IMPLEMENTATION OF CAPACITY CALCULATION IN THE SECTIONS WITH AN INTERMEDIATE JUNCTION IN IS KANGO

Petr Veselý[1], Pavel Krýže[2]

Summary: This article deals with the specification of new methodology of capacity calculation in the crossing or overtaking sections with one or more junctions as well as with a concrete implementation of the methodology as standalone computing unit within information system that is used for timetable construction and production of related train traffic diagram aids. The basic theoretical description is introduced in (1) and (2).

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

INTRODUCTION

One of the very important tasks in railway transport that have to be solved by traffic engineers is to set capacity of lines, because specified practical capacity with degree of occupancy is a significant factor for railway transport quality. In spite of the fact that simulation methods are supposed to be struggled, also analytical methods have their pros and foundation.

To calculate capacity of crossing of overtaking section there has been used methodology that is based on ČD Regulation D24 of 1966 applicable until now, is not up to scratch any more from today's point of view. The effort to amend present methodology for capacity calculation led to absolutely new methodology for capacity calculation. Basic principle of the new methodology is described in (1) and detailed elaboration is in (2).

To verify the new methodology principles there was created standalone testing tool that is not suitable for calculations on real data. To achieve this it is needed to connect to database that stores detailed information about railway network topology. In the database there are also data about traffic on the railway network that are based on train traffic diagram. Due to this, the new methodology was implemented as a new module that is fully integrated into information system KANGO that is currently in use by SŽDC.

1 BRIEF SUMMARY OF THE METHODOLOGY

Calculations are realized within chosen crossing or overtaking section between points A and B. Terminal points might be either stations or junctions. In crossing or overtaking

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[1] Ing. Petr Veselý, University of Pardubice, Faculty of Electrical Engineering and Informatics, Department of Software Technologies, náměstí Čs. legií 565, 530 02 Pardubice, Phone: +420 466 036 531, E-mail: Petr.Vesely@upce.cz
[2] Ing. Pavel Krýže, Ph.D. SŽDC, s.o., Timetable & Path Capacity Department, Dlážděná 7, Praha 1, Phone: +420 972 241 580, E-mail: kryze@szdc.cz

section there might be any number of intermediate points that divide crossing or overtaking section to traffic sections. Intersection traffic points can be of various types (see traffic points code-list) except traffic point railway station as defined in Regulation D23. Allowed exception is capacity calculation through way station in case when there is not allowed overtaking or crossing – with regard to lines relevant for calculation due to operational conditions or topology of yard.

To calculate capacity of a section there is chosen so call observed line between points A-B that is defined as sequenced order of line tracks from particular traffic sections. Exact specification of the observed line is stated in (2).

Due to the fact that the methodology is primarily designed for sections with an intermediate junction (junctions), it can be presumed that the observed line will be used by trains in its full length as well as by trains that use only a part of the observed line. It is obvious that number of trains might change in any segment of observed line and because of this it is impossible to set linear order of trains to define consecutive train couple. According to these conditions every train might have different successor in various parts of observed line (successor train is defined as the second one from consecutive train couple). To express train sequence in each part of the observed track it is efficient to use network diagram.

Each train is interpreted as a node of the graph. Oriented edges are created between pairs of trains. The edge always runs from the first to the second train within the given pair on observed track – edges orientation is from proceeding to subsequent train. The evaluation of edge is given by the time of occupation of the observed line track by the relevant pair of trains.

Basement for all additional calculations is setting the total time of occupation for all trains using the observed line track. With respect to above mentioned matter of fact (impossibility of ordering trains to sequence) it is impossible to calculate total time of occupancy as common sum of train couple occupancy time. In this case it is needed to calculate total occupancy time using CPM method with created network diagram. Total occupancy time of observed track is equals to length of critical path.

The methodology distinguishes between three types of trains – trains that run full length of the observed track (so called „basic trains"), trains that run only some part of observed track (so called „another trains") and all trains taken into calculation. Train number is given by this equation:

$$N_{CELK} = N_Z + N_J \tag{1}$$

Calculation procedure is divided to three basic phases. In first phase there is created network diagram on the basis of all trains that are considered for calculation. Total occupancy time by all trains T_{OBS_CELK} is estimated with length of critical path using CPM method.

In second phase there are considered only basic trains whereas their total occupancy time T_{OBS_Z} can be calculated either by standard method or by length of critical path using reduced graph that is produced using only these basic trains.

In final phase there is calculated total occupancy time for trains that run only some part of observed track T_{OBS_J} according to equation:

$$T_{OBS\_J} = T_{OBS\_CELK} - T_{OBS\_Z} \tag{2}$$

Further on there are calculated average occupancy times, degree of occupancy for particular train groups, practical capacity and other parameters according to valid regulations (see Regulation D24).

Average occupancy times

$$t_{OBS\_CELK} = T_{OBS\_CELK} / N_{CELK}$$

$$t_{OBS\_Z} = T_{OBS\_Z} / N_Z \tag{3}$$

$$t_{OBS\_J} = T_{OBS\_J} / N_J$$

Practical capacity

$$n_{CELK} = S_{O\max} T / t_{OBS\_CELK} \tag{4}$$

$$n_Z = S_{O\max} (T - T'_{OBS\_J}) / t_{OBS\_Z}, \text{kde}$$

- $S_{O\max}$ is specified value of allowed degree of occupancy
- T is time interval for which is capacity calculation investigated
- T'_{OBS_J} is occupancy time by other trains which is increased by margin that comes from maximum allowed degree of occupancy $S_{O\max}$. It can be calculated as follows:

$$T'_{OBS\_J} = T_{OBS\_J} / S_{O\max} \tag{5}$$

2 MODULE IMPLEMENTATION IN INFORMATION SYSTEM KANGO

To be able to realize capacity calculation using above mentioned methodology it is needed to have access to huge amount of input data that describe topology of traffic points along the observed track as well as information about all considered trains. The needed data describe train movement across traffic points, information about transit or train stops, sojourn train times, travel times, data about railway stations tracks, information about switches occupancy etc.

All the needed data are available within information system KANGO that is used by SŽDC staff. For full use of developed tool it was needed to integrate the methodology as a standalone module into the information system.

Basic problem was to create network diagram on the base of selected traffic sections, lines and trains that should be considered for calculation.

The graph on itself is implemented using list of edges and list of nodes. Connection of edges and node is marked in class diagram in Fig. 1. List of nodes contains instances of cNode class. Every node in graph represents concrete train, so instance of cNode class contains cTrain as an attribute which is reference to complete data about a concrete train.

To be able to go through graph easily when calculating critical path using CPM method there is stored list of references for incident trailing edges of a given node. For reverse motion during critical path determination (determination of edges that are part of critical path), there is stored a list of references of inlet edges for every node.

Every edge represents train couple that run in certain section of line subsequently. Important attribute for edge is it's evaluation that represents observed track occupancy time

by the train couple. As redundant information that helps to process the graph, there is for every node stated reference for initial and tail edge.
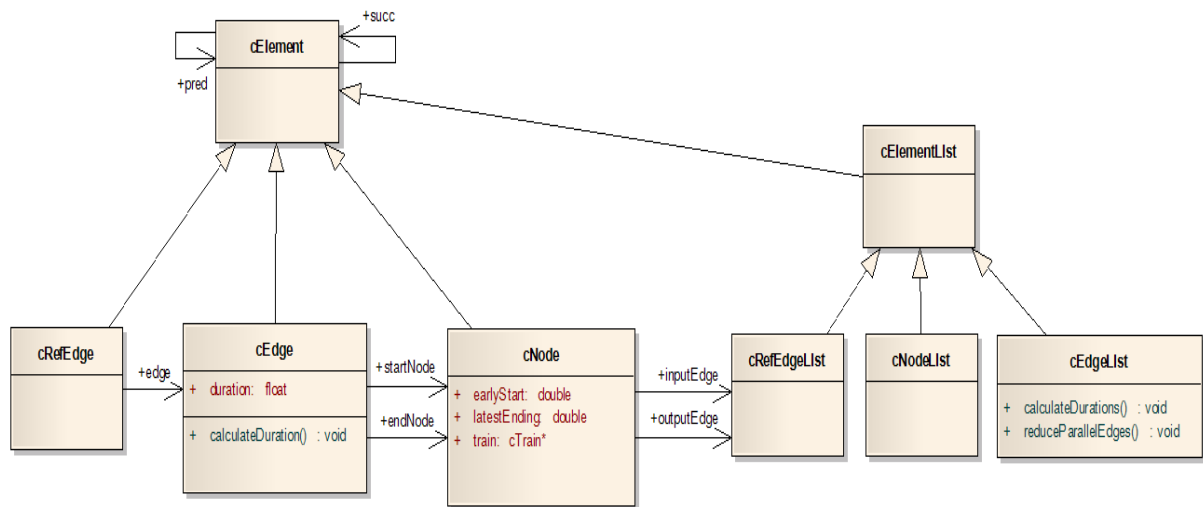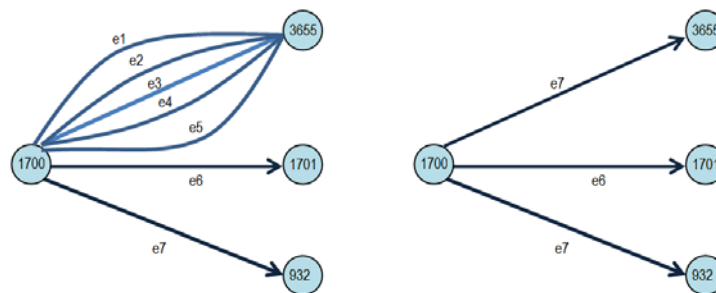

Source: Authors

Fig. 1 – Class diagram (classes used to implement network diagram)

In detailed semi-conducted methodology (see (2)) it is supposed that the edge in graph represents both trains running immediately in sequence all the way the line. In Fig. 3 there is a fragment of train traffic diagram where train 3655 is successor of train 1700 in several sections (Ruda nad Moravou–Bartoňov z,   Bartoňov z–vl. v km 56,162, vl. v km 56,162–vl. v km 55,959, …) that represent connected part of observed track from Ruda nad Moravou to Bludov km 50,072. Thus, in final graph there must be only one edge between nodes 3655 and 1700 that represents a part of observed line Ruda nad Moravou–Bludov km 50,072.

To find connected parts of observed track for individual train couples the best approach seems to be usage of train lists for individual line sections. On the base of these lists there were produced temporary edges that represent successors for all sections. For every section within observed line there is added edge to the graph that represents train couple – last train⇒first train from the list of the section. This way there were produced multiple edges that are then reduced to final edges according to the methodology. There is a fragment of unfinished multi graph with multiple edges in Fig. 2 as well as graph after multiple edges reduction.

Source: Authors

Fig. 2 – Graph with temporary multiple edges and their reduction

Before starting CPM calculation it is needed to find initial node in graph. For this purpose it is needed to find at least one train that runs all the observed line. When there is no such a train it is impossible to calculate section capacity. This case is not solved by the methodology at the moment because it doesn't make sense to calculate capacity for section without basic trains (with just other trains).

When the first train that runs all the observed line is found, then the node that corresponds to the train is denoted as V_0. There is added copy of node V_0 that is denoted as V_n, where n is original number of nodes. Then there are left only its original incident trailing edges of a given node and all it's inlet edges are redirected to edge V_n. The graph then has to be sorted so that V_0 is initial node and V_n is tail edge of sorted graph.

Evaluation of edges (occupancy time) is based on technological time in referential traffic point and the evaluation is done by standalone interval module. This module is part of the information system KANGO and the module has been recently rewritten in accordance with the new Regulation SŽDC (4) that provides rules to calculate headway for selected traffic point (railway station, junction, train stop) and two trains. Referential traffic point is for the purpose of capacity calculation such a traffic point that is relevant for calculating occupancy time for train couple. Detailed determination of referential point is denoted in (2). We choose relevant headway according to following rules:

- In case both trains run the same direction and they both use at least one section in common, then we use time of subsequent running.
- Otherwise, if the traffic point is railway station then we use crossing time which means, according to real trains route one of the following headways: headway of arrival and departure (I_{VO}), headway of transit and departure (I_{PO}), headway of arrival and transit (I_{VP}) or headway sequent departures (I_{PP}).
- Otherwise, if the point is junction, then we use headway with maximum value from all headways. This value is then in some cases (see (2)) increased about the value of the second train sojourn time or decreased about the value of the first train sojourn time.

To keep flow of individual steps of calculation, there must be made following edge evaluation correction (for detailed explanation see (2)):

- It is needed to add travel time of first train between traffic point where train enter observed line and referential traffic point.
- It is needed to subtract travel time of second train between traffic point where train enter observed line and referential traffic point.

All used values of travel times come from train traffic diagram and are obtained from travelling times module that is available within the information system KANGO.

3 USER INTERFACE AND CALCULATION EXECUTION

Capacity calculation in section with intermediate junction is always realised for selected and displayed train traffic diagram sheet. Basic presumption for calculation is timetable without conflicts (see Fig. 3) and additional trains are amended to the timetable.

Observed line is selected using input form (see Fig. 4) where user can select line tracks for observed line. Observed line can be defined by selection of line tracks within selected sections.

In case we are unable to make up the connected observed line (when we miss a section or there is no track interconnection between sections), then the calculation can't be done. In Fig. 5 there is schema of observed line and its definition using input form (Fig. 4).
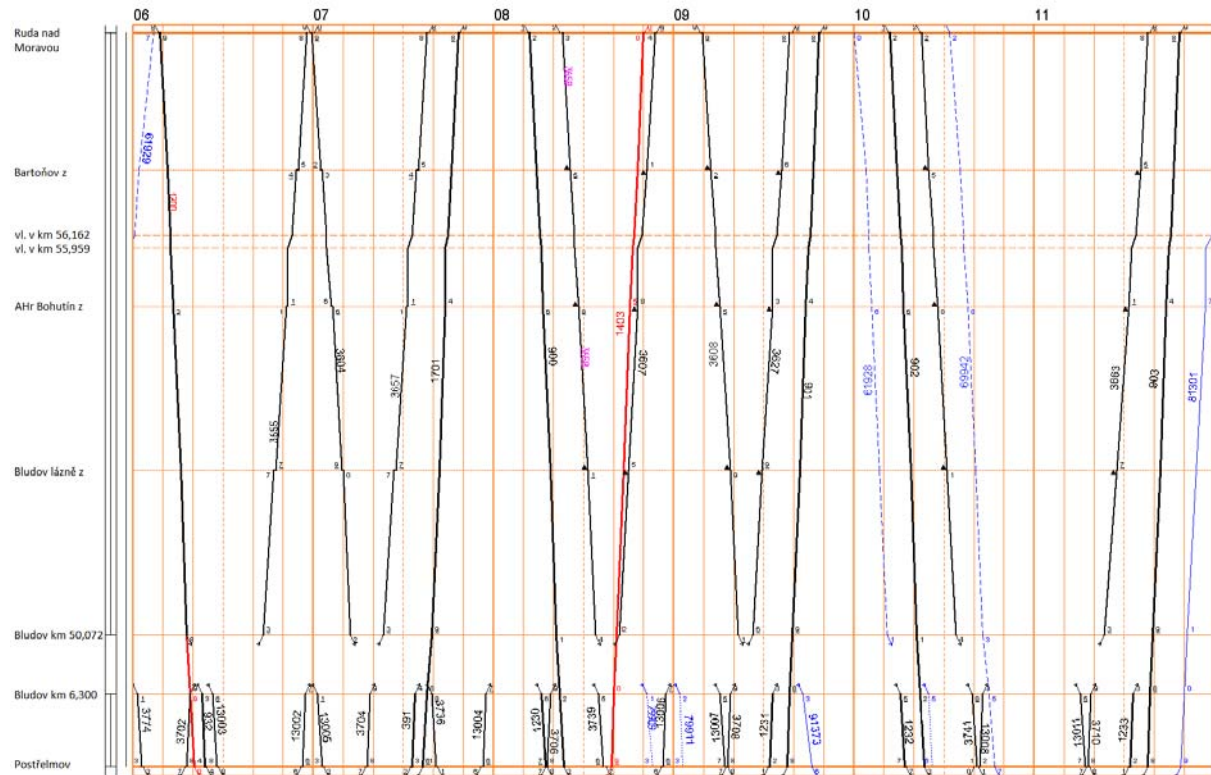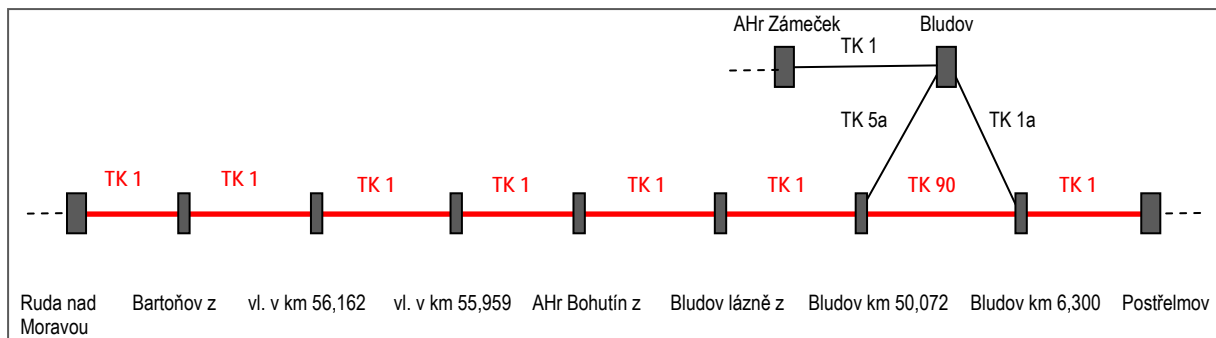

Source: Authors

Fig. 3 – Example of train traffic diagram sheet

Another user option is to select time slot for calculation (starting time – finish time). List of trains that is listed corresponds to selected time slot.

Source: Authors

Fig. 4 – Input form for calculation

Source: Authors

Fig. 5 – Scheme of observed line

Within input form a user is able to select all listed trains, to deselect disturbing trains or to select only requested trains.

When the calculation is executed the graph is created on the base of selected observed line as well as on the base of selected trains and graph is checked if it's acyclic. When there is any loop in the graph, then it is impossible to do the calculation. This can happen in cases when there is a reversal train or disturbing train that run in the time slot of other train. These situations are not in the methodology solved yet.

At the beginning of the calculation at least one train that run all the observed line must be found and then the graph has to be sorted (see chapter 2). In case there is no such train it is impossible to do the calculation.

Then there is calculated critical path length and it is stored for another usage. Example of created graph for all selected trains is in Fig. 6.
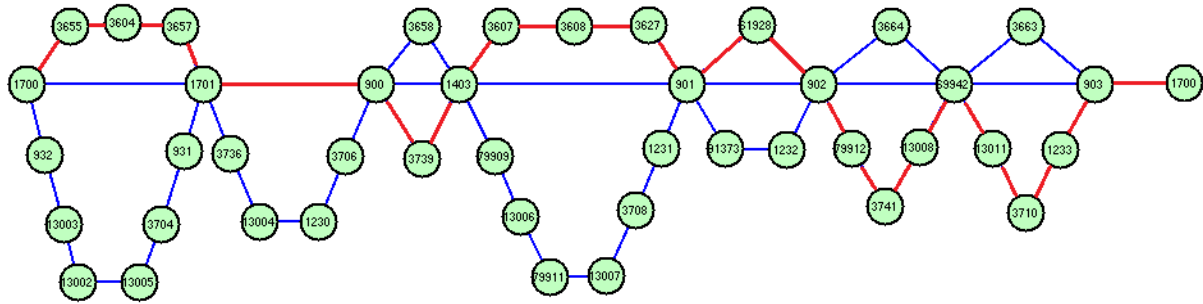
Fig. 6 – Graph example – first step

During next step there is created new graph that contains only basic trains (trains that run all the observed line). Then the critical path length is calculated again and is stored for another usage. Graph that is constructed only for basic trains is in Fig. 7.
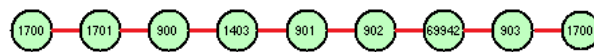
Fig. 7 – Graph example – second step

Results of the calculation are then used to calculate other capacity indicators for observed line. There is an example of calculated values in Fig. 8.

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Total time (T) = 360.00

Total number of trains (N_z + N_j)                  = 43
Number of trains that run all the section (N_z)     =  8
Number of trains that run any part of the section (N_j) = 35

Occupancy time (TObs_celk) = 176.50
Occupancy time (TObs_z)    =  84.00
Occupancy time (TObs_j)    =  92.50
Occupancy time (TObs_j')   = 138.06

Average occupancy time (tObs_celk) =  4.10
Average occupancy time (tObs_z)    = 10.50
Average occupancy time (tObs_j)    =  2.64

Max. degree of occupancy (SoMax)   =  0.67
Degree of occupancy (So_celk)      =  0.49
Practical capacity (n_celk)        = 58.76
Practical capacity (n_z)           = 14.16
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Fig. 8 – Selected results

CONCLUSION

The new methodology for capacity calculation in the crossing or overtaking sections with junction has been successfully implemented into information system KANGO and is in testing phase these days. When it is fully tested (methodology itself as well as correct

connection to database and to other modules of the information system) then it will be passed to common service. It is supposed to use this module (with small changes) also for crossing or overtaking sections without junctions so it could replace current module that calculates capacity of interstation section.

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