# THE PERIODIC TIMETABLE INFLUENCE ON LINE CAPACITY

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**Abstract:** This paper deals with the influence of timetable periodicity on line capacity. First, there is created a simulation in the simulation program SimuT, and then they are for individual train branches formed and subsequently simulated periodic schedules. The output of the simulation is always a number of train routes (quantitative parameter), the average delay increments (qualitative parameters).

**Keywords**: timetable, periodic, line capacity, simulation, train.

## 1. Introduction

Determining the timetable periodicity influence on line capacity is one of the research topics, which can optimize the rail operation and rail transport operation without the implementation of costly building measures.
As part of this research, it is necessary to consider both qualitative and quantitative aspects of the issue. The main interest of the railway infrastructure manager is the realization of quantity (the highest number of train routes) generating revenues in the form of a fee for the allocation of capacity and fee for the use of railway infrastructure, the main concern of individual carriers is mainly the realization of quality, respectively maximally stable train routes in sufficient number.

## 2. The list of used methods

Due to the complexity of the problem are the most effective means and methods for its solving modelling and simulation. They are based on multiple repetitions of examined phenomenon with the requirement for high accuracy due to subsequent use in real operation. Since it is a dynamic stochastic model, computer support is necessary – it was chosen a simulation program SimuT.
SimuT – it means program Simulation of Tracks, whose primary purpose is verification of operational concepts (including timetables (TT)) according to transport infrastructure (TI). This simulation tool was created and is still improved by Ing. Pavel Krýže, Ph.D. and Ing. René Amcha from Czech Railway Infrastructure Administration (CRIA). As input data are required TI data, examined range of rail traffic data and the definition of alternative solutions. The overall output of the simulation program SimuT is then created TT sheet with all of the attributes, as well as capacity indicators, including an overall average delay increment. Through this indicator is evaluated the TT stability and the train routes quality..

## 3. Problems solving

Solving the periodic timetable (PTT) influence on line capacity was done by means of simulations implemented in the simulation program SimuT. They were implemented following simulations:
- current operating range (TT 2016),
- created PTT, maximizing periodicity,
- created periodic freight train paths in network (PFTP).

The TT periodicity influence on line capacity was solved by calculating permeability characteristics according to the prescription SŽDC (ČD) D24, according to the UIC 406 leaflet and due to average delay increment calculation for each simulation scenario. Results for simulation scenarios were compared and on this basis it was created a flowchart of the optimum utilization of train routes in terms of quantity and quality in relation to the implementation of PTT.
The simulation scenarios are characterized by periodicity rate, which is designed by the author of this article like the share of trains kept within PTT or PFTP and all the trains contained in the TT (1).

$$\mathrm{R_P} = \frac{\mathrm{N_P}}{\mathrm{N_C}} \cdot 100\ [\%] \qquad (1)$$

| | |
|---|---|
| $R_P$ | the periodicity rate |
| $N_P$ | the number of trains in PTT/PFTP |
| $N_C$ | the whole number of trains |

As a TT stability indicator is calculated average delay increment ADI (2), which is calculated by dividing the difference between total output and total input delay and the total number of trains. If the increment is positive, the resulting delay isn't eliminated and TI is not able to compensate the extraordinary generated within the established operation range.

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Average delay increment (ADI) is calculated for all simulation runs as the difference between total output and total input delay and the total number of trains (2).

$$\text{ADI} = \frac{\text{D output} - \text{D input}}{\text{N}} \text{ [min/train]} \qquad (2)$$

| | |
|---|---|
| *D output* | the total output delay [min] |
| *D input* | the total input delay [min] |
| *N* | the number of trains |

Within all simulation scenarios there was in the simulation program SimuT set for all simulation runs random input delay based on the exponential probability distribution, freight trains were allowed to go with a lead and for each simulation scenario was done a total amount of 365 runs (for each day of the TT).
In this paper there were calculated capacity indicators according to the SŽDC (ČD) D24 methodology and according to the UIC 406 leaflet – for selected area in terms of current operation, in terms of created PTT and in terms of PTT with PFTP. In the selected area there was impossible to construct ITTT because it was not possible without significant interference to the selected operational concept to meet all the conditions for the ITTT creation.

## 4. Results

On the basis of problems solving, which is mentioned in the previous chapter, the results have been summarized so that they can be compared the different types of TT with each other.
Table 1 shows the number of trains on five defined sections for each type of TT, where the upper number in a cell represents the total number of trains in the TT, numbers at the bottom of each cell then the number of trains long-distance passenger transport/regional passenger transport/freight transport. If there is an X, it means the kind of traffic doesn't occur on the section.

**Table 1: Number of trains in the TT**

| Section/TT | TT 2016 | PTT | PFTP |
|---|---|---|---|
| Kolín - Choceň | 384<br>171/62/151 | 336<br>104/83/149 | 336<br>104/83/149 |
| Choceň – HK – VO | 174<br>30/106/38 | 108<br>50/40/18 | 114<br>50/40/24 |
| Pardubice hl. n. – HK hl. n. | 137<br>19/105/13 | 179<br>118/40/21 | 179<br>118/40/21 |
| Kolín – VO | 213<br>16/78/119 | 221<br>38/40/143 | 221<br>38/40/143 |
| Moravany - Borohrádek | 48<br>X/42/6 | 57<br>X/38/19 | 57<br>X/38/19 |
| The whole amount | 956<br>236/393/327 | 901<br>310/241/350 | 907<br>310/241/356 |

*Source: Authors*

In PTT and PFTP was routed generally lower number of trains than in TT 2016 – it was caused by the formation of comprehensive train routes within PTT and PFTP, when one train number (in SimuT it means one train) covers on average longer distance than in TT 2016. Especially in regional passenger transport was used only one train number, which replaces in a few cases up to 4 numbers (the train was in the TT 2016 three times renumbered).
For all three mentioned variants (TT 2016, PTT and PFTP) are calculated parameters for the closed rail network – the total delay in a closed network, both for all trains and various types of transport. The total delay over a closed network is calculated as a scalar product of the total number of trains (number of trains in the segment) and related average delay increments. Furthermore, for each TT is calculated average delay increment in a closed network, both overall and for different types of transport. Average delay increment is calculated by dividing the total delay over a closed network and the total number of trains on the network. For each TT is also calculated total periodicity rate, as a share of trains routed on the network periodically and all trains on the network.
Furthermore, they are compared average delay increments in the TT versions, here for the entire closed network – Table 2.

**Table 2. ADI, entire network**

| TT | ADI (min/train) | ADIL (min/train) | ADIR (min/train) | ADIF (min/train) |
|---|---|---|---|---|
| TT 2016 | 0,21 | 1,88 | -0,43 | -0,23 |
| PTT | -0,49 | 1,02 | -1,03 | -1,46 |
| PFTP | -0,62 | 1,07 | -1,00 | -1,83 |

*Source: Authors*

Due to the PTT construction was reduced all average delay increments within the closed network, through PFTP creation was further reduced overall average delay increment.
In the evaluation there has been already mentioned the number of trains, their periodicity and average delay increments. However, it is necessary to compare the capacity indicators (such as decisive methodology was chosen methodology according to the UIC 406). Capacitive indicators must be compared especially for the most occupied interstation departments, of which were selected as a representative sample three departments, namely Pardubice hl. n. - Přelouč, Třebechovice pod Orebem - Hradec Králové – Slezské předměstí and Pardubice - Rosice nad Labem - Stéblová.
To formulate generally valid conclusions, it is necessary to analyse various aspects of the results. The quantity parameter is defined primarily by the amount of realized train routes, which is unfortunately partially distorted by the creation of integrated routing in PTT, when one train route means only one train number. Despite this fact, it was found the quantity is similar in TT 2016, PTT and in PFTP.
The basic parameter determining the quality is the overall average delay increment, which is the lowest in the PFTP, then in the PTT and the highest values reaches in the TT 2016. The fundamental research task was to relate the indicators to the TT periodicity – for this purpose was counted for each TT the indicator periodicity rate. Railway lines capacity utilization verifiers are then UIC 406 capacity indicators, primarily total consumed capacity indicator C. All these indicators for closed network there are shown in Table 3; the total consumed capacity indicator is displayed for most capacitive loaded TT section.

**Table 3: Indicators for entire closed network**

| TT | Number of routes | ADI (min/train) | Periodicity (%) | C (%) |
|---|---|---|---|---|
| TT 2016 | 956 | 0,21 | 44,04 | 93,42 |
| PTT | 901 | -0,49 | 98,34 | 115,39 |
| PFTP | 907 | -0,62 | 98,57 | 115,39 |

*Source: Authors*

Based on the Table 3 is possible to confirm, with appropriate periodic routes construction within PTT is possible under comparable routes quantity conditions to increase the routes quality (decreasing the overall average delay increment on a closed network), despite high capacity utilization of some infrastructure facilities. As the subject of further research it offers methodology UIC 406 revision to extend the capacity indicators calculations not only for day period and rush hours, but also for defined ranges within the periodicity rate. For standard calculation according to the current methodology it was in fact expected that at high capacity utilization of infrastructure facilities will worsen TT stability (overall average delay increment increasing). But if all the trains are kept in PTT, including freight trains (assumption just in time delivery), it is possible through effective bundling to achieve higher train routes quality with increasing periodicity. The whole process of PTT implementation on defined rail infrastructure is clearly shown in flow chart form in Fig. 1.
The PTT construction is within the defined infrastructure divided according to the number of line tracks, when on multi-track lines there should be monitored especially trains bundling and on single-track lines the edge times and crossing possibilities. In terms of comparable quantity and increasing TT periodicity within the entire closed network is created a model like the basis of a simulation. If there is no decrease of overall average delay increment, it is essential to change the concept (heterogeneity, number of stops, etc.) or to modify the infrastructure and then continue again from the beginning. If the ADI decreases, it is possible to undertake further measures, such as the ITTT or PFTP construction or other possible tracing change – and then create a new simulation. If the ADI doesn’t decrease, this procedure could be repeated iteratively, if there is a downturn, it is possible to evaluate the control parameter – the UIC 406 total consumed capacity indicator C. If this indicator is higher than 100%, the constructed TT can be considered functional operational concept with infrastructure capacitating recommendations, if this indicator is lower than 100%, the constructed TT can be considered functional operational concept with the option of inserting additional routes.
Since the key parameter of this research is the quality of the rail operation and rail transport operation, respectively reducing the total average delay increment on a closed network, there is shown in Figure 2 the Ishikawa diagram as one of the tools for quality assurance.

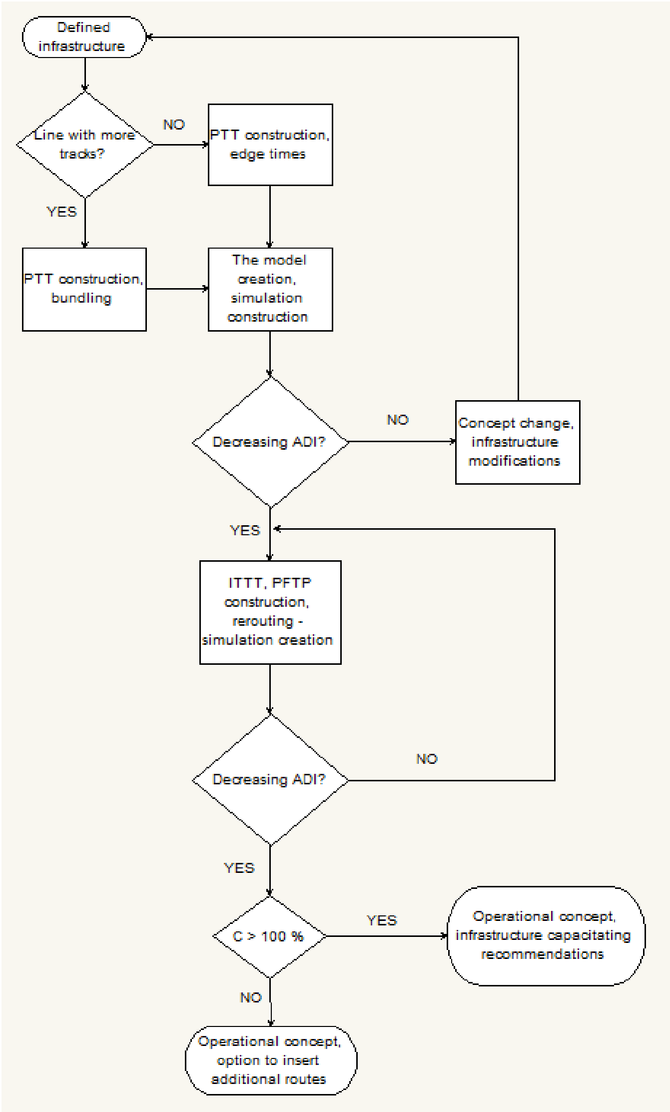


**Fig. 1. The PTT implementation on defined rail infrastructure**
*Source: Authors*

According to Fig. 2 may be a cause of failure of the desired PTT quality achievement inadequate TI, wrong selected operational concept or inadequate operational train priority. The cause of inadequate TI can be long distances between railway stations or low line speed, leading to the failure of edge times. Lacking railway station tracks can also be problematic.

Selected operational concept can be wrong in terms of train composition (inadequate to demography, not using double track sections), inadequate number of trains, inadequate number of stops (at capacitating may arise Braes paradox) or in terms of incorrect train routing (waiting for crossing, too tight sequence). Within inadequate operational train priority could be mentioned low freight trains priority, which then causes the improper utilization of available capacity due to frequent freight expresses overtaking by passenger transport trains and the associated delay generation (starting, stopping), or incurrent implementation of the operational priorities in peak periods (e.g. increasing freight trains priority during passenger traffic peak). As a further research subject on the quality field it offers compiling of FMEA analysis on the Ishikawa diagram basis.

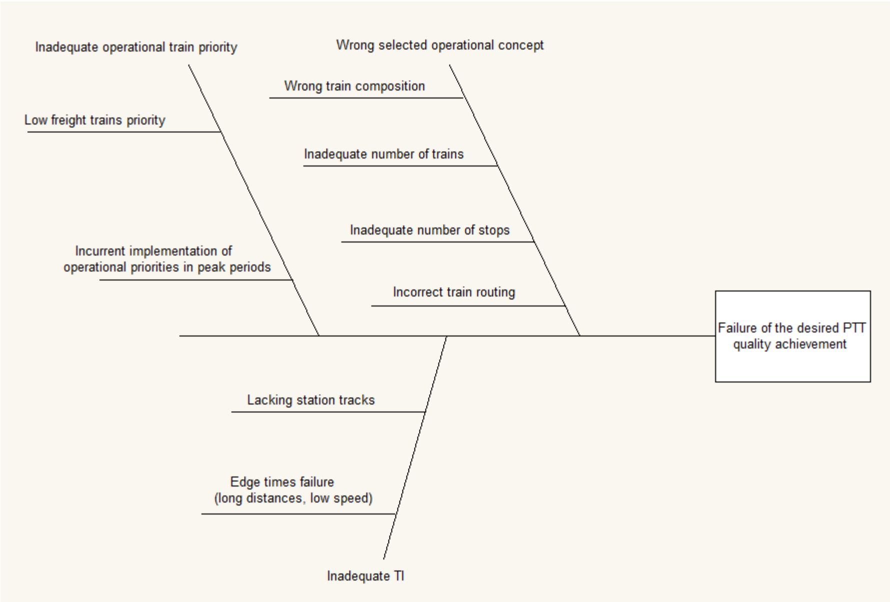


**Fig. 1. The Ishikawa diagram of failure of the desired PTT quality achievement**
*Source: Authors*

## 5. Conclusion

Despite all expectations it was demonstrated increasing TT periodicity does not cause deterioration of the optimum utilization of train routes - under the terms of comparable quantity improve the network quality parameters with the increasing TT periodicity. Since a closed network, on which there were done simulations in the simulation program SimuT, was chosen to include single-and multi-track lines (single track lines suitable for different operational concepts) can be the research considered universally valid. It can be said with increasing TT periodicity and PTT (PFTP) implementation in freight transport it is possible to satisfy infrastructure manager in terms of routes quantity and at the same time it is possible to satisfy carriers by improving the quality of routes.

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