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INFRASTRUCTURE PARAMETERS AFFECTING CAPACITY OF RAILWAYS IN TEN-T

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Abstract. The article presents possible solutions of the issue of the lost capacity on a double-track line. It is shown a solution where an inserted train on the double-track line use the lost capacity of the opposite line track using active overtaking. The feasibility of such a solution is discussed and the length of sections suitable for active overtaking is calculated.

Keywords: Capacity, UIC 406, speed ratio .

1. Introduction

The capacity of the railway infrastructure can be considered as a usable time space for the train paths. Capacity is thus influenced not only by the parameters of the infrastructure, but also by the character of the traffic – by the designed train paths and their heterogeneity. With increasing degree of heterogeneity the capacity consumption increases too and the number of possible train paths in a defined time windows declines.

This phenomenon is also called "capacity balance" [1]. In the capacity balance there are four factors on whose interdependencies the capacity is based: number of trains, average speed, stability and heterogeneity. Relationships among the individual factors are shown in Figure 2 [1].

Principle of Figure 2 is explained as follows: "In this qualitative model, an axis for each parameter is drawn from a unique origin. A chord links the points on the axes, corresponding to the value of each parameter. The length of the chord represents the capacity. Capacity utilisation is defined by the positions of the chord on the four axes. Increasing capacity means increasing the length of the chord".

General effect associated with the modernization of the Trans-European conventional rail network (typically the modernization of the transit railway corridors in the Czech Republic in the original routes to a maximum speed of 160 km/h) is the rising heterogeneity of the traffic on some routes in the network. It is caused by increasing the line speeds. On the one hand regional passenger train paths remains after increasing the line speed about as fast as before the modernization (journey speed of the regional trains usually does not exceed 60 km/h due to the higher number of stops). On the other hand long-distance passenger trains should logically utilize all characteristics of infrastructure for the maximum journey speed (at the fastest trains the journey speed of 120-140 km/h can be reached in some line sections). These both cases are thus usually marginal and between these limits the freight trains paths occur (with journey speeds in the range of 70-100 km/h).

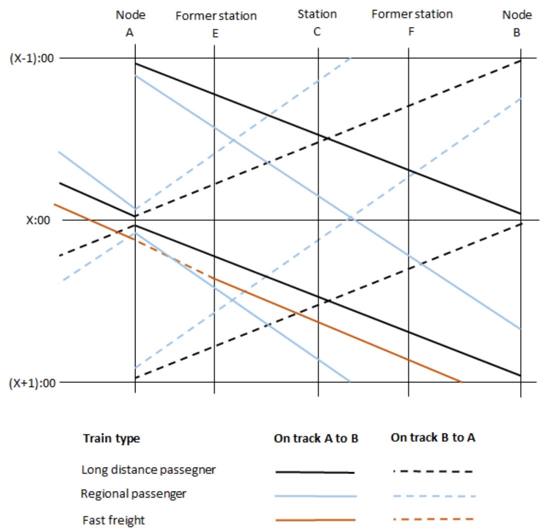

Figure 1. Possible situation of active overtaking on a double-track line.

2. Heterogeneity and its measuring

Heterogeneity can be measured in different ways. One way is to compare running speeds of individual train (or train paths). For this purpose Krueger [2] proposed and used so called Speed Ratio (SR). The Speed Ratio is the ratio of the fastest train speed to the slowest train speed:

$$SR = \frac{max(v_1, v_2, ..., v_n)}{min(v_1, v_2, ..., v_n)}$$

So the SR on the typical line section on some transit railway corridor in the Czech Republic can reached value of 3 (the speed of the fastest train about 140 km/h and the speed of the slowest train about 45-50 km/h).

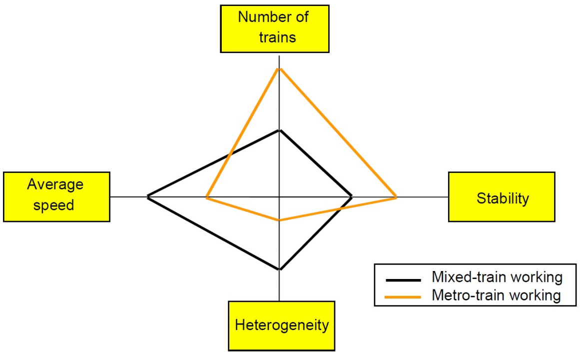

Figure 2. Capacity balance [1].

The very high SR is problematic only when it comes to the line or line section with a high number of train paths. But the lines of the Trans-European conventional rail network usually show a high number of train paths. Line sections with high demand for train paths and a high SR can usually be solved by segregating the various types of traffic. This entails increasing the number of line tracks (e.g. quadruple-track line sections in urban agglomerations with two tracks for long-distance passenger trains and fast freight trains and two tracks for slower regional passenger trains and slower freight trains) or construction of lines dedicated exclusively for a certain type of traffic (typically on the one hand high-speed railway lines and, on the other hand, lines dedicated only for freight train as e.g. BetuweLijn). This approach, however, is not yet common in the Czech Republic.

3. Active overtaking

On double-track lines, where high degree of heterogeneity is because of the mixed traffic and high requirements for the number of the train paths, so called lost capacity arises. Lost capacity is unusable time space between train paths with different train speeds, where any additional train path cannot be inserted (e.g. because there is no other station). Lost capacity can be limited by reducing heterogeneity of train paths. Either the slowest trains can be accelerated (e.g. these trains can pass some stops), or vice versa the fastest trains can be slowed. Lost capacity may be also used for active overtaking[1]. An example of this solution is shown in the Figure 1.

Active overtaking is a very interesting possibility of using a part of the lost capacity. This idea can be very helpful in cases, when the number of stations on a line section is reducing within modernization of infrastructure. In the former stations there are only crossovers for crossing between the line tracks for cases of interruptions. In such cases there is no possibility to insert one more train path into a sequence of differently fast train paths, but they can also be used for crossing between line tracks and in regular operation.

The actual possibility of using these crossovers for regular traffic, however, depends on the diverging speed that affects the train speed (and thus journey time) of the overtaking or the overtaken train and thus affects the length of the section required for overtaking. Furthermore, it is obvious that the greater the heterogeneity of the train paths in the reference section is (i.e. the larger the difference of the journey speeds between the overtaken and the overtaking train), the shorter the section required for overtaking is. With regard to the above mentioned borderline cases it is evident that the overtaken slower train is always a regional passenger train.

There are generally two cases possible:

(1.) The slower train crosses over to the other line track and runs against the right direction, the faster train runs in the right direction.

(2.) The faster train crosses over to the other line track and runs against the right direction, the slower train runs in the right direction.

The cases from the first group are suitable for situations, in which the platforms of stations and stops in the line section are situated between the line tracks, or in which only stations equipped with a good visual and audible information system are. This system should provide clear information about platforms and tracks of arriving and departing trains.

The cases from the second group are suitable, if the speed limit over the crossovers between the line tracks corresponds or is close to the line speed or the maximum train speed.

4. Case study: the first transit railway corridor between Prague and Děčín

The part of the first transit railway corridor between Prague and Děčín links the Prague Metropolitan Area [4] with the Ústí Metropolitan Area and with the north part of Germany. The most typical situation for the active overtaking is an interaction of a fast freight train (maximum train speed about 100 km/h) and a regional passenger train (journey speed about 50 km/h).

The active overtaking of the first type can be used in the line sections:

- Hněvice – Hněvice seř.n.
- Roudnice nad Labem – Hrobce
- Lovosice jih – Lovosice
- Prackovice nad Labem – Ústí nad Labem jih – Ústí nad Labem hl.n.

Now we have to analyse these line section, whether the active overtaking leads to time saving in comparison with overtaking of the regional passenger train

[1] Active overtaking can be defined as an overtaking of slower train by faster train, when the slower train does not have to stop [3].

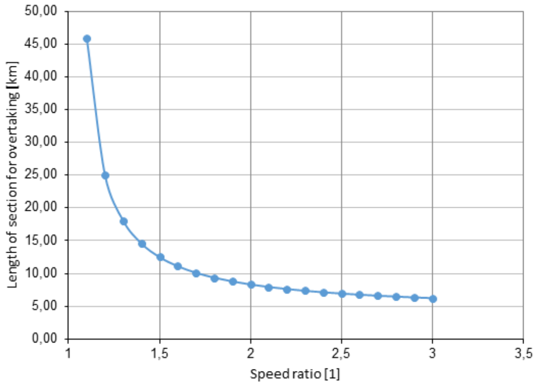

FIGURE 3. Relationship between speed ration and Length of section for overtaking.

Sum of operating intervals and time reserves [min]		5
Journey speed of slower train [km/h]		50
Speed Ratio [1]	**Speed of faster train [km/h]**	**Length of section for over-taking [km]**
1,1	55	45,83
1,2	60	25,00
1,3	65	18,06
1,4	70	14,58
1,5	75	12,50
1,6	80	11,11
1,7	85	10,12
1,8	90	9,38
1,9	95	8,80
2	100	8,33
2,1	105	7,95
2,2	110	7,64
2,3	115	7,37
2,4	120	7,14
2,5	125	6,94
2,6	130	6,77
2,7	135	6,62
2,8	140	6,48
2,9	145	6,36
3	150	6,25

TABLE 1. Length of section for overtaking.

by the fast freight train, when the regional passenger train is dwelling in some station.

Sections Hněvice – Hněvice seř.n. and Lovosice jih – Lovosice can be excluded immediately, because the result time savings will be negative. In both cases the regional passenger train is stopping only once in the line section and in both cases the speed limit over crossovers in the stations which bounds the line section is lower than the speed limit on passing sidings in these stations.

Sections Roudnice nad Labem – Hrobce and Prackovice nad Labem – Ústí nad Labem jih – Ústí nad Labem hl.n. show always positive time savings. In both cases the regional passenger train is stopping twice in the line section[2]. In these cases, the parallel run is generally about 2 minutes more effective then overtaking of the slower train in the station. It is very important that the overtaking train is guided precisely to the desired time position. The accuracy of this guidance may have a significant effect on the resulting time savings.

By the active overtaking of the second type the journey time of the overtaking train is extended because of the diverging speed of the crossovers in the bounding stations. In Table 1 values for typical situation on the first transit railway corridor are shown. The values were calculated with linear margin 9%. Value are graphically illustrated in Figure 3.

From Table 1 it is possible to determine the length of the line section which is needed for active overtaking. If the actual line section is shorter, then the dwell times of the slower train have to be extended.

5. Conclusions

The Verification of heterogeneity in relation to the partial use of the lost capacity by active overtaking of differently fast trains showed clearly that in the case of the interaction of regional passenger trains and freight trains there are solutions which can be divided into two situations. Either if the diverging speed over the crossovers in the bounding station of the line section is clearly lower than the running speed of the fast freight train, then the regional passenger train should run against the right direction on the other line track. Or if the diverging speed over the crossovers in the bounding station of the line section is high enough (minimum is 80 km/h), then then the fast freight train should run against the right direction on the other line track. It is important to mention that by modernizing the infrastructure, which should also allow such use of the lost capacity, platforms should be mostly located between the main line tracks.

With regard to the actual length of the line sections for active overtaking and with regard to demand for the train paths it is necessary to mention that on

[2] Also the stops in bounding stations of the line section are counted, if the regional passenger is being already overtaken during the stay in the station.

Trans-European conventional rail network this solution will be usually marginal. Furthermore, it is likely that the heterogeneity of demanded train paths will not decline. Authorities ordering the long distance passenger trains and open access operators do not want to, on the one hand, slow down artificially their trains. On the other hand, local authorities ordering the regional passenger trains do not want to reduce the number of operated railway stops, which is a very problematical political topic.

In the Czech Republic the construction of quadruple-track line sections remains as a permanent challenge in cases where a high degree of heterogeneity connected with high demand for train paths occurs. Only such a solution leading to the segregation of various types of traffic allows homogenization of the train paths and effective elimination of the lost capacity.

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