

IMPLEMENTATION of the UIC 406 CAPACITY CALCULATION METHOD at AUSTRIAN RAILWAYS (ÖBB)

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Abstract

Increasing railway traffic in the Europe requires a universal and transparent capacity consumption calculation method. This will provide a common view on different types of lines and stations in different European countries and can be the basis to schedule more trains at high quality standard levels. Such a calculation method was defined by the UIC and published as UIC-Codex 406 in September 2004. The Austrian railways (ÖBB) decided to use the UIC 406 method to analyse all their lines and made use of the simulation tool SIMU to assist in the calculations. The tool SIMU has been used by the ÖBB for several years to calculate the effect of changes in infrastructure, timetable or operational constraints in their network. The ÖBB mandated the consulting company IBS to implement and assist the UIC 406 method. From then onwards all their lines have been calculated to provide a data-basis from which future capacity calculations and scheduling can be performed.

1. Introduction

The rising volume of traffic along with a simultaneous demand increase in terms of quality and quantity require a transparent and generally-valid understanding and definition of the term capacity. This is especially necessary for international traffic on long transport axis through Europe or on lines of different infrastructure suppliers, where every operator has a different understanding of capacity and its calculation. Capacity as such does not exist. It rather depends on the way it is utilised. This means that on two lines of the same characteristic complete different results can occur, if the operational process differs. E.g. a double track line with an extensive number of commuter trains has a different capacity than a double track line with long distance trains mixed with freight traffic. Basic parameters for the calculation of capacity are the characteristic of an infrastructure. This data is normally used to calculate the headways between two or more trains. The attributes to consider are:

- Layout (single or double track)
- Stations (overhauling tracks)
- Speed
- Signalling

As mentioned above the characteristics of the operational process must also be taken into consideration. Typical operational parameters are:

- Number of trains (often described as number of trains/hour or trains/day)
- Average Speed of the trains
- Desired stability (depends often from the number of passenger trains)
- Heterogeneity (number and configuration of slow and fast trains)

Unfortunately these parameters are interdependent. A higher level of stability requires additional margins and buffers to suppress minor delays resulting in fewer trains. More trains running on a line leave less capacity for quality. Differences in acceleration, maximum speed and train characteristics result in different headways compared to lines with harmonised train runs.

The relationship between these parameters are normally shown in a so called “capacity balance diagram” (see fig 1). Each axis represents the value of a parameter and the length of the chord represents the capacity. Increasing capacity means increasing the length of the chords.

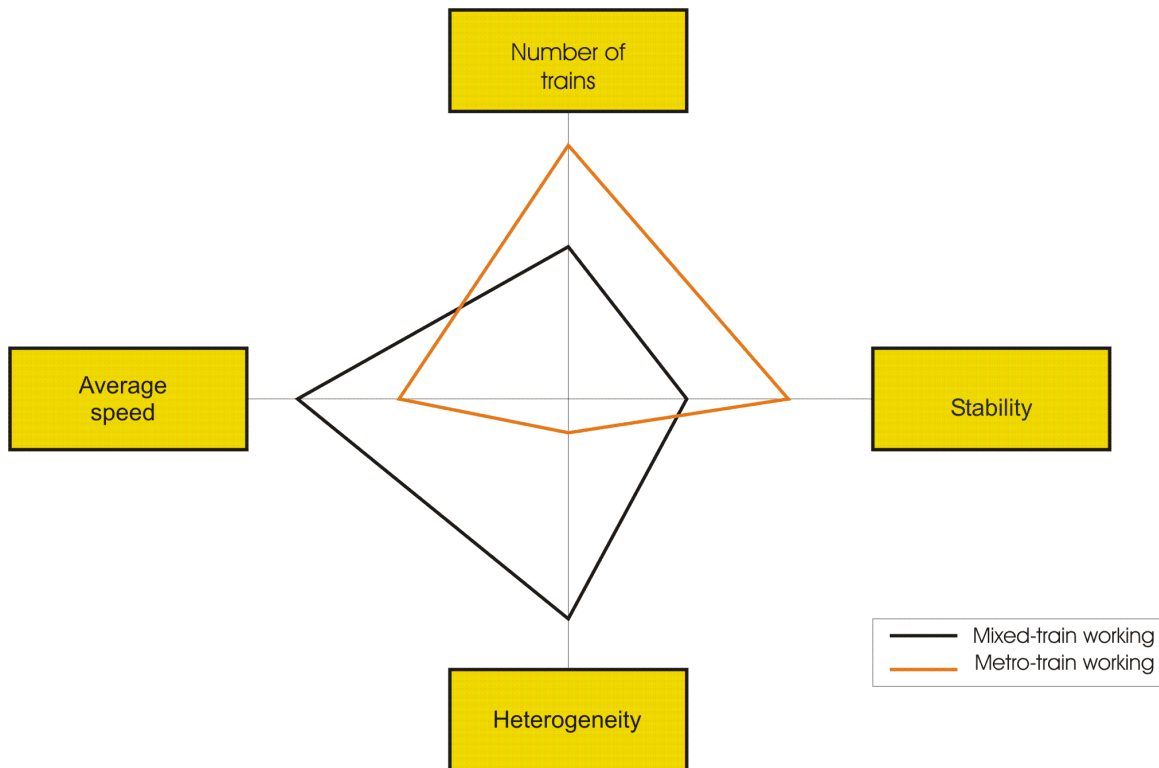


Figure 1: Capacity balance

There are other parameters, which has to be taken into consideration if capacity is calculated. Examples are technical constraints and safety aspects. The system, the operational guidelines or view of the railway environment also influence the capacity (e.g. maintenance requirements or actual conditions of the infrastructure).

To summarise the above capacity in general can only be calculated under very special conditions and with many user-depended assumptions. This results in the idea to calculate the capacity consumption instead of the capacity itself.

2. Capacity Consumption

A detailed description of the capacity calculation method is described in [1]. Only the basic concepts and some key values will be presented.

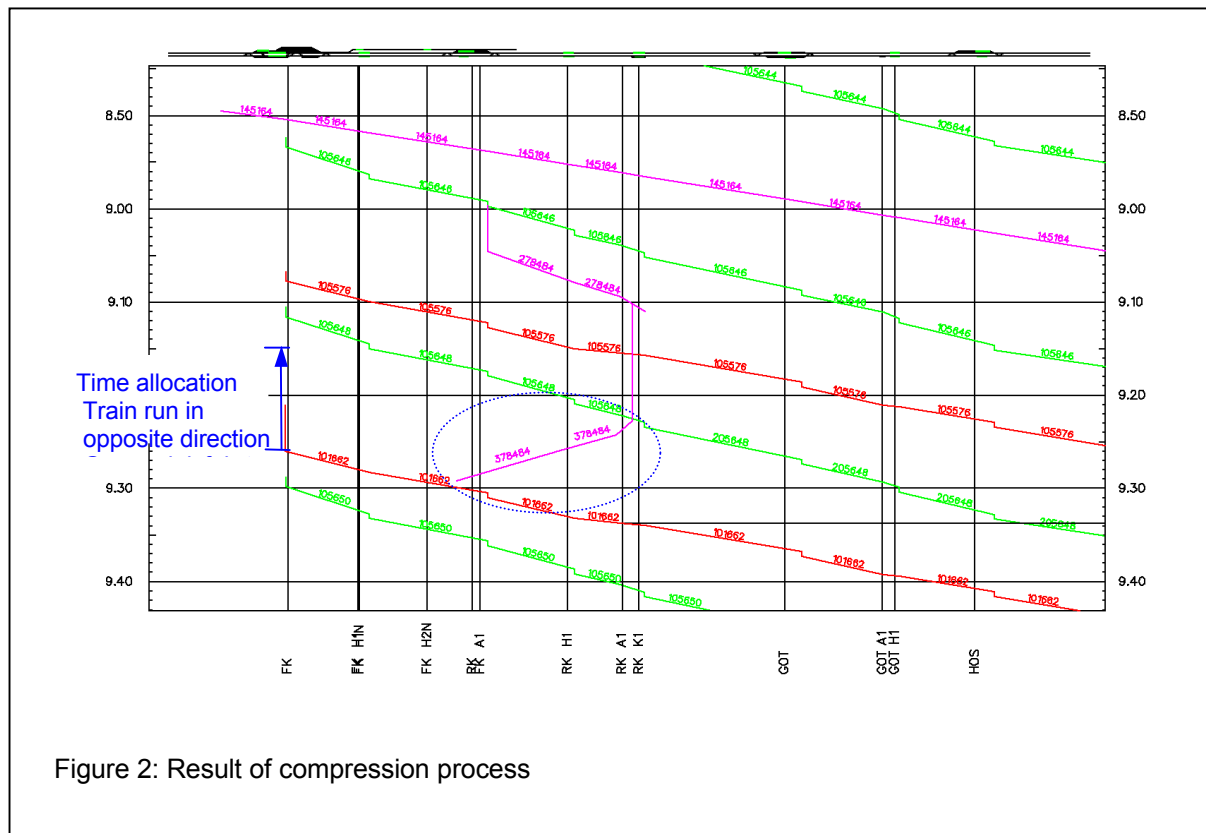
2.1 Basic approach

To calculate the capacity consumption, the railway company use a pre-constructed timetable on a given infrastructure. It is assumed, that such a timetable expresses and translates the market needs. This includes the mixture and characteristics of trains, the train’s path with their regular stops and over takings. Only scheduled trains are taken into consideration.

To calculate the headways between the trains a given infrastructure is used, whereas the layout and signalling of a line must be provided.

2.2 Compression

The capacity calculation is based on the compression of the timetable. Therefore an area (e.g. part of a line) must be defined, which is the so called "compression area". Then all single train paths are pushed together up to the minimum theoretical headway (without buffers) according to their timetable order. During the compression neither the running times, scheduled over-takings, crossings nor any stopping times may be changed. The effects of the compression on neighbouring line section are not taken into account. Also indirect occupations have to be taken into consideration. This means the time of a train path, which crosses the line. Indirect occupations are treated similar to the compression procedure (e.g. no change of train order).



2.3 Capacity Consumption

After compression the infrastructure occupation can be measured at the beginning of the first block section within the line section. The difference between the ends of the last occupation and the beginning of the first occupation gives the infrastructure occupation time (value A). To take the buffer time and supplements into consideration an additional percentage of the infrastructure occupation time is added (value B). The value of the buffer time depends at the ÖBB on the number of passenger trains on the line of the ÖBB. The sum of infrastructure occupation and buffer time is the capacity consumption ($K = A + B$). The difference between the time window (U) and the capacity consumption is called the unused capacity on the line ($N = U - K$).

2.4 Usable capacity

The final step is to calculate the amount of usable capacity. The unused capacity calculated in the step before can be partly used for additional train runs. These additional train runs must be included in the present timetable before a new calculation is started. The additional train runs are constructed in a larger area than the compression area. This part of the line is called the “construction area”.

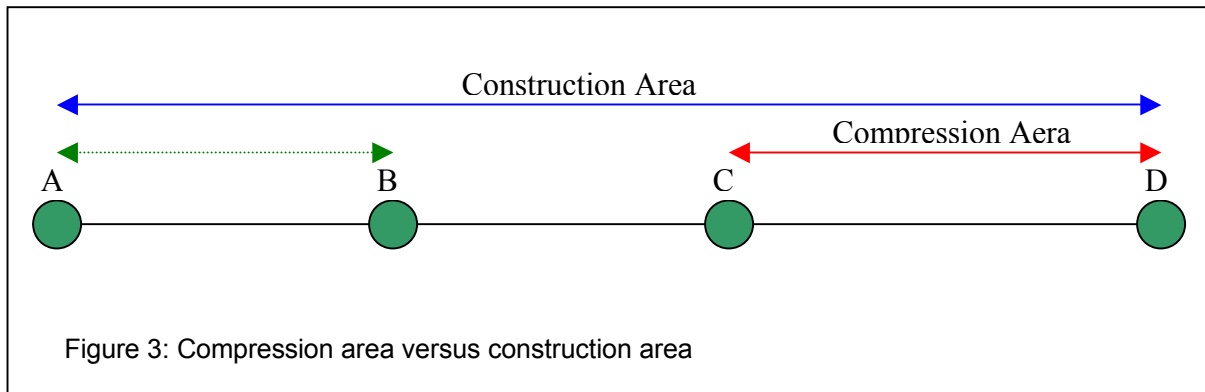


Figure 3 shows the difference between the compression area (here C to D) and the construction area (A, B, C to D). Only trains which can be constructed between A and D will be taken into consideration. If there are no more trains, which can be constructed into the timetable the remaining difference between the time-window and the capacity consumption is named lost capacity.

3. Calculation tool SIMU for capacity consumption

The ÖBB has used the simulation tool SIMU [2] for several years for strategic and operational planning tasks. Because of the positive experience the decision was made also to use this tool for calculation of the capacity consumption in their network.

3.1 Depiction of Infrastructure and timetable

The track infrastructure and the layout of the line are depicted as a graph model. The graph has nodes and edges. The nodes represent those points in the track, which are evident for the operational process (e.g. signals, speed points, switches). The connections between the nodes represent the track sections and have attributes such as length, speed and gradient.

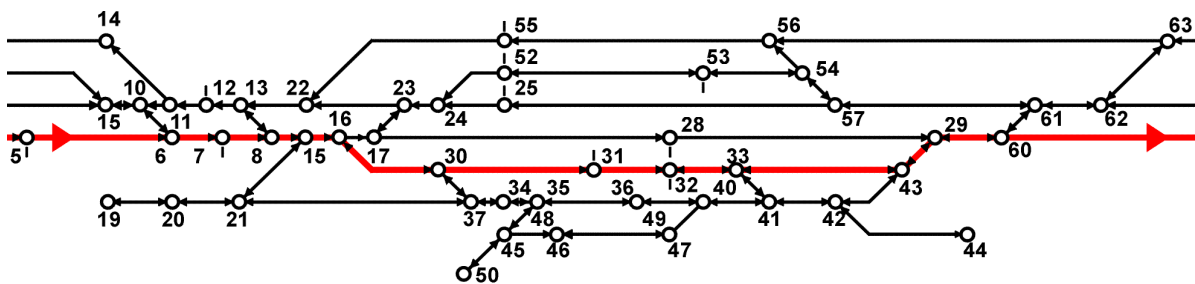


Figure 4: Depiction of layout

The signalling system is depicted in the model by sequences of edges. Each sequence represents a block section with all the relevant attributes (e.g. signal box technology, level of ETCS). Speed indicators, release points and overlaps can also be depicted in the model. The infrastructure data can be imported from an existing database and can then be modified by interactive track editors.

The complete network of the ÖBB is depicted by SIMU and is used for simulation tasks and maintenance site planning [3].

A train run is depicted in the SIMU-model by the path of the train (sequence of stations). In each station the track, stopping times and connections to other trains are included. The characteristics of the train (e.g. traction, length, weight) are included in the train definition. In reference to these parameters the running times of the trains are automatically calculated. For simulation disposition parameters like overtaking tracks and disposition rules are included. SIMU can simulate all the train runs, calculate the headways, detect conflicts and solve them with respect to the disposition rules.

The train runs of a timetable can also be imported from an existing database, whereas these timetables can be modified on demand by a timetable construction module.

3.2 UIC 406 planning module

The UIC 406 calculation method was included in the existing timetable planning tool of SIMU. The planning process is described in figure 5.

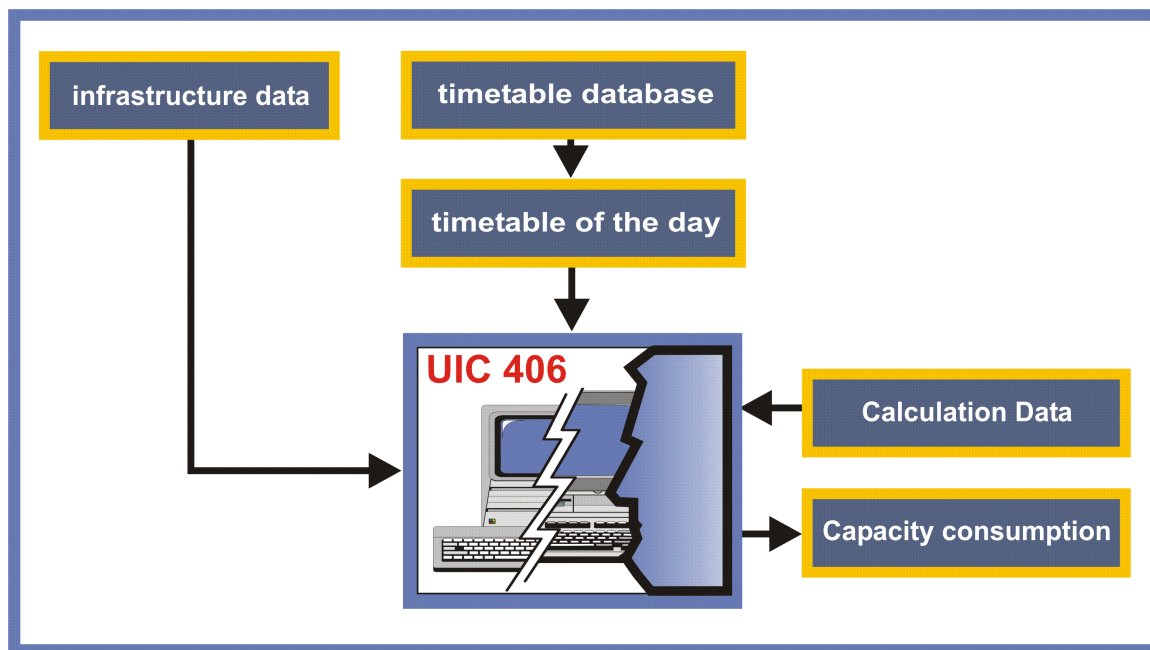


Figure 5: Process of planning

As a first step the user defines the network or the track section. Here the existing database of the simulation is available. The timetable automatically serves as an input from the timetable database and, if required, modifications can be made to the timetable by adding new trains or changing train runs. Finally the UIC 406 calculation process is initialised to get the capacity consumption. The capacity calculation is implemented as described in the UIC 406 code, which also includes the calculation of headways through the usage of indirect occupation and the compression algorithm. For the calculation the user has to create the basic calculation data. For each network or line the user can define different configurations. So an existing configuration can select a new calculation or to modify the calculation parameters.

Each configuration includes:

- Compression area
- Compression trains
- Quality factor
- Time-window
- Construction area
- Construction trains and construction rules

The compression area defines the start and end of the section, which are used in the compression algorithm. By the compression trains the compression area (set of stations, path) is defined in detail. This concept has the advantage that the user can separate between two or more possible paths between start and end. The quality factor can either be defined in percentage or in minutes and the time-window can be 24 hours or any part of that. In that case the compression method is used several times for each time slot. The construction area and construction trains are only used, if the user likes to calculate the usable capacity on the line.

3.3 Train path generator

The train path generator is used to create additional train paths in the timetable. For each configuration the user can define various construction trains and allocate construction options to them. Possible options are:

- Number of additional trains
- First departure time
- Distribution (e.g. one train/hour)
- Buffer times
- Disposition rules

With regards to these options additional train runs are added automatically to the timetable. The train runs are included in a way that the existing timetable is not altered and the new train runs do not generate conflicts in the timetable. As an option the user can define additional disposition rules. In that case the new trains might cross existing trains or will be overtaken by existing trains. Otherwise additional trains would not be included in the timetable.

3.4 Documentation of results

The results of capacity calculations are listed in a standard format. This standard format includes the time-window, the number of existing trains, the percentage of passenger trains and the result of the compression and train generator algorithm.

Construction area		Capacity consumption (%)		Number of existing trains		Number of additional trains		Available capacity			Time window
from	To	Dir 1	Dir 2	Dir 1	Dir 2	Dir 1	Dir 2	Dir 1	Dir 2	Sum	
Bruck-M.	Graz Hbf	89,1	90,7	128	128	18	16	146	144	290	24
W.Hütteld	Rekawinkel	110	114	165	182	-23	-30	142	152	294	24

Table 1: Documentation of results

The summary of all the results are presented in a more condensed format, which only includes the line, the capacity consumption, the number of trains and additional train paths.

4. Examples

The following screen shots illustrate some examples from the capacity consumption process. Figure 6 shows the present timetable line Passau-Wels. This line is a double track line connecting the Westbahn (Vienna – Salzburg) with the German railway network. On this line there are long distances, local passenger traffic and also freight traffic.

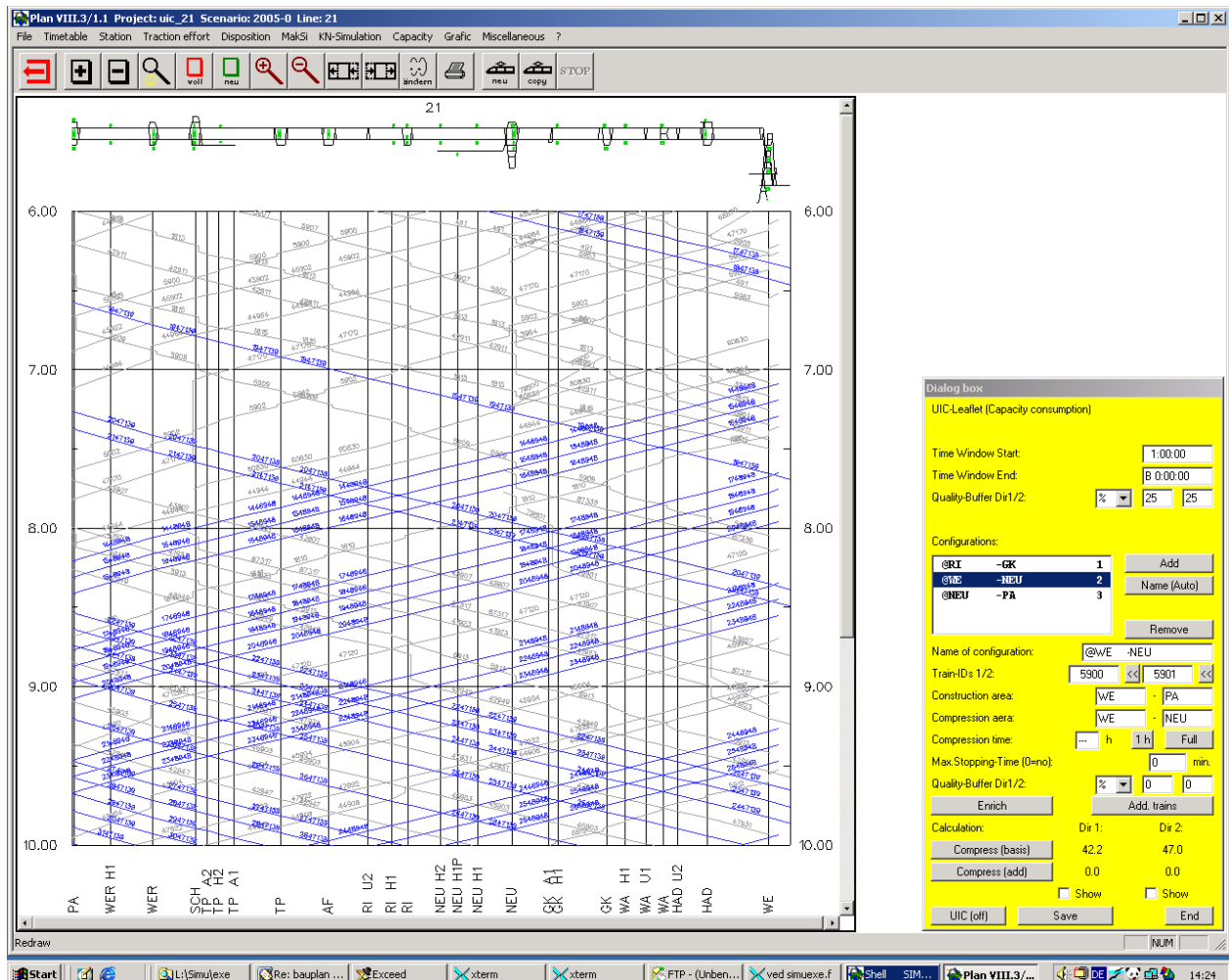


Figure 6: Basic timetable including additional trains

The compression area is from Wels (We) to Neumarkt-Kallham (Neu) and the construction area is the complete line from Wels to Passau. In both directions additional freight trains have been added automatically by the train generator (see figure 6).

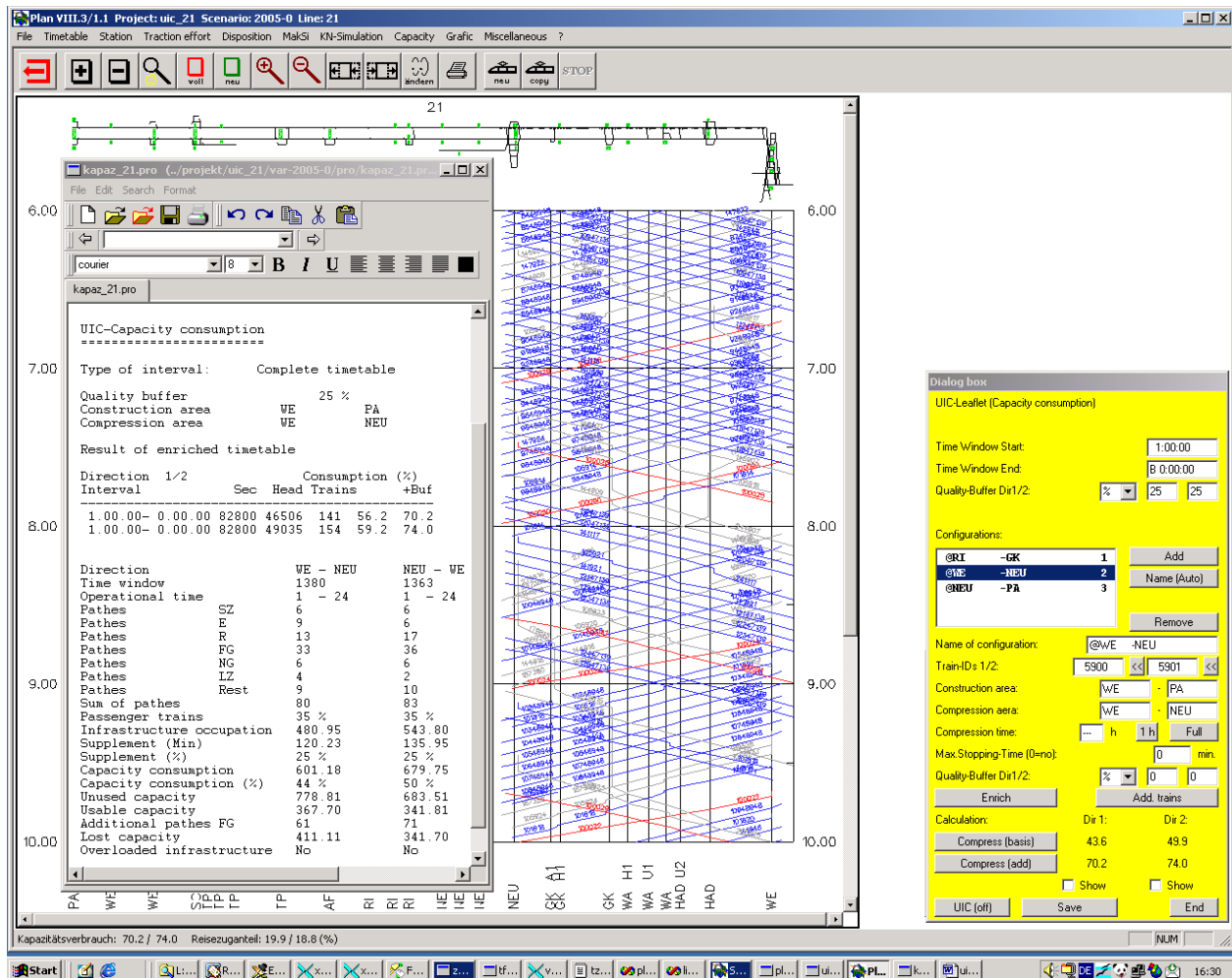


Figure 7: Result of capacity consumption calculation

Figure 7 shows the result of the compressing algorithm. The protocol file indicates the basic results (e.g. number of trains classified by type of train, capacity consumption listed in minutes and percentage).

5. Experiences

The UIC 406 method is an effective approach to calculate the capacity consumption on lines. Due to the number of calculations an efficient software tool is required. The current simulation model SIMU offers a good basis to perform these calculations. After the configurations are defined a new or modified timetable can be analysed without additional effort. An additional advantage is the train path generator, which creates additional train runs automatically.

Figure 8 shows the lines of the Austrian railway network, which have been calculated using the UIC 406 compression method.

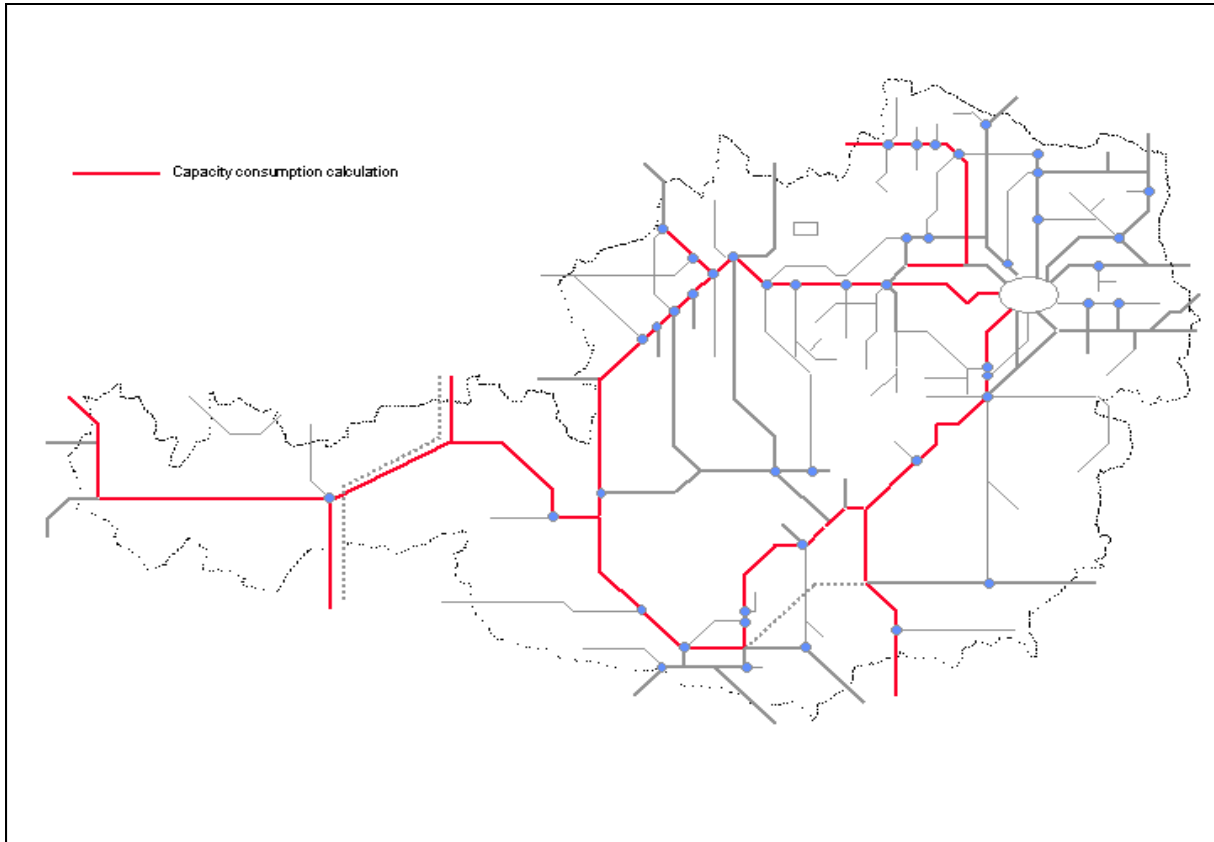


Figure 8: Railway network of ÖBB

No fixed decision has been reached regarding the initial parameters of the compression method. A general assumption is that the existing timetable including stopping times should be kept unchanged. This constriction can however generate poor results in the compression process. For example longer stopping times will be present on the line, if a train is overtaken by two or more trains. If the stopping time remains unchanged a third train runs much later on the line. An example is given in figure 9. In the regular timetable (part I) the train 10 stops in B and is overtaken by train 1 and 3. A third train 5 follows train 10. After compression (part II) the train 10 stops very long in B. A possible solution is to reduce the stopping time of train 10 in B. The result is printed in part III of figure 9.

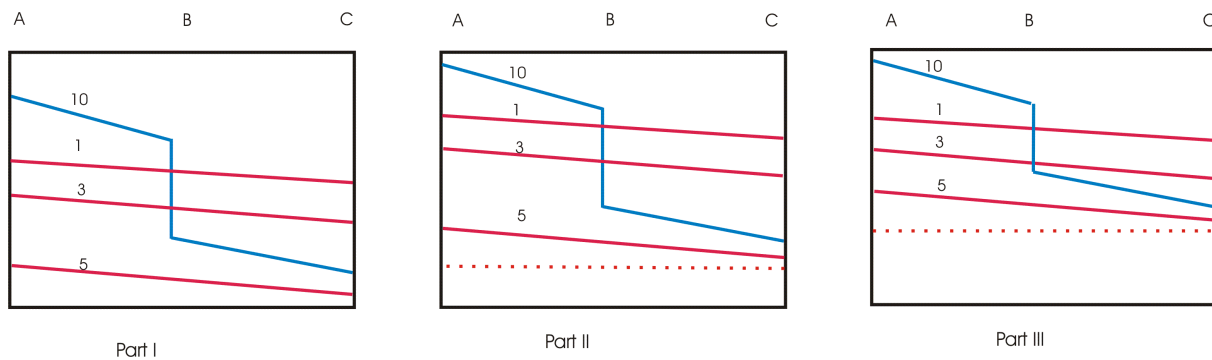


Figure 9: Compression with overtaking

In discussion are the percentages of buffer time, which has to be added to the calculated infrastructure occupation. Currently the ÖBB uses a standard buffer time table, which depends on the number of passenger trains and the type of operational process (commuter trains or mixed traffic). On 24 hour timetables the number of trains differs extremely between peak hours and non peak hours. After compression the capacity consumption might be very low, because of the low density in the off-peak hours. On single track lines the result of the compression depends very much on the length of the compression area. If the compression area contains several crossing stations the result of capacity consumption is much higher compared to the result of a compression over only one crossing section. An example is given in figure 10. For that reason on single track sections the maximum of the capacity results is used.

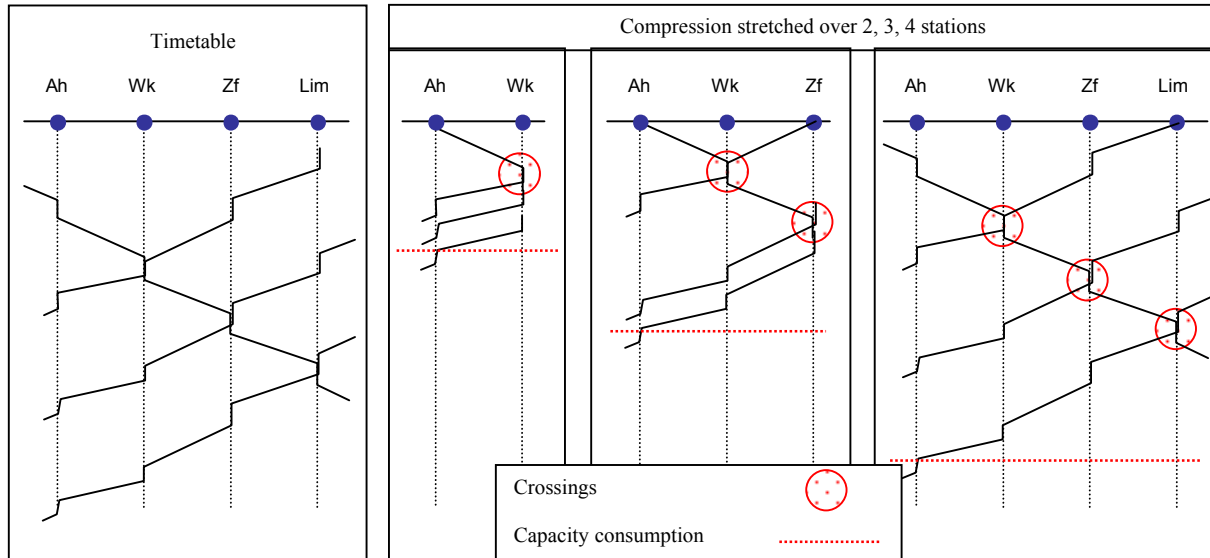


Figure 10: Capacity consumption on single track sections

Summary

The UIC 406 method is a new approach to calculate the capacity consumption on a line. In the last three months all main lines of the ÖBB were analysed with this method and the results are compatible to further calculation in the network. An advantage is that the calculation is based on hard facts like infrastructure and existing timetable and “weak” influences like different views, priorities or current level of quality were not taken into consideration.

The calculation of capacity consumption requires an efficient software tool. The ÖBB uses the simulation model SIMU, which provides a good platform for infrastructure and timetable data. The initial calculation parameters are stored in configurations, which can be employed to perform all the calculations automatically.

References

- [1] UIC-Kodex 406. Paris, September 2004.
- [2] Klahn, Volker: Die betriebliche Simulation großer Eisenbahnnetze. ETR 43 (1994), Heft 10.
- [3] Klahn, Volker: Planning maintenance site timetables. IRJ, March 2004.