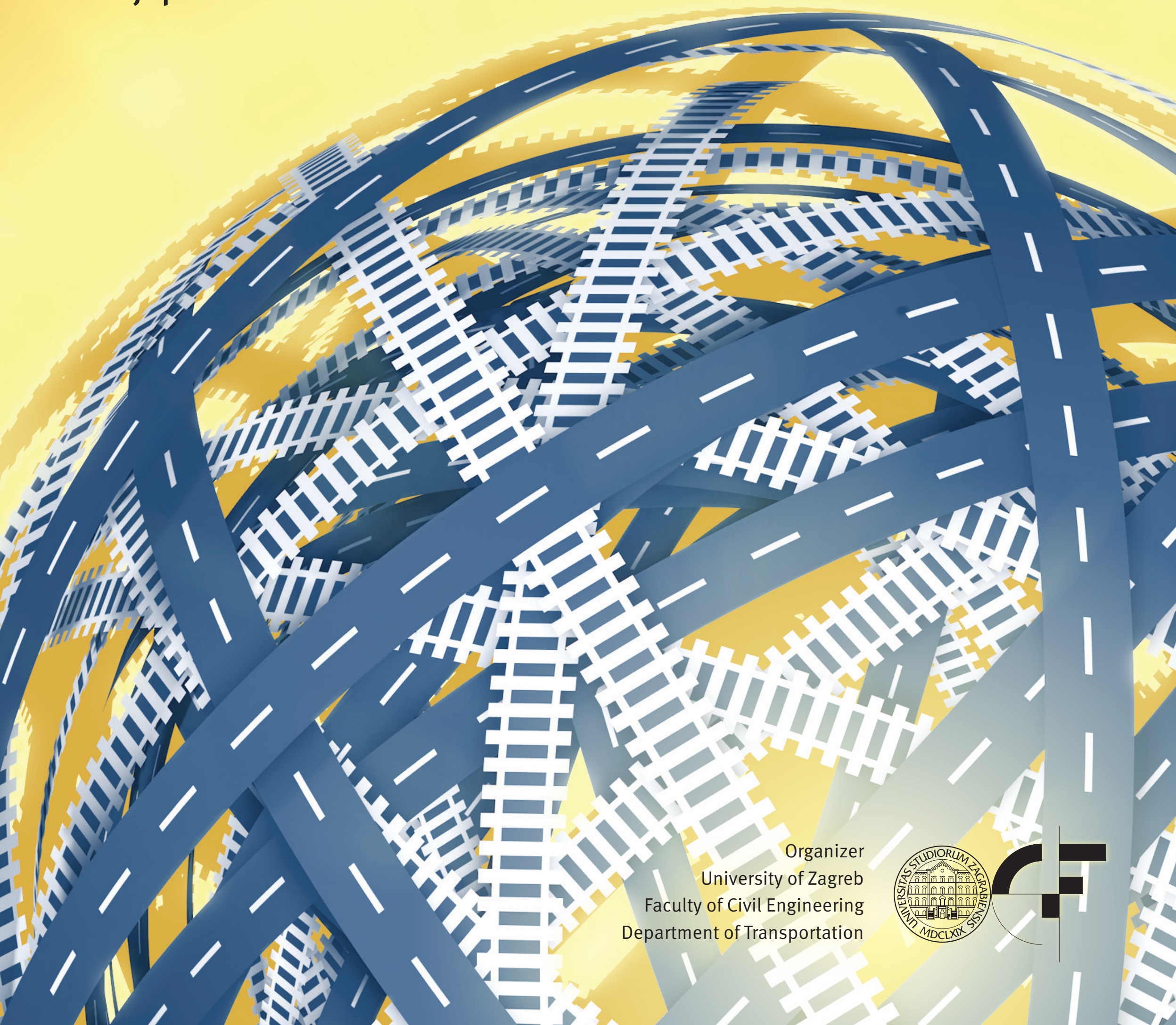
CETRA[2016]

4th International Conference on Road and Rail Infrastructure
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

Stjepan Lakušić – EDITOR



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OPENTRACK – A TOOL FOR SIMULATION OF RAILWAY NETWORKS

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Abstract

OpenTrack began a few years ago as a research project at the Swiss Federal Institute of Technology. The aim of the project, Object-oriented Modeling in Railways, was to develop a user-friendly tool that would answer questions about railway operations by simulation. One of the tasks OpenTrack supports is calculation of minimum headways (headway calculation), e.g. using the OpenTrack tool Headway Calculator. Based on a number of input parameters, the headway calculator computes the minimum headway between two trains and is able to identify the critical block section. The two trains may vary in type (e.g. intercity, commuter, freight, etc.), route and stopping pattern. The headway calculation works for fixed block (discrete block), moving block and CBTC systems. During the simulation predefined trains run on a railway network according to the timetable and under the constraints of the signaling system. After a simulation run, OpenTrack can analyze and display the resulting data in the form of diagrams, train graphs, occupation diagrams and statistics.

Keywords: Simulation of railway operation, operational performance

1 Introduction

Railroad planning is particularly challenging because different improvements can be used to achieve project objectives; improvements can be divided into three general categories: infrastructure, rolling stock, and operations. Improvements in each category need to be evaluated against improvements in other categories to develop the optimal investment plan.

A good example of a structured approach to trading off different types of improvements in these categories is the Swiss National Railroad's (SBB) Integrated Product Planning Process. [1] The SBB views this process as a Planning Triangle with three elements at the corners: Products, Rolling Stock, and Infrastructure. Products are the services and schedules operated (e.g. commuter rail, intercity rail, freight); rolling stock means the type of rolling stock used to provide a particular service; and infrastructure consists of the physical system (e.g. tracks, signal systems, stations). SBB planners use iterative techniques to evaluate changes in each of these elements to optimize the system as a whole. This triangular depiction effectively communicates the relationship between the three elements and their ability to meet market demand. In an example of this process, the SBB decided to use tilting trains to provide high speed service (a rolling stock solution) rather than fully rebuilding tracks on a particular corridor (an infrastructure solution) because the former was found to be more cost effective.

Computer simulation is a particularly important and useful tool for evaluating different railroad improvement strategies for the following reasons:

- Understanding Capacity – Railway capacity is not intuitively obvious. Even lines with very little service may be operating at capacity.

- Highly Interrelated Infrastructure – An infrastructure improvement in one location can have significant impacts in another location, sometimes far from the improvement. A rail simulation program can identify the impacts of such changes throughout the modeled network.
- High Cost of Rail Infrastructure – Improving a railroad is expensive, not only are the physical improvements costly, but costs for taking a line out of service during construction and for additional right-of-way can be significant. Furthermore, a poorly planned improvement will increase the railroad's long term operating costs and problems.

Given these factors, many rail-planning experts recommend completing as much modeling as possible before starting a railroad improvement program. In general, the more modeling done up front, the less expensive the overall project will be, since modeling enables the plan to be refined to its most essential elements [2].
The first step in using computer models in the railroad planning is to calibrate the base case model. This should accurately replicate observed railroad operations with the existing infrastructure, rolling stock, and schedules. Once the model has been calibrated it can be used to investigate many issues including estimating the stability of new timetables, determining the minimum infrastructure requirements for a given timetable, or evaluating the impact of rolling stock changes. A significant benefit of models is their ability to evaluate the impact of incidents or time-based network changes (e.g. maintenance) on railroad operations.
Computer simulation is especially valuable for railroad planning since, once developed and calibrated, models can be used for the comparison of the benefits, impacts, and costs of various different improvement packages. To analyze more than a few improvement packages by hand would be prohibitively time consuming. Thus, effective railroad simulation models enable planners to identify and evaluate more alternatives, ultimately leading to more creative and comprehensive problem solutions. While computer simulation is an excellent tool for analysis and planning of railroads, railroad network simulation programs have the following limitations:
- Programs must be validated to actual conditions.
- Yard operations must be modeled separately.
- Resource constraints such as crew scheduling are largely ignored (although some specialized software does address resource constraints).
- Simulations only include the modeled study area.
- Simplifying assumptions generally create an inherent optimism about overall congestion, schedule adherence, and recoverability [3].

Given these limitations, especially the last one, it is critical that all simulation results be carefully reviewed and discussed with those familiar with operations. There is no substitute for real experience in the planning process.

2 OpenTrack – railway simulation software

OpenTrack was developed at the Swiss Federal Institute of Technology's Institute for Transportation Planning and Systems (ETH IVT). The project's goal was development of a user-friendly railroad simulation program that could run on different computer platforms and could answer many different questions about railway operations, [5]. Figure 1 illustrates the three main elements of OpenTrack: data input, simulation, and output.
OpenTrack is a microscopic synchronous railroad simulation model. As such it simulates the behavior of all railway elements (infrastructure network, rolling stock, and timetable), as well as all the processes between them. It can be easily used for many different types of projects, including testing the stability of a new timetable, evaluating the benefits of different long-term infrastructure improvement programs, and analyzing the impacts of different rolling stock.

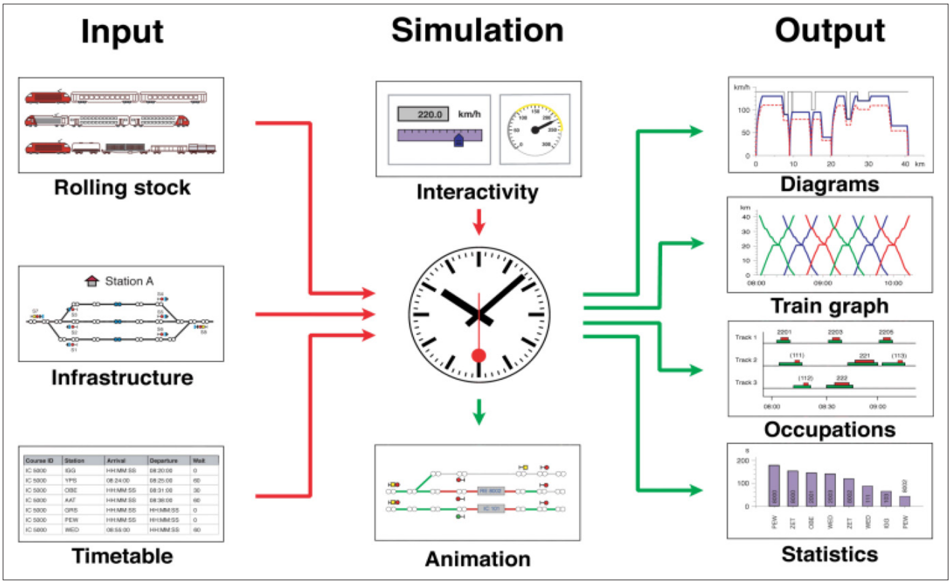

Figure 1 Data flow in simulation of railway operation

2.1 Input Data

OpenTrack manages input data in three modules: rolling stock (trains), infrastructure, and timetable. Users enter input information into these modules and OpenTrack stores it in a database structure. Once data has been entered into the program, it can be used in many different simulation projects. For example, once a certain locomotive type has been entered into the database, that locomotive can be used in any simulation performed with OpenTrack. Similarly, different segments of the infrastructure network can be entered separately into the database and then used individually to model operations on the particular segment or together to model larger networks.
Train data (locomotive and wagons) is entered into the OpenTrack database with easy to use forms displayed using pull down menus. Infrastructure data (e.g. track layout, signal type/location) is entered with a user-friendly graphical interface; quantitative infrastructure data (e.g. elevation) is added using input forms linked to the graphical elements. Following completion of the RailML [4] data structure for rolling stock and infrastructure, OpenTrack will be modified to enable train and infrastructure data to be directly imported from RailML data files.
Timetable data is entered into the OpenTrack database using forms. These forms include shortcuts that enable data input to be completed efficiently. For example, users can designate hourly trains that follow the same station stopping pattern an hour later. Since OpenTrack uses the RailML [4] structure for timetable data, timetable data can also be entered directly from various different program output files as well as database files.
One advantage of OpenTrack is that it enables users to adjust many variables that impact railroad operations. For example, users can simulate the impact of weather on traction by specifying the adhesion scenario (good, normal, bad). OpenTrack then estimates locomotive traction power using a percentage (also user-defined) of that calculated using the Curtius and Kniffler formula, [6]. While OpenTrack provides standard default values for all variables, having the ability to adjust variables makes the program quite useful.

2.2 Simulation

In order to run a simulation using OpenTrack the user specifies the trains, infrastructure and timetable to be modeled along with a series of simulation parameters (e.g. animation formats) on a preferences window. During the simulation, OpenTrack attempts to meet the user-defined timetable on the specified infrastructure network based on the train characteristics. OpenTrack uses a mixed continuous/discrete simulation process that allows a time driven running of all the continuous and discrete processes (of both the vehicles and the safety systems) under the conditions of the integrated dispatching rules.
The continuous simulation is dynamic calculation of train movements based on Newton's motion formulas. For each time step, the maximum force between the locomotive's wheels and the tracks is calculated and then used to calculate acceleration. Next, the acceleration function is integrated to provide the train's speed function and is integrated a second time to provide the train's position function. [6]
The discrete simulation process models operation of the safety systems; in other words, train movements are governed by the track network's signals. Therefore, parameters including occupied track sections, signal switching times, and restrictive signal states all influence the train performance. OpenTrack supports traditional multi-aspect signaling systems as well as new moving block train control systems (e.g. European Train Control System – ETCS signaling).
OpenTrack is a dynamic rail simulation program. As such, the simulated operation of trains depends on the state of the system at each step in the process as well as the original user-defined objective data (e.g. desired schedule).
A simple way of describing dynamic rail simulation is that the program decides what routes trains use while the program is running. For example, when building the network, users identify various different routes that trains can use between two points; OpenTrack decides, during the simulation, which route the train will use by assigning the train the highest priority route available. If the first priority is not available, OpenTrack will assign the train the second highest priority route and so on.
OpenTrack's dynamic nature allows users to assign certain attributes to specified times in the simulation. Thus, users can assign a delay to a particular train at a given station and time, rather than being limited to assigning a delay at the start and using it through the entire simulation. Similarly, users can define other types of incidents (e.g. infrastructure failures, rolling stock breakdowns) for particular times and places.
Finally, dynamic simulation enables users to run OpenTrack in a step-by-step process and monitor results at each step. Users can also specify exactly what results are displayed on the screen. Running OpenTrack in a step-by-step mode with real time data presented on screen helps users to identify problems and develop alternative solutions.

2.3 Output

One of the major benefits of using an object-oriented language is the great variety of data types, presentation formats, and specifications that are available to the user. During the OpenTrack simulation each train feeds a virtual tachograph (output database), which stores data such as acceleration, speed, and distance covered. Storing the data in this way allows users to perform various different evaluations after the simulation has been completed.
OpenTrack allows users to present output data in many different formats including various forms of graphs (e.g. time-space diagrams), tables, and images. Similarly, users can choose to model the entire network or selected parts, depending on their needs. Output can be used either to document a particular simulation scenario or as an interim product designed to help users identify input modifications for another model run. [7]

3 Use of OpenTrack in Croatia

Figure 2 shows a detailed outline of Zagreb Gl. kolodvor infrastructure. The importance of any modelling system lies in the accurate representation of reality. For this reason, OpenTrack takes all important parameters into consideration, so that everything that happens during simulation will happen in reality as well.

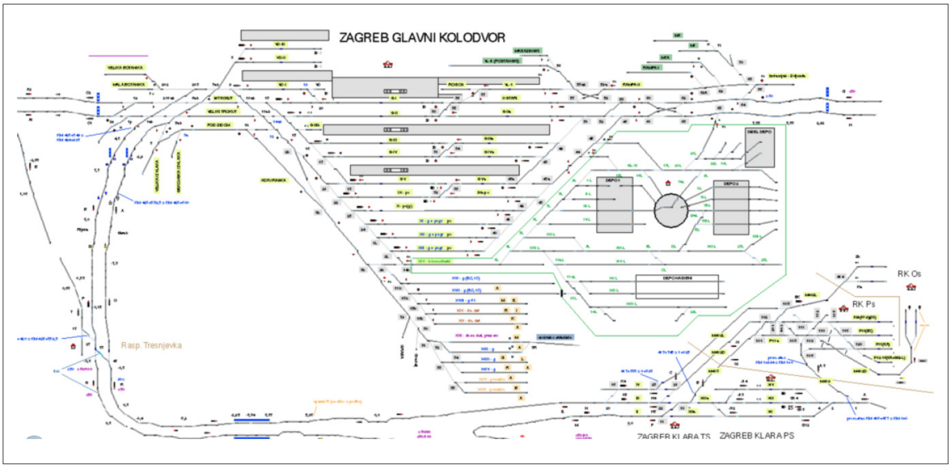

Figure 2 Infrastructure: Zagreb Glavni kolodvor

Another example of infrastructure layout is depicted in Figure 3. The station Hrvatski Leskovac is presented with all tracks, signaling system and needed infrastructure characteristics.

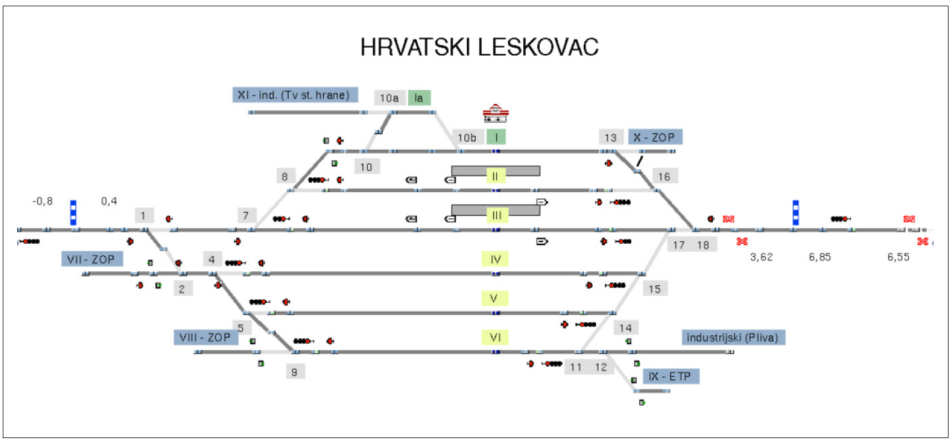

Figure 3 Infrastructure: Hrvatski Leskovac

Figure 4 shows an example of a train graph with blocking time stairway between Zdencina and Karlovac, Croatia, including distance, as well as information about double- and single-track sections.

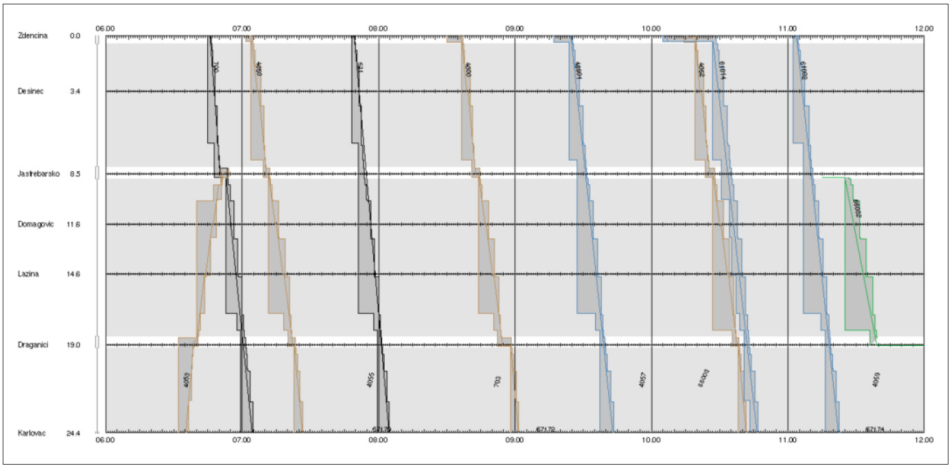

Figure 4 Timetable with block section: Zdencina – Karlovac

4 Conclusion

OpenTrack is an efficient and effective railroad simulation program. It has been used successfully in many different railway planning projects throughout the world. The program's use of object-oriented programming and the RailML data structure makes it particularly effective since the program can be modified relatively easily to address specific applications and since data can be transferred easily to and from other programs based on RailML. Therefore, it is highly recommended to use it for simulation of railway operations because it covers a wide range of possible output data that can be used in decision making processes.

References

[1] Grossenbacher, P.: Service Planning Strategies: The Example of the Passenger Transport Department of the Swiss Federal Railways. Rail International, June/July 2001, 118.

[2] Nash, A.: Best Practices in Shared-Use Rail Operations; Mineta Transportation Institute, San Jose State University; San Jose, California; June 2003.

[3] Gibson, J.: Train Performance Calculators and Simulation Models. Handout, Transportation Research Board, "TRB Workshop on Railroad Capacity and Corridor Planning." January 13, 2002.

[4] For more information on RailML see the project website: www.railml.org

[5] Huerlimann, D.: Object oriented modeling in railways; ETH Dissertation Nr. 14281; 2001 (in German).

[6] Huerlimann, D., Nash, A.: OpenTrack – Simulation of Railway Networks. User Manual Version 1.3; ETH Zurich, Institute for Transportation Planning and Systems; May 2003; Page 58.

[7] For more information on OpenTrack see the project website: www.opentrack.ch

[8] Theeg, G., Vlasenko, S.: Railway Signalling & Interlocking. DVV Media Group. 2009. ISBN 978-3-7771-0394-5.

[9] Schoebel, A., Volcic, M.: Microscopic Simulation of Railway Operation for Developing Integrated Timetables; 3rd International Conference on Road and Rail Infrastructure – CETRA 2014, 28-30 April 2014, Split, Croatia