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Train punctuality analysis in a rolling stock perspective

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Abstract

This paper studies how time delays spread through the railway system. We evaluate timetable and rolling stock interaction in relation to medium size delays. In particular, we study the connection between arrival and departure delays for trains that are operated by the same rolling stock individual. We studied one year of data for trains circulating in the Oslo area.
Research questions in this study are:
• What is the connection between arrival and departure delays for the same piece of rolling stock?
• How can delays be tracked through the route schedules and the rolling stock circulation plan?
Punctuality analysis was performed to investigate if there is a connection between arrival and departure delays. A correlation analysis of the arrival delays and the corresponding departures was done in order to find the possible connection.
There was a connection between the size of arrival delays and the size of the corresponding departure delays. We found a threshold at around 20 minutes. An arrival delay over this threshold is expected to cause departure delays. Below the threshold most of the arrival delays are absorbed.

Keywords: Type your keywords here, separated by semicolons ;

1. Introduction

1.1. Background

Robustness related to the railway is often related to the timetables (Palmqvist et al. 2018) This paper is based around the topics of punctuality and robustness in railway schedules. Robustness related to the railway is often related to the timetables (Salido at al. 2008). In a similar way, punctuality is related to trains running according to schedule (Zakeri and Olsson, 2017, Schöbel and Kratz, 2009; White et al. 2011). We define a robust timetable as a

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timetable that can absorb smaller disturbances and that in a given time will return to its original state, a definition based on Parbo et al. (2016).

1.2. On timetabling rolling stock planning

The timetable provides the basis for railway traffic (Ponnuswamy, 2012; Pachl, 2002). In order to estimate the scheduled running times, you first need to estimate the pure running time between the scheduled stops (Hansen and Pachl 2008). You need certain information to do this. These include route details with distance, traction unit characteristics, rolling stock characteristics and data about the operating cycle such as starting points, stops and timetable restrictions where this is applicable (Hansen and Pachl, 2008).

In addition to the pure running time the scheduled running time consists of the scheduled duration of stay at stations, recovery time and scheduled waiting time. (Hansen and Pachl, 2008). Running time margins are generally added to the nominal running time when setting up a timetable (Palmqvist et al. 2017), to make a timetable realistic. Margins are added to allow for a number of variations, including, individual driving patterns for drivers, different rolling stock performance, weather conditions and other factors. The recovery time can be split in regular and special recovery time, where the regular is usually added as a percentage of the pure running time, while the special run time is added where found appropriate. Recovery time increases the before mentioned reset capabilities of the schedule and thereby also the robustness of the timetable.

Once a time table has been established it is possible to establish a rolling stock circulation plan (Giacco et al. 2014; Harris et al. 2016). This plan shows how trains are supposed to move through the railway network for a given period. It also gives information like how many trains are needed, the capacity needed for each train, where the train has nightly stop-overs and the distance covered by the train among etc. A graphical timetable is normally used as a basis for the rolling stock circulation plan, and it is assumed that the route schedule can actually be run. The difference is that a line in a graphical rolling stock circulation plan only shows the movement of one single train set at a time. The decision of which actual train set that is going to run a line on a particular day is made later on.

1.3. Punctuality

Punctuality is related to trains running according to schedule (Palmqvist et al. 2017). Parbo et al. (2013) says that punctuality as a numerical measurement is usually the part of trains arriving on time to the stations. In most cases this is measured to the terminus, but in some cases, it could also be measured at intermediary stops. In order to measure punctuality, one must therefore first define the threshold for when an arrival is counted as a delay.

The Norwegian railway has two different definitions for punctuality for long distance trains and local trains respectively. A local train is registered as being on time if it reaches the terminus within 3 minutes and 59 seconds of the timetable, while a long-distance train is counted as being on time if it reaches the terminus within 5 minutes and 59 seconds of the timetable (BaneNOR 2019).

It is common to separate between primary and secondary delays (Olsson and Haugland, 2004). Primary delays in are delays caused by direct influence on the trains (not including influence by delayed trains), while secondary delays are caused by other delayed trains. Secondary delays are often referred to as knock-on delays (Olsson and Haugland, 2004).

1.4. Robust timetables

There are slightly different definitions of robustness in the railway literature. Andersson (2014) defines a robust timetable as “a timetable in which trains should be able to keep their originally planned train slot despite small delays and without causing unrecoverable delays to other trains” (Andersson, 2014, p.11). Salido, Barber and Ingolotti (2008) provide two definitions for robustness in railway timetables. The first is that robustness is the number of smaller disruptions the timetable is able to handle without modifications. Second, they say that a timetable is robust if it after a disruption is able to return to its original form in a given time. According to Hansen and Pachl (2008), robustness of timetables has one or more of the following effects:

1. Initial disturbances can be absorbed to some extent so that they do not lead to delays
2. There are few knock-on delays from one train to another
3. Delays disappear quickly, possibly with light dispatching measures

According to Profilidis (2006) and Andersson (2014), delays should be absorbed by robust production plans, including timetables and rolling stock circulation plans, which what is studied in this paper.

1.5. Research purpose and contribution

The purpose of this paper is to study punctuality and robustness from a rolling stock perspective. This is different from the bulk of punctuality studies, which typically focus on a train numbers, or lines. We study punctuality for rolling stock individuals.

The research questions in this study are:

- What is the connection between arrival and departure delays for rolling stock individuals at end stations?
- How does train vehicle individuals recover from can delays?

It is a tendency that train punctuality mainly is analyzed in an infrastructure perspective. This study benefits from the access to vehicle planning information. The knowledge added by this research is important both from a theoretical and practical perspective. Theoretically, the concept of punctuality and robustness are discussed in detail and defined for railway systems. For practice, railway management can use the punctuality analysis as a tool to improve the delays within same rolling stock circulation plan.

2. Methodology

The punctuality data used in the punctuality analysis was provided by Jernbaneverket (now BaneNor). The punctuality data contains punctuality data from the line Skøyen – Oslo – Moss for one year of train traffic. Fig. 1 shows the location of these stations. The studied trains are typical urban and suburban commuter trains, NSB type 72 with 310 seats per train set.

The delays on the line are followed from arrival at the suburban station Moss. We included delays of more than 10 minutes to Moss in the study. The arrival delay to Moss was the baseline, and we studied how these delays followed the train vehicle through the rolling stock circulation plan. The first relation was to compare arrival and departure to and from Moss, where the vehicles turned. We then studied the delays for the same vehicles when arriving Oslo central station, arriving Skøyen station on the other side of Oslo, and delays when departing from Skøyen after having turned around there. For all relation between arrival Moss, and the other studied points, correlation coefficients and scatter diagram were created. After this the initial delay was followed through the rolling stock circulation plan, and the same process was done for connecting delays to Moss with delays to Oslo, from Oslo, to Skøyen and from Skøyen. Correlation analysis were performed to study the relationship between arrival and departure delays.

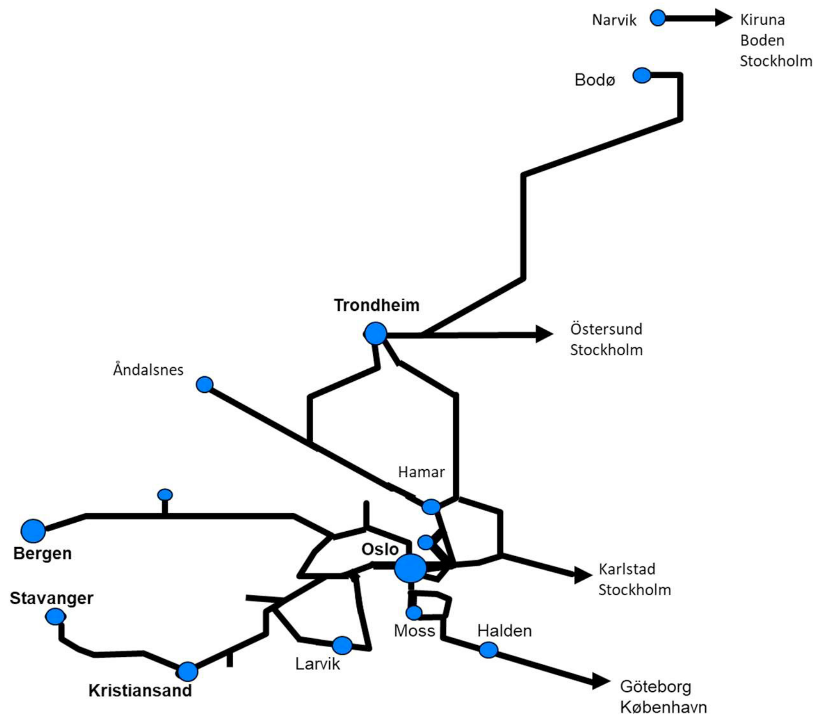

Fig. 1. The Norwegian railway network, including the stations Moss, Oslo and Skøyen.

Fig. 2 shows the general timetable and rolling stock circulation plan. For the vast majority of the departures, there was 23 minutes between arrival and departure at Moss. This is relatively generous time, and the turnaround time include slack for recovering from delays.

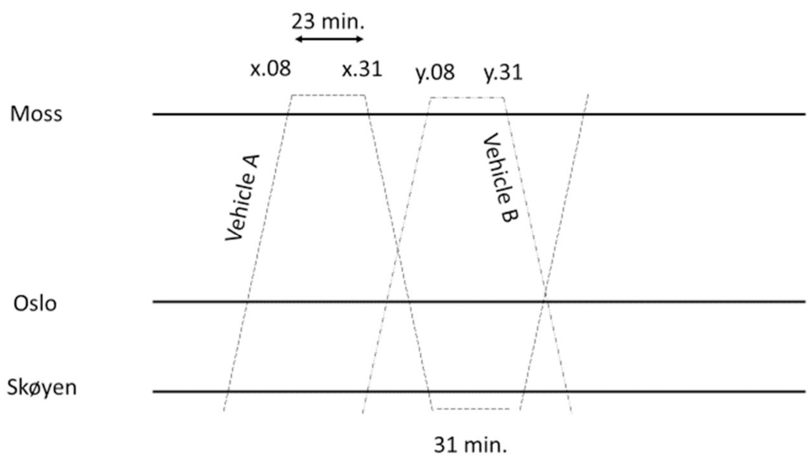

Fig. 2. Illustration of typical timetable and rolling stock circulation on the line. The pattern was repeated for most of the day.

Train type 72 has 6 minutes as the necessary turnaround time for single train sets and 7 minutes for double train sets used in peak traffic hours. These times does not include embarking and disembarking of passengers, which typically is scheduled for about 1 minute of a station like Moss, or time for moving train between platforms if that is needed.

We expected that delays up to a threshold value would be absorbed by the generous turnaround time at Moss. A number of correlation analyses were made to identify such a threshold. We found that a suitable threshold for delay recovery was 20 minutes, 1200 minutes, as illustrated in Fig. 3. We therefore present results for delays below and above this threshold.

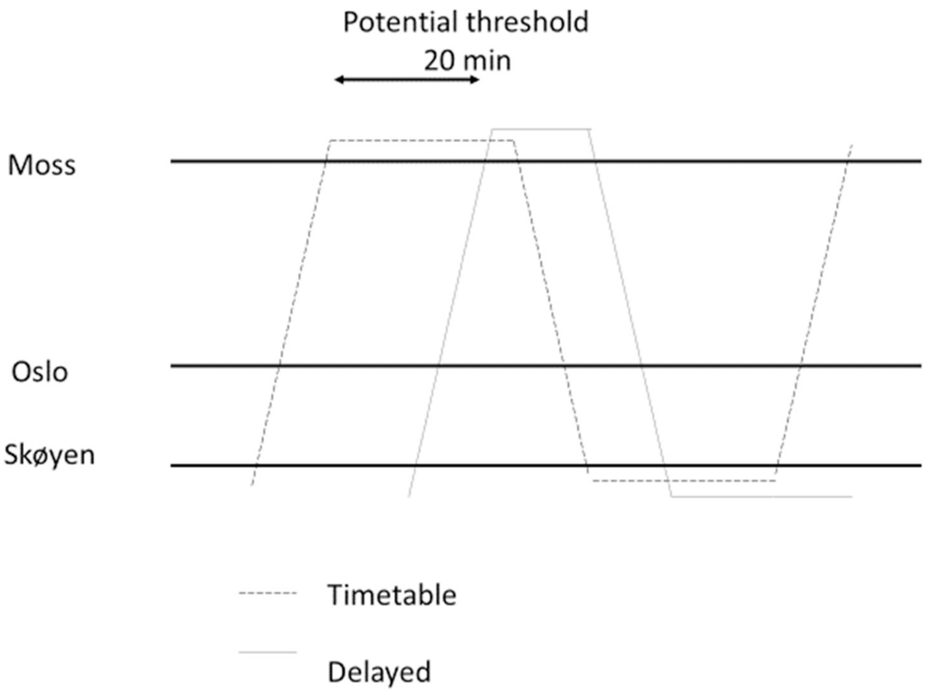

Fig. 3. Illustration of planned timetable and rolling stock circulation (long dash line) and delayed train (dotted line).

A previous version of this study was presented at the Euroma conference in 2016 (Olsson et al., 2016). This paper has further elaborated and quality assured the results, expanded the literature study and summarized the results for scientific publication.

3. Results

Table 1 summarizes results from the correlation analyses. Results are presented for the whole sample, trains arriving Moss with delays above the 20 minutes threshold, and departure arriving Moss less than 20 minutes late.

Table 1. Summary of results from correlation analysis. * = Significant at the 0.05 level

	Whole sample		Above threshold (>1200 sec)		Below threshold (<1200 sec)	
	n	Correlation coefficient	n	Correlation coefficient	n	Correlation coefficient
To Moss vs. from Moss	103	0.694*	20	0.552*	83	0.181
To Moss vs. to Oslo	103	0.643*	20	0.904*	83	0.222
To Moss vs. to Skøyen	103	0.607*	20	0.893*	83	0.158
To Moss vs. from Skøyen	96	0.158	20	0.522*	76	0.092

Of the studied arrivals to Moss, 103 vehicles could be followed a complete cycle from Moss and to Skøyen, and 96 of them also to departure from Skøyen. As shown in table 1, 20 of the trains were delayed more than 20 minutes to Moss.

There is a connection between arrival delays and the size of the corresponding departure delays, both in the whole sample and in the subset with delays above the threshold of 20 minutes. The correlation is relatively similar for departures from Moss, arrival Oslo and Skøyen and departure from Skøyen

4. Concluding discussion

Punctuality analysis was performed to investigate if there is a connection between arrival and departure delays. A correlation analysis and scatter plot of the arrival delays and the corresponding departures was done in order to find the possible connection. This was made possible by the fact that on the case line Skøyen – Oslo - Moss the norm is that the same train vehicle runs the timetable throughout a day.

For delays below the threshold most of the arrival delays are absorbed, and correlation between arrival and departure delay is relatively low. Especially for delays below the threshold, there might be other factors causing delays.

We found that the timetable for the line Skøyen – Oslo – Moss was able to absorb disturbances up to a certain threshold level at Moss station, and that it in a given time was able to return to its original state after suffering from impact. Based on our definition of robustness for timetables, this timetable is robust in terms of absorbing delays up to 20 minutes at Moss station. However, delays of more than 20 minutes were still affecting the trains even at departure from Skøyen, at the other side of the city center.

While it has been shown that robustness can be used to evaluate timetables, it is important to underline the inherent simplicity of the line used for analysis in this report. The fact that it is the same train vehicle that runs the line through a day, together with the relatively large buffer times at the terminuses, effectively keeps the complexity at a minimum. Further research on using robustness to evaluate timetables could thus be directed towards timetables and rolling stock circulation plans that have a higher interdependency, larger heterogeneity of traffic and a higher utilization of the rolling stock.

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