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Microsimulation as a tool for evaluation of infrastructure and operational concept alternatives in a complex railway node

Introduction

Railway junctions and its capacities are typical bottlenecks for developing periodic timetable concepts. The usefulness of the infrastructure is crucial in this timetable nodes - railway stations, where the trains (and other means of transport) meet providing optimal interchange option to passengers to all destinations, but with as short as possible waiting times for other passengers travelling through the node on the same train. Unfortunately these nodes situated rather in the middle of urban areas and being equipped with a lot of traditional technology are very costly for adaption to comply with ever changing needs and very complex to project all possible variants up to a detailed level.

Usually the changes are discussed in rough details for a long time in many options. But once a rather political decision is made about funding a reconstruction in a specific way, there is usually at once too little time for developing more variants in detail and evaluating long-term effectiveness of them and only one or very few sub variants are being developed. In many recent cases, one finds out just after its completion the project doesn't suit today's needs. This was for instance the case of the main railway station in Prague, which was (and still is) unable to accommodate the ever rising number of passenger trains, starting just in the very first year after its reconstruction finished. A precise estimation of future demand for use in different time perspectives, its transfer to infrastructure plans tailored to suit those specific operational concepts and their evaluation using microsimulation tools – which allows to test a virtual track before it is actually built - is always a better option in such cases.

Microsimulation software opentrack

Microsimulation software Opentrack has been developed between 1995 and 2000 as a research project by Dr. Daniel Hürlimann at Swiss Federal Institute of Technology Institute for Transport Planning and Systems (ETH IVT). Over the past years, OpenTrack has been continuously improved based on comments from users. The program has increased its functionality to become a comprehensive tool for the simulation of railway and Maglev train systems. It is used by railway companies, consulting firms, and research units worldwide

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to simulate and analyze the processes of railway business operations with a good degree of accuracy.

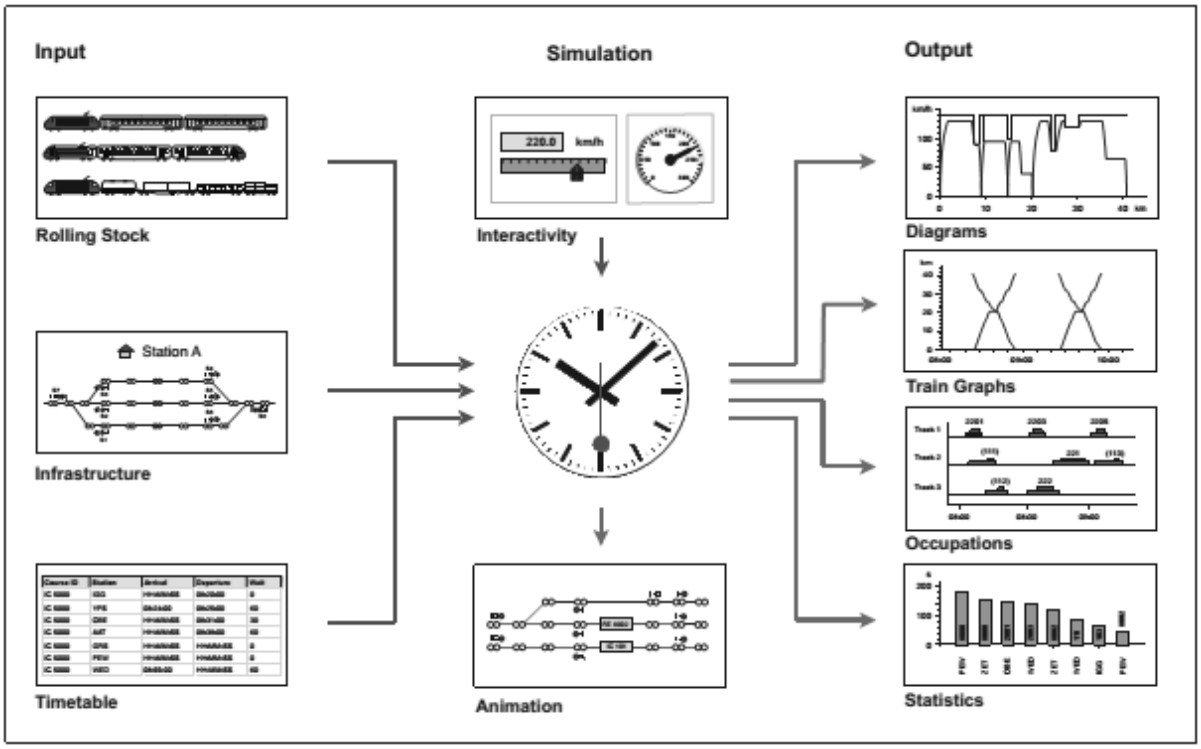

Fig. 1. OpenTrack Simulation Process: Input – Simulation - Output

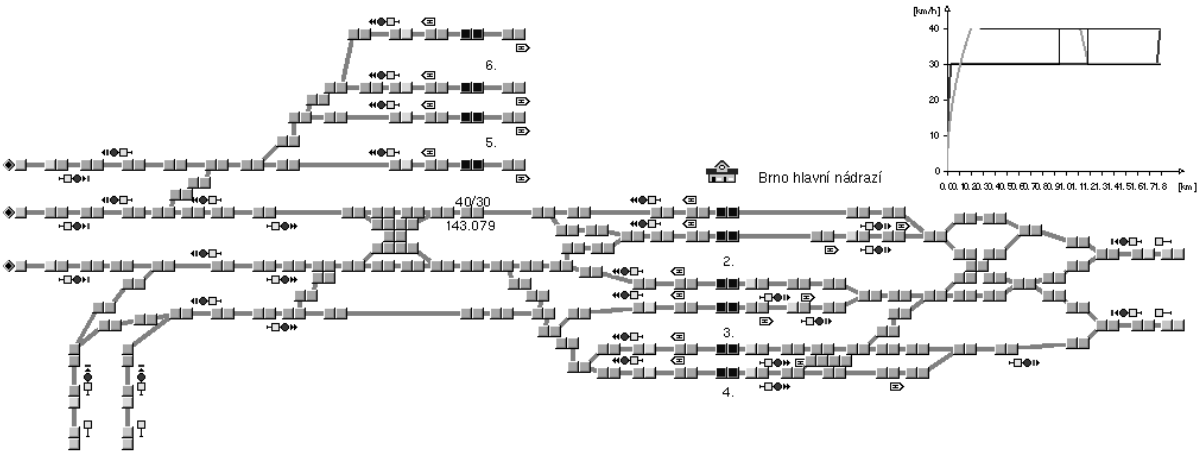

Fig. 2. OpenTrack infrastructure diagram sample of current passenger railway station

The core idea is in simulating the railway infrastructure down to a very detailed level including f.e. every switch, signal, speed restriction and grade changes in an infrastructure graph in the form of a double vertex – this means that every node of this graph has two endpoints. A train "rolling" on such an "infrastructure" goes on an edge (representing a piece of track) to one endpoint of a vertex (symbolizing a km-point with a switch, signal, station platform or whatsoever), moves to the other endpoint of the same vertex and continues on another edge (scaled with speed limits, length, gradient etc.) to another vertex. These routes (between signals) in the graph are connected into paths (from one station to another) and itineraries (possible ways for

a scheduled train in the graph).

The actual “train movements” – the simulation itself – is operated by a discrete module based on two more data sources – the rolling stock data (weight, maximum velocity, traction and other characteristics of trains/train components) and the timetable itself (lines, course numbers, defined rolling stock and itineraries, scheduled timetable and connections from and to each course, distribution of delay probability etc.).

One can loop through the simulation many times under different conditions. The result is a detailed protocol of all specified values in form of a text file and a graph.

Railway junction Brno

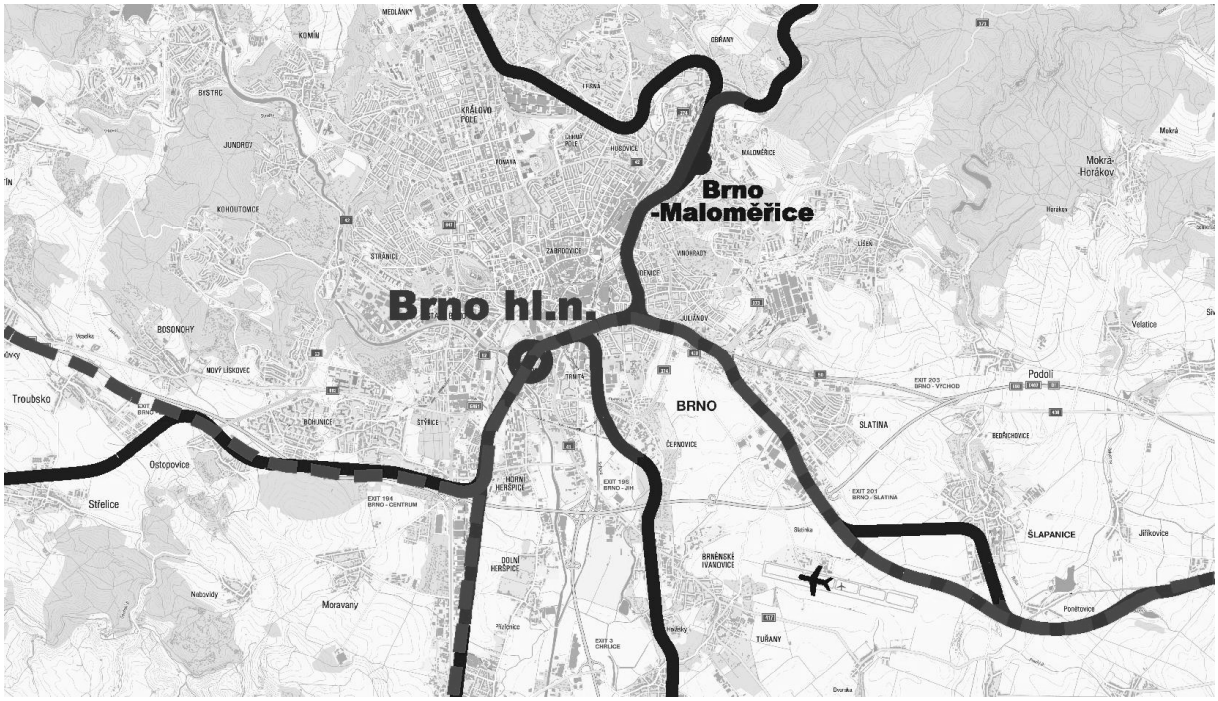

Fig. 3. Brno railway junction – proposed infrastructure, strategy “at the river Svratka”

Brno railway junction is user by all modes of railway transport. It is served by long-distance trains connecting the capitals of Germany and Poland to Austria and Hungary, including the planned high-speed lines. It is also a vital hub of national long-distance railway lines. Both of these modes are operated in conformation to national periodic timetable model with a period of one or two hours, partly with more lines leaving Brno in the same direction axis. Suburban areas of Brno are serviced by a dynamically growing number of suburban trains with a period down to 10 minutes in most used directions in the peak times. There is a large marshalling yard in the north and a considerable amount of transit cargo trains using a cargo track bypassing the passenger station, which is today connected without cross-overs to the main lines.

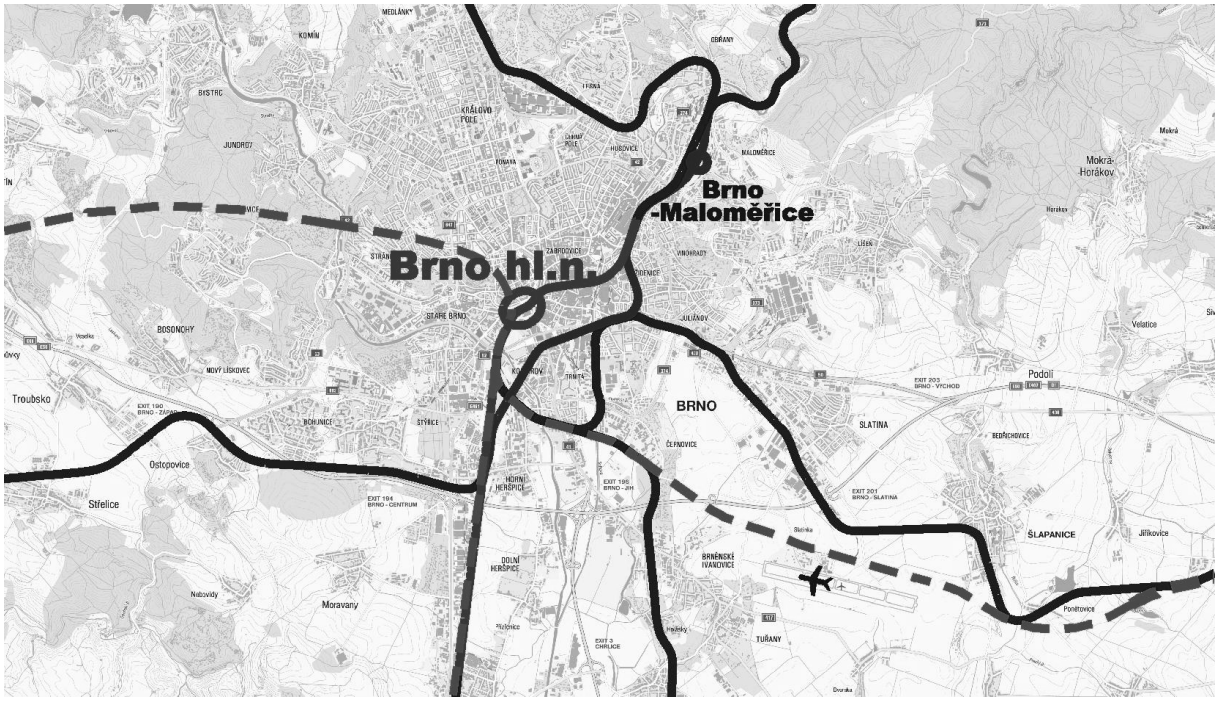

Fig. 4. Brno railway junction – proposed infrastructure, strategy “Petrov”

The question of the reconstruction of the railway junction of Brno has been discussed for a very long time. As it is one of the most important railway junctions in the Czech Republic, the official project of the reconstruction was generously conceived. A new passenger station should have been built in the brownfield area by the river Svitava, allowing Brno to dispose of the railway line near the City Centre and expand to the south. This led to massive protests and creation of an alternative study conserving the station today's position on the outskirts of the City Centre of Brno, under the Petrov castle. After years of presenting only one preferred solution the question of the new railway station became a sensitive political issue, involving also European funds, land speculators and referendums. Since the issue of the new position of the railway station is still not considered closed by the public, there is an urgent need to make an independent comparison of both variants in a transparent manner.

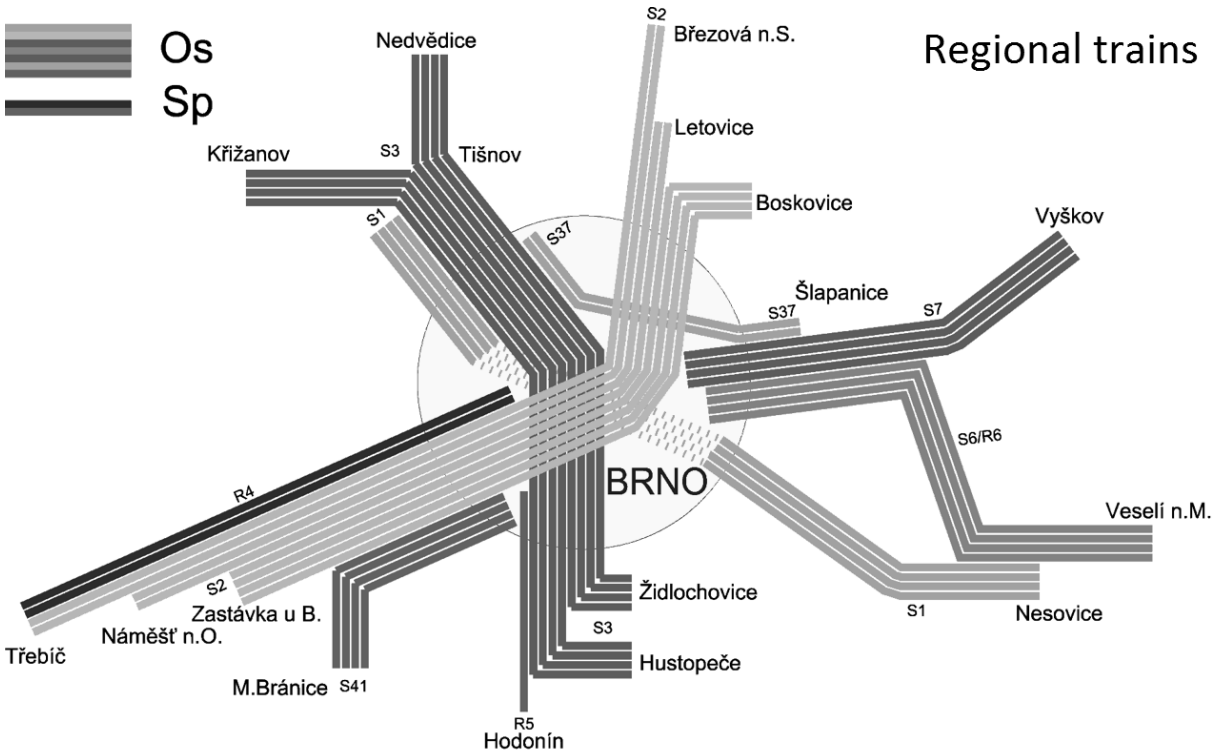

Fig. 5. Number of pairs of regional and suburban trains in the rush hours (2 hours) in the long-term perspective

The scope of the project is:

- Actualization of the anticipated number of trains with the infrastructure manager, the train operating companies and the public authorities ordering services in passenger and cargo transport in the short, medium and long-term, including the construction of the high-speed lines and its connection to Brno junction
- Further development of both strategies into a comparable level – both have a different level of processing with some elements unaddressed in detail, such as the location of signals, storage sidings etc.
- The proposed infrastructure of both strategies is analyzed and adjusted to ensure compliance to the updated expected traffic volumes in each time perspective represented with a peak timetable period schedule. Both strategies have slightly underestimated the long-term perspective.
- The railway junction should expand, however there are serious limitations of the City of Brno for its further development to fit in space not only in width, but also in height for considered cross-overs.
- The resulting minimalistic infrastructure conforming the traffic needs with only minimum space consumption will be tested for the reliability of the operational concepts achieved on it not only using the traditional static methods using the occupation times, but using microsimulation of the peak timetable period, including its stability against input delays and robustness to typical maintenance outages and other disturbations.

– The results for both strategies will present a solid background for a Cost-Benefits Analyze allowing to choose the better option.

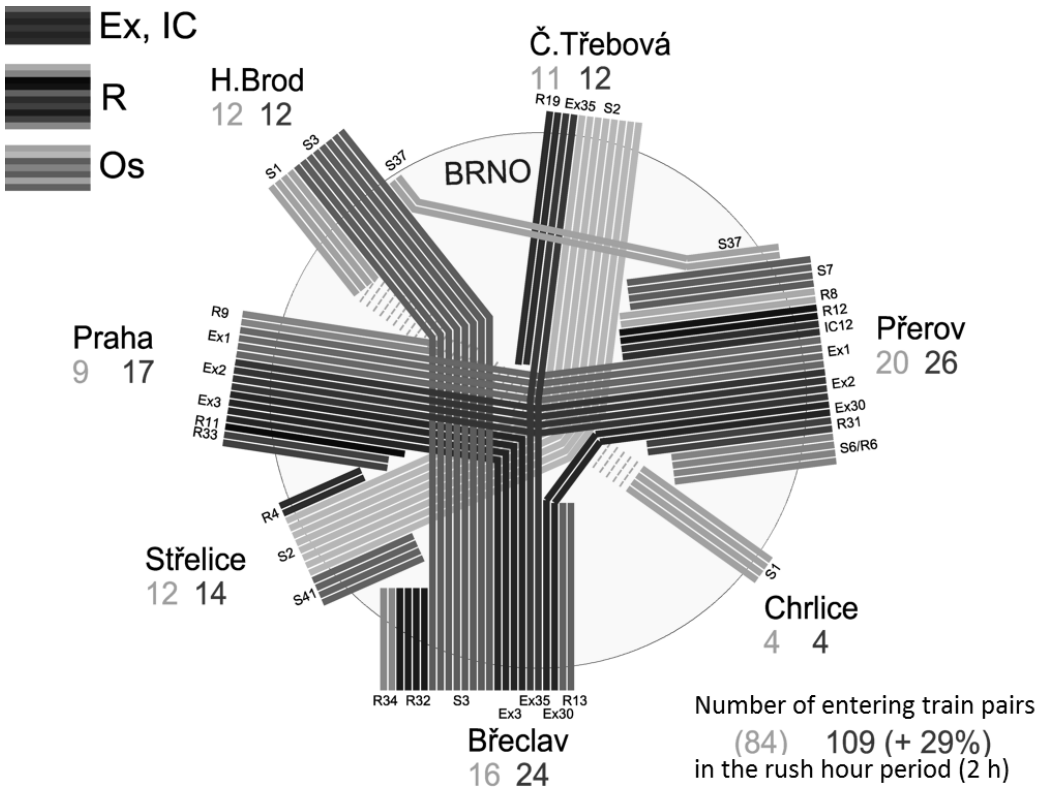

Fig. 6. Number of pairs of passenger trains in the 2 rush hours in the long-term perspective

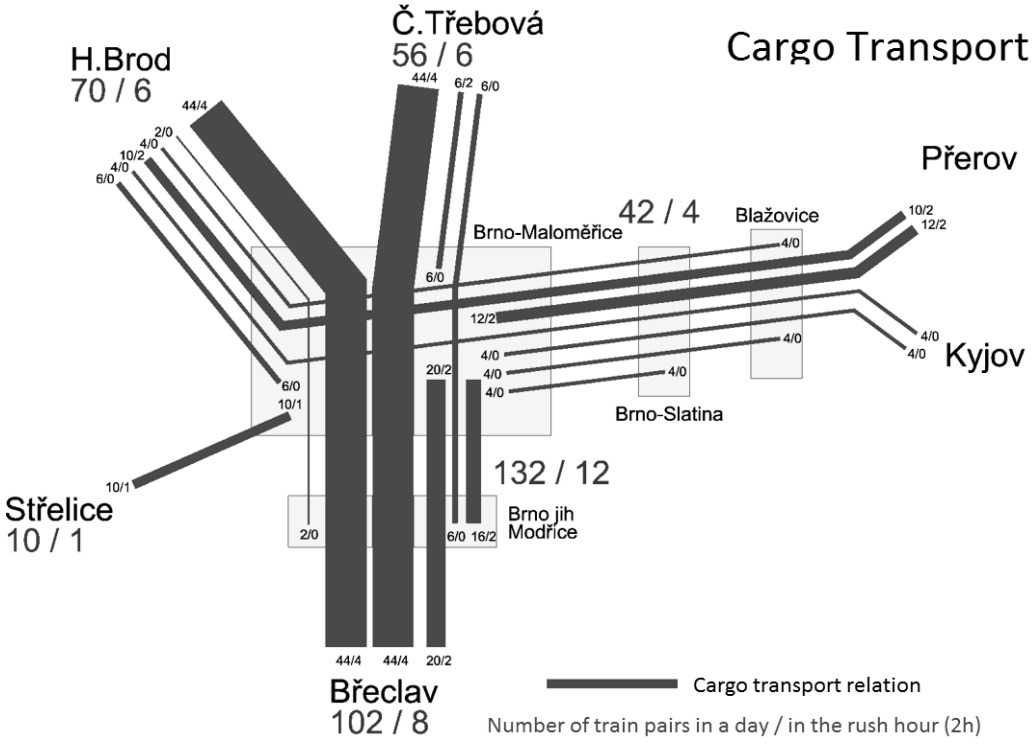

Fig. 7. Number of pairs of cargo trains in the long-term perspective

Conclusions

In the area of the Prague railway node we have many conflict areas, where the lines of trains of same or different train types cross in one level, and not all of them are to be solved with fly-overs. Opentrack was used to evaluate the impact of a train being delayed on other trains in the node.

Opentrack was also successfully used for determining the maximal waiting time for connections on a suburban one-track line which won't still impact the robustness of the proposed traffic program.

Other goal was trying to find a robust exclusion diagram on a double-track suburban railway during maintenance work, when always one section of this track was operated only as a one-track railway.

And the last project was an evaluation for the best traffic programm on a three-track railway with mixed suburban, long-distance and cargo traffic from the perspective of timetable robustness.

The simulation of the final proposed infrastructure in the long term period for both strategies in Brno railway junction is being evaluated in summer 2013 and will be presented in September in Katowice.

Microsimulation was accepted as a good tool for testing infrastructure improvements and new timetable concepts. As it uses a lot of simplified data on infrastructure, rolling stock and timetable with different level of errors, one has to precisely check the accuracy of the model, to what extend the simplified infrastructure graph still actually corresponds to the real infrastructure represented in it. Once the simulation is done, it produces a lot of output data. It is necessary to decide in advance, which data should be collected and saved, in how long time step and how should they be treated to deal with the result produced.

Abstract. Brno is one of the most important railway junctions in the Czech Republic. Two strategies of its reconstruction have been developed, differing primarily in the position of the passenger station either in the location of the current station or by the river Svitava. In the scope of the project is at first the actualization of the anticipated number of trains with the infrastructure manager, the train operating companies and the public authorities ordering services in passenger and cargo transport in the short, medium and long-term, including the construction of the high-speed lines. Both strategies are further developed into a comparable level and analyzed for compliance to the expected traffic volumes in each time perspective, represented with a peak timetable period schedule. Subsequently, the infrastructure modifications of both strategies ensuring the possibility of technical implementation of this updated traffic volume are proposed. The results are compared with the costs of implementation measures and the reliability of the operational concepts achieved on such infrastructure not only using the traditional static methods using the occupation times, but actually using microsimulation of the peak timetable period, including its robustness to typical maintenance outages and other disturbations.

Mikrosymulacja jako narzędzie do oceny możliwości przebudowy infrastruktury kolejowej i koncepcji obsługi złożonego węzła kolejowego

Streszczenie. Brno jest jednym z najważniejszych węzłów kolejowych w Czechach. Zostały opracowane dwie strategie jego przebudowy, różniące się przede wszystkim położeniem stacji pasażerskiej Brno hl.n. Pierwszą możliwością jest utrzymanie aktualnej pozycji, drugą umieszczenie jej w nowym miejscu nad rzeką Svitava. Pierwszym etapem prac projektowych było dostosowanie prognozowanej przez zarządcę infrastruktury wielkości przewozów pasażerskich i towarowych do krótko-, średnio- i długofalowych planów przewoźników i zamawiających przewozy, tzn. również do sytuacji po uruchomieniu linii dużych prędkości. Obie strategie zostały doprowadzone do wzajemnie porównywalnej formy oraz była poddana analizie ich zgodność z prognozowaną wielkością przewozów. Następnie zostały zaproponowane zmiany w projekcie umożliwiające techniczną realizację przewozów po aktualizacji prognoz. Wyniki porównano pod względem kosztów realizacji i niezawodności za pomocą metod statystycznych z wykorzystaniem czasów zajętości, a także za pomocą mikrosymulacji przewidywanego ruchu włącznie z wzięciem pod uwagę ograniczeń ruchowych związanych z utrzymaniem i awariami.

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