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Rail platform allocation for reliable interchanges

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Abstract

Changing trains is a crucial part of many rail journeys, and it is important that arrival and departing trains are allocated close to each other for a swift interchange. Today the platform allocation of trains is often based on local traditions, where trains of the same type to the same destination depart from the same track. In this paper we address the problem of using the platform tracks in the best way, balancing crossing train paths with easy interchanges at the same platform. We use a RailSys model of the station in Norrköping, Sweden, to assess three platform allocation strategies with respect to crossing train paths and train changes at the same platform. Moreover, the capacity utilisation is calculated by a timetable compression-based method. The results show that a platform allocation maximising the changes at the same platform leads to more crossing train paths and higher capacity utilisation. Future work includes more accurate modelling of train connections, assessment of delays through simulation, and a cost-benefit analysis to find the best balance between easy interchanges and conflicting train paths.

Keywords: Railway; Capacity; Platform allocation; Transfer

1. Introduction

Changing trains is a crucial part of many rail journeys. It is essential for reaching all destinations, but it takes time and is often stressful, especially when the arriving train is delayed. In models for cost-benefit analyses, interchange time for the railway is typically considered 2-3 times more expensive than in-vehicle time, see, e.g., ASEK (Trafikverket, 2020). Designing and operating railway stations in a way that could minimise the required interchange time is therefore vital for making rail travel attractive.

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Today the platform allocation of trains is often based on local traditions, where trains of the same type to the same destination depart from the same track. (Throughout this paper we distinguish between *platform* and *track*, where a common layout is that two adjacent tracks share one (island) platform.) Decisive is also often the track layout and how the train paths can be set with the given interlocking system. If two trains are stopping at a station close in time, from a dispatching point of view, it is advantageous, if possible, to give them train paths that are completely separated. In practice that often also means, they will be assigned to different platforms and so, any passengers changing trains will need to move from one platform to another, which increases the interchange time. Since level crossings are very rare at major interchange stations, changing platforms typically means multiple uses of stairs, escalators and/or elevators.

Another aspect of train platform allocation is how efficiently the capacity of the railway station is utilised. From a capacity utilisation point of view, it is preferable to spread out the trains to separate train paths to enable more trains at the same time at the station. This conflicts with the interests of passengers who want quick interchanges from the same, or a neighbouring, platform.

The overall research question in this paper is how to balance the conflicting goals of (i) few crossing train paths, (ii) many easy interchanges across the same platform, and (iii) low capacity utilisation. We address the question by comparing today's platform allocation with two disparate alternatives. Primarily, we look at the problem on a tactical level, i.e., timetable planning, but the insights are also useful on a strategic level for designing and re-designing railway stations, and on an operational level, doing the dispatching. This work is inspired by Johansson and Nilsson (2021), who have made an initial simulation study of various platform allocation strategies using the Arena Simulation Software for general event-based simulation.

2. Literature review

Lusby et al. (2011) have made an overview of models and methods for railway track allocation, which also includes platforming and discusses the aspect on a strategic, tactical and operational level. They identify several model approaches; conflict graph, constraint programming, set packing, alternative graph and multi-commodity flow, and conclude that the conflict graph approach is by far the most common.

Most of the models proposed for the train platforming problem focus on *feasibility*, i.e., to find a conflict-free solution, where no two trains are assigned to the same resource at the same time. The objective is less important, and typically just expresses some cost or weight for each train and/or platform. Carey and Carville (2003), for example, define for each pair of train and platform a “platform obstruction cost”.

The models proposed by Lu et al. (2022) and Wang and Li (2022) focus on the impact of different interlocking modes, i.e., how train paths are locked and released. They both conclude that the sectional release of train paths is beneficial for avoiding route conflicts.

Clarke et al. (2010) have developed a genetic algorithm-based system to automate the platform allocation. The system aims for feasibility, including platform re-occupation and various other constraints. The system does not consider interchange connections between trains, but the authors admit that human skills are necessary to ensure a satisfactory solution, meaning that interchanges may be considered in a manual post-editing phase.

Zhang et al. (2023) show how locomotive operations can lead to additional decision-making challenges for dispatchers and potentially result in scheduling conflicts. They propose a 0-1 integer programming model that simultaneously optimises the routing and scheduling of trains and locomotives.

Some models for platform allocation focus on re-scheduling, that is, to find a new platforming plan after some disturbance. An example is given by Y. Zhang et al. (2020). Q. Zhang et al. (2020) address the problem of simultaneously adjusting timetable and platform allocation during maintenance work.

The railway platform allocation problem is also related to similar problems in other modes of transport, for example, the bus platform allocation problem (Lindberg et al., 2022), the berth allocation problem at a container terminal (Bierwirth and Meisel, 2010) and the airport gate allocation problem (Daş et al., 2020). Modelling of crossing train paths and how different platforms can be reached simultaneously is a significant difference for railway applications.

One way to evaluate different platform allocation principles is by how much capacity they consume. A recent method to calculate the capacity utilisation at railway stations has been developed by Weik et al. (2020). The method applies timetable compression in line with the specifications in the UIC Code 406 Capacity Leaflet (UIC, 2013). It enables a comparison of the capacity utilisation resulting from different track allocation principles.

We conclude that previously proposed models typically focus on feasibility, i.e., to find a platform allocation that is compatible with the timetable at all. In this study, we are aiming for a platform allocation that balances the need for short interchange time for the passengers across the same platform towards the risk of knock-on delays when two trains are forced to use the same infrastructural resources. We also analyse the resulting capacity utilisation.

3. Method

This is a preliminary study where we aim to explore principal differences when prioritising having few crossing train paths versus fast interchanges. To highlight the difference we will use some very simple, ideal principles for allocating trains to platform tracks. These principles are using the track allocation from a given timetable, using the lowest numbered track that is free, and maximising train changes at the same platform. The contribution of this paper lies in the comparison of the principles with respect to intended goodness measures for convenient passenger interchange, simple dispatching and efficient capacity use, i.e., the number of interchanges not requiring a change of platform, the number of crossing train paths, and an existing method (Weik et al., 2020) for calculating the capacity consumption, respectively.

The analysis is performed for the medium-sized station Norrköping, Sweden, using the timetable of a normal Thursday in autumn 2016. In the microscopic railway simulation tool RailSys, the infrastructure as well as the timetable is modelled in detail (Bendfeldt et al., 2000). At stations, each train has a specific platform track allocated, including the detailed train path through the station. To investigate track allocation changes and their effects, two alternative track allocations have been established in RailSys and studied by counting the resulting number of crossing train paths and changes at the same platform. For this study, possible connections between trains are defined as when there is a minimum of 5 minutes and a maximum of 30 minutes between the arrival time of a train and the departure time of another train. If the time is less than 5 minutes, the time is too short for changing trains, and if it is more than 30 minutes, we assume that the track allocation is of less importance to the passengers, who most likely do not want to stay at the platform anyway, but instead use the time to, e.g., visit the station building shops and facilities.

When counting the number of possible connections as described, it is also observed how many of these train pairs have crossing train paths, i.e. to some extent use the same infrastructure at the station, and how many of the possible train changes that would take place at the same platform, either between two adjacent tracks at the platform or between two trains at the same track, but separated in time.

Furthermore, the resulting capacity utilisation in per cent for the considered time periods of the different alternatives has been calculated with the method introduced by Weik et al. (2020). This method considers the full station, from the entry signal to the exit signal, and performs a timetable compression based on the standard by UIC (2013) for a given time period. The exact block occupation times and conflicts between trains regarding infrastructure usage are accounted for in the compression.

Some simplifications have been made in this work. One is that the platform lengths have not been considered when rescheduling the trains, instead, all platform tracks have been assumed to accommodate all trains. The rescheduled track allocation plans are theoretically possible to use but their operational feasibility in practice has not been studied, e.g. through simulation. Such a study would most likely show that the track allocation is too dense to be acceptable for operations, but the extent of the resulting delays would be an additional measure of the feasibility of the allocations. A reasonable assumption is that the spread of delays between trains is strongly related to the number of crossing train paths. When counting possible connections, the freight and service trains have been excluded but all passenger trains have been considered, counting the unique train numbers for them. This means that arriving trains and the few passenger trains that do not stop in Norrköping have been included.

Train platforming is a well-known problem and optimising the platform assignment while accounting for train changes can be approached by optimisation models, e.g. as done by Calderon (2022) In this paper, however, a simpler approach is chosen to illustrate the principle of the trade-off between on the one hand train changes at the same platform and, on the other hand, an increased risk for delays from trains sharing infrastructural resources.

4. Norrköping case study

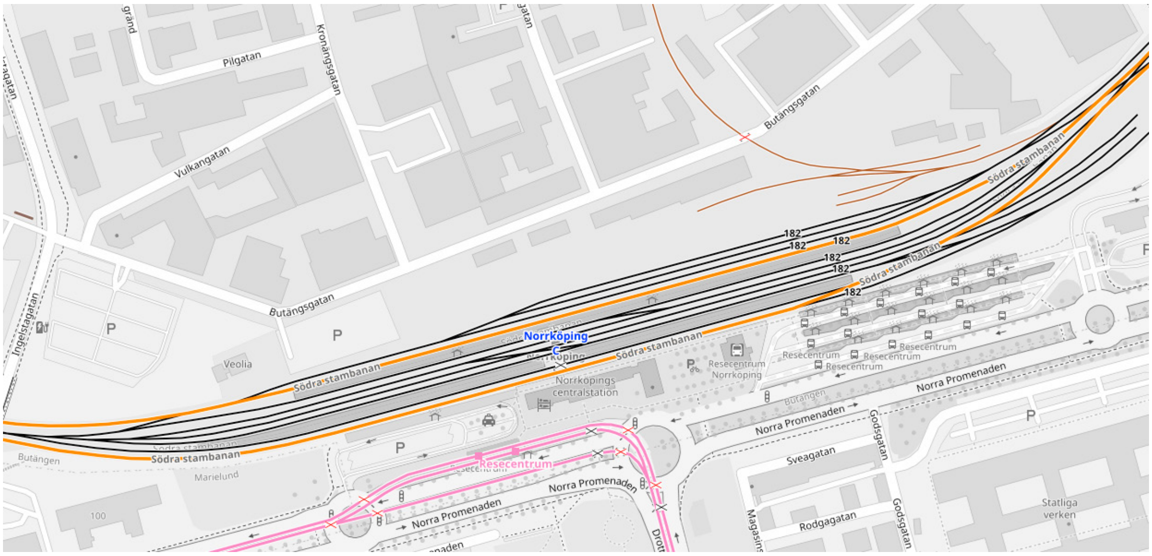

Fig. 1. An overview of Norrköping C showing the tracks (black and orange) and the platforms (dark grey rectangles). Map data from OpenRailwayMap, https://www.openstreetmap.org/copyright

Norrköping C is a medium-sized through station with 5 platform tracks and mixed traffic. It has been used for previous studies, e.g., by Weik et al. (2020), and was chosen for the case study. At the station, track 1 has a platform where you step out straight to the bus terminal and city centre, while tracks 2 + 3 and 6 + 7, respectively, are located on each side of a platform. See Fig. 1 for an overview of the station. For long-distance trains and most regional trains, Norrköping is an intermediate station and for commuter trains and some regional trains, it is the terminal station.

For the analysis, the timetable for a normal Thursday in autumn 2016 was used. Both the full day (midnight to midnight) and the rush hours between 4 pm and 6 pm were investigated for each track allocation principle. The first alternative was the original timetable with the track allocation as it was, which had trains mainly using tracks 1, 3, and 7, but a few trains scheduled for tracks 2 and 6, see Fig. 2. The second alternative was a platform track allocation where the lowest numbered available track was used. From the original track allocation plan, trains were rescheduled to the lowest-numbered track that could accommodate them, filling up tracks 1, 2, and 3, while a few trains had to use tracks 6 and 7 due to conflicts, see Fig. 3. The third alternative was an attempt to maximise the number of train changes at the same platform. This was obtained by rescheduling all trains from track 1, which does not share its platform with any other track. In most cases, the trains were moved to track 2, but when that was not possible, track 3, 6, or 7 was used to collect the trains at the tracks that pairwise share platforms. See Fig. 4 for the resulting track allocation.

5. Results and discussion

We have analysed the stated platform allocation principles from three aspects. The first aspect is the number of crossing train paths. The second aspect is the portion of enabled fast train changes (at the same platform), and the third aspect is the capacity utilisation of the station, in per cent. Table 1 presents the results for the full day (midnight to midnight), and Table 2 the corresponding numbers for the rush hours between 4 pm and 6 pm.

During the full day, 233 trains (unique train numbers) were operated at Norrköping C. This includes freight, passenger, and service trains routed through Norrköping C in both directions. When removing the freight and service trains from consideration, 205 passenger trains remained. The total number of possible connections between these passenger trains, defined as described in Section 3, was 1,033.

During the defined rush hours 4 pm - 6 pm, 34 trains, of which 32 were passenger trains, were routed through Norrköping C in both directions. The total number of possible connections between the passenger trains between 4 pm and 6 pm was 203.

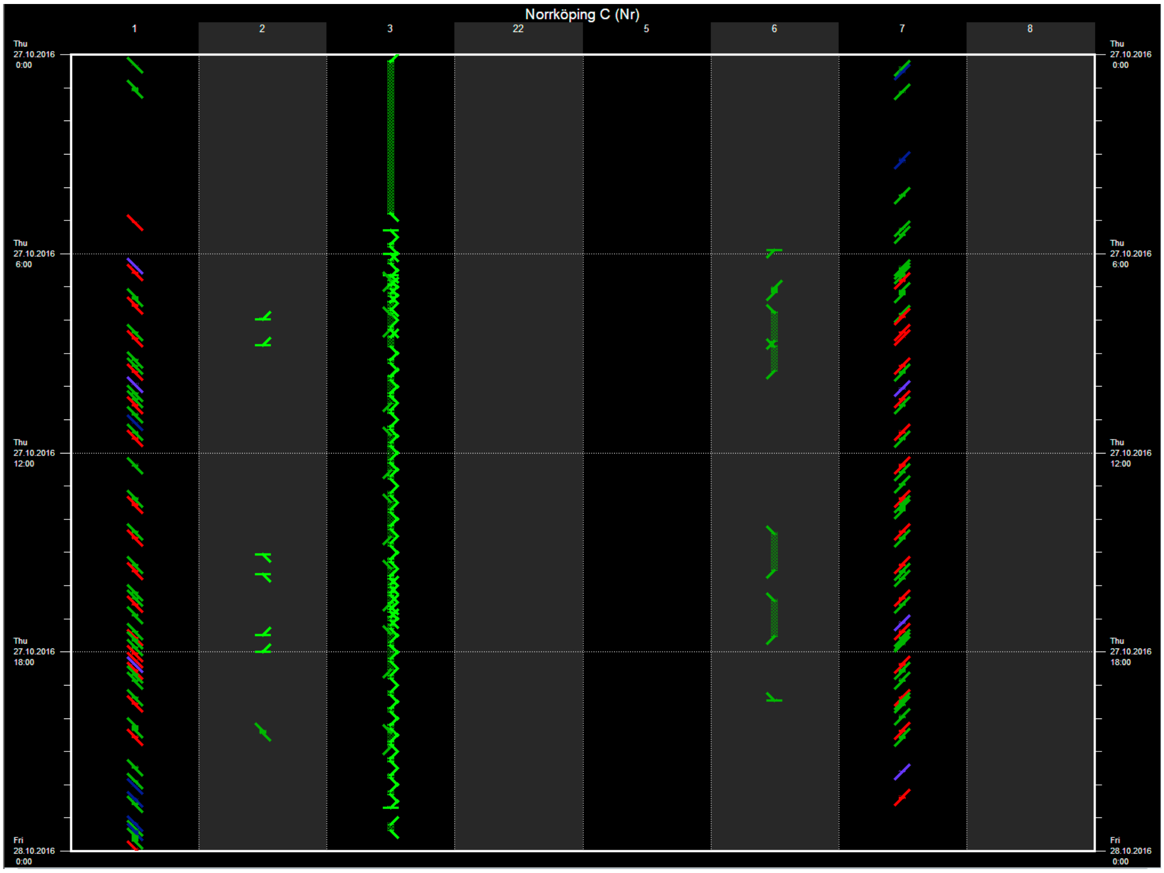

Fig. 2. The original track allocation at Norrköping C during 24 h. Time is on the y-axis and each numbered column is a station track. Each coloured bar represents a train.

For the original track allocation scheme, the number of connections with crossing train paths is roughly half of the total number of possible connections, while the number of connections from the same platform is a bit lower, around 40% of the total possible connections. This pattern holds for the full day as well as the rush hour scenario. As expected, the traffic is denser during the rush hour period with the capacity utilisation being 56%, while the utilisation is only 36% measured over the full day.

In the scenario where trains are scheduled to the available track with the lowest number, it can be noted that this approach, compared to the original scenario, results in a higher number of connections with crossing train paths as well as a higher number of connections from the same platform. Here, trains have been moved from tracks 3, 6, and 7 to tracks 1 and 2, meaning that those trains now have to cross more of the station area to reach their assigned platform track. This results in a higher number of crossing train paths. The increase in connections from the same platform can be explained by the moving of almost all trains from tracks 6 and 7. In the original timetable, many trains are assigned to tracks 1, 3, and 7, while only a few trains are assigned to tracks 2 and 6. Given the station layout, this setup results in a minimum of possible connections at the same platform since there are very few connections across the platforms, almost only connections by preceding trains at the same track. When the trains are allocated more densely at tracks 1-3, it results in more possible connections at the same platform. For the full day, the capacity utilisation increases to 43% compared to the original scenario. The increase is expected since more crossing train paths means more infrastructure conflicts at the station. Interestingly, the capacity utilisation for this track allocation during the rush hour period is also 43%. Even though the number of connections with crossing train paths has increased compared to the original allocation plan, capacity utilisation has decreased.

In the scenario where changes at the same platform are maximised, it is clear that the number of connections at the same platform is considerably higher than for the other two scenarios and constitutes more than 60% of the total number of possible connections for the full day as well as the rush hours. For the full day, the number of connections with crossing train paths is higher than for the original scenario but lower than for the scenario using the lowest numbered free track. The capacity utilisation being 40% also follows this pattern, which is to be expected since more crossing train paths means more infrastructure occupation conflicts, resulting in a less dense compression of the timetable, thus a higher capacity utilisation. Looking at the rush hour period, however, the number of crossing train paths is the highest in this case, coupled with the highest capacity utilisation. The number of crossing train paths is merely one more than for the track allocation plan using the lowest numbered available track – 143 compared to 142 – but the capacity utilisation is now as high as 59%. Likely, this result stems from the specific routing and block occupation times in the scenario variants. More experiments and analyses than were performed in this preliminary study are needed to fully understand this.

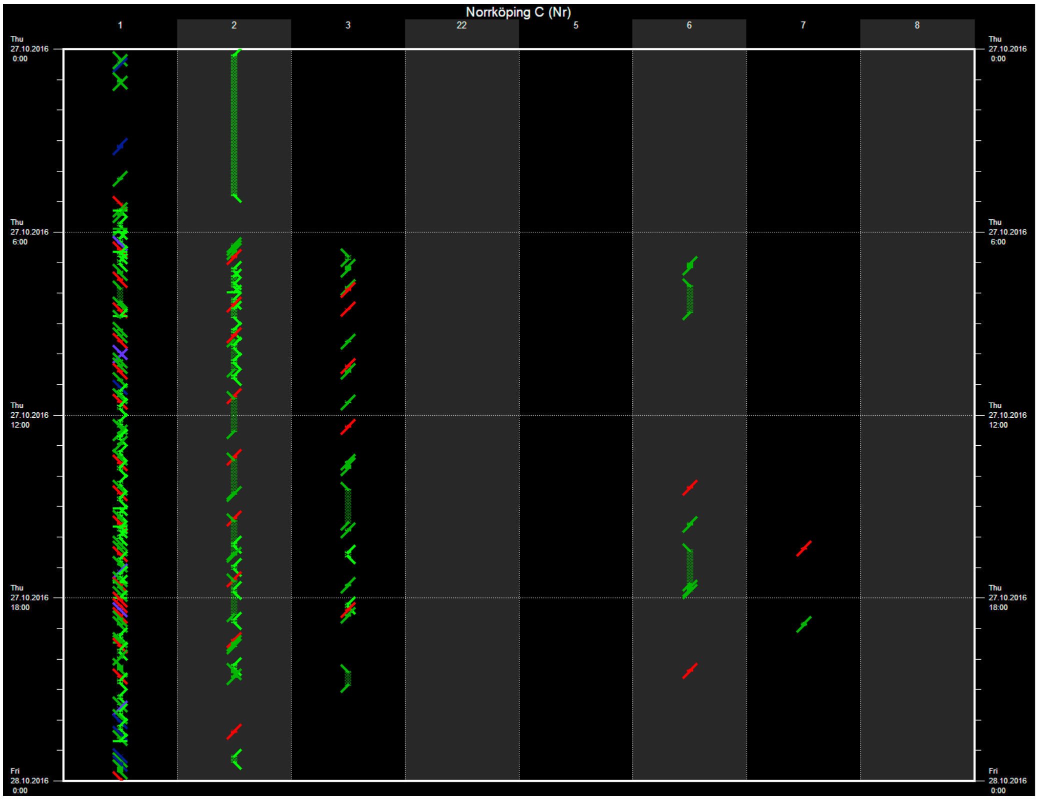

Fig. 3. The track allocation at Norrköping C during 24 h when the trains are scheduled to the lowest numbered available track. Time is on the y-axis and each numbered column is a station track. Each coloured bar represents a train.

6. Conclusions and future work

This study has investigated some simplified principles for platform track allocation from the perspective of the number of crossing train paths, the number of train changes at the same platform, and the station capacity utilisation. The results show that track allocations aiming for an increased number of train changes at the same platform compared to the original allocation do achieve that, but it comes with a cost of more crossing train paths and higher capacity utilisation, which may cause more delays.

Table 1. Results for a full day.

	Original allocation	Use lowest numbered available track	Maximise changes on the same platforms
Connections with crossing train paths	560	735	684
Connections from the same platform	407	509	636
Capacity utilization [%]	36	43	40

Table 2. Results for the rush hours 4 pm - 6 pm.

	Original allocation	Use lowest numbered available track	Maximise changes on the same platforms
Connections with crossing train paths	110	142	143
Connections from the same platform	76	82	134
Capacity utilization [%]	56	43	59

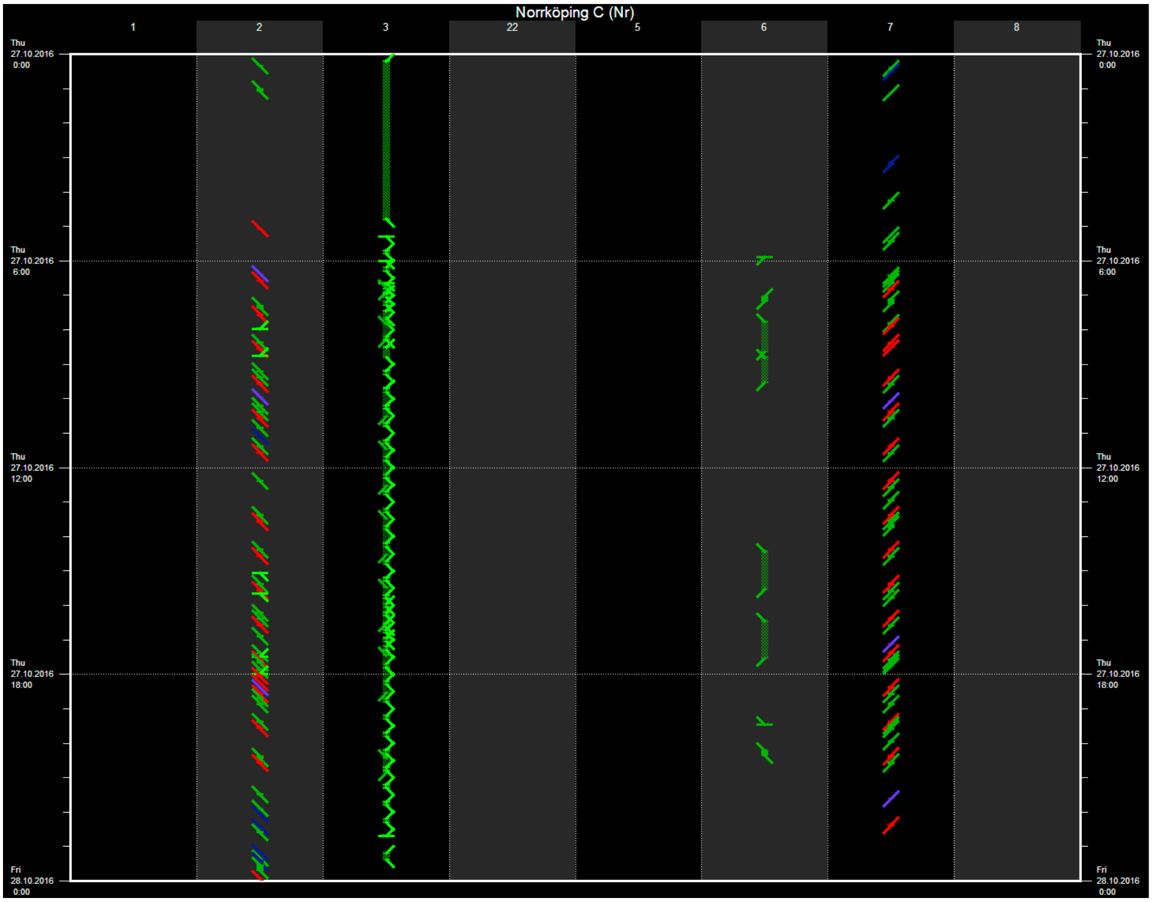

Fig. 4. The track allocation at Norrköping C during 24 h when the trains are scheduled to the lowest numbered available track. Time is on the y-axis and each numbered column is a station track. Each coloured bar represents a train.

Simplifications and assumptions have been made regarding which trains should be passenger connections. In this paper, we focus on train changes at the same platform, either across the platform or to a later train arriving at the same track. One way to extend this work is to analyse train changes at a complete station, accounting for a minimum interchange time that varies depending on the considered platform pairs. A more accurate modelling of what constitutes a connection is also desired. Not every two trains constitute a relevant connection, depending on their direction of travel, or if the interchange time is so long that it is not reasonable to expect the passengers to wait on the platform. A more accurate model for “optimal” platform allocation than just the greedy strategy could be used, see, e.g., Calderon (2022). In this paper, we have used the number of crossing train paths and capacity utilisation as a proxy for the spread of delays. It would be more accurate to simulate the timetable with RailSys, using the different track allocations, to assess the spread of delays in each case.

Another extension of the work is to weigh together the three aspects of crossing train paths, changes at the same platform, and capacity utilisation in a cost-benefit analysis (CBA) of the platform allocation principles, e.g. using the ASEK CBA model (Trafikverket, 2020) to find the best balance between the conflicting goals. Future use of the model may also include analyses of different timetable and track-layout scenarios, which can be helpful not only for platform allocation but also to determine when to announce or not announce a connection between two trains close in time, and not least on a strategic level when re-designing the track layout or constructing complete new stations.

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