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Timetable performance evaluation

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Abstract
This article deals with the methodology of timetable performance evaluation. To provide one result number for timetable evaluating is necessary to rebuild some processes and create a new methodology. This methodology uses the quality parameters of timetable (average delay increment), the quantity parameters of timetable (number of trains) and the infrastructure coefficient. The infrastructure coefficient is based on the occupancy rate of operational rail equipment and according to this it is related to the concrete infrastructure.
KEY WORDS: *capacity, infrastructure coefficient, timetable performance evaluation.*

1. Introduction

The timetable fulfilment is nowadays in the whole world based on the many different methodologies with many different capacity indicators. For example, there is the UIC 406 capacity methodology widespread. In the Czech Republic, there is the national capacity methodology SŽDC (ČD) D 24 [1]. If we think about all these methodologies and about the possibility of their combination, it will be sure, the timetable evaluation is very difficult, and the result depends on the methodology choice and on the interpretation. Therefore, it is eligible to think over the methodology, based only on one number, which will be able to evaluate really the timetable performance.

The quality aspect of capacity – in the paper [2] there was found, the quality aspect of capacity counted via ADI can be influenced by the timetable periodicity. There was suggested the flow chart of periodic timetable implementation on defined rail infrastructure and the quality Ishikawa diagram of failure of the desired timetable quality achievement. This case of using ADI was verified and it was the evidence to use more often the average delay increment indicator. Therefore, the Ishikawa diagram is shown in the following figure (Fig. 1).

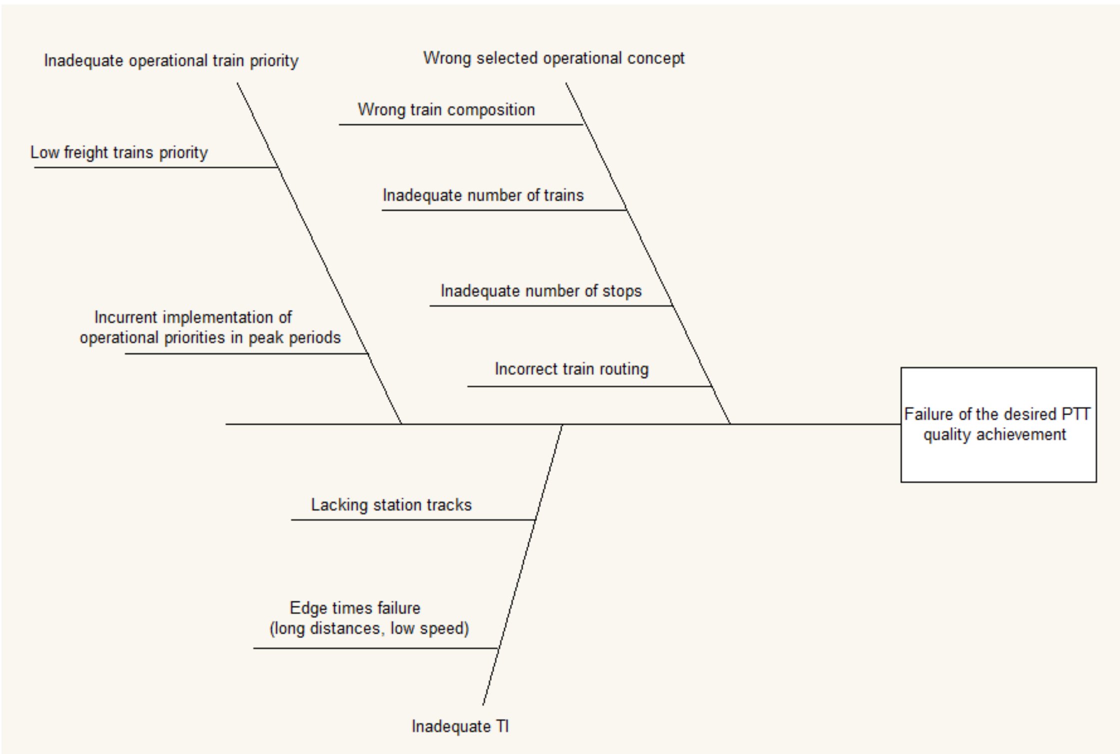

Fig. 1 The Ishikawa diagram of failure of the desired periodic timetable quality achievement

The capacity range parameter is related to identify a wrong selected operational concept. Due to the capacity range calculation is possible to evaluate on the one number basis the quality of the operational concept, including the wrong train composition, the inadequate number of trains, the inadequate number of stops and the incorrect train routing [3].

2. Materials and metods

There are mentioned some information about the occupancy rate of operational rail equipment, average delay increment (ADI) calculation and new capacity methodology suggestion.

Occupancy rate of operational rail equipment

Occupancy rate of operational rail OC_R equipment is defined in the SŽDC D24 prescription – it is displayed in Formula 1 (1).

$$OC_R = \frac{N \cdot t_{oc}}{T - (\sum t_{excl} + \sum t_{man})} \tag{1}$$

where T - the whole time for evaluation; N - the number of trains; t_{oc} - technological time of the occupancy of the operational rail equipment by 1 train; $\sum t_{excl}$ - the whole time of exclusions of the operational rail equipment (repairs and maintenance); $\sum t_{man}$ - the whole time of the occupancy of the operational rail equipment for permanent manipulations.

Average delay increment calculation

The average delay increment (ADI) – it is calculated by dividing the difference between total output and total input delay and the total number of trains. As part of the simulation it is set for all simulation runs random input delay based on the exponential probability distribution. It is displayed in Formula 2.

$$ADI = \frac{total\ output\ delay - total\ input\ delay}{number\ of\ trains} \tag{2}$$

For ADI calculation is appropriate to use some simulation tool [3].

The cuboid capacity methodology

All required values could be expressed through a cuboid capacity methodology (CCM), where there are on 3 axes displayed the occupancy rate of operational rail equipment, the quality value (ADI) and the quantity value (number of trains). These parameters have limitations:

- Occupancy rate of operational rail equipment <0;1>,
- ADI (-∞, +∞),
- number of trains <1; +∞).

The calculation is difficult due to 2 problems – lower ADI is better than the higher one and if the occupancy rate of operational rail equipment is higher than 0.67, we should consider, that the operational equipment could be overloaded – therefore, we must take these measures:

- occupancy coefficient definition,
- determination of the primary timetable performance value.

Occupancy coefficient definition

This coefficient must express the limitation of the occupancy rate of operational rail equipment, exactly the fact, that for 0.67 and higher value the operational rail equipment is overloaded. Therefore, the values form 0.67 (excl.) – 1 must be corrected:

OC_R = <0;0.67> → $OC_C = OC_R$
OC_R = (0.67;1> → $OC_C = 1 - OC_R$

OC_R is in this case the occupancy rate of operational rail equipment, OC_C is the occupancy coefficient. OC_C has limitations: <0;0.67> Due to this measure it cannot be reached, that the high performance of a timetable is unreal because of the operational equipment overloading.

Determination of the primary timetable performance value (PTPV)

For further computation it is necessary to determinate the primary timetable performance value – PTPV. It is based on the cuboid capacity methodology – it is displayed in the figure 1 a in the formula 3.

$$PTPV = \sqrt{ADI^2 + N^2 + OC_C^2} \tag{3}$$

On the figure 2 is displayed an outline of PTPV.

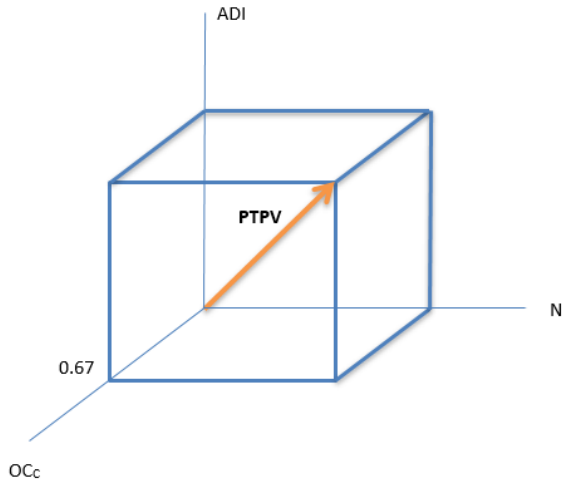

Fig. 2 The primary timetable performance value outline

The PTPV is determining timetable parameter in the terms of quality and quantity and it is related to the infrastructure due to occupancy coefficient. Because of PTPV is possible to get only one determining basic value for timetable evaluation. To harmonize the increasing value with the increasing timetable performance it is necessary to emend the PTPV according to ADI (lower ADI is better than higher one). Therefore, it must be divided into 2 formulas of timetable performance evaluation (TP_E) – formula 4 and formula 5.

- For affirmative ADI

$$TP_{E+} = -\left(\frac{ADI \cdot \sqrt{\mathrm{ADI}^2 + N^2 + OC_C^2}}{N \cdot OC_C}\right) \tag{4}$$

- For negative ADI

$$TP_{E-} = -\left(N \cdot OC_C \cdot \mathrm{ADI} \cdot \sqrt{\mathrm{ADI}^2 + N^2 + OC_C^2}\right) \tag{5}$$

3. Timetables for evaluation

It was chosen a closed railway network in the Czech Republic consisting of various lines (different number of tracks, different security equipment e. t. c.), among others of overlapping section of Rail Freight Corridors RFC 7 and RFC 9 (namely section Kolín – Choceň) [4]. The whole chosen closed railway network is yellow marked on Figure 3 [5].

In the chosen closed railway network there are a total amount of 29 railway stations, in which it is possible overtaking trains (double track line) or crossing trains (single track line). The amount of trains, ADI, the occupancy rate of operational rail equipment and the occupancy coefficient on whole closed network are displayed in the Table 1. The occupancy rate of operational rail equipment and the occupancy coefficient are displayed for the most occupied section of the network. It is displayed for the real timetable (RTT), constructed periodic timetable (PTT) and constructed periodic timetable with periodic freight train paths (PFTP, rescheduling of freight expresses) [6, 7].

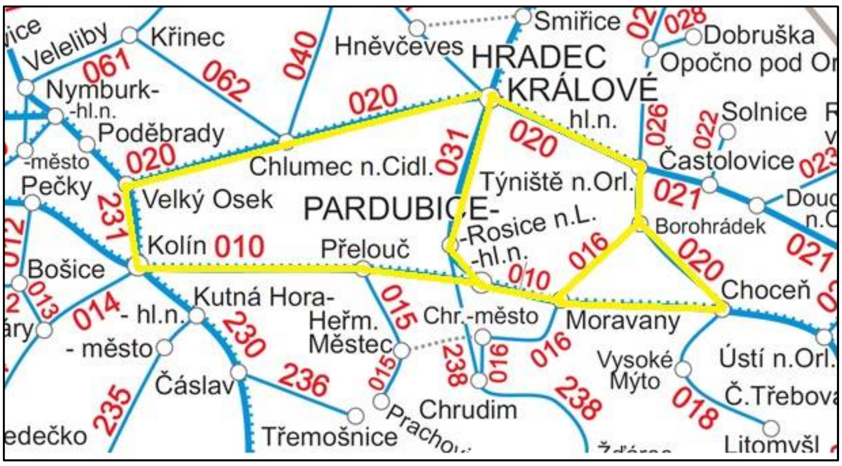

Fig. 3 The chosen closed railway network

Table 1

The parameters for whole closed network

TT	Amount of trains	ADI (min/train)	OCR	OCC
RTT	956	0.21	0.56	0.56
PTT	901	-0.49	0.69	0.31
PFTP	907	-0.62	0.69	0.31

To be more concrete, in Table 2, Table 3 and Table 4 are displayed the same parameters for each line [8].

Table 2

The section parameters, RTT

Line section	Amount of trains	ADI (min/train)	OCR	OCC
Kolín - Choceň	384	1.05	0.56	0.56
Choceň – HK – VO	174	- 1.26	0.40	0.40
Pardubice hl. n. – HK hl. n.	137	- 0.20	0.36	0.36
Kolín – VO	213	0.27	0.27	0.27
Moravany - Borohrádek	48	- 0.29	0.36	0.36

Table 3

The section parameters, RTT

Line section	Amount of trains	ADI (min/train)	OCR	OCC
Kolín - Choceň	336	- 1.03	0.60	0.60
Choceň – HK – VO	108	- 2.21	0.58	0.58
Pardubice hl. n. – HK hl. n.	179	0.76	0.69	0.31
Kolín – VO	221	0.26	0.28	0.28
Moravany - Borohrádek	57	- 0.88	0.58	0.58

Table 4

The section parameters, PFTP

Line section	Amount of trains	ADI (min/train)	OCR	OCC
Kolín - Choceň	336	-1.03	0.60	0.60
Choceň – HK – VO	114	-3.14	0.64	0.64
Pardubice hl. n. – HK hl. n.	179	0.76	0.69	0.31
Kolín – VO	221	0.26	0.28	0.28
Moravany - Borohrádek	57	-0.88	0.58	0.58

In these tables there are founded all parameters for TPE calculation.

4. Results and Discussion

First, it is necessary to modify the parameters: the ADI parameter could be in same form, the occupancy rate of operational rail equipment and the occupancy coefficient could not be in percent – it is appropriate to write it like dimensionless parameter (like in the tables). The amount of trains is then necessary to indicate like one thousandth of the amount due to corresponding value of PTPV. In the following tables there are displayed modified parameters with PTPV (calculated according to Formula 3) and TPE (calculated according to Formula 4 and Formula 5) [9].

Table 5

The modified parameters for whole closed network with PTPV

TT	N	ADI (min/train)	OC_C	PTPV	TPE
RTT	0.956	0.21	0.56	1.13	-0.442
PTT	0.901	-0.49	0.31	1.07	0.147
PFTP	0.907	-0.62	0.31	1.14	0.199

According to TPE it seems the most convnient timetable is the PFTP – it corresponds to previous research and it is its validation. However, it must be said, the main corrective parameter is ADI – it is due to the second power in Formula 3. In the following tables there are displayed the section parameters for timetables, in the Table 6 for RTT.

Table 6

The section modified parameters TP_E, RTT

Line section	N	ADI (min/train)	OC_C	PTPV	TP_E
Kolín - Choceň	0.384	1.05	0.56	1.25	-6.106
Choceň – HK – VO	0.174	- 1.26	0.40	1.33	0.117
Pardubice hl. n. – HK hl. n.	0.137	- 0.20	0.36	0.43	0.004
Kolín – VO	0.213	0.27	0.27	0.44	-2.053
Moravany - Borohrádek	0.048	- 0.29	0.36	0.46	0.002

In this table there is apparent, affirmative ADI leads to the lower timetable performance. The ADI parameter is the main corrective parameter of these calculations due to its expression of timetable quality [10]. There are displayed the results for periodic timetable in the Table 7.

Table 7

The section modified parameters with TP_E, PTT

Line section	N	ADI (min/train)	OC_C	PTPV	TP_E
Kolín - Choceň	0.336	- 1.03	0.60	1.24	0.257
Choceň – HK – VO	0.108	- 2.21	0.58	2.29	0.317
Pardubice hl. n. – HK hl. n.	0.179	0.76	0.31	0.84	-11.506
Kolín – VO	0.221	0.26	0.28	0.44	-1.855
Moravany - Borohrádek	0.057	- 0.88	0.58	1.06	0.031

In this table, there is displayed, that for affirmative ADI and overloaded infrastructure on the line Pardubice hl. n. – HK hl. n. the timetable performance is not good. It means, this methodology works [11]. There are displayed the results for periodic timetable with periodic freight train paths in the Table 8.

Table 8

The section modified parameters with TP_E, PFTP

Line section	N	ADI (min/train)	OC_C	PTPV	TP_E
Kolín - Choceň	0.336	- 1.03	0.60	1.24	0.257
Choceň – HK – VO	0.114	- 3.14	0.64	3.21	0.735
Pardubice hl. n. – HK hl. n.	0.179	0.76	0.31	0.84	-11.506
Kolín – VO	0.221	0.26	0.28	0.44	-1.855
Moravany - Borohrádek	0.057	- 0.88	0.58	1.06	0.031

The main improvement of timetable performance is in the section Choceň – Hradec Králové – Velký Osek due to decreasing ADI (it was caused by periodic freight train paths).

5. Conclusion

In this paper there was described the timetable performance evaluation – it is the new methodology for timetable evaluation based on one number, one value. Via this methodology it is possible to summarize all important parameters of a timetable – the quality parameter (ADI), the quantity parameter (number of trains) and the implementation of the timetable to the concrete railway infrastructure.

The TPE was counted for different timetables and the methodology was confirmed. For all cases is generally valid, that higher TPE means better timetable.

This paper unequivocally proved, the capacity range calculation based on the mathematical analysis is generally valid. The consequence in part one, which there was counted without reaching zero ADI point, was very similar to the consequence in part two with the zero ADI point reaching. However, the result is valid only for one track – for more-track lines must be multiplied by the number of tracks.

In this paper, there is interesting, for one track after the planned modernization the CR number is lower than for the old single-track line. It means the capacity growth connected with the building up of new track is not 100 %, exactly. It could be caused by one of the reasons mentioned in the Ishikawa diagram (the question of train priority and train number) and it will be the objective of the further research.

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