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DEVELOPMENT OF METHODOLOGY FOR CAPACITY CALCULATION IN THE SECTIONS WITH AN INTERMEDIATE JUNCTION

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Summary: This article deals with the methodology of capacity calculation in the crossing or overtaking sections with one or more junctions. The basic methodology adumbrated in (1) is developed with emphasis on thorough specification of input data and the process of setting total time of occupancy of observed line with successive trains.

Key words: capacity calculation, crossing or overtaking section, junction, CPM method, critical path, headway

INTRODUTION

The methodology for capacity calculation in the sections with an intermediate junction, issued from ČD Regulation D24 of 1966 (2) applicable until now, is not up to scratch any more from today's point of view. Due to the fact that in contemporary network of SŽDC more than 100 intermediate junctions are operated, the effort to amend present methodology for capacity calculation in these sections is understandable. The basic process of new methodology for capacity calculations was stated in (1). This way of calculation is general for any type of junction: classic attachment of two line tracks, branch-lines because of the change in number of line tracks in the section, branch-lines because of change-over between individual line tracks in the section or a branch-line in the station.

To carry out the correct calculation, we need to set a large number of input data correctly, such as correct determination of trains included in the calculation, correct specification of pairs of trains, using corresponding operating intervals (headway) for given pairs of trains, including corresponding running times etc. First of all it is essential to set total track occupation time from given input data, which is crucial for further calculations. The above mentioned aspects will further be described in following chapters.

1 METHODOLOGY OF CALCULATION

1.1 Definition of observed line track

The railway network consists of transport points (hereafter points, e.g. station, junction point, stop, signal box, train announcing point etc.) and transport sections (hereafter sections) that connect the points.

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The observed line track can be defined as sequenced order of line tracks, the elements of which are subset of the set of all line tracks of sections situated between points A–B, whereas the following points must be applicable:

- Points A-B must be either a station or a junction point;
- Just one line track is chosen from each section;
- The order of chosen line tracks in observed line track corresponds with the order of sections between A-B;
- There is at least one change-over (i.e. rail connection) between each pair of successive line tracks.

The calculation of capacity of observed line track is carried out in crossing or overtaking section between stations (or junctions) A-B.

While choosing the observed line track in the section between A-B with junctions we should consider the fact that its identification will not be the same in all its sections, e.g. TK1-TK101 or TK1-TK2, see Figure 1. This fact does not influence the calculation, it only complicates determining of observed line track and correct choice of trains considered for the calculation.

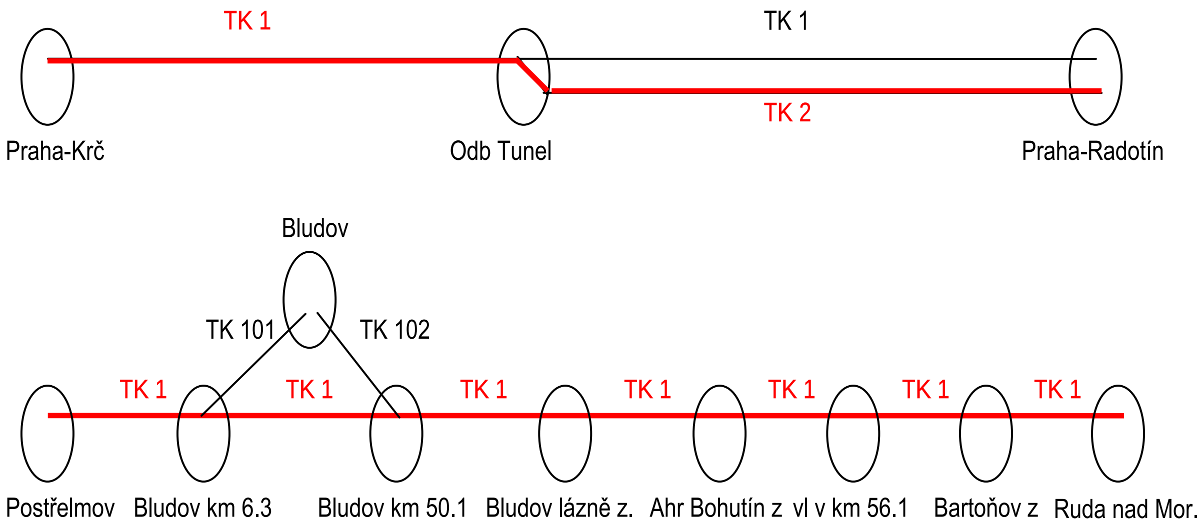

Fig. 1 – Schematic representation of the observed line tracks

1.2 Basic principles

In a crossing or overtaking section without a junction all trains go through the line in its whole length. The number of trains entering the observed line equals the number of trains which leave it. That is why the number of trains going through individual line tracks which make up the observed line track is constant.

However, the situation in a crossing or overtaking section with junctions is different as for the number of trains. On such a observed line track, there can be both trains going through its whole length and trains going through only a certain part of it. Owing to the changing number of trains in individual parts of the observed line track each train can have more than one successor, i.e. the second of two successive trains. And that is why we cannot put these trains into unambiguous succession for the need of simple determining of consecutive pairs of trains. This means that it is not possible to create linear arrangement in the given set of trains within the whole observed line track. For these reasons the basic methodology for the calculation of permeability of the crossing or overtaking section without junctions is not applicable for crossing or overtaking sections with junctions.

New methodology (1) differentiates trains going through the whole length of the observed line track (number N) and trains using only parts of the observed line track (number N_J). The following definitions are necessary for the calculation:

- Time T_{OBS_N}, stating for time of occupation by trains going through the whole length of observed line track;
- Time T_{OBS_CELK}, stating for time of occupation by all trains in general ($N + N_J$);
- Time T_{OBS_NJ}, stating for time of occupation by trains going through any section of observed line track.

Time T_{OBS_N} can be calculated by simple sum of track occupation times by individual consecutive pairs of trains. The same process which was used for the calculation of total time of occupation of section without junctions can be applied for the calculation of T_{OBS_N}.

Time T_{OBS_CELK} cannot be calculated in the same way since linear arrangement in the given set of trains cannot be created. Potential sum of times of occupation of all occurring pairs of trains (preceding-consecutive) does not correspond with the total time of occupation. The solution of this problem is stated in chapter 3.

Also, the calculation of time T_{OBS_NJ}, stating for the total occupation of observed line track only by trains going through only some of its parts, cannot be made in classic way. Although it is possible to find some pairs of trains in this set of trains (depending on specific paths of trains) using the common part of the observed line track. We can also calculate the time of occupation of a specific part of the observed line track by this pair of trains. However, the total time of occupation of the whole line track cannot be determined using by simply sum of the particular occupation time. Time T_{OBS_NJ} can be obtained from:

$$T_{OBS\_NJ} = T_{OBS\_CELK} - T_{OBS\_N} \quad (1)$$

The calculation of further indices is based on above stated total times of occupation and is given in (1) and (2).

When determining total track occupation time of the whole observed line track, we need to re-count particular times of occupation by single pairs of trains so that they all could be related to the same point, e.g. to one of the terminal points of the observed line track. The fact that there is at least one train going through it in any direction could be a sufficient condition for making the calculation.

Thus, the main problem of the calculation is setting the total time of occupation for all trains using the observed line track.

2 INPUT DATA

2.1 Choice of trains included in the calculation

Following trains are included:

- Those going through the observed line track in at least one section
- Those going through a junction point (between A-B) at least through one switch in a standard change-over connecting relevant line tracks. We suppose there is no junction point where a pair of line tracks would be joined only by a variant change.
- Other trains going through relevant station gridiron in terminal points A or B. These trains influence the time of occupation of relevant gridiron and thus they influence the time of occupation of observed line track. Including these trains in the calculation methodology will be the subject of further papers. The ride of these trains is mainly determined by the conditions on the line which are not relevant to observed line track and so including them in the calculation might reflect problems on other lines.

With each train entering and leaving point of the line track must be defined. They may be:

- Station (or junction) A or B;
- A junction lying between A and B where the train comes from another line track which is not included in given calculation;
- Any point lying between A and B which is at the same time a starting or a finishing point of a train.

If a train reaches only a junction point of a observed line track, it only goes through a change of points on the observed line track. Then with such a train, its entering points is identical with its leaving point.

A train can also enter the observed line track, leave it subsequently and enter it again. Such train must be considered as two individual trains (e.g. by adding an index number to the train number).

The variant of multiple enter is shown in Figure 2. The observed line track is marked in blue. The path of the train, which was entered twice, is marked red. The given train (e.g. R421) first enters the observed line track at point Odb.Rybník and leaves it at the same point, because it follows another line track which is not included in the observation. It enters it for the second time at point Odb Chomutov město and it leaves it again at the same point. In our calculations, such train must be considered as two individual trains, e.g. $R421_1$ a $RR21_2$.

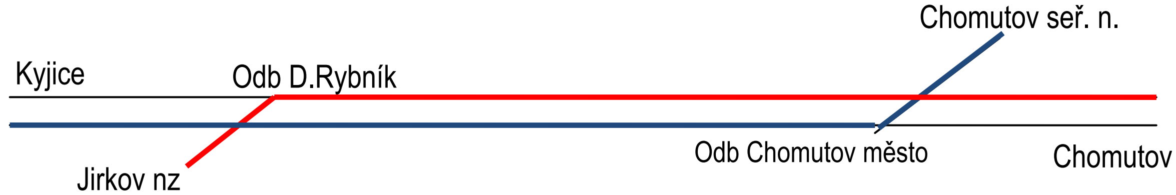

Fig. 2 – Schematic representation the track of the train, which was entered twice on the observed line track

2.2 Creating chronological lists of trains

The calculation is made in given time period (from time $ČAS_{OD}$ to time $ČAS_{DO}$).

A list of trains chosen according to criteria stated above is made within a given period of time. They are listed in the chronological order of their departure (or passing along) times at points where they enter the section.

Similarly, for each junction point a list of trains is made according to “relevant” time. In the case of a passing along train relevant time is the time of its passing through, in case of a still train there can be two possibilities. If it stops before the change-over, departure time is relevant. If it stops after the change-over, arrival time is relevant.

The calculation of total occupation time must be started with the first train, which passes along the whole observed line track and finished with the same train (Train 1). All lists need to be rearranged in the following order:

- Train_1 will be listed first;
- All trains subsequent Train_1 in original order until the end of given time period ($ČAS_{DO}$);
- All trains preceding Train_1 in original order from the beginning of given time period ($ČAS_{OD}$) up to Train_1;
- A copy of Train_1 is listed last.

2.3 Determining of pairs of trains included in the calculation of the time of occupation

The successors (successive trains) to each train need to be determined. The successive trains of train *X* need to be looked up like this: train *X* is found in each list made according to instructions stated above and a train directly succeeding it. Indexes stated in 2.1 must be considered.

If the observed line track goes through more sections, then usually more than one successor of train *X* are found. This successor can be remembered only once.

The list of all pairs “train and its successor” determines the pairs among which track occupation period will be calculated. (See Figure 3).

2.4 Determining of the point to which the calculation of occupation time between the pair of trains refers (hereafter referring point)

Referring point is the point that refers to the calculation of partial time of occupation by a given pair of trains.

First, the set of points needs to be determined, then one referring point is chosen. The elements of the set have to meet the following requirements:

- They lie between the entering and finishing point of the first train of given pair;
- They lie between the entering and finishing point of the second train of given pair.

The interval stated in the conditions is a closed interval including its terminal points.

Referring point can be defined from the set of points as the first point on the track of the second train (see Figure 3)

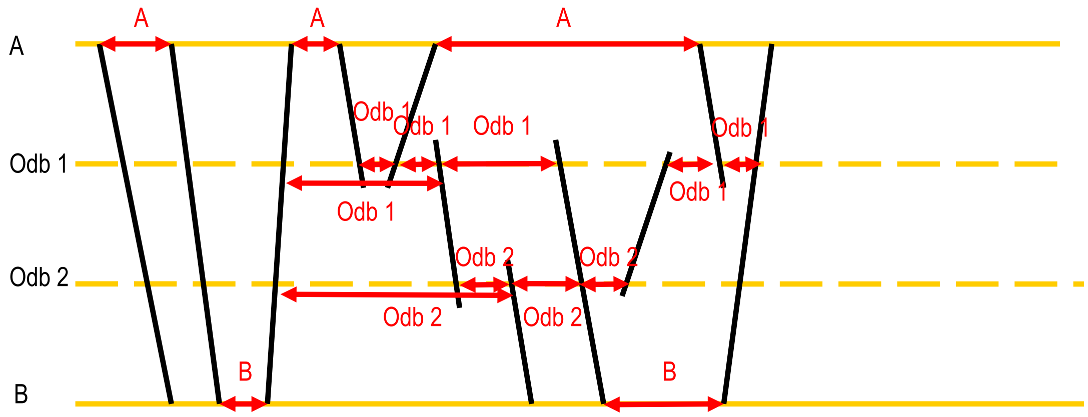

Fig. 3 – Examples of determining of referring point for various situations, referring points are marked red

2.5 The choice of used train headway (operating time)

2.5.1 Time of subsequent running

It is used in case that the trains are going in the same direction and the referring point is not the leaving point for neither of them (i.e. both of them have at least one common section after passing through their referring point).

2.5.2 Crossing time in terminal points A and B

It is used for oncoming trains, if the referring point is A or B

2.5.3 Headway at the junction

It is used if the referring point is junction point with oncoming trains and with trains going in the same direction if the conditions of 2.5.1 were not fulfilled.

All intervals have to be considered (except interval of subsequent running), which occur in given referring point between the two given trains. If the entry of the first train is included in the considered interval, we have to subtract the stopping time of the first train from the interval. If the entry of the second rain is included in the considered interval, we have to add the stopping time of the second train to the interval.

From these intervals we choose and use the one with maximal rate.

2.6 Adding running time and stopping time

This step ensures the link-up between successive calculations of occupation by sequences of trains. Each of the calculations starts with departure / passage in entering point of the first train and finishes with departure / passage in entering point of the second train. This implicates the rule that the train appearing in a certain calculation as second will appear as the first in the following calculation.

If referring point does not correspond with entering point of the first train, it is necessary to add to the calculated headway the difference between departure / passage in referring point and departure / passage in entering point.

The process is the same for the second train. If referring point does not correspond with entering point of the second train, it is necessary to subtract from the calculated headway the difference between departure / passage in referring point and departure / passage in entering point.

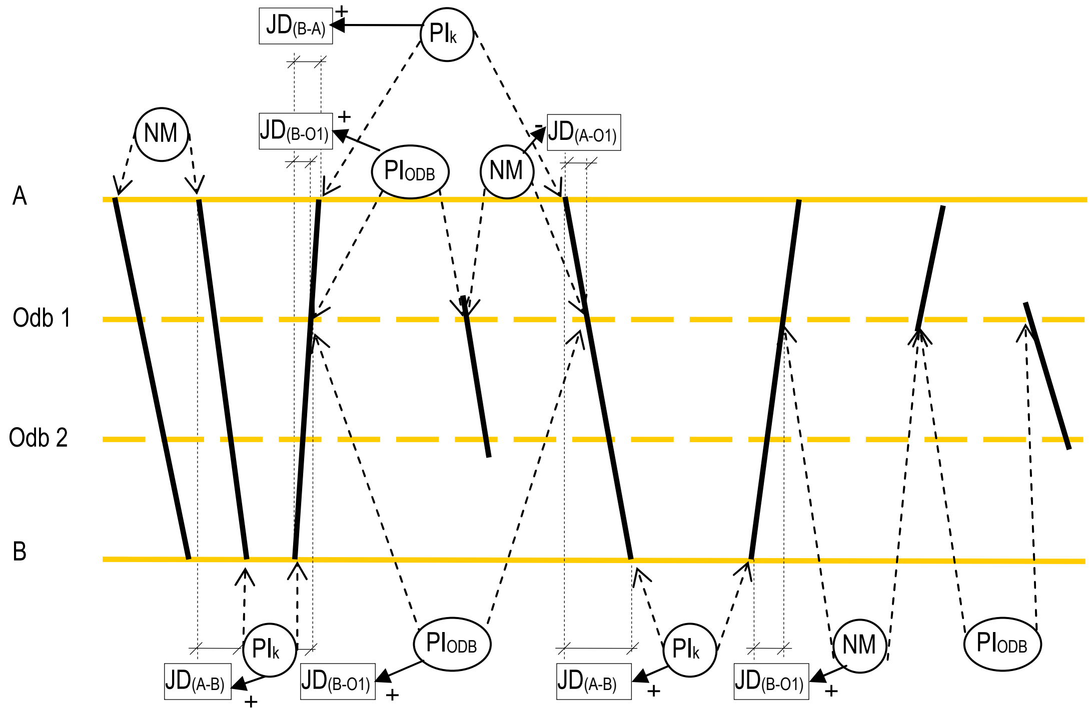

Fig. 4 – Examples of applying the appropriate headway

3 CALCULATION OF TOTAL TRACK OCCUPATION TIME

As stated in chapter 1.2, linear arrangement cannot be created in general case within the whole observed line track for the given set of trains. However, the arrangement of trains can be generally shown on a network graph. Each train is interpreted as a node of the graph. Oriented edges are created between pairs of trains determined in 2.3. The edge always runs from the first to the second train within the given pair. The evaluation of edge is given by the time of occupation of the observed line track by the relevant pair of trains. This occupation time is given by headway according to 2.5 appropriately modified by adding running times according to 2.6.

To calculate the total occupation time and to determine decisive occupation time we use critical path method (CPM) and algorithm to determine maximum path (3) (4).

The length of critical path corresponds with the total occupation time T_{OBS_CELK}.

Figure 5 shows the situation on observed line track viewed with Trains Schedule Diagram. Red arrows mark the found pairs of trains and their corresponding referring points for the calculation of partial occupation time by this pair of trains. The length of arrow does not correspond with occupation time. Figure 6 shows the given situation after its conversion into a network graph.

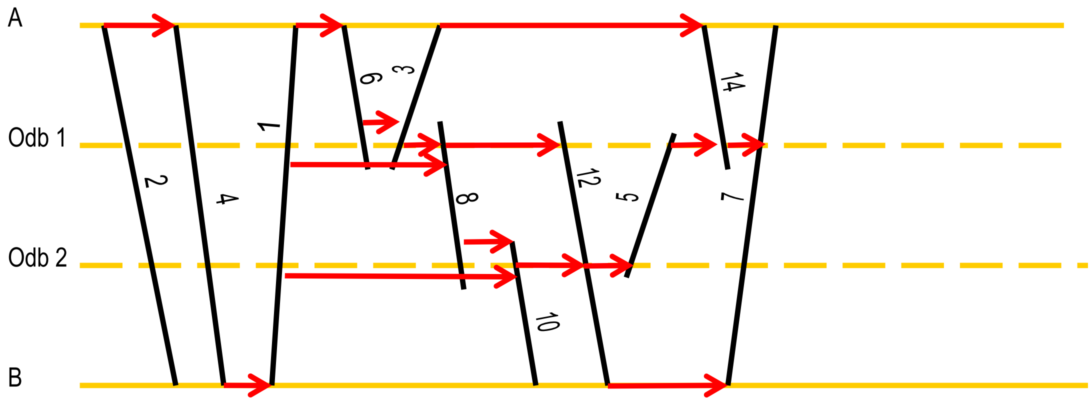

Fig. 5 – Schematic representation of pairs of trains

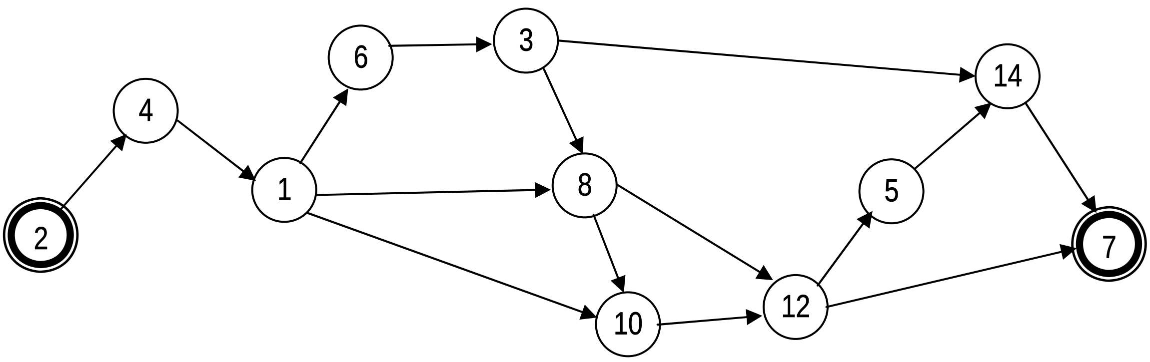

Fig. 6 – Generated graph

CONCLUSION

Such detailed development of methodology for capacity calculation in the crossing or overtaking sections with an intermediate junction is a necessary assumption for follow-up implementation of a testing tool, which will have the task to test the new methodology on real data. Correct specification of input data is essential for successful implementation.

They are mainly determining proper pairs of trains and headway of these trains which are used for occupation by relevant pairs of trains on the observed line track.

REFERENCES

(1) KRÝŽE, Pavel, AMCHA, René, VESELÝ, Petr. *Nová metodika výpočtu propustnosti mezistaničního úseku s odbočkou.* Perners Contact, 2008, roč. 3, č. 5, s. 183–189. ISSN 1801-674X.

(2) *Směrnice D24 pro zjišťování propustnosti železničních tratí*. Praha, 1996.

(3) PALÚCH, Stanislav. *Algoritmická teoria grafov*. Žilinská univerzita v Žilině, 2008. [online]. [cit. 2011-08-12]. Dostupné z http://frcatel.fri.uniza.sk/users/paluch/grafy.pdf

(4) VOLEK, Josef. *Operační výzkum I, skripta DFJP*. Pardubice, 2002. ISBN 80-7194-410-6.