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**REAL ENVIRONMENT SIMULATION MODELS ON RAILWAY  
TRANSPORT NETWORK**

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## **1. Introduction**

Transport network simulation models become integral part of innovation processes in transport technology. They approximate an actual operation especially in conjunction with realization of information and control systems. References concerning partial applications were published on various occasions. The authors try to offer integrated up-to-date information about the results of their work in this area.

## **2. Real Environment Models**

Models the parameters and data structures of which encompass terms and parameters adapted from the real system to a considerable amount are referred under this name.

In regard to railway operation, the first concept of network diagram is mostly concerned. Nodes of the diagram represent the stations and edges represent track sections. The topology of the diagram matches the topology of the railway network or the topology of the monitored interactions. The numbers of station tracks and line tracks,

other capacity data and elements of operation technology represent other typical attributes. Consecutive detailing can describe the length of tracks, crossing intervals, train data, description of track sections between stations, capacity parameters of the line tracks, running times, track profiles, headways etc.

Operation on railway infrastructure can be simulated on a structure described above in different ways – mostly by train movements. Their movement is mostly described as a sequence of used nodes and edges, whereas the most often tracked data, e.g. running times or headways of trains, are mostly interpreted by the occupation time of these objects. Generally the operation can be characterized by the number of the train movements realized in the model. More complex models target more complicated processes of the railway operation, e.g. railway operation control, lock-out activities, etc.

A significant element of real environment's models is an ability of their close connection with the existing transport system. Retrospectively many parameters for the construction of a hypothetical model of a realistic range can be obtained by the analysis of the existing system. Such procedure ensures the high reliability and authenticity. Possibilities of direct connection with railway operation control information systems are used successfully in the operation, addressing railway timetable construction, train assembling, rolling stock and crew circulation plans and also operational management systems.

Moreover it offers the possibility to use real data records for some components of the model (e.g. infrastructure, operation, running time, etc).

In comparison with more common (theoretical) models, the problems with the applicability and credibility become non-existent thanks to generalization.

The interconnection between a model and a real system can be also seen in possibilities of practical application of obtained results. Frequent application is e.g. in the process of quality evaluation of the real transport systems and their operation (the quality of the railway timetable, etc.)

The model is often created targeting a specific solution on the basis of operation requirements.

### **3. Basic data**

- Information about railway infrastructure (basic data):
  - description of the railway network (mainly at level of railway track, permanent and temporary speed limits, gradient attributes, etc.).
- Information about railway vehicles:
  - basic characteristics,
  - additional features,
  - number of vehicles used.

- Railway operation data:
  - running times, traction energy consumption characteristics of the train movement
  - train characteristics from the point of view of the commercial requirements,
  - train characteristics from the point of view of the operational level (rolling stock and crew's circulation plans).
- Organization and management of the railway operation:
  - timetable construction,
  - train planning, train routings on railway network,
  - service optimization of transport nodes (from the point of view of single node and also the whole network),
  - real time operational control.

#### **4. Key tasks and algorithms**

Some areas of problems must be solved at a high level level to enable a construction of the realistic models:

- Algorithm for calculation of running time which requires relatively complicated input data preparation. It must be possible to calculate also the consumption of traction energy needed for the train movement.
- Algorithm for crossing intervals in stations and headways in line sections, which is based on algorithm for running time calculations and technological service times of the signalling and interlocking equipment. The algorithm must be connected with real data.
- Algorithm for searching and solving conflicts in railway operation. It includes conflicts in nodes and line sections.
- Investigation of characteristics and evaluation of the timetable quality, construction and evaluation of an alternative timetable, construction of the lock-out timetables.
- Analysis of disturbance of the regular operation by large lock-out activities (track reconstruction, civil engineering works).

#### **5. Several practical examples of the application of the real environment model in railway transport**

- Construction of the conflictless train timetable:

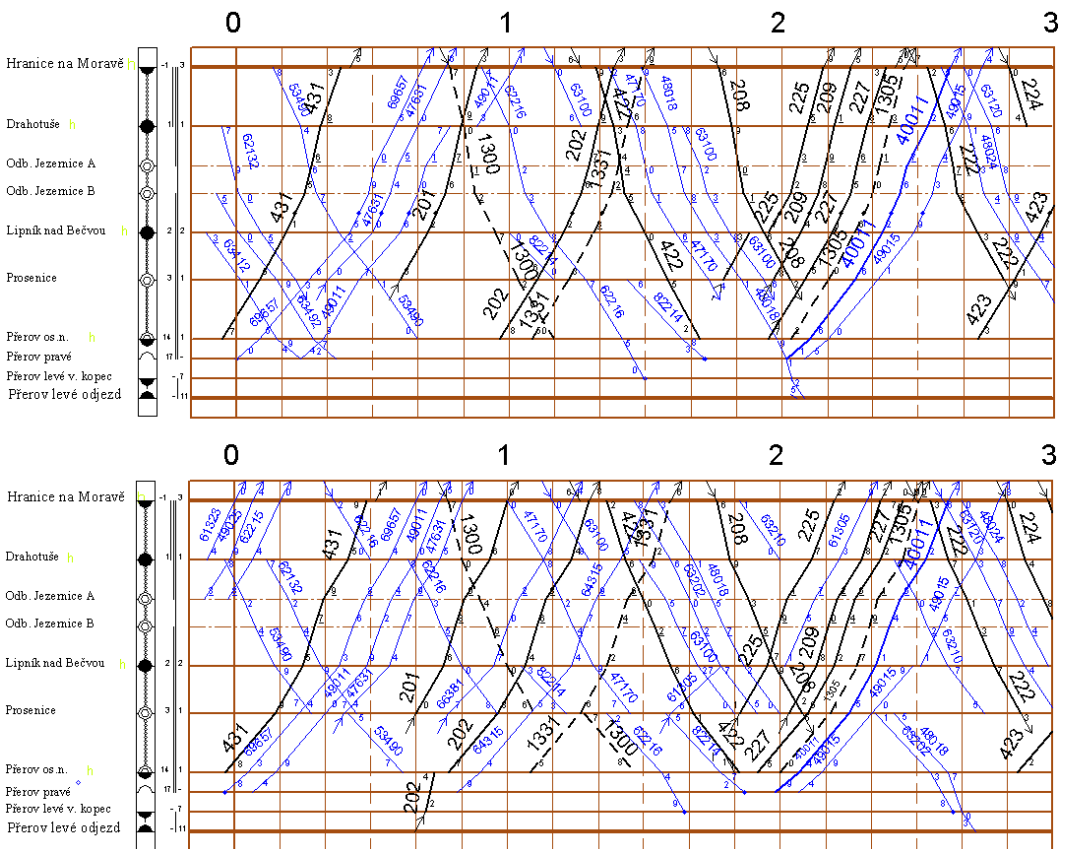
A large segment of the main line was loaded with data from the valid operational timetable which according to the valid methodology of the Czech Railways contained some conflict situations (e.g. conflicting train paths). The algorithms for searching and

solving conflicts were applied to these data iteratively. The goal was to achieve a timetable without any conflicts. This goal was accomplished. The capacity parameters of the line (the occupation of the station and line tracks, number of spare train paths for different train types etc.) were analyzed and verified on this modified timetable

- Construction of the lock-out timetable due to large building activities:

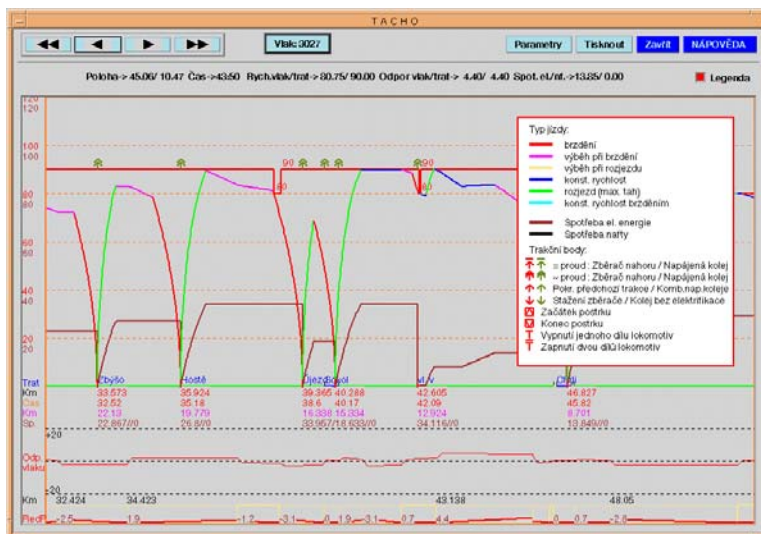
A model of the variant lock-out line timetables for line sections during reconstruction (1st and 2nd transit corridor). SENA-JŘ-VT project. Specific solution for the needs of Infrastructure Division ČD (Fig. 1).

### Hranice na Moravě - Přerov levé odjezd



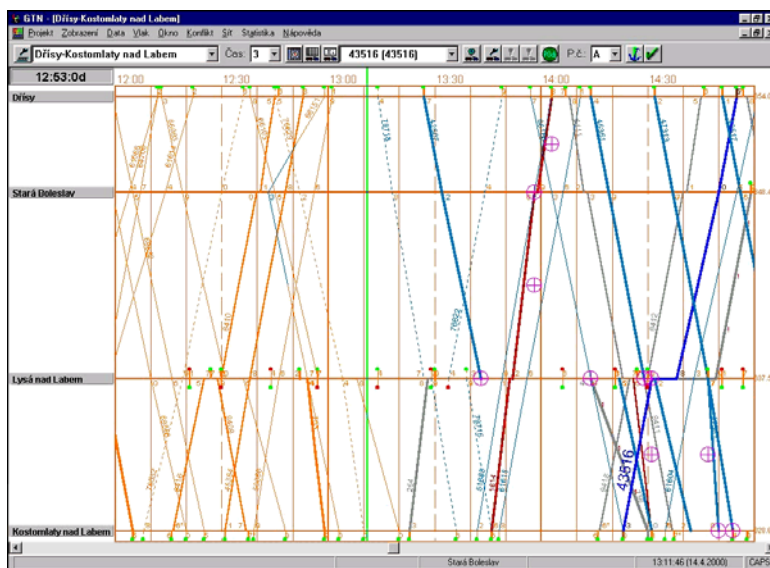
**Fig. 1** Variant graphical timetable, April and August 2000 – line section of the 2<sup>nd</sup> corridor

- Model of train movement expressed in the form of the speed-distance diagram. Each train path drawn in graphic timetable can be converted into the speed-distance diagram (Fig. 2). SENA-JŘ-VT project.

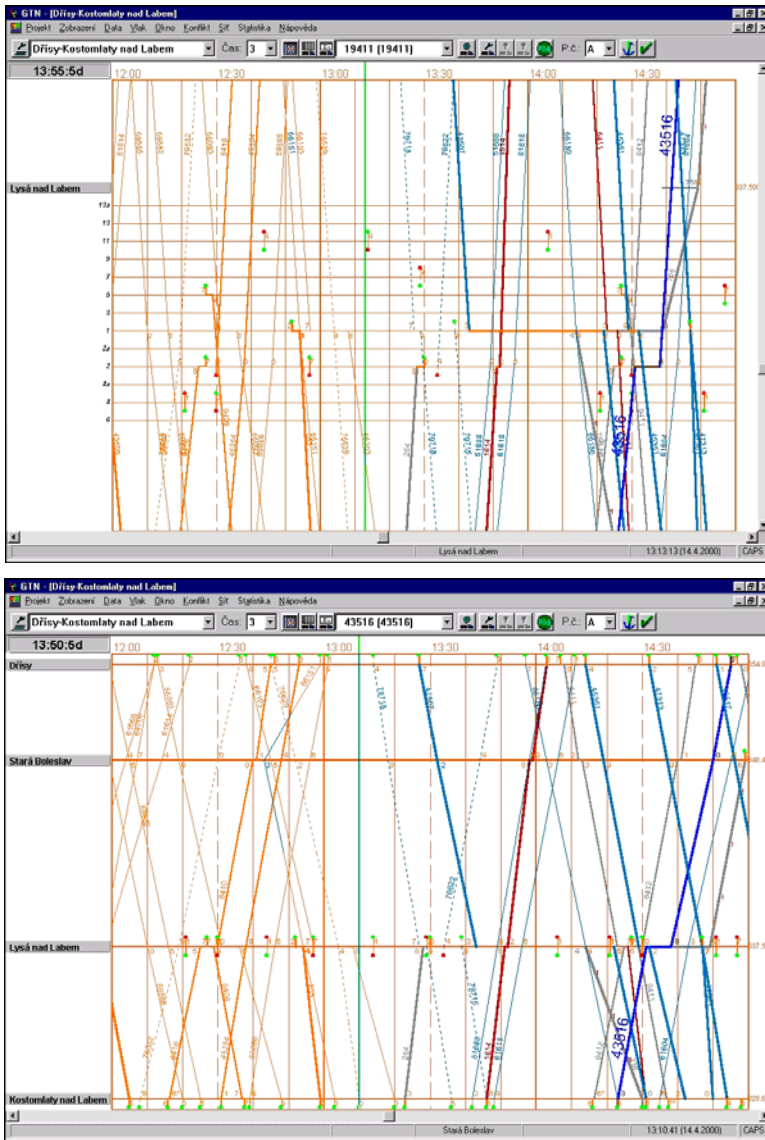


**Fig. 2** Speed-distance diagram of the train from graphic timetable

- GTN-DOZ project (Graphic-technological extension of remotely controlled signalling and interlocking equipment AŽD). A display of the actual operational situation in the controlled line section and the railway station is an integral part of GTN module. This model not only monitors the operational situation, but also generates prognosis of the operational situation in the controlled line section for a given period (mostly two hours) based on the obtained data. As a matter of fact it is one of the first simulation models operating in real time in the environment of our railway transport (Fig. 3).



**Fig. 3a** Examples of working environment of the GVD-DOZ application



**Fig. 3b, Fig. 3c** Examples of working environment of the GVD–DOZ application

- SENA simulation module.

It enables construction of variant models of railway operation on the basis of an alternative timetable.

Key features of the modeled system:

- Calculation of the crossing intervals and headways
- Searching and solving of conflicts

- Calculation of theoretical and regular running times
- Calculation of traction energy consumption and power demands of the timetable
- Ability to enter train paths diverted onto alternative routes (mainly during lock-outs)
- Possibility to work with more variants of the infrastructure data
- Possibility to work with more variants of the train data
- Algorithms for input of initial delays of trains and irregularities of train movement
- Possibility to modify pre-set priorities of the trains, conditions for diverting and rerouting train paths to the alternative routes or cancellation of the trains, possibility to substitute the passenger train on the part its route by bus transport, etc.
- Resources for monitoring of simulation and evaluation of its results
- Resources for setting-up simulation parameters and database administration
- Basic time loop of simulation
- An actual infrastructure database of the network of the Czech and Slovak railways and an actual or planned timetable can be used as a input database for simulation
- Wide and rich features of the IS SENA can be used both for entering input data of simulation and presentation of its results, too.
- The level of detail and depth of the description of the infrastructure and train database meets challenging requirements of the IS SENA
- Future development of the simulation model is in progress in close co-operation with operators of the customer

The simulation run and all relevant interventions into simulation by means of changing input data are continuously recorded into simulation log which can be viewed in graphic form (see *Fig. 4* and *Fig. 5*). Further resources for statistical and qualitative evaluation, for example:

- Delay on entry into and exit out of the simulated area (for separate trains and sum total, too)
- Values of running times and stopping times within the simulated area (for separate trains and sum total, too)
- Occupation times of stations and particular tracks
- Power consumption (gas and electricity)

The user controls the resources for preparation and management of simulation data. If he uses graphic timetable construction data, he can remove various flags and data used only during the timetable construction, reduce timetable data into simulation area only, etc. A further possibility is to copy data of the “master” trains into three “simulation” variants and by the gross recalculate the running times of all trains (when the infrastructure data has been changed), etc. These service algorithms are being completed according to actual requirements.

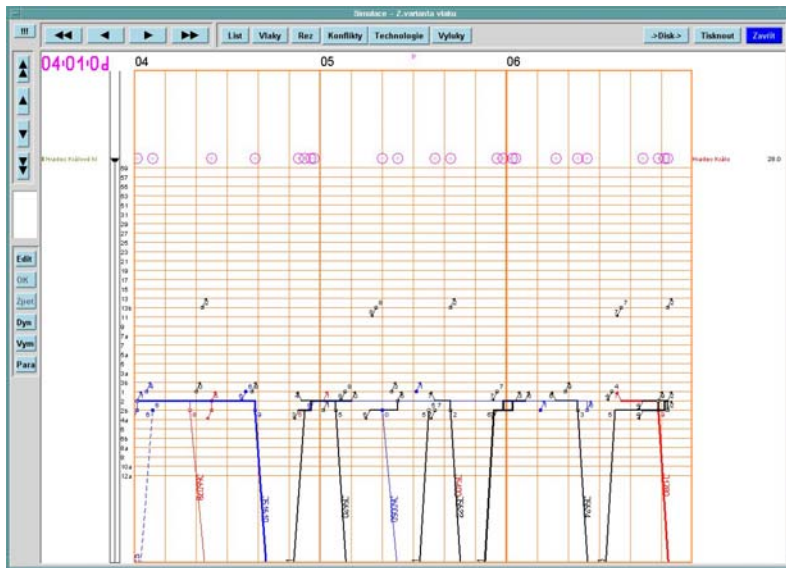
Particular running of individual simulations can be influenced by input of some parameters. So far the user can select different types of searched and solved conflicts during simulation, specify the lines or the line sections submitted to simulation, etc. Next development of the simulation model will encompass extended set of optional parameters, which will enable selecting “style” of conflicts’ solutions.

Essentially the proper simulation consists of constructing the real transport plan, i.e. the plan without any conflicts, which is based on real data from the simulated area. The operation consists of three basic stages. In the first stage the user prepares basic infrastructure and train data for the simulation. They can be based on valid timetable or can be created by the user. This proposal can represent both conflicting or conflictless transport plan. During the second stage the user can modify these input data by means of infrastructure data update, applying of lock-outs, incorporating delays and irregularities of trains’ running times, adding or cancelling trains, etc. The third stage is the proper simulation consisting of iterative searching and solving of traffic conflicts. Conflicts are solved in order of their origin in time with regard to pre-set parameters. The user specifies time range of the simulation and the simulation time step. The simulation can be interrupted after each step, the user can change the simulation parameters or data and then resume it.

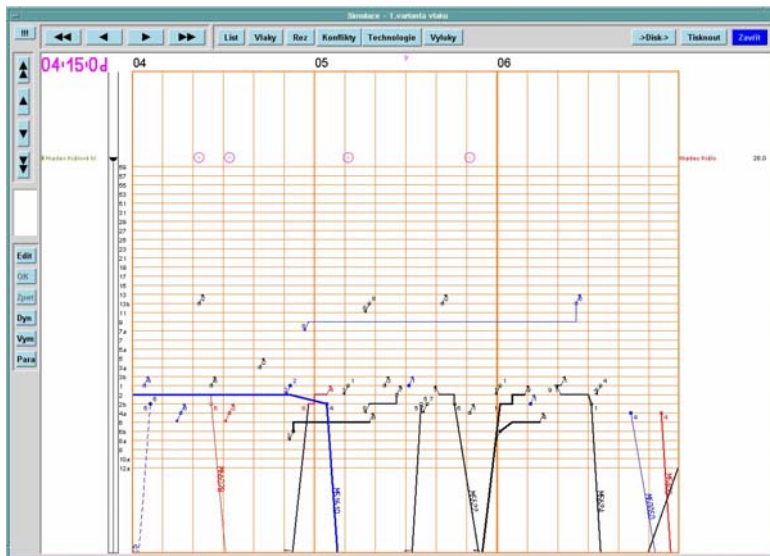
## **6. Conclusion**

The shown results prove the applicability of the real environment simulation models as parts of information systems used in daily operation. Customers keep at their disposal an effective tool, which makes possible not only evaluating the quality of IS outputs, but also essential extending of their practical application.





**Fig. 4** Station conflicts before and after simulation



**Fig. 5** Station conflicts before and after simulation

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### Literature

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### **Summary**

#### **REAL ENVIRONMENT SIMULATION MODELS ON RAILWAY TRANSPORT NETWORK**

Karel ŠOTEK, Hynek BACHRATÝ, Ján RUŽBARSKÝ, Viliam TAVAČ

This paper describes new principles of transport line control simulation models and possibilities of its practical application.