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# Capacity at Railway Stations

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## Abstract

Stations do have other challenges regarding capacity than open lines as it is here the traffic is dispatched.The UIC 406 capacity method that can be used to analyse the capacity consumption can be exposed in different ways at stations which may lead to different results. Therefore, stations need special focus when conducting UIC 406 capacity analyses.This paper describes how the UIC 406 capacity method can be expounded for stations.

Commonly for the analyses of the stations it is recommended to include the entire station including the switch zone(s) and all station tracks. By including the switch zone(s) the possible conflicts with other trains (also in the opposite direction) are taken into account leading to more trustworthy results.

Although the UIC 406 methodology proposes that the railway network should be divided into line sections when trains turn around and when the train order is changed, this paper recommends that the railway lines are not always be divided. In case trains turn around on open (single track) line, the capacity consumption may be too low if a railway line is divided. The same can be the case if only few trains are overtaken at an overtaking station.

For dead end stations and overtaking stations, the dwell/layover time is recommended to be reduced to the minimum required time as it results in the lowest possible capacity consumption. For dead end stations it is furthermore recommended that the trains can use all possible tracks and not only those tracks they originally was assigned.

For complex stations with shunting movement, the results of UIC 406 capacity analyses are imprecise due to different possible routes and no exact knowledge of shunting movements. For these stations it is instead recommended that they are analysed with a supplement to compensate for the inaccuracies.

## Introduction

Railway capacity is a complex, loosely defined term that has numerous meanings [6], and the definitions differ by country [14]. In 2004 the International Union of Railways (UIC) (re)defined railway capacity as: “Capacity as such does not exist. Railway infrastructure capacity depends on the way it is utilized” [17].

This definition of railway capacity is followed by a guideline for how railway capacity can be measured given the actual infrastructure and the actual timetable – the so-called UIC 406 capacity method.This method defines railway capacity as “the total number of possible paths in a defined time window, considering the actual path mix or known developments respectively…” [17]. To measure the railway capacity consumption, timetable graphs can be used whereby the given infrastructure and the type of rolling stock are implicitly included as they determine the size of the blocking stairs. The capacity consumption is measured by compressing the timetable graphs so that the buffer times are equal to zero, cf. figure1. This considers the minimum headway times, which depend on the signalling system and train characteristics [15].

The examples in figure1 are schematic representations of the UIC 406 capacity method, and thus do not describe the stations in detail. Stations do have other challenges than the open line as it is here the traffic is dispatched. This is e.g. due to changes in the train order (overtakings), trains turning around and conflicting train routes. Therefore, stations need special focus whenconducting UIC 406 capacity analyses.

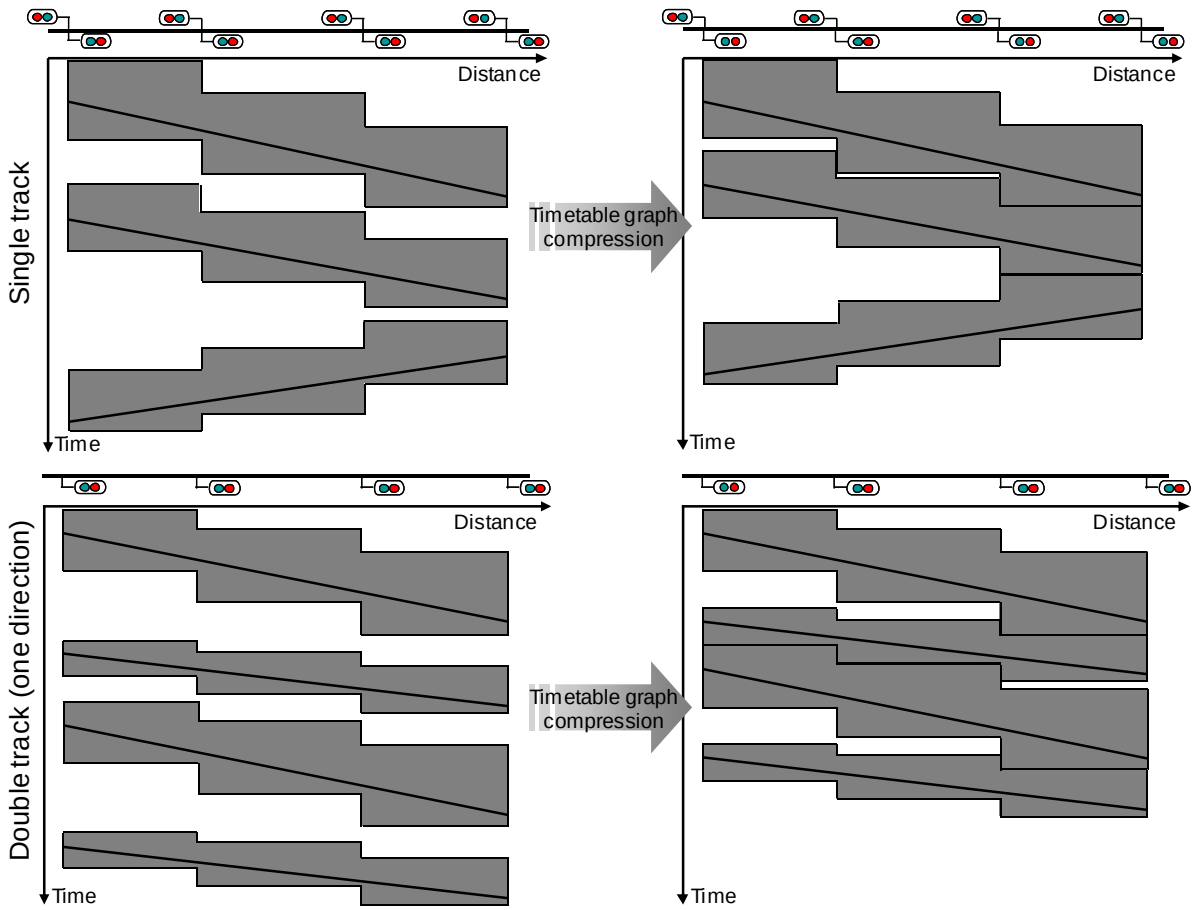


Figure1: Compression of timetable graphs according to the UIC406 capacity method. Based on [9].

**Practical use of the UIC 406 capacity method**

It is difficult, or even impossible, to compress the timetable for an entire complex railway network as train routes are interwoven. Therefore, it is necessary to divide the network into smaller line sections that can be handled by the UIC 406 capacity method. Railway lines are, according to [17], divided into smaller line sections at junctions, overtaking stations, line end stations, transitions between double track and single track (or any other number of tracks) and at crossing stations.

In the UIC 406 capacity method, each line section is examined by compressing the timetable graphs to the minimum headway time, so no buffer time is left. The compression of the timetable graph must be done with respect to the train order and the running times. This means that no changes are permitted in the running times, running time supplement, or block occupation times. Furthermore, only scheduled overtakings and scheduled crossings are allowed.When the timetable has been compressed it is possible to work out the capacity consumption of the timetable by comparing the cycle times (the compression ratio).The line section with the highest capacity consumption is the dimensioning line section of the given railway line.

In practice, the UIC 406 capacity method can be used manually for any given line section by using a timetabling system that has conflict detection, e.g., RailSys[16] and the TPS system [5] used in Denmark. Some timetabling systems (e.g. RailSys and Viriato) have built-in functionalities that can assist the user in calculating the capacity consumption according to the UIC 406 capacity method [1][2]. However, different automatic UIC 406 calculators handle stations in different ways why it may be necessary to analyse (some) stations manually.

As capacity consumption on railway lines depend on both the infrastructure (both open lines and stations) and the timetable, the capacity calculation according to the UIC 406 method is based on an actual timetable. The timetable is worked out for the entire network and not only the line or line section, which is of interest according to the capacity analysis. This means that the timetable in the analysis area depends on the infrastructure and timetable outside the analysis area [4][10]. Since the

effects of the timetables from outside the analysis area are not taken into account in the UIC 406 capacity method, the result of the analysis will be less than or equal to the actual capacity consumption.

There are different possible ways of handling stations when conducting UIC 406 capacity analyses. These differences may lead to different capacity consumptions for the stations and hence line sections. This may lead to different identifications of bottlenecks which may lead to incorrect allocation of resources leading to a reduced level of service on the railway. Identifying and analysing these bottlenecks makes it possible to improve freight capacity and service.

**Dead end stations**

Trains turning around often have longer dwell timesthan technically necessary due to recovery and/or fit into the right train path.These long dwell times can block the train path for the following train(s). To include the layover time, in the UIC 406 capacity analyses, it is necessary to examine the arriving train until it passes the exit signal on its way out of the station or it arrives at the shunting yard/depot. In this way, both the layover time and the possible conflicts at the switch zone(s) are included in the analysis. Due to the often long dwell times, only the minimum dwell/layover time (and the train order) should be considered when compressing the timetable graphs.

Although trains often can use different tracks at the stations, trains are sometimes scheduled to use only one of these tracks due to e.g. to ensure a track that is long enough for the train. Using only one track may result in high capacity consumption as it is possible to operate more trains by also using the other possible track(s) too. Therefore, changing between tracks at stations while the train order remains unchanged should be included in the UIC 406 method for dead end stations, cf. figure 2.

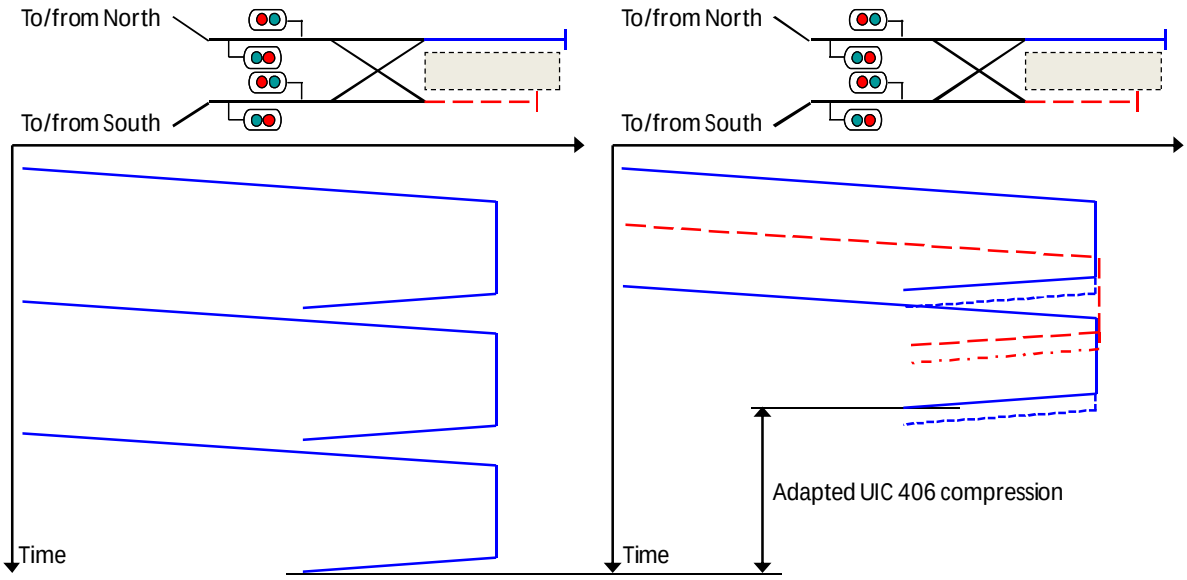


Figure 2: Adapted UIC 406 compression for stations.

**Line end stations on open line**

Sometimes (passenger) trains are scheduled to turn around on the open line instead of at a station. The reason being that the operator has seen the possibility to use a long layover time to service the next halt but without enough time to run the trains all the way to the next station. This means that the (passenger) trains turn around on the open line. In these cases, the railway line should not be divided into line sections since the capacity would then be calculated as too low for other (passenger and freight) trains running on the line. This is because it would seemingly be possible to compress the timetable graphs more than is actually the case cf. figure3.

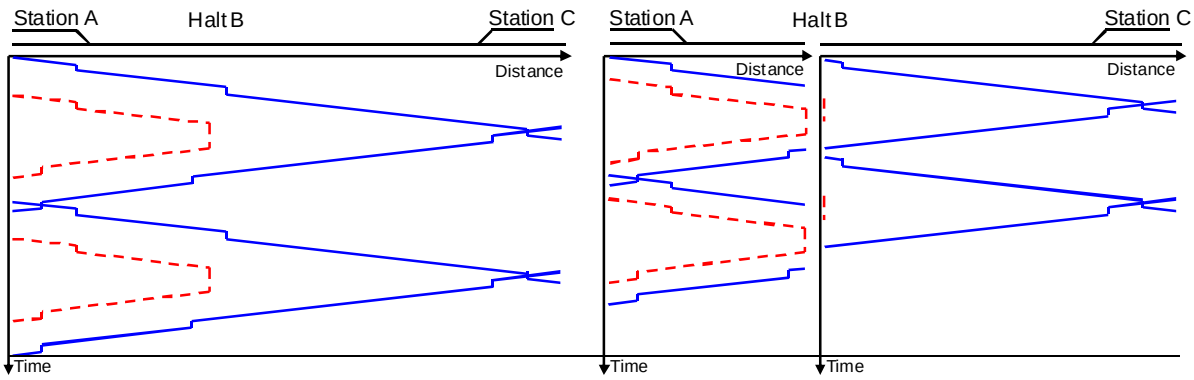


Figure3: Passenger train turning around on open (single track) line. Based on[12].

Not dividing railway lines into line sections at halts where (passenger) trains turn around has the advantage of it being easier to compare capacity consumptions over time. This is because the paradox situation where fewer trains on the railway line would result in higher capacity consumption (and vice-versa) is avoided.

**Crossing stations**

For single track railway lines, special attention must be paid to the crossing stations. Some crossing stations have parallel movement facilities, while other crossing stations can handle only one approaching train at a time.To have parallel movement facilities, it is necessary to create a sufficient safety distance behind the exit signal. This can be achieved in two ways. Either by means of a dead-end track or by placing the exit signal at the necessary safety distance from the fouling point [10].

If a crossing station is unable to handle parallel movement, one of the trains must stop at the crossing station for a longer time while the other train enters the station, cf. figure 4 (left).

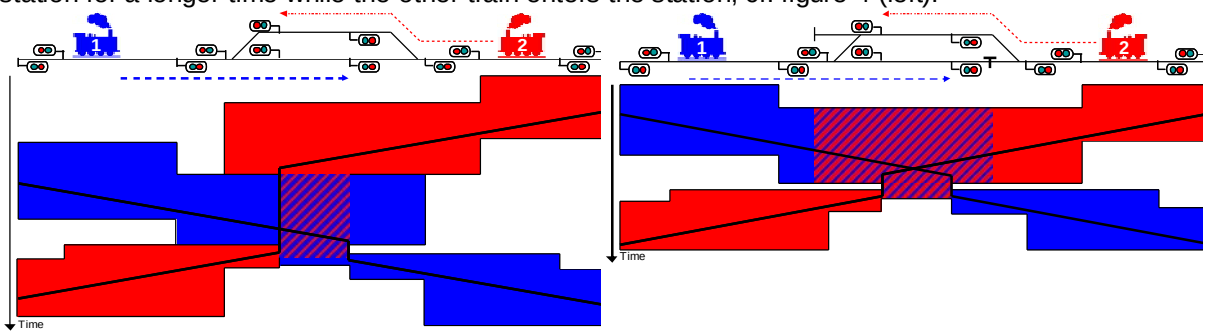


Figure 4: Crossing station without (left) and with (right) parallel movement facility [8].

The detailed blocking times in figure5 indicate the capacity consumption of the crossing station without parallel movement facility. Here, the dwell time of train 2 is considerably longer than that of train 1 because the route of train 2 has to be released before train 1 may enter the crossing station. After train 1 has entered the crossing station its route has to be released to set up the departure route of train 2 from the station.

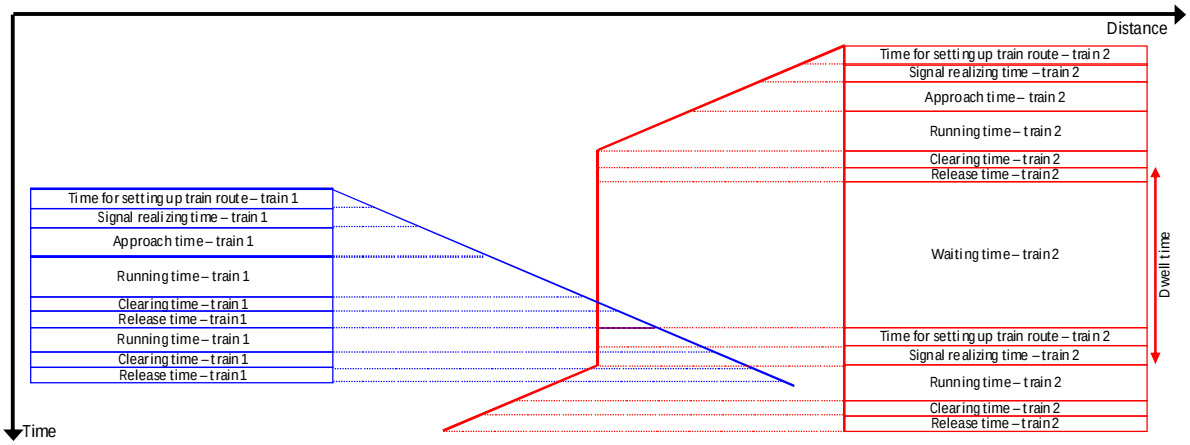


Figure5: Detailed block occupation time for tracks of a crossing station. Based on [8].

If the crossing station is able to handle parallel movement, both trains can enter the station at the same time, cf. figure 4(right). Here, it is not necessary to release the route for one train before the next train can enter the station because the routes from both directions to the tracks are locked independently. Thus the time for crossing of freight trains is reduced to the time necessary for possible (un)loading of freight, potential brake release, and switching signals and routes. If no intermediate stop of a train is scheduled, the trains may proceed after the opposite train has passed the fouling point of the switch – if the tracks are of sufficient length, the first arriving train may not come to a complete halt.

The less time needed for crossing, the higher the infrastructure capacity. The amount of gained capacity depends on the configuration of signals, the speed of the trains, and the maximum allowed speed in the switches. At the crossing stations of single track lines, the blocking times of the trains in opposite directions overlap to a certain degree, and conflicts in the timetable might be detected at the departure from the station when the timetable graphs are compressed. Therefore, there should be an overlap of the two line sections. This overlap is achieved when examining the crossing station all the way to the exit signal in both directions.

The capacity gained at crossing stations with parallel train movements is mainly due to reduced dwell times. Therefore, it should be allowed to change the dwell time at the crossing stations. However, it must be taken into account thatit might take some time before a fully loaded freight train has enough brake pressure to start moving after a complete stop.

### Junctions

It is not only at dead end stations and crossing stations that it is necessary to extend the line section so that the area further ahead is examined. At junctions it is also necessary to include the entire junction and the conflicting train movements to estimate the capacity.

At the junction shown infigure 6, train route 2 may limit the capacity for two other trains running immediately after each other on train route 1. The reason for the “lost” capacity is that the order of the trains according to the UIC 406 leaflet should be maintained [17]. This is because the train order (in Europe) is a result of a thorough planning process where market issues, network effects, timetable stability etc. have been taken into account, and a change in the train order would ignore this planning process.

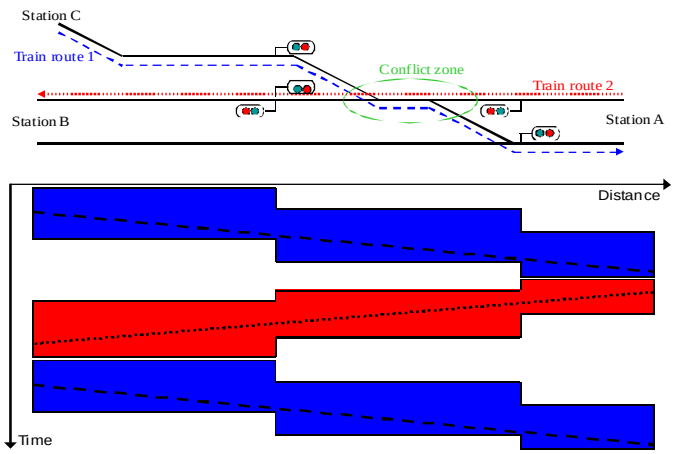


Figure 6: Capacity reduced for two trains running immediately after each other at a junction (only signals in use included). Based on [8].

For junctions, conflicting train routes can reduce the capacity as seen infigure 6; however, the conflicting train routes in the junctions can also reduce the capacity on the adjacent railway lines as seen in figure 7 (left). The blue (dotted) trains in figure 7 (left) must pass through a level junction to pass through the station. In the level junction, the blue (dotted) trains come into conflict with the purple trains (the unbroken line) going in the opposite direction before the trains have to converge with the green (semi-dotted) trains in the conflict zone. Both the (unbroken) purple trains and the (semi-dotted) green trains reduce the capacity for the (dotted) blue trains while the (semi-dotted) green and (unbroken) purple train do not conflict with each other.

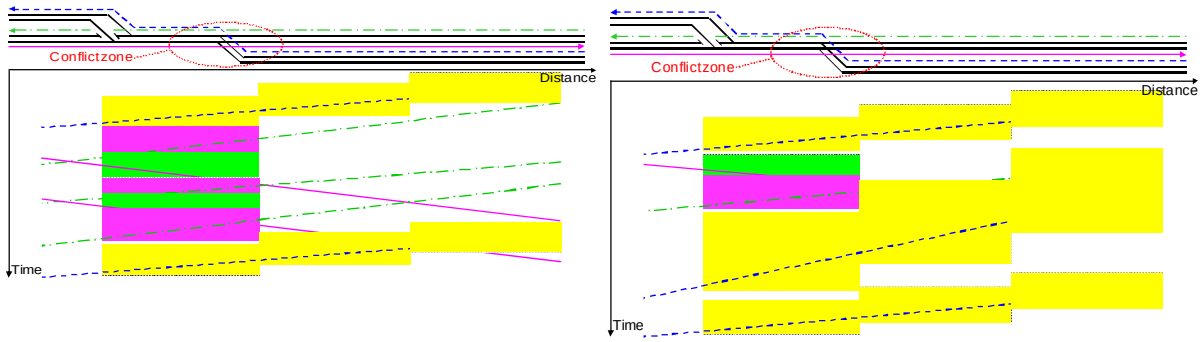


Figure 7: Capacity limitations in junction result in reduced capacity on railway line (left) and capacity in junction limited by railway lines (right).

On examining figure 7 (left) it can be seen that the (dotted) blue trains can be compressed on the open line while it is the conflict zone at the junction which reduces the capacity. This can in UIC 406 capacity analyses appear as if there is less capacity on the railway line of the (dotted) blue trains and that it is difficult to operate more trains on the railway line. It is, however, possible to operate more trains on the railway line if the trains turn around before the junction or if the junction was out of level. Accordingly, it could be argued that the junction and the railway line should be analysed separatelyor possibly even that the junction should be divided into several small line sections that are examined independently. However, with another timetable it might be that it is the railway lines rather than the junction which are limiting for the capacity, cf.figure 7 (right).

As the capacity in and around junctions can be limited by both the junctions and the adjacent railway lines, the entire junction (all the way to the exit signal) should be included in the analysis of the capacity on the railway lines.

When evaluating infrastructure improvements in the junction (e.g., building a flyover instead of having a level junction) it is often seen that the improvement will improve the capacity on the adjacent railway lines too. This is because the infrastructure improvement might make it possible to operate more trains on the adjacent railway lines and/or the adjacent railway lines might get an improvement in the quality of service.

**Overtaking**

Using the UIC 406 method strictly, railway lines must be divided into line sections at all junctions and each time an overtaking or turn around takes place. By changing the lengths of the line sections, the capacity consumption will also vary.

An overtaking can gain some capacity on a railway line with high capacity consumption because fast trains can overtake slower trains (cf. figure 8 part a and b). However, using the UIC 406 method cogently the line section should be divided into two line sections due to the overtaking (cf. figure 8part c1 and c2), which results in even less capacity consumption (cf. figure 8part b and c).

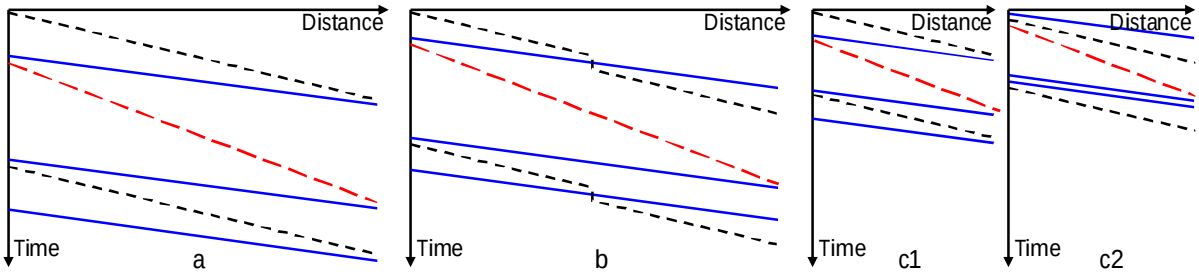


Figure 8: Capacity consumption for line section (a), line section with overtaking (b) and divided line section due to overtaking (c1 and c2)[11].

The reduced capacity consumption resulting from dividing the line section into smaller line sections due to an overtaking is a paradox the planner/analyst should be aware of. The paradox becomes even more distinct when it becomes clear that the overtaking (and thereby improved capacity) is caused by lack of capacity. The paradox cannot be eradicated as the overtaking(s) is a choice of the person making the timetables to operate more trains. Therefore, line sections are (in Denmark) not divided for few overtakings.

When overtaking and not dividing the railway line into line sections, a new challenge arises—how should the timetable graphs be compressed? By compressing the timetable graph as in figure 9part a without changing either the train order or the dwell time, little capacity is gained, cf. figure 9part b. However, it is possible for more trains to overtake the dwelling train, cf. figure 9part c.

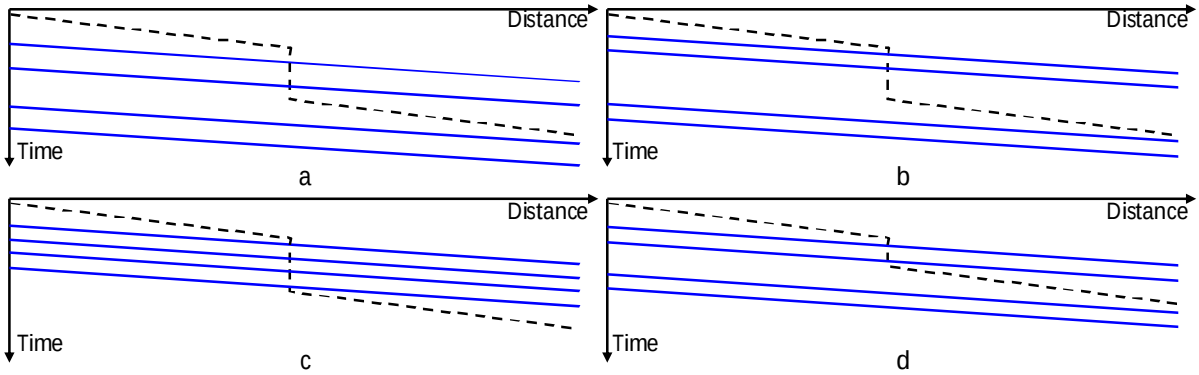


Figure 9: Timetable compression when overtaking. Based on[11].

If the timetable is changed to allow more trains than timetabled to overtake a train at a station (part c infigure 9), the train order is changed at the end of the line section. This can result in new conflicts outside the analysis area (or line section) if, for instance, no timetable slot is available. Therefore, the train order should remain fixed when compressing the timetable graphs.

Instead of changing the order of the trains (by having more trains overtaking a train), the dwell time of the train that is overtaken can be reduced, cf. figure 9part d. However, it should be noted that it may take some time before a fully loaded freight train has sufficient brake pressure to start moving after a complete halt, and that passengers need sufficient time to alight and board the passenger train. Therefore, it should be allowed to reduce dwell time for the train that is overtaken providing the minimum dwell time for the train is not exceeded.

**Large stations and shunting**

Larger stations have more trains operating in different directions and can, therefore, be more difficult to analyse than smaller, simpler stations. The trains may have different possible train routes through the station. Often, larger stations have shunting operation too, which also should be dealt with in the capacity analysis.

Due to the high complexity of the larger stations with many different train routes and shunting operations, it may be necessary to analyse these stations separately—possibly using other methods than the UIC 406 capacity analysis (e.g. [3] and [7] use a methodology to examine stations based on [13]). Large stations (including shunting) can be analysed using the UIC 406 capacity method, but it is necessary to know all the train movements and their order. However, it may not be possible to know the exact train movements for large stations as there are many shunting operations for freight trains such as:

- Shunting between station tracks and shunting yard
- Attaching and/or decoupling of wagons to the train
- Shunting operation at the depot that blocks a main track or train routes in the switch zone
- Changeover or turn round of locomotives

Typically, the shunting operations vary during the day and over time—some shunting movements may not even be planned due to break down in rolling stock, for example, or cancelations due to delays. Consequently, it is difficult to predict the number of shunting operations at the larger stations. Furthermore, some of the “non-critical” shunting movements may be allowed only in non-critical periods.

Due to the complexity of the larger stations and the shunting movements, great care must be taken when analysing these stations. A simple approach is to analyse only the scheduled trains and the known shunting and to include a higher quality factor or another type of supplement to the block occupation times. This implicitly takes into account the necessity of reserving extra time in the timetable for shunting operation.

As most of the shunting operations are planned (in detail) after the timetable has been finalised, they are adapted to fit in with the fixed schedule. In the case of delays, the shunting operation adapts to the realized timetable as far as possible and with as little disturbance as possible to trains. This means that the shunting operation strives to use the “idle capacity” within the station for its operation. Therefore, the “time slots” for the shunting operations can be changed to some extent, which makes it even more difficult to use the UIC 406 capacity method strictly.

Opposite simple stations, the uncertainties for complex stations with shunting movements result in inaccurate results when using the UIC 406 capacity method. This is because several routes may exist and the exact movements are not known. Due to the uncertainties,it is recommended that that the larger stations with many shunting movements are analysed with a higher quality factor or another type of supplement along with the UIC 406 capacity method to compensate for the unknown train movements.

**Conclusions**

The UIC 406 capacity method can be exposed in different ways – especially at stations where trains are dispatched – leading to different results. Therefore, stations need special focus conducting UIC 406 capacity analyses. This paper has described and suggested how the UIC 406 capacity method can be expounded when trains turn around at dead end stations and halts, at crossing stations, at junctions, and at overtaking stations as well as large stations with shunting.

To identify all potential conflicts analysing stations with the UIC 406 methodology (e.g. non-parallel movement at crossing stations and conflicting train movements at junctions), the entire station has to be included in the analysis. For stations/halts where trains turn around, it should further be allowed to reduce the dwell/layover time to the minimum (with respect to the train order) when compressing the timetable graphs. In cases where trains turn around at halts, the railway line should not be divided into line sections as it then may result in too low capacity consumption.

Overtakings generally result in increased line capacity. However, in case only few trains are overtaken at a station it may lead to too low capacity consumption why capacity problems may not be recognised. Therefore, in case of few trains are overtaken, the railway line should not be divided into line sections. If the railway line is not divided in case of a overtaking, the dwell time of the overtaken train should be reduced to the minimum technical possible time but the train order should be kept.

For complex stations with shunting movement, the results of UIC 406 capacity analyses are imprecise due to different possible routes and no exact knowledge of shunting movements. For these stations it is instead recommended that they are analysed with a supplement to compensate for the inaccuracies.

**References**

[1] M. Abril, F. Barber, L. Ingolotti, M.Á. Salido, P. Tormos, A. Lova. ”An assessment of railway capacity” Transportation Research Part E, vol. 44, no. 5, pp.774-806 (2008).
[2] F. Barber,M. Abril, M.Á. Salido, L.P. Ingolotti, P. Tormos, A. Lova. “Survey of automated Systems for Railway Management, Department of Computer Systems and Computation, Technical University of Valencia (2007).
[3] D. Crenca, G. Malavasi, S. Ricci. ”Carrying Capacity Constraints for Railway Networks” Proceedings of the 2nd International Seminar on Railway Operations Modelling and Analysis (2007).
[4] S. Hansen, A. Landex, A.H.Kaas.”The network effects of railway investments” Proceedings of the 10th International Conference on Computers in Railways, pp. 45-54 (2006).
[5] A.H. Kaas, R. Goossmann. “Implementation of the Timetable Planning System STRAX/TPS in Denmark”, Proceedings of the 9th International Conference on Computers in Railways, pp. 93-102, (2004).
[6] H. Krueger. ”Parametric modeling in rail capacity planning” Proceedings of the 31st Conference on Winter Simulation, pp. 1194 (1999).
[7] A. Landex.“Station Capacity” Proceedings of the 4th International Seminar on Railway Operations Modelling and Analysis (2011).
[8] A. Landex. “Evaluation of Railway Networks with Single Track Operation Using the UIC 406 Capacity Method” Networks and Spatial Economicsvol. 9 pp. 7-23, (2009).
[9] A. Landex, A.H. Kaas, E.M. Jacobsen, J. Schneider-Tilli. “The UIC 406 capacity method used on single track sections” Proceedings of the 2nd International Seminar on Railway Operations Modelling and Analysis (2007).
[10]A. Landex, A.H. Kaas,S. Hansen. ”Railway Operation”, Centre for Traffic and Transport at Technical University of Denmark (2006).
[11]A. Landex, A.H. Kaas, B. Schittenhelm, J. Schneider-Tilli. “Evaluation of railway capacity” Proceedings of the Annual Transport Conference at Aalborg University, (2006).
[12]A. Landex, B. Schittenhelm, A.H. Kaas, J. Schneider-Tilli. “Capacity Measurement with the UIC 404 Capacity Method” Proceedings of the 11th International Conference on Computers in Railways, pp. 55-64, (2008).
[13]G. Potthoff.“Verkehrsströmungslehre I – Die zugfolge af Strecken und in Bahnhöfen” (1962).
[14]W. Rothengatter. “Bottlenecks in European Transport Infrastructure” Proceedings of the 24th PTRC European Transport Forum (1996).
[15]B. Sewcyk, A. Radtke,G.Wilfinger. ”Combining Microscopic and Macroscopic Infrastructure Planning Models” Proceedings of the 2nd International Seminar on Railway Operations Modelling and Analysis (2007).
[16]T. Siefer, A. Radtke.“Railway-Simulation Key for Better Operation and Optimal Use of Infrastructure” Proceedings of the 1st International Seminar on Railway Operations Modelling and Analysis (2005).
[17]UIC.“Capacity (UIC code 406)” (2004).