LINE TRACK CAPACITY - ANALYSIS OF THE IMPLEMENTATION OF THE UIC 406 METHODOLOGY IN ŽSR CONDITIONS

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Abstract. *A variety of A variety of methodologies are used across Europe for the estimation of railway infrastructure capacity. This paper introduces the basic principles of the analytical methodology (e.g. Slovak railways) and UIC methodology. On the basis of these new approaches, dependencies between occupation time and buffer time is researched. The aim is to compare the needed buffer time and its impact to the line capacity.*

Keywords: CAPACITY, METHODOLOGY, TIME TRAFFIC DIAGRAM, BUFFER TIME, OCCUPATION TIME

1. Introduction

In the allocation of the capacity of train paths to railway undertakings, it is necessary for the infrastructure manager to know the capacity of the infrastructure. Defining the capacity of the railway infrastructure (transport route) is relatively difficult and there are many different approaches to its definition.

In view of the different concepts and procedures relating to railway infrastructure capacity and the subsequent calculations applied by railway infrastructure managers, the International Railway Union (UIC) has developed new one methodology. At the nowadays the various of methodologies across the Europe are used. The unification was done so that the results of the assessments on the corridors are reciprocally comparable. The UIC 406 Code, called "Capacity" [5], contains the adopted principles for detecting rail infrastructure capacity using of a compression method with IT support for these practices. Unlike theoretical concepts, the compression method is used in real-time schedules with practical measures and is designed to create a common basis for infrastructure capacity determination. In the second edition of the UIC Code 406 (2013), for the first time there is also a methodology for determining the capacity of stations and nodes based on the same principles. The UIC 406 Code is a recommendation, allowing to the infrastructure managers to use a national methodology for their own needs. [1]

Therefore the aim of the paper is to analyse the equivalence of the results determining the line capacity according to the UIC 406 Code recommendation and according to the applicable national methodology of ŽSR.

2. Methodology of capacity calculation according to national methodology ŽSR D24

In the Slovak infrastructure manager ŽSR, the methodology of the D 24 Regulation is applied, which establishes relations for calculating the quantitative and qualitative indicators of the capacity. [4]

Line practical capacity - nprakt defined as practical throughput performance which is expressed by the number of trains for the defined time period.

$$n_{prakt} = \frac{T - (T_{výl} + T_{stál})}{t_{obs} + t_{medz}} \quad [vl.T^{-1}] \qquad (1)$$

where the variables already referenced on the line (line section) are:

T – calculation time [min]

$T_{výl}$ – total time in which the operating device within the computing time is barred from operation for prescribed inspections, repairs and maintenance [min]

$T_{stál}$ – total time of permanent manipulations, i.e. the time in which the operating device is occupied by other actions than those for which throughput capacity is calculated [min]

t_{obs} – technological time of occupation by one train (or act) in which the throughput capacity is calculated [min]

t_{medz} – average buffer time for one average train [min]

As a result of this quantitative indicator, we evaluate the line practical capacity as well as qualitative indicators, which are in particular the infrastructure occupancy time rate - s_o and the usage of the line practical capacity Kprakt.

$$s_o = \frac{T_{obs}}{T - (T_{výl} + T_{stál})} \quad [-] \qquad (2)$$

$$K_{prakt} = \frac{N_{prav}}{n_{prakt}} \cdot 100 \quad [\%] \qquad (3)$$

where:

T_{obs} – total occupancy time of the line [min]

N_{prav} – total number of regular trains[vl.T^{-1}]

A sufficiently occupied train traffic diagram is considered that one with the infrastructure occupation rate of 0.5 to 0.67. The normative capacity is characterised with the usage of the line practical capacity Kprakt by the regular transport in the range of 80-90%. [4]

These qualitative indicators constitute an optimal limit between acceptable use of the infrastructure capacity and time reserves. These buffers are particularly necessary for compensation of delays in irregularities and failures in rail transport, as well as the reasons given in the literature [2] for the average additional times tdod and the average time of probable interference of runs - truš. The average time of gaps for one average train (1) tmedz is the parameter for evaluation and assuring the balance and also the quality of the train traffic diagram.

Recommendation of the ŽSR D 24 Regulation observes to a great extent to the line section character and the occupancy time. The average time of gaps for one average train tmedz deposit is recommended for operating conditions difficult (A), normal (B) and simple (C) depending on the occupancy time of the railway section by train. The list of recommended time of gaps is shown in Table 1.

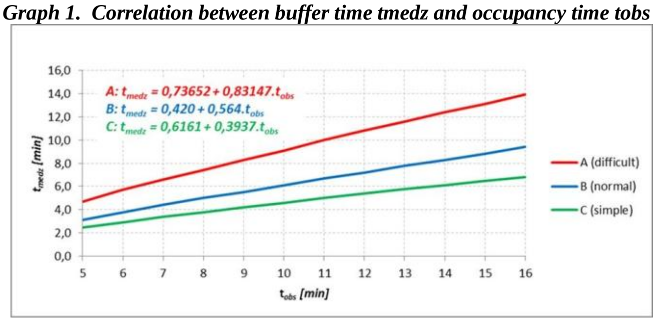
Table 1. *Required buffer times tobs [min] according to the Regulations of ŽSR D 24*

t_{obs}	5	6	7	8	9	10	11	12	13	14	15	16
A	4,7	5,7	6,6	7,4	8,3	9,1	10,0	10,8	11,6	12,4	13,1	13,9
B	3,1	3,8	4,4	5,0	5,5	6,1	6,7	7,2	7,8	8,3	8,8	9,4
C	2,5	2,9	3,4	3,8	4,2	4,6	5,0	5,4	5,8	6,1	6,5	6,8

Source: [4], authors

Thus, it is evident from Table 1 that with the increasing t_{obs}, the value of the t_{medz} is increasing too, but the slower rate. This property can also be expressed graphically.

Graph 1. Correlation between buffer time tmedz and occupancy time tobs



If the calculated value of the buffer time t_{medz} for one average train from the formula (1) $_{is}$ lower than the recommended value according to the ŽSR D 24 (Table 1), then there is a high risk of causing danger of the train traffic diagram quality disruption and its planned feasibility.

Capacity calculation methodology according to UIC 406 Code

Line capacity utilisation, referred to as "capacity consumption", is assessed on the line section and at defined calculation time according to this $_{\text{methodology}}$.

$$\mathit{Capacity\ consumption} = \frac{\mathit{Occupancy\ time} + \mathit{Additional\ times}}{\mathit{Defined\ time\ period}} \cdot 100 \quad [\%]$$

In this case of UIC 406 Code formula, the optimal boundary between the use of $_{\text{infrastructure}}$ capacity and buffer time, it means the same as t_{medz} in the ŽSR D 24 methodology, is an additional time.

The criteria necessary for determining and assessing the "optimal" $_{\text{additional}}$ time are based on the operating characteristics of the existing train traffic diagram and actual delays, as well as in the case of time of gaps in the ŽSR methodology. However, extrapolation of time series may be time-consuming or impossible. For this reason, the standard value of the occupancy time rate was determined as an expression of the required level of services quality provided and is given in percentage expression:

$$\mathit{Occupancy\ time\ rate} = \frac{\mathit{Occupancy\ Time}}{\mathit{Defined\ Time\ Perion}} \cdot 100 \quad [\%]$$

In the graphical process of the train paths compression, UIC 406 Code recommends the standard values of the occupancy time rate according to the type of train traffic on the line as follows:

Table 2. *Recommended values of the occupancy time rate*

Type of line	**Peak hour**	**Daily period**
Dedicated suburban passenger traffic	85 %	70 %
Dedicated high-speed line	75 %	60 %
Mixed-traffic lines	75 %	60 %

Source: [5]

Depending on the occupancy time rate, the recommended values of the additional time rate are given in the following table 3. It is derived from the occupancy time rate.

$$\mathit{Additional\ Time\ Rate} = \left[\frac{100}{\mathit{Occupancy\ Time\ Rate}} - 1\right] \cdot 100 \quad [\%$$

Table 3. *Recommended values of the additional time rate for the types of line*

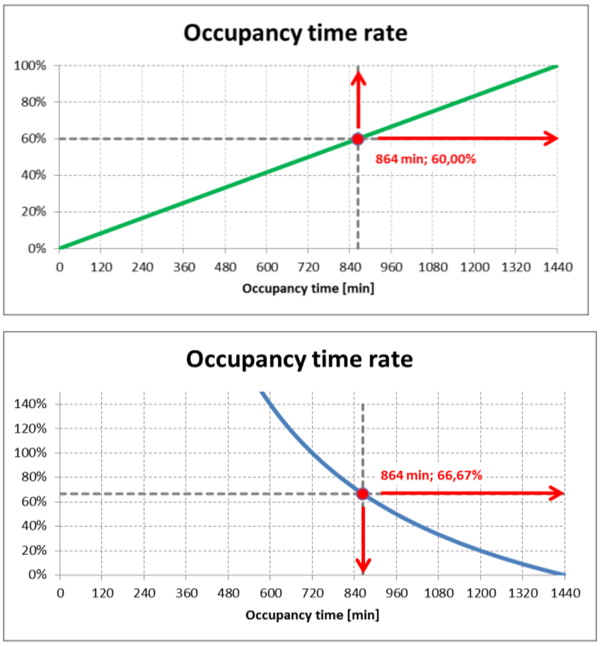
Type of line	**Peak hour**	**Daily period**
Dedicated suburban passenger traffic	18 %	43 %
Dedicated high-speed line	33 %	67 %
Mixed-traffic lines	33 %	67 %

Source: [5]

Capacity consumption values reflect the basic concepts of capacity expressed through the train traffic diagram features of individual train paths. Therefore they are used for bottlenecks identification. Therefore, the assessment of the capacity consumption (as well as the recommended weight between the occupancy time and the additional time) will be made according to the relationship:

$$\mathit{Capacity\ Consumption} = \frac{\mathit{Occupancy\ time} \cdot (1 + \mathit{Additional\ Time\ Rate})}{\mathit{Defined\ Time\ Period}} \cdot 100 \quad [\%]$$

Graph 2. Occupancy time rate



Source: authors

The occupancy time rate logically increases by the increasing of occupancy time. It is obvious from the formula (5). But there is evident from the formula (6) that with the increasing occupancy time the value of the additional time rate decreases. Thus, the dependence of the occupancy time rate and the additional time rate from the occupancy time at the constant defined time period can also be expressed graphically (see the graph 2)..

For the defined time period (1440 minutes), the recommended limits for mixed traffic lines(the majority) are indicated in the graphs 2 and 3 according to tables 2 and 3. The limit values and their direction, where the value is exceeded, are indicated red in the graph.

Overall, it can be assessed if the capacity consumption value is below the 100% limit, some of the line section capacity is still unutilised. Otherwise, if the recommended limit values are exceeded (for example Tables and graphs 2 and 3), there is a high risk of the causing danger of the train traffic diagram quality and its planned feasibility.

Comparison of methodologies through the calculations achieved

The presented methodologies for calculating and assessing of the line capacity use different calculation methods to achieve their results, although apparently different parameters are ultimately mutually comparable.

Therefore, the above mentioned methodologies will be referred in practical calculations. Their aim is to maximize the line capacity consumption (according to ŽSR practical capacity, according to UIC the capacity utilisation) using the maximum train paths, while the required quality and stability of the train traffic diagram is maintained. For both methodologies, the delimited time for capacity calculation is 24 hours (1440 minutes), and we do not expect to cut it off by $T_{výl}$ *and* $T_{stál}$.

Calculation of the practical capacity according to the methodology of ŽSR D24

If the occupancy time is tobs = 5 min, and for a line with complicated ratios (A) is determined average time of gaps for one average train t_{medz} = 4,7 min, according to Table 1. Then the practical capacity according to formula (1) is:

$$n_{prakt} = \frac{1440}{5 + 4{,}7} = 148{,}45 \cong 148\ trains\ during\ 24\ hours$$

Because it is done $T_{obs} = n\ .\ t_{obs}$, then the infrastructure occupancy time rate s_o according to formula (2) is:

$$s_o = \frac{148 \cdot 5}{1440} = 0{,}514$$

The usage of the line practical capacity K_{prakt} converges to 100% (it is counted with the integer value of the trains number and not with the exact number). It can be verified with the following formulas (we put formula 3 into relationship 1 and modify it):

$$K_{prakt} = \frac{n \cdot (t_{obs} + t_{medz})}{T - (T_{výl} - T_{stál})} \cdot 100 \quad [\%] \quad (9)$$

$$K_{prakt} = \frac{148 \cdot (5 + 4{,}7)}{1440} \cdot 100 = 99{,}69\% \quad (10)$$

The all calculated values of these indicators for all occupancy times (t_{obs}) from Table 1 are as follows in the table 4.

Table 4. *Calculation of indicators*

	$n_{prakt} = N_{prav}$			s_0			K_{prakt}		
t_{obs}	A	B	C	A	B	C	A	B	C
5	148	177	192	0,514	0,615	0,667	99,69%	99,56%	100,00%
6	123	146	161	0,513	0,608	0,671	99,94%	99,36%	99,51%
7	105	126	138	0,510	0,613	0,671	99,17%	99,75%	99,67%
8	93	110	122	0,517	0,611	0,678	99,46%	99,31%	99,97%
9	83	99	109	0,519	0,619	0,681	99,72%	99,69%	99,92%
10	75	89	98	0,521	0,618	0,681	99,48%	99,51%	99,36%
11	68	81	90	0,519	0,619	0,688	99,17%	99,56%	100,00%
12	63	75	82	0,525	0,625	0,683	99,75%	100,00%	99,08%
13	58	69	76	0,524	0,623	0,686	99,08%	99,67%	99,22%
14	54	64	71	0,525	0,622	0,690	99,00%	99,11%	99,10%
15	51	60	66	0,531	0,625	0,688	99,52%	99,17%	98,54%
16	48	56	63	0,533	0,622	0,700	99,67%	98,78%	98,75%
			average:	*0,521*	*0,618*	*0,682*	*99,47%*	*99,45%*	*99,51%*

Source: [4], authors

Calculation of practical capacity according to UIC 406 methodology

The UIC calculation methodology will be also applied to the same times of the line section occupancy. If there is the mixed traffic on the line, the recommended value of occupancy time rate is 60% according to Table 2 and the recommended value of the additional time rate is 67% during the day according to Table 3. Then, according to the formula (5), the value of the line occupancy time is [5]:

$$Occupancy\ time = \frac{Defined\ time\ period \cdot Occupancy\ time\ rate}{100} [min] \quad (10)$$

$$Occupancy\ time = \frac{1440 \cdot 60}{100} = 864\ min$$

Subsequently the additional time value is 576 minutes. It is possible to calculate the practical capacity from these values (similarly as in the previous methodology):

$$n_{prakt} = \frac{Occupancy\ time}{t_{obs}} [vl.T^{-1}] \quad (11)$$

$$n_{prakt} = \frac{864}{5} = 172{,}8 \cong 172\ trains\ during\ 24\ hours$$

The average additional time t_{dod} for one train according to this methodology is:

$$t_{dod} = \frac{Additional\ times}{n_{prakt}} = 3{,}35\ min$$

$$t_{dod} = \frac{576}{172} = 3{,}35\ min$$

All calculated values of these measures for all occupancy times t_{obs} from the Table 1 are shown in Table 5. Comparison of the practical capacity calculated according to the UIC methodology and the ŽSR methodology is shown in this table in the differences between the routes, not only in quantitative expressions in number of routes, but also in qualitative expressions - percentage expression.

Table 5. *Calculation of indicators*

Mixed traffic line

t_{obs}	n_{prakt}	t_{medz}	paths differences	
(min)	(path)	(min)	(path)	(%)
5	172	3,35	-5	97,18%
6	144	4,00	-2	98,63%
7	123	4,68	-3	97,62%
8	108	5,33	-2	98,18%
9	96	6,00	-3	96,97%
10	86	6,70	-3	96,63%
11	78	7,38	-3	96,30%
12	72	8,00	-3	96,00%
13	66	8,73	-3	95,65%
14	61	9,44	-3	95,31%
15	57	10,11	-3	95,00%
16	64	10,67	-2	96,43%
				96,66%

Dedicated suburban passenger traffic

t_{obs}	n_{prakt}	t_{medz}	paths differences	
(min)	(path)	(min)	(path)	(%)
5	201	2,15	9	104,69%
6	168	2,57	7	104,35%
7	144	3,00	6	104,35%
8	126	3,43	4	103,28%
9	112	3,86	3	102,75%
10	100	4,32	2	102,04%
11	91	4,75	1	101,11%
12	84	5,14	2	102,44%
13	77	5,61	1	101,32%
14	72	6,00	1	101,41%
15	67	6,45	1	101,52%
16	63	6,86	0	100,00%
				102,44%

Conclusion

There were practiced two capacity methodologies. Despite the different computation methods, their results are relatively similar. Current minor differences between the results of these methodologies are caused only by the limit of the acceptable line occupation time, limit of the required time of gaps. Practically, we can accept the UIC 406 and implement its methodology into national practices to estimate the practical capacity at ŽSR lines.

Acknowledgement

The paper is supported by the VEGA Agency by the Project 1/0791/18 "The Assessment of Economic and Technological Aspects in the Provision of Competitive Public Transport Services in integrated Transport Systems", that is solved at Faculty of Operations and Economics of Transport and Communication, University of Žilina.

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