SIMULATION AS A SUPPORT FOR PLANNING INFRASTRUCTURE WITHIN PRAGUE MASARYK STATION

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ABSTRACT

The paper pays attention to presentation of realised simulation study focused on a prognostic traffic within Prague Masaryk station with the special interest to variants of track infrastructure as well as to alternatives of local technological processes. Relevant simulation model was built within integrated environment of software tool Villon, which represents worldwide top tool for railway-based simulations.

INTRODUCTION

Simulation of systems is a method supporting analysis, design and optimisation of real systems. Three steps can be distinguished:

- Substitution of a real system by its simulation model.
- Experimenting with the simulation model with the aim to disclose its properties, behaviour and reactions under selected conditions.
- Application of obtained results in the real system (existing or designed).

Simulation model should be as accurate and detailed as possible so that its results are applicable to the reality. At the other side, there is also certain limit of detail, which should not be trespassed.

The software product Villon belongs to simulation tools which are based on above described principles and was successfully verified in practice. Villon is not only a very efficient tool for verification of infrastructure modifications but it is also very suitable mean for investigation of possibilities how to increase the efficiency of service resources and improve decision activities. Villon enables the user to construct complex, detailed and interactive simulation models, make experiments with them and analyse the results. Simulation model built within experimental environment of the tool Villon can be an effective aid for solution of described problems linked with infrastructure and operational planning.

The tool Villon itself, however, does not give automatically ready-to-use optimal solutions of complex problems but offers an experimental environment, a "laboratory" for investigation of various configurations of a station/junction infrastructure configuration, operational strategies and all consequences of their application. Simply said, using Villon, a user-experimenter can answer questions "What happens, if ...?". It is supposed that the user himself is expert in railway technologies and, moreover, cooperates closely with the management officers of the station.

Several basic stages of work with Villon can be distinguished according to the typical activities, which are carried out:

- Acquisition, processing and analysis of data concerning real or planned station/junction.
- Construction of infrastructure model.
- Construction of dynamical operation (traffic) model, which serves for investigation of the station properties with proposed infrastructure configuration.
- Experimenting with the simulation model. It is an iterative process of consequent runs of simulation experiments with modified parameters with the objective to disclose the behaviour of the system in correspondence with the given set of parameters leading to the solution of the problem. It is evident that a number of simulation experiments should be performed. This number depends on the degree of expertise of experimenter, on the quality of the simulation model and also on tools available for evaluation of experiments. A correct evaluation of results undoubtedly shows the direction and next steps in the quest for solution.
- Analysis of results of simulation experiments. Villon enables the user to follow on-line animation of movements of all mobile resources and of technological processes. Moreover, Villon is capable to submit information on properties of all both static and dynamic station elements including clients of the system, via so called Explorer. The broad scope of tools

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includes the possibility to obtain up-to-date statistics about the performance (state) of all mobile and fixed elements of the station. This information is given in a graphic form.

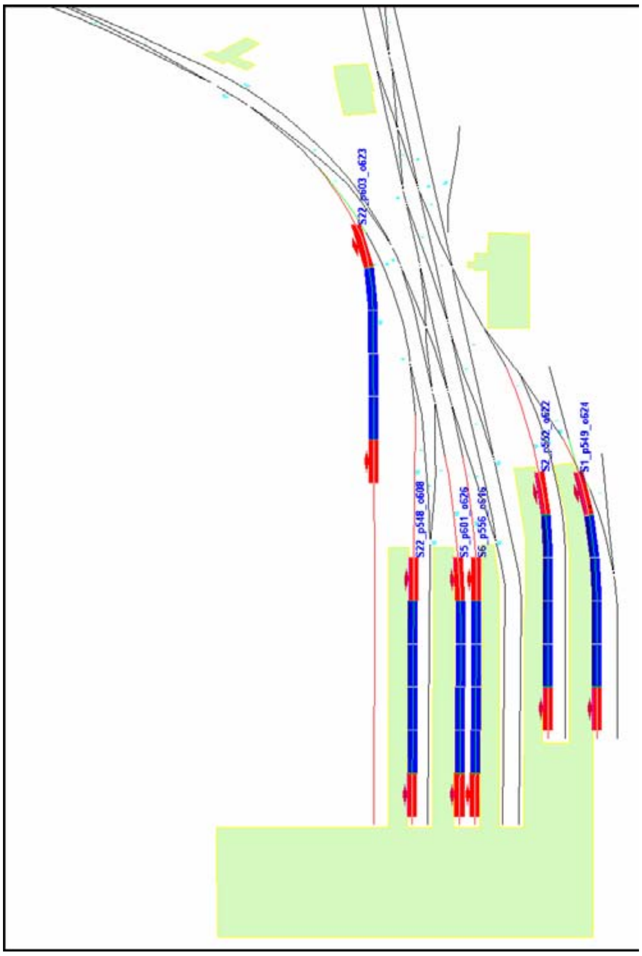

Figure 1: Animation of train movements

It is clear that during the simulation run we are not able to discover all aspects of the system behaviour. Villon however offers the possibility of recording simulation run into a simulation protocol, which can be used later as a data source for post-simulation evaluation of results. Again, Villon offers a user a set of tools for statistical evaluation of protocol data, for construction of schedules of resources and activities in graphic form, exploitation of infrastructure, etc. If needed, all recorded data can be exported e.g. to MS Excel format.
Credibility of the experiment results strongly depends on the good fit of the infrastructure model and of the operation model to the reality.

MODEL OF MASARYK RAILWAY STATION

Simulation model was built on the request of General Headquarters of Czech Railways in order to verify several prognostic variants of track infrastructure, technical equipment and technological processes (operation) within studied station and its close surroundings.
Building of simulation model within the frame of Villon tool represents several steps specialised in elaboration of various kinds of data. The following examples illustrate the most important pieces of data constituting the mentioned model.

Physical infrastructure – represents the plan of the trackage (usually using 1:1000 scale), which can be provided in electronic form (e.g. in DXF format related to AutoCAD software application) or in a classical/paper form (in that case a paper form has to be transformed into electronic one – i.e. scanning and vectorisation is carried out). Physical infrastructure is composed of: individual tracks, switches, signalling devices, platforms, buildings and other important facilities.
The model of Prague Masaryk station reflected two main versions of track infrastructure with different layouts and positioning of platforms.

Logical infrastructure – keeps functions of individual elements from physical infrastructure (reception tracks, departing tracks, shunting tracks etc.) and definitions of isolated track circuits.

Train routes – are mostly dynamically calculated during a simulation run (reflecting current situation within the trackage) or for special cases statically predefined in a relevant database. It is also possible to define further attributes related to train routes, e.g. movement to occupied track, time needed for train route preparation etc.

Technological procedures applied to train attendance – describe recipes related to relevant technological processes. Every procedure represents a different succession of individual activities related to a corresponding kind of train elaboration. Those procedures are specified in the form of acyclic network (as defined in graph theory) whereas the edges reflect relevant technological activities (brake test, technical inspection etc.).

Locomotives – define numbers and kinds of locomotives, parameters of running dynamics etc.

Trains – contain all important characteristics associated with studied trains, i.e. train numbers, arrival and departure times, technological procedure applied to train attendance, utilised locomotive etc. Simulated incoming trains can follow either deterministic or stochastic approach, i.e. those trains either arrive exactly according to the relevant timetable or are delayed. The delays can be generated on the base of statistical examination applied to a historical data or on the base of an expert estimate (namely in case of a prognostic traffic).

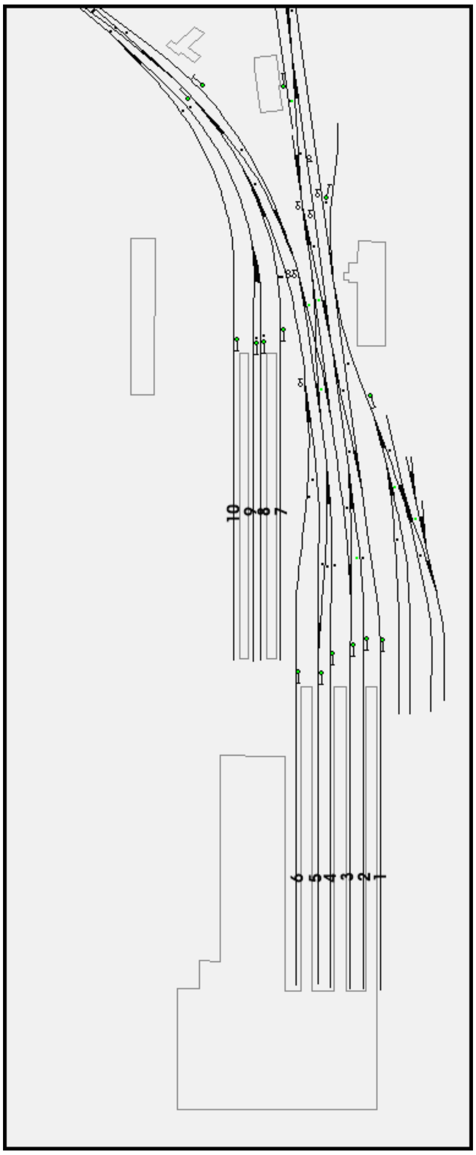

Figure 2: First infrastructure Variant (scenarios #1 – #7)

Simulator of Prague Masaryk station (Praha Masarykovo nádraží) reflects the prognostic traffic (expecting utilisation of electric multiple-unit trains) within the frame of morning peak hours (from 6:00 a.m. to 9:00 a.m.), where the original timetable contains the following lines:

- **S1**: (Kolín –) Praha-Libeň – Praha Masarykovo nádraží and back, period 30 minutes, sojourn time 35 minutes.
- **S2**: (Lysá nad Labem –) Praha-Vysočany – Praha Masarykovo nádraží and back, period 30 minutes, sojourn time 30 minutes.
- **S5**: (Kralupy nad Vltavou –) Praha-Bubeneč – Praha Masarykovo nádraží and back, period 30 minutes, sojourn time 25 minutes.
- **S6**: (Kladno –) Praha-Dejvice – Praha Masarykovo nádraží and back, period 15 minutes, sojourn time 20 minutes.

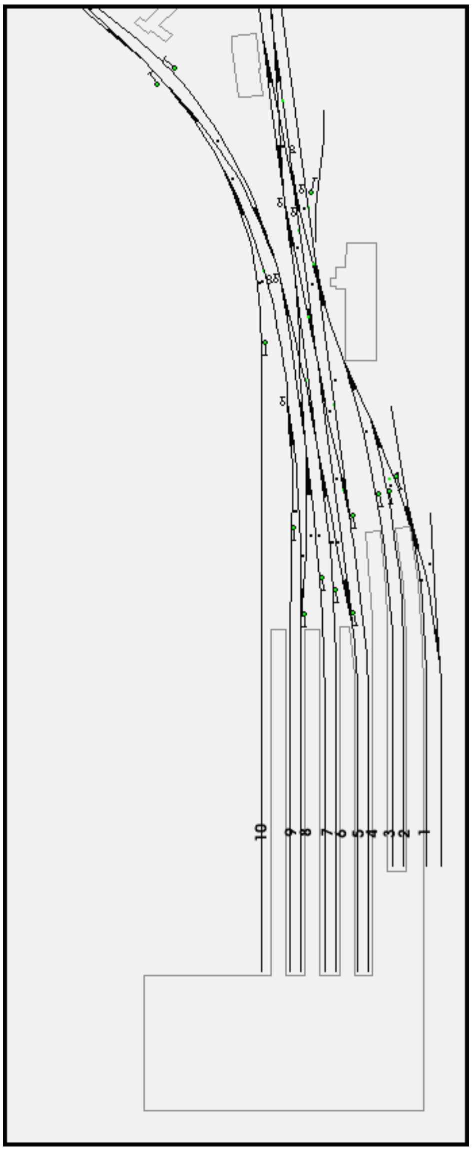

Figure 3: Second infrastructure variant (scenarios #8 – #10)

- **S22**: (Letiště Ruzyně –) Praha-Dejvice – Praha Masarykovo nádraží and back, period 15 minutes, sojourn time 20 minutes.

The process of model validation was based on empirical methodology because the study was supposed to investigate the newly planned variants of infrastructure and the prognostic timetable. It means in fact that the independent top professional from the field of station operation and train movement dynamics examined in detail the results of validation experiments in order to find out if the simulator's behaviour (outputs) plausibly reflects relevant processes (technological processes, movements of the trains etc.).

SIMULATION EXPERIMENTS

Simulation experiments were focused on the operational characteristics associated with selected scenarios, the conceptions of which differ from each other mainly by numbers and positioning of considered edges of platforms and train sojourn times. Simulation study paid attention entirely to ten scenarios of prognostic railway traffic.

First Variant of Infrastructure

First set of simulation experiments studied railway traffic on the trackage as presented within figure 1:

- **Scenario #1** – number of edges of platforms: **6+4**.
- **Scenario #2** – number of edges of platforms: **6+4**, **partially left-sided traffic**.
- **Scenario #3** – number of edges of platforms: **6+2**.
- **Scenario #4** – number of edges of platforms: **6+2**, **partially left-sided traffic**.
- **Scenario #5** – number of edges of platforms: **7+2**, **partially left-sided traffic**.
- **Scenario #6** – number of edges of platforms: **7+2**, **partially left-sided traffic**, **reduction of a train sojourn time** (related to the line S5) **to 19 minutes**.
- **Scenario #7** – number of edges of platforms: **7+2**, **reduction of a train sojourn time** (related to the lines S6 and S22) **to 10 minutes**.

Second Variant of Infrastructure

Further simulation experiments concentrated on traffic within the frame of the trackage variant depicted on the figure 2:

- **Scenario #8** – number of edges of platforms: **7+3**, **partially left-sided traffic**.
- **Scenario #9** – number of edges of platforms: **6+3**.
- **Scenario #10** – number of edges of platforms: **6+3**, **reduction of a train sojourn time** (related to the lines S6 and S22) **to 10 minutes**.

The results of realised simulation experiments (based on ten above mentioned scenarios) were statistically elaborated with the aim to obtain namely the following kinds of factors:

- utilisation rate of platform tracks,
- numbers and locations of train conflicts,
- values of potential delays (related to train arrivals and departures),
- numbers of replacements of selected switches.

In addition, the occupation plans of tracks were elaborated for all scenarios in order to provide conventional materials related to station operation.

Evaluation of Simulation Experiments

The traffic based on the scenario #2 (6+4 edges of platforms) represents the second best result on the first version of infrastructure (from the point of view of utilization rates related to platform tracks). Utilisation rate of each platform track does not exceed 80 % for the given prognostic timetable. The scenario #7 shows the lowest utilisation rate related to platform tracks (relevant with first infrastructure version). The reason of that advantageous result originates from sojourn time reduction (applied to trains related to lines S6 and S22) from original 20 minutes to 10 minutes.

The traffic linked with the second infrastructure version was studied within simulation experiments following scenarios #8 – #10. The lowest utilisation rate of platform tracks is associated with the scenario #10, which is based mainly on the reduction of train sojourn times within the lines S6 and S22. On the other hand, the scenario #8 provides the most convenient operational solution for the primary prognostic timetable (originally with no reductions of train sojourn times) with the utilisation of all individual platform tracks not exceeding 80%.

Selected scenarios (#2, #8 and #10), which disposed of required quality of operational characteristics, were simulated once more using stochastic delays related to train arrivals. In order to distinguish them from the original (deterministic) ones we denote those scenarios as #2a, #8a and #10a.

The scenario #10a enabled to reach the lowest utilisation rate of platform tracks. However the highest values of consecutive delays associated with train departures were achieved (namely because of shorter train sojourn times determined for lines S6 and S22). So in that case the considerable traffic sensitivity related to delays on arrivals was manifested.

Simulation experiments following scenarios #2 and #8 show almost the same results linked with utilisations of tracks as well as average and maximum departure delays.

CONCLUSIONS

Final evaluation of realised simulation experiments led to the following recommendations. The most convenient infrastructure configurations linked with a corresponding traffic conceptions are involved within scenarios #2, #8, #7 and #10. Traffic organised according to those scenarios did not cause utilisation rate of tracks higher than 80%. The difference between scenarios #2, #8 and #7, #10 represents above adduced reduction of train sojourn times within Prague Masaryk station applied to the lines S6 and S22. The mentioned sojourn times reductions originate from realistic feasible technological times reflecting the scheme of prognostic railway traffic.

The range of track infrastructure as defined within scenarios #7 and #10 represents a sufficient layout for the studied traffic on the required level of quality determined by utilisation rates of relevant tracks and departure delays namely depending on arrival delays.

Track infrastructure configuration specified in scenarios #2 and #8 enables to reach better operational characteristics comparing to configuration utilized within scenarios #7 and #10. There is also a lower degree of sensitivity related to arrival delays with regard to departure delays for that trackage configuration.

Presented simulation study (project) succeeded in comparison of various prognostic trackage alternatives and timetable variants related to Prague Masaryk station. Achieved results (based on realised simulation experiments) demonstrated advantages and weak points of individual scenarios. Applied approach, i.e. experimental method of computer simulation, as well as utilised software simulation tool Villon can be recommended for solutions of similar projects not only in the Czech Republic but also worldwide.

Finally we can make a remark that the mentioned tool Villon was successfully utilised within many other projects focused on simulations related to passenger and freight railway traffic as well as factory rail-road traffic in European countries (Germany, Switzerland, Austria, United Kingdom, Slovakia and Czech Republic) and also in Asia (China).

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