

# TIMETABLE ENGINEERING IN RAILWAY TRANSPORT IN CZECH REPUBLIC

## ОРГАНИЗАЦИЯ РАССПИСАНИЯ В ЖЕЛЕЗНОДОРОЖНОМ ТРАНСПОРТЕ ЧЕХСКОЙ РЕСПУБЛИКИ

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**Abstract:** *High quality of operational concepts in railway transport represents one of the basic premises of functional public transport system and public transport services. In this area the systematic timetable engineering plays an important role. Advanced timetable engineering brings a strong contribution for an effective use of infrastructure capacity. This effectiveness is particularly fundamental by investment-consuming railway infrastructure.*

**KEYWORDS:** RAILWAY TRANSPORT, PUBLIC TRAFFIC, RAILWAY TECHNOLOGY, TIMETABLING, FBS, OPENTRACK

### ***Transport planning and timetabling***

The timetable is a basic instrument for organizing railway transport. Though, it represents supply of connections in network for passengers. Generally, timetables can be divided into fixed (periodic) and commercial (non-periodic).

The way from the basic idea of transport concept to final daily operation is long and complicated – from the transport planning with regards to present infrastructure parameters through timetable planning to the simulation of the transport concept. Within the stage of transport planning are the traffic relations (OD-Matrix) and estimated Modal-Split of railway passenger transport to measure. The next coming line network scheme defines the lines, period of services and capacity of operating vehicles. These two phases generate the background for a rough draft of operational concept. Finally, this proposal of operational concept has to be verified by tool for timetable planning. Inputs for this verification should be represented by infrastructure parameters, e.g. track station lay-out and location, velocity and propensity profile, curve radii and tunnel profiles. For the running time calculation are required speed-traction-effort curve, distribution of traction effort, tonnage of train and the stopping time at the stations.

Real operation is negative touched especially by infrastructure bottlenecks and modernization. The timetable stability has to be proved by simulation of operational concept.

The first one to experimentally use a software tool to plan the railway operations was the University of Hannover (Germany) in late 70's. But these early tools were able just to support single steps of the planning process (e.g. timetable construction). In the 80's were introduced first more complex simulation tools which were integrating more planning steps efficiently and the 90's the performance of hardware and the development of complex simulation software tools enabled the functional usage of railway operations simulation to construct and prove the timetable as well as to specify and demonstrate the contribution of infrastructural or technological improvements especially in Germany and in Switzerland.

In Czech Republic the main railway operator – České dráhy – and later also the infrastructure manager – SŽDC – has been using a timetable planning system SENA JR VT (developed by České dráhy and the Universities of Pardubice and Žilina) since 1997.

In a similar way our Faculty of Transportation Sciences (CTU in Prague) has used the software FBS (iRFP Dresden – Germany) since 1999. And, since 2003, CTU Prague, Faculty of Transportation Sciences has been finally using also a really complex simulation tool – the OPENTRACK (ETH Zurich – Switzerland). Czech Technical University in Prague has adapted both tools FBS and OpenTrack to Czech operational conditions.

### ***FBS-programme***

FBS is a programme family for railway conception, which has been developed since 1993. Naturally, it combines the opportunities of today's computer technology with scientific calculations and the knowledge of daily railway operation. FBS represents an efficient tool concerning creation of timetables and utilization of obtained data.

**Fpl – GRAPHIC TIMETABLE Programme** - The train diagram is the most important document when conceptualising a new timetable. Here, position and sequence of trains are being fixed. When creating timings, two difficulties may occur: firstly, calculation of timings depend on a host of different factors which need to be taken into an account, secondly, drawing a train diagram is very time-consuming.

FPL is able to solve both problems successfully. After estimating the running time for a desired train, the train is pictured immediately in the diagram. Following the estimations for each train, the train diagram can be printed instantaneously.

Besides the data of engines, which are contained in the programme, the following infrastructure data has to be imported or entered in order to use FPL's ability of estimating running times:

- position and character of operating stations
- number of stations and line tracks
- gradient ratio between stations / gradient profile
- speed at station and main tracks and at lines
- regulations for station and main tracks

After choosing train properties as head codes, travelling time supplements, stop-off points and departure times the available train slot may be determined.

The more complicated the timetable, the more indispensable is FPL for the user. Inserting train data into the computer does not only determine possible arrival and departure times, it also suggests the next available train slot or train crossing on single-track lines. If the position of the train is not suitable, the line can be moved effortlessly with the mouse. Executing this procedure, FPL always checks if the desired train slot is available every day, not only on weekdays but for the whole operating period. Current methods of modern forms of traction such as the so-called train-coupling and sharing do not represent any problems for FPL; any number of parts per train may be entered while considering different sections and days. Thus, different loads or several tractions may be taken into account easily. Compiled timetable data such as running times or train position may be directly taken over into the other FBS components. It goes without saying that copying times or other data are not needed anymore.

FPL provides timetable statistics for business management calculations, including train mileage and storage balance, which can be transferred into text processing or spreadsheet analyses.

Balances and orders are simplified and changes in quantity of business conceptions become observable. Neutral timetable evaluation decides whether timetable versions are practicable regarding their quality, moreover, it compares the debit sides, which were tracked and manifested in the disposition mode of FPL, with the credit sides in timings. Those factors turn out to be of growing importance to the increasingly regional commuter traffic market.

In order to employ FPL's current knowledge of driving dynamics, one has to know about the technical data of the particular motive power units.

FPL comes with an extensive data-base, containing many European manufacturers and engines. When calculating running times, FPL considers employed types of brakes as well as the effects of different ATP and ATO devices on running and braking conditions.

**BFO - Programme for Timetables of Stations** - It is quite easy to keep an overview of a station with two tracks, usually, there is one direction running or there are simple rules for the use of tracks. On the other hand, a variety of timetable documents to secure track occupation are used at larger stations.

BFO provides these documents by importing train data from FPL train diagram files. In case these files are not complete, train data may also be entered manually.

Besides that, BFO is capable of independently assigning trains according to a defined rule for the use of tracks. This proves that modern and clear timetable documents need not to be reserved to the main stations. BFO creates train sequence tables and track-occupation charts within minutes!

Track-occupation charts used in the initial planning process may be shown according to the local conditions either vertically or horizontally by a click with the mouse.

The familiar train sequence tables are illustrated in colour for the staff in signal boxes or signalling centres. By doing so, subordinated locations may be assigned, either jointly or separately. BFO facilitates the compilation of additions or changes to BFO or to an entire special operation orders.

BFO carries out troubleshooting, for example if a track has been assigned for two trains on a certain day or if platform or track lengths are insufficient. By doing so, problems can be detected far in advance.

**NETZ - Programme for Network Timetables** - In most cases trains do not run on a single line section. NETZ combines several graphic timetable files created by FPL, to the daily-used operating network. Changing locomotives, multiple units and train staff that needs internal timetables, vehicles need to be used economically within the entire network. After all, the best timetable conception seems useless if customers are not notified. Timings and informative material need to be printed and kept up-to-date.

Furthermore, NETZ assists in the daily work simple and fast. The application NETZ imports existing timetable data from FPL and BFO. After having been processed in the modules Driver's Timetable, Customer's Timetable and Circulation Plan, ready-for-print documents and data are available to further planning and information systems. Here, conclusions regarding optimisation of timings may be taken.

The basis of NETZ-programme is in present already extended and combines current possibilities and user-benefits of the NETZ with FPL to the very user-friendly and well advised software application iPLAN.

**TFZ - Engine Data Programme** - TFZ is a database containing all important parameters of locomotives and DMU/EMU for the use with FBS. Data from the operators and manufacturing

companies (e.g. Siemens, Bombardier, Škoda) will be added for the use of the FBS. It is also possible to get interaction between timetable and rolling stock data in an easy way.

### ***Practical using of FBS in theory and praxis***

FBS defines an optimised interaction between infrastructure, rolling stock and operation. CTU in Prague prepares with iRFP every year the whole timetable of the railway long-distance traffic in Czech Republic in FBS – for Czech ministry of transport which orders this traffic by Czech railways (ČD a.s.).

### ***OPENTRACK-programme***

The basic principle of railway operations simulation can be described in following way:

The real railway operations - as a cooperation of man, infrastructure and vehicles - is presented by a model that enables to experimentally imitate those parts of the processes in the transportation system which are important for the performed research. The statistical processing of its outputs (the range and accuracy may slightly differ according to needs and the used tool) brings us respectable results.

Every simulation tool consists of following components:

- Entry data input:
  - o Infrastructure data
  - o Vehicle data
  - o Transport demand data (proposed timetable, needed interval, needed interchange possibilities, needed departure or arrival settings)
- Specific simulation algorithm
- Results output enabling efficient interpretation of the achieved data

The key component is obviously the simulation algorithm. There are two basic algorithm arts – the synchronous and the asynchronous one.

#### ***The asynchronous simulation algorithms***

The asynchronous simulation tools take the operating trains one by one as they appear in the proposed timetable and calculate the whole ride of the train in dependence on the infrastructure and vehicles' traction parameters. The calculated routes are compared afterwards and detected conflicts are being solved.

#### ***The synchronous simulation algorithms***

The synchronous simulation tools calculate the movement of all trains "in the real time" and the appearing conflicts are being solved "ad hoc". It is usually possible to set a specific period in which the conflicts are being forecasted. The OPENTRACK is one of the synchronous systems.

#### ***The synchronous simulation algorithms***

The synchronous simulation tools calculate the movement of all trains "in the real time" and the appearing conflicts are being solved "ad hoc". It is usually possible to set a specific period in which the conflicts are being forecasted. The OPENTRACK is one of the synchronous systems.

#### **Multiple simulation**

The multiple simulation is a specific feature developed in the last years which is very efficient especially to prove the robustness of a timetable.

This component enables to enter some time elements (entering delay, stop duration, interchange duration) or incidents (traction performance, appearing of infrastructure obstructions) in form of a mean value with a probability distribution.

Later the simulation can be set to be performed many times when the mentioned time elements are sampled according to the probability distribution. When the number of simulation runs is high enough (tens till hundreds of runs according to the complexity of the model), the results can prove the robustness of a timetable very accurately and also determine the critical system points.

## **Practical using of OPENTRACK in theory and praxis**

One of the first applications of this tool in czech praxis was simulation of a new operation concept on the track Praha-Kladno in the timetable for the period 2008-9. As a part of the Praha suburban transport system, the track should offer a much more intensive traffic with morning and afternoon interval of 15-30 minutes. This was quite a challenging task, as the track is almost in full length single tracked and the traffic is mostly operated locally by an elderly electromechanical signal box.

### **A prove of the timetable feasibility**

The first important result of the operations simulation was the conclusion, that the proposed timetable is feasible. Under standard conditions (calculated performance reserve of 4%) there were no delays longer than 20 seconds (at the 30 sec. accuracy of the timetable). Under bad conditions (calculated performance reserve of 10%) some trains reached a delay of up to 130 seconds but the timetable still remained robust in a way, that no trains have to be cancelled and the order of trains passing the stations did not have to change even slightly.

### **Proposed basic operation rules**

Based on the simulation of bad conditions as well as the simulation of train entry delays three basic rules for the case of traffic irregularities were proposed:

- to minimize waiting for delayed trains (for the purpose of interchange) – on the simulated track absolutely and on the following part of track (Kladno – Rakovník) to a maximum of 7 minutes
- to become very flexible in changing the stations where the trains cross or overtake
- to prefer trains having a delay up to 7 minutes not respecting their specific preference class instead of the typical preference of fast and other specific class trains

### **Individual reports about the influence of entry delay for every train**

For every train (or tact group of trains) the entry delays of 5, 10 and 15 minutes were simulated. According to the results of these simulations the critical delays were determined for every train. The critical values were the periods over which the delay came over to other trains, the train crossing points had to be changed or the traffic caused the delay to rise further on in the simulated part of track.

### **The differences between Swiss and Czech railway operations**

The SW FBS and Opentrack are based on the German, Swiss and Austrian railway operation law, rules and conditions. So as to keep some specific Czech rules, we had to find some improvised solutions (the most crucial one was to keep the appropriate period between two trains entering one station almost at the same time, which was finally solved by using the overlaps/skid distances, which are practically used very rarely on Czech railways).

These measures took quite much time to set up and especially to calibrate to reach the needed period and - what is even worse – they brought a slight risk, that in critical situations (e.g. when the train tries to shorten the existing delay) the reaction of the model will not be absolutely adequate.

Since we can't suppose the OPENTRACK or any other simulation tool to be soon adapted to the Czech legal and technological conditions, we will probably have to optimize our alternative solutions further on, and be aware of the possible inaccuracy caused by these processes. We calibrate options in Opentrack with evaluation in FBS, so the final results of these programmes are full usable for the Czech infrastructure manager (SŽDC s.o.).

## **Conclusion**

This paper has presented, which tools are used as support for transport planning on the Czech technical university in Prague. All research problems in the area of transport planning (creating the new transport concepts and new technological solutions on the railway), as well as all practical successful results of application of the new IPT- Concept (integrated periodic timetable, in the Czech Republic massively applied since 2003) are prepared using these tools. Advanced timetable engineering brings a strong contribution for an effective use of infrastructure capacity – it's possible to say, where are current limits and bottlenecks of the infrastructure – using these support tools it is possible to enumerate, what are the most important precautions in operation and investment in relation to capacity, reliability and safety. This effectiveness is particularly fundamental by investment-consuming railway infrastructure. Practical application of these tools makes necessary link between theory and praxis.

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