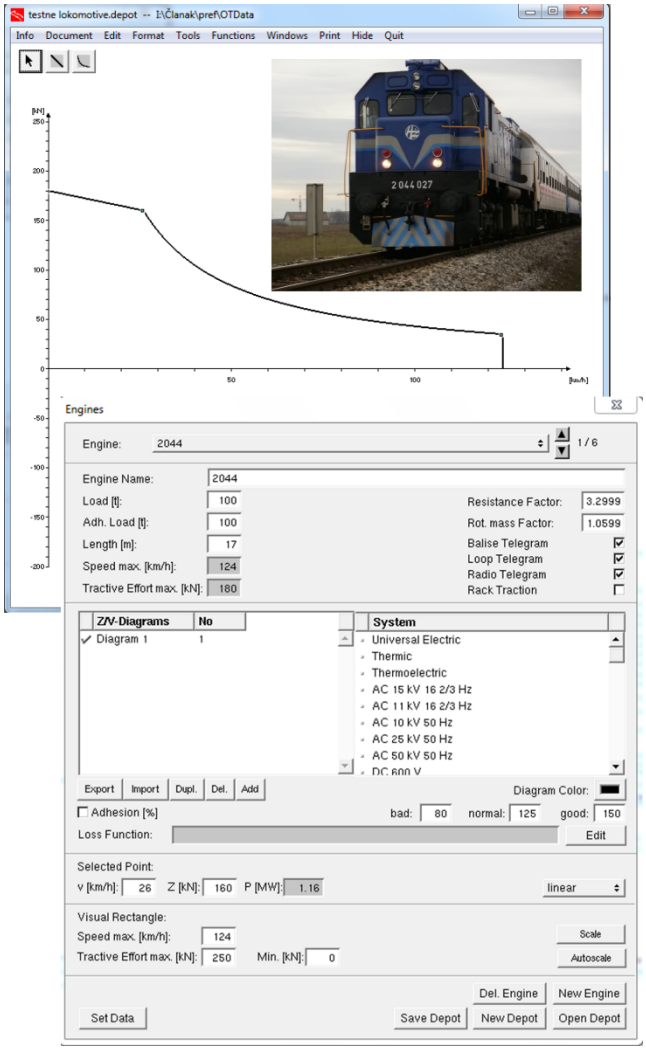

Fig.3. Modelling of engines and trains

The second level of train operation definition in OpenTrack is called a path. Paths consist of series of successive routes in one direction of travel. In the single path unlimited number of routes can be included. The top level of train operation infrastructure definition in OpenTrack is called an itinerary. An itinerary consists of one or several successive paths [2]. The next step of making a simulation model is defining courses and services. In OpenTrack a course consists of a set of itineraries with an associated set of timetable entries, a train definition, a course number, a train category, and an entry speed.

Simulation of railway operation on the line Varaždin – Dalj

A simulation can be made in real time or accelerated in any time interval of the day. OpenTrack can simulate various incidents which can be used for testing of the timetable stability. Figure 4 shows the layout of the Koprivnica railway station and animation of train 3607 during its movement in the station. Figure 5 shows the timetable simulated in OpenTrack for the line from Koprivnica to Dalj and figure 6 is showing timetable for the line from Varaždin to Koprivnica [5]. The created model of the railway line from

Varaždin to Dalj was tested on running time calculation for all trains in the timetable. The running times calculated by simulation of railway operation where the same as they are previously planned by infrastructure manager in the official timetable. By this the quality of model was proved. After the simulation process output data can be displayed in a variety of charts and tables. Figure 7 shows the speed profile of the train 3607 on the line from Varaždin to Koprivnica.

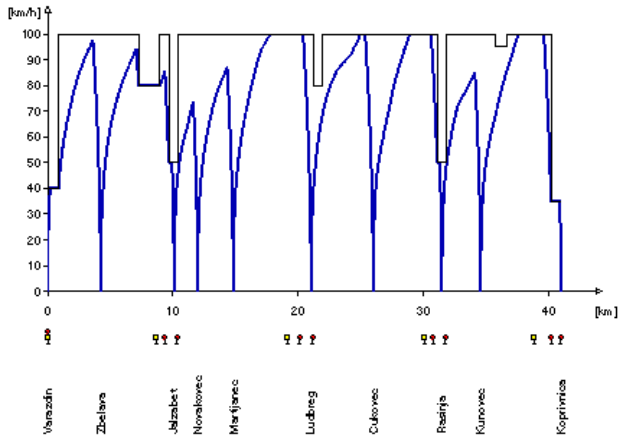

Fig. 7 Speed profile of the train 3607

The second example shows the difference in energy consumption between diesel multiple unit (HŽ series 7121) and train powered by diesel electric locomotive (HŽ series 2044) with five wagons. In Figure 8, line 1 shows the energy consumption of the train with diesel electric locomotive and line 2 is showing energy consumption of the DMU on the line Koprivnica – Varaždin.

Conclusion

Computer modelling and simulation of railway operations is very useful decision support method for improvement of efficiency of railway system. Application of railway simulations can be used for decision making regarding infrastructure modification, selection of the most appropriate rolling stock or timetable planning process. In this paper modelling of the railway line from Varaždin to Dalj is presented. The model was tested on train running time calculation and the comparison in energy consumption between selected diesel multiple unit (HŽ series 7121) and train powered by diesel electric locomotive (HŽ series 2044) with five wagons. Thereby the simulation results proved the quality of the model.

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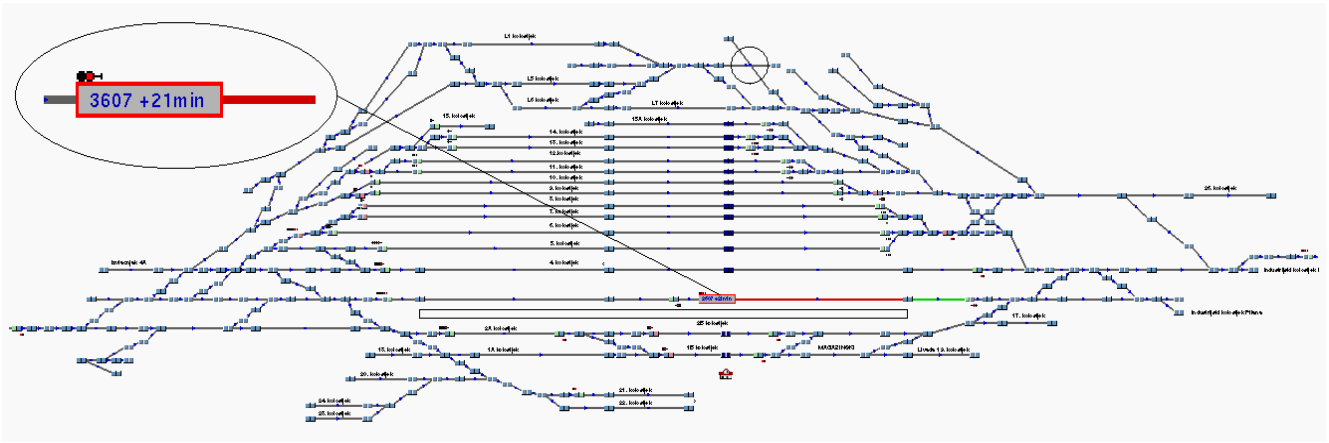

Fig. 4 Animation of the simulation process in the Koprivnica railway station

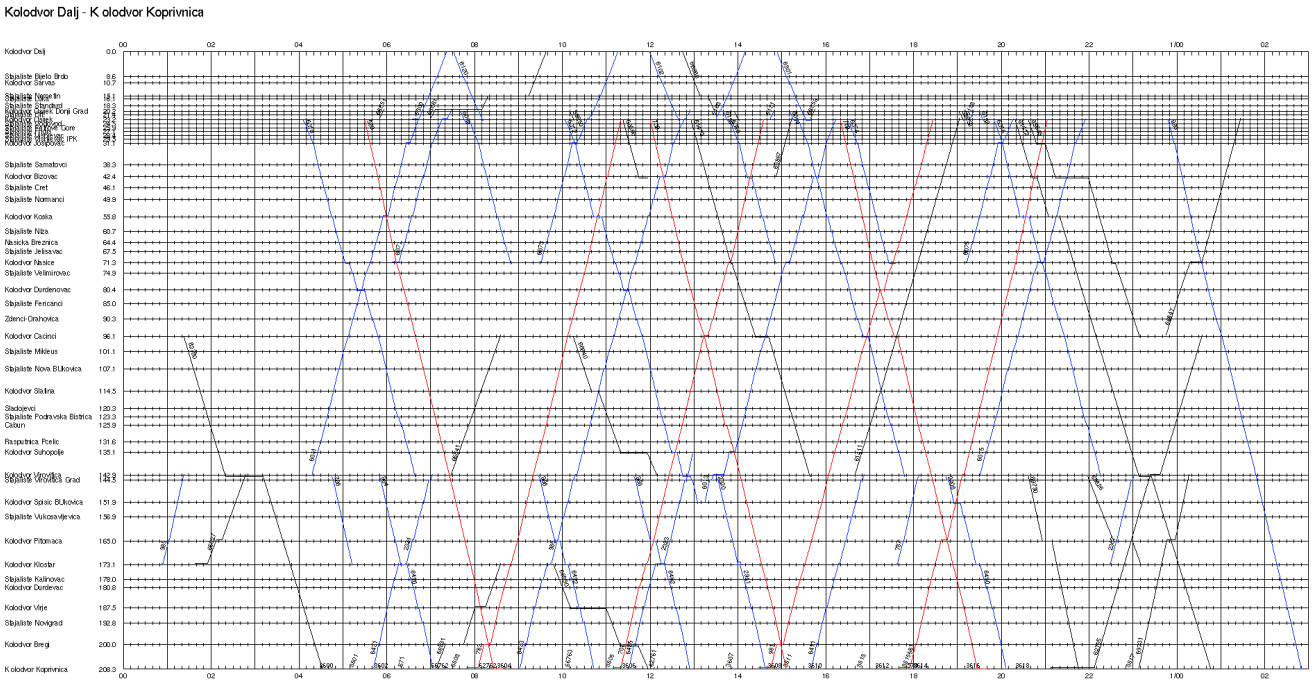

Fig. 5 Simulated timetable for the railway line from Koprivnica to Dalj

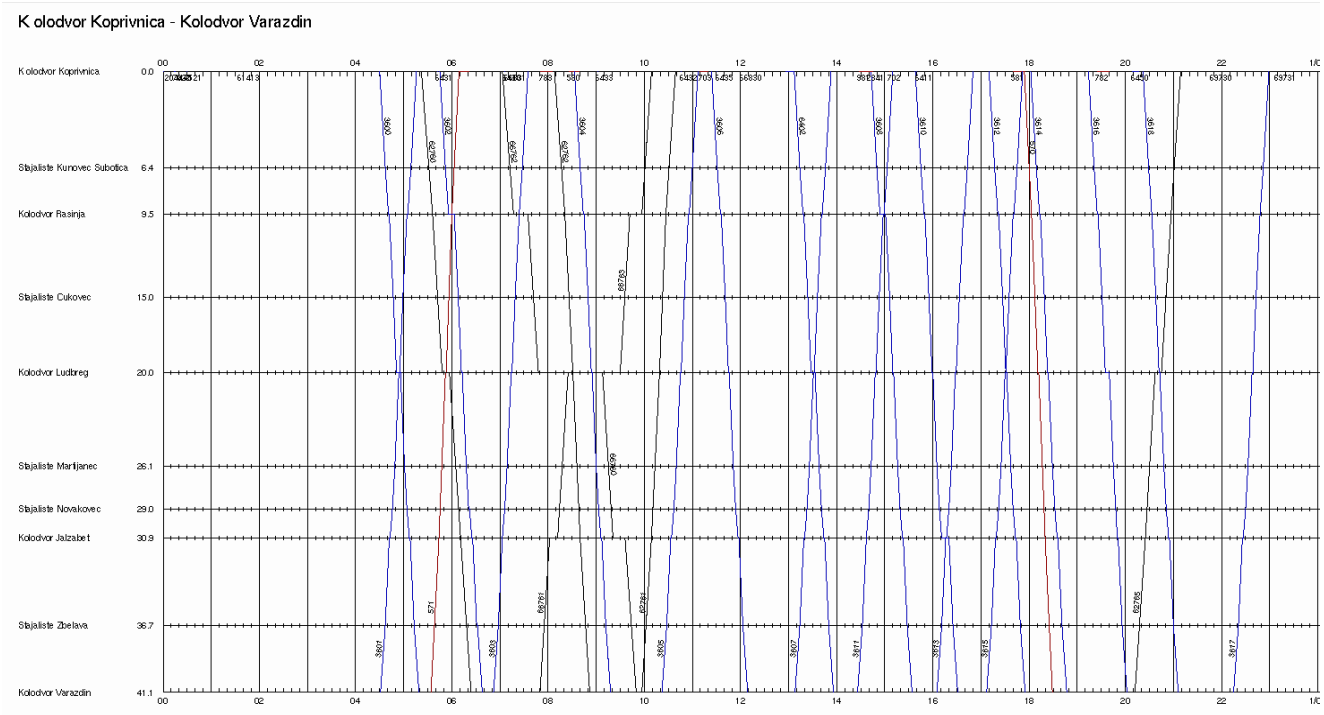

Fig. 6 Simulated timetable for the railway line from Varaždin to Koprivnica

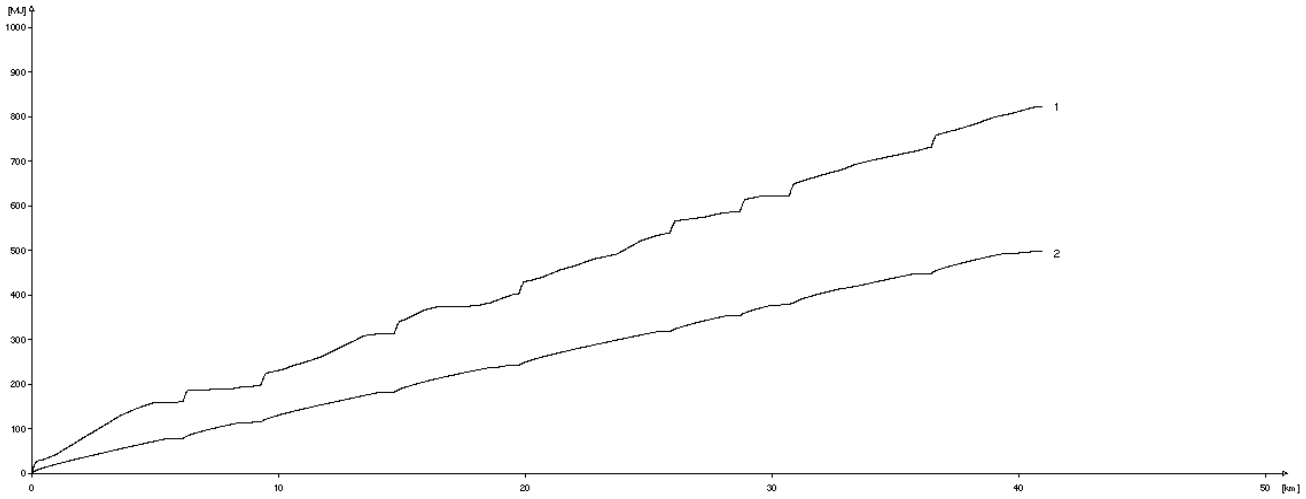

Fig. 8 Energy consumption of diesel electric locomotive (HŽ series 2044) + 5 wagons - **(line 1)** and diesel electric multiple unit (HŽ series 7121) - **(line 2)**