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Measures for track complexity and robustness of operation at stations

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ABSTRACT

Stations are often limiting the capacity of a railway network. However, most capacity analysis methods focus on open line capacity. This paper presents methods to analyse and describe stations by the use of complexity and robustness measures at stations.

Five methods to analyse infrastructure and operation at stations are developed in the paper. The first method is an adapted UIC 406 capacity method that can be used to analyse switch zones and platform tracks at stations with simple track layouts. The second method examines the need for platform tracks and the probability that arriving trains will not get a platform track immediately at arrival. The third method is a scalable method that analyses the conflicts and the infrastructure complexity in the switch zone(s). The fourth method can be used to examine the complexity and the expected robustness of timetables at a station. The last method analyses how optimal platform tracks are used by examining the arrival and departure patterns of the trains.

The developed methods can be used to analyse a station to gain comprehensive knowledge about the capacity and complexity of the different elements at the station.

1. Introduction

The effective management and utilisation of assets become more important as railways strive to reduce costs, improve service and handle increasing traffic (Krueger, 1999). This is done by operating more trains on today's railway infrastructure resulting in higher capacity consumption. It has been proved that there is an exponential increase of the delay propagation factor in case of increased capacity consumption (Landex, 2008; Yuan and Hansen, 2004).

Examination of railway capacity is crucial to ensure effective management and utilisation of the capacity. Several methods, e.g. UIC 406 (UIC, 2004), have been developed to evaluate capacity consumption. Most of these methods focus on the capacity of open lines although it is often the stations that become bottlenecks determining the line capacity (Harris, 2006; Yuan and Hansen, 2004). To examine the possibility to operate more trains without an increase in delays, it is hence necessary to evaluate the capacity of the entire network focusing on both stations and junctions.

The capacity of stations is determined by the characteristics of the track layout, platforms, signals, rolling stock and the timetable (Hansen, 2000). A station becomes a bottleneck in case the station does not have sufficient platform tracks. Furthermore, a station or junction may also become a bottleneck if the track layout results in many conflicting train routes although the platform capacity is sufficient.

Examining the capacity of junctions and stations is more complicated than for open lines due to possible shunting movements and conflicting train routes at the stations. Some conflicts at the stations may be avoided as there are often different possible train routes through the station. The examination of the station capacity may be further complicated by extended dwell times due to e.g. many passengers, trains changing direction, transfer possibilities, catering of the trains, or some trains having their terminus at the station.

Larger stations cannot be evaluated using the same methods as open lines, so they require a separate capacity study. Furthermore, specific conditions of the larger stations can determine how the traffic can be operated on the railway lines. The capacity of stations can be evaluated by two principal methods (Fernández, 2010):

Analytical models which estimate capacity with steady state formulas
Simulation models that can estimate capacity as well as other performance measures

This paper uses analytical models to describe and estimate capacity at stations using measures for track complexity and robustness of operation. In Section 2 an adapted UIC 406 capacity method is described, and in Section 3 the number of needed

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platform tracks is calculated. Section 4 presents methods to estimate infrastructure complexity of stations by analysing conflicts in the switch zone(s). In Section 5 methods to estimate the robustness and complexity of timetables at stations based on buffer times and infrastructure are described. Section 6 presents methods to examine the usage of platform tracks by analysing the distribution of the trains during a rush hour. At the end of the paper, before the conclusions (Section 8), Section 7 uses the method presented in Section 3 to evaluate capacity enhancements for Copenhagen central station.

2. The UIC 406 capacity method for stations

The UIC 406 capacity method (UIC, 2004) published by the International Union of Railways (UIC) does not take station capacity into account (Lindner and Pachl, 2009). Still, many organisations have adopted the UIC 406 capacity method as it (with the right tools) is a straightforward, fast and effective way to measure the capacity consumption of railway lines by compressing timetable graphs. This has lead to the method being applied in several studies in recent years (e.g. Höllmüller and Klahn, 2005; Wahlborg, 2004).

The use of the UIC 406 capacity method has shown that the method can be expounded in different ways (which is also stated by the UIC (2004)), and can to a certain extent be used to evaluate stations too (Landex, 2008). This section describes how the UIC capacity method can be applied for analysing stations too.

Landex (2009) showed how the UIC 406 capacity method can be applied analysing the capacity of crossing stations for single track lines and junctions by including all train routes at the station all the way to the exit signal. As with crossing stations and junctions, special attention also has to be paid to stations with several platform tracks and/or where trains turn around.

To include the layover time, 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 depot. In this way, both the layover time and the possible conflicts at the switch zone(s) are included in the analysis. At terminal stations, trains often dwell for longer time than necessary due to recovery and/or to fit into the right train path. Therefore, only the minimum dwell/layover time (and the train order) should be considered when compressing the timetable graphs.

Although trains can often use different tracks at the stations, the trains are sometimes scheduled to use only one of these tracks due to e.g. easier or more consistent transfers for the passengers. Using only one track may result in high capacity consumption, as it is possible to operate more trains by also using the other track(s). Therefore, changing between tracks at stations, without changing the train order, should be included in the UIC 406 method, cf. Fig. 1. This is supported by Lindner (2011) who states that all routes have to be considered synchronised to get significant results.

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 from the entrance signal to the platform and/or from the platform to the exit signal. Often, larger stations have shunting operations too, which should also 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 like those described in Sections 3–6. 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 unscheduled shunting operations, cf. Table 1.

Few models are able to analyse the exact number of shunting operations or the exact consequences of unscheduled shunting as shunting may be due to break down of rolling stock or cancellations due to delays. Furthermore, the exact time of shunting is not known as the shunting is carried out when it disturbs the operation as little as possible and/or as required.

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 quality factor or another type of supplement in the analysis of the station. This implicitly takes into account the necessity of reserving extra time in the timetable for unscheduled shunting operations.

As most of the shunting operations are planned (in detail) after the public timetable has been finalised, they are adapted to fit the fixed schedule. In case of delays, the shunting operation adapts to the realised timetable as much 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" available for shunting operations can be changed to some extent, which makes it even more difficult to use the UIC 406 capacity method strictly. It is therefore recommended to analyse larger stations with many shunting movements with a higher quality factor or another type of supplement along with the UIC 406 capacity method.

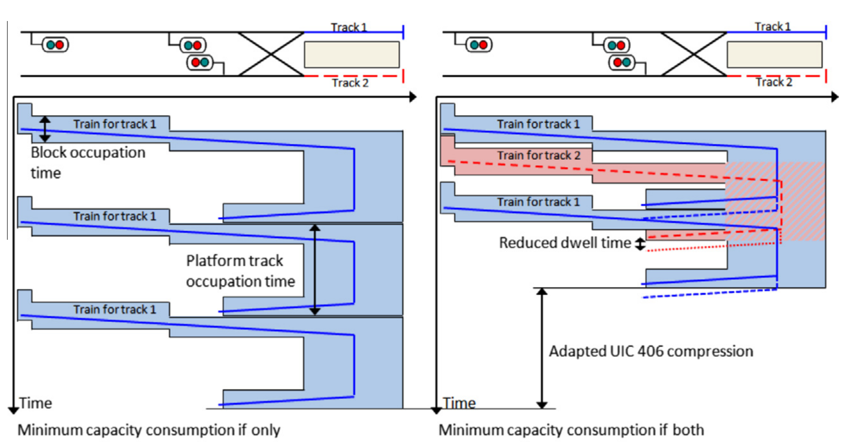

Fig. 1. Adapted UIC 406 compression for stations.