A Traveller Perspective on Railway Punctuality: Passenger Loads and Punctuality for Regional Trains in Sweden

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Abstract
This paper examines the extent to which delayed trains are also trains with more passengers. The paper uses unique passenger load data about regional trains in Sweden and combines this with Swedish delay statistics for the same train numbers and from the same time periods. Results show that trains with high passenger numbers are not delayed to a greater extent compared to trains with fewer passengers. Train punctuality is thus a good indicator of traveller punctuality in this case. These results also suggest that long boarding and alighting times due to high passenger numbers are not a main cause of delays, possible causes of delays are instead external factors such as track maintenance or dense train movements. Therefore, this result suggests that policy makers should look further into the latter causes. Furthermore, the paper also compares the share of travellers and trains that are more than half an hour late, i.e. that are significantly late. These differences are also small but larger than for the less delayed trains. For one of the railway lines, trains with high passenger loads are more than proportionally hit by long delays. Such cases suggest that train control priorities could be re-examined with more focus on improving the service for railway travellers.

Keywords
Train punctuality, Passenger load, Regional train, Train traveller demand, Delays

1 Introduction

Punctuality is a key issue for the railway in order to be an attractive mode choice for travellers. After safety, punctuality is the most important performance indicator for most railway infrastructure managers including the Swedish Transport Administration (Swedish Transport Administration, 2018). Furthermore, passengers rate punctuality as the key success factor for railway travel, and requests for trains to be more punctual are more common than requests for trains to be more frequent (Transport Focus, 2015).

A substantial amount of research has been conducted to understand which factors influence railway punctuality. These studies use different modelling techniques: analytical models (Bergström and Krüger, 2013), multiple regression models (Olsson and Haugland, 2004; Palmqvist et al., 2017) and machine learning (Marković et al., 2015). There are also a number of studies in the literature focusing on construction of time tables that are more robust to disturbances (Andersson et al., 2015; Cerreto et al., 2016; Liebchen et al., 2010; Solinen et al., 2017).

However, all the above-mentioned studies focus on *train* punctuality rather than on *traveller* punctuality. Traveller punctuality is an important area, as there is reason to believe that passenger loads can vary considerably both between trains on the same railway segment, and for the same train on different railway segments. Such research has, however been difficult to conduct in this area in Sweden (and in many other countries) due to the reluctance of railway operators to give access to passenger load data. The issue is of the magnitude that new methods to calculate number of train travellers from mobile phone data is under development (Sørensen et al., 2018). It is only recently that it has become possible to get access to historic passenger load data for certain railway lines in Sweden.

Average punctuality of all trains in Sweden has been around 90% in the latest years (Trafikanalys, 2018), i.e. 90% of trains arrive less than six minutes after schedule to the destination. This could be seen as a fairly high figure with a vast majority of the trains being punctual, but traveller expectations on punctuality are very high (Transport Focus, 2015). There is no reliable evidence that delays are larger in Sweden than in other European countries, but comparisons with other European countries suggest that Sweden has lower levels of punctuality than comparable countries (BCG, 2017). It is also possible that travellers experience more delays, since trains might be delayed to a greater extent at times when many people travel. This could be due to disturbances spreading, and thus more trains are affected by disturbances, at times when there is a high capacity utilization in the railway network, or because of delays at stations due to long boarding and alighting times when passenger numbers are high. It is also possible that travellers' perception of punctuality has more to do with a psychological phenomenon that people are more likely to remember outstanding events (Phelps and Sharot, 2008), i.e. train journeys with long delays compared to journeys when everything goes according to plan. A third possibility is that travellers concern about punctuality is driven by a very strong negative valuation of a small risk of facing a very long delay (Börjesson and Eliasson, 2011). Whether trains are more delayed when many people travel is still an open question, since there is a lack of studies combining passenger load data with punctuality data. One study of commuters in the greater Stockholm area in Sweden investigates delays during peak hours and find that, to be 95% certain to arrive on time, a buffer time corresponding to up to 37% of the travel time needs to be added (Föreningen TIM-pendlare, 2015).

There is also no clear consensus on which measures are the most cost-efficient measures for reducing delays in Sweden. With punctual trains defined as trains arriving less than six minutes after schedule to the destination, there has been a focus on cutting short delays.

Long delays are however extra disturbing to passengers, since it may imply that passengers miss connections or do not arrive in time for a meeting. Nelldal (2016) analyse the causes of long delays but includes no information about how many passengers were affected by these long delays.

In this paper, rare Swedish passenger load data (Jansson et al., 2017) is combined with train punctuality data in order to extend previous work on train punctuality with analyses of two aspects of traveller punctuality:

1) The share of *punctual* travellers (arriving 5 minutes and 59s after schedule or earlier to the destination) compared to the share of *punctual* trains.
2) The share of *significantly late* travellers (arriving 30 minutes after schedule or later to the destination) compared to the share of *significantly late* trains.

2 Context

2.1 The Study Area

The study area in this paper is the so called Mälarbanan between Stockholm and Hallsberg[1], see the green line in Figure 1. This is an electrified track about 200 km long which mainly constitutes of double track, e.g. the Stockholm-Västerås part of Mälarbanan constitutes solely of double track. Train traffic on Mälarbanan is mainly regional trains running from Hallsberg to/from Stockholm and from Västerås to/from Stockholm. On the part of Mälarbanan located in Stockholm County, the regional trains also share tracks with commuter trains.

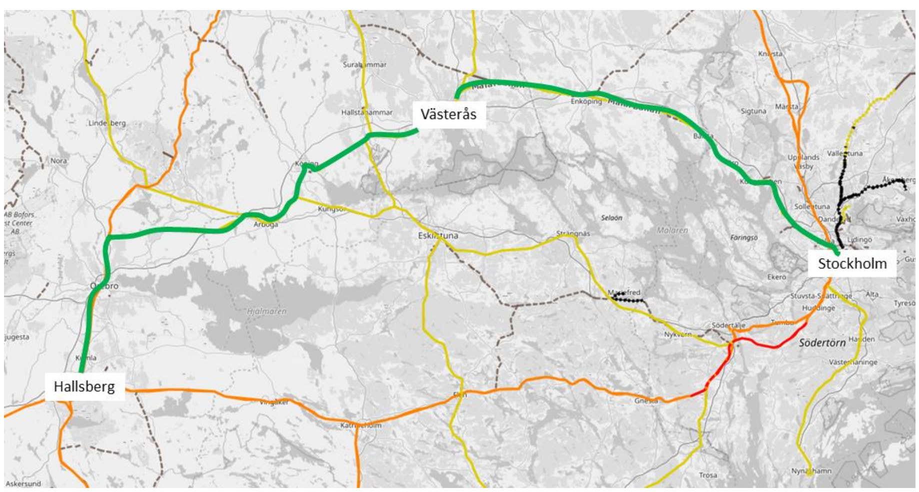

Figure 1: The studied track Mälarbanan north of the lake Mälaren in Sweden.

[1] To be exact, Mälarbanan does not go all the way to Hallsberg, rather it merges with another railway track in Hovsta about 35 km north of Hallsberg.

2.2 Efforts to Increase Punctuality of Swedish Trains

In Sweden, the infrastructure manager and train operators work together to increase punctuality in a cooperation called TTT (Together for Trains on Time). Data on disturbances, reasons for disturbances and time deviations at stations are collected and analysed within TTT. This data shows that regional trains in Sweden are in general more punctual than long-distance trains, but not as punctual as commuter trains (all measured with 5min and 59s allowed time deviation at the destination), see Table 1. Note that the difference between high-speed long-distance trains and other long-distance trains is quite large.

Table 1: Comparison of punctuality across different train types for the year 2015.

2015	Highspeed long-distance	Other long-distance	Regional	Commuter train
Total number of trains	41145	29482	376054	406056
Number of trains <6 min late	30303	24902	337996	383270
Share of punctual trains	73.6%	84.5%	89.9%	94.4%

Punctuality is higher on Saturdays and Sundays. For regional trains during 2015, the average share of punctual trains was 92.7% on weekends, compared to 89.2% on weekdays.

A train leaving a station three minutes or more after schedule is registered as a disturbed train and a reason for the disturbance needs to be given. Total number of disturbance minutes for each train is registered in the TTT database, called LUPP. The disturbance minutes varies depending on time of day. Figure 2 shows the variation of disturbance minutes depending on time of day for different types of trains for the year 2015. For all train types it is clear that disturbances are not evenly spread over the day, rather two clear peaks can be seen, one in the morning and one in the late afternoon. For regional trains on Mälarbanan (studied in this paper) there is a more distinct morning peak compared to other train types, suggesting a high share of commute travelling. Disturbance minutes per hour is highest around eight in the morning and around six in the afternoon. This observation combined with the observation from Jansson et al. (2017) that trains have the largest passenger loads in these time periods suggests the hypothesis that passengers could be more than proportionally hit by delays compared to trains.

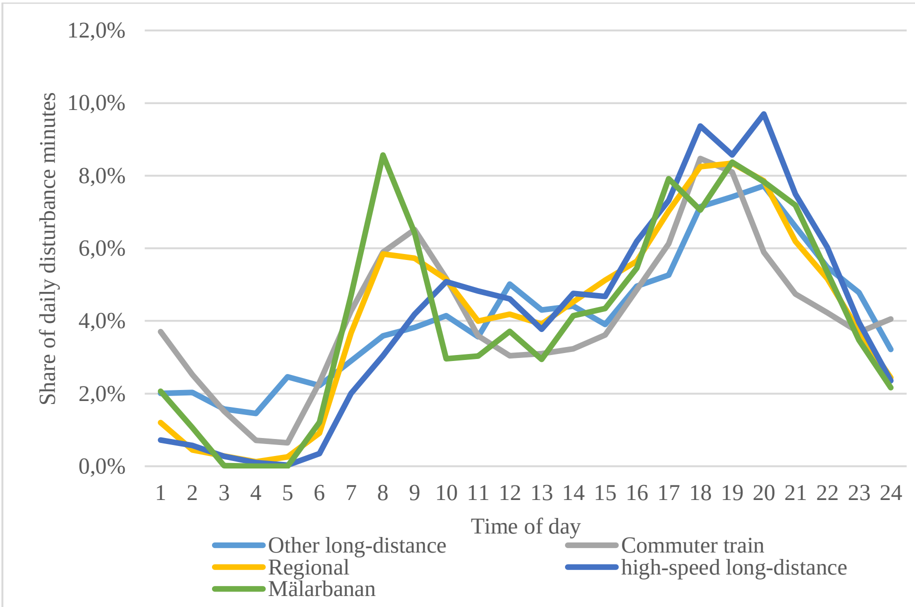

Figure 2: Share of daily disturbance minutes depending on time of day for regional trains compared to other train types for the year 2015. Data from the LUPP-database.

In the report from TTT for the year 2017 (JBS, 2018), the relative importance of different causes for delays are analysed. The results suggest that management of the railways and train operations are two large categories of causes for delays. So far not much is reported about the distribution of delays in time and geography.

3 Method and Data

3.1 Definitions

Two definitions are used in this paper:

1. A train or traveller is considered **punctual** if arriving to the destination of the train 5 minutes and 59s after schedule or earlier.

2. A train or traveller is considered **significantly late** if arriving to the destination of the train 30 minutes after schedule or later.

Both punctual and significantly late trains and travellers are thus binary measures that adopt the values true or false.

3.2 Passenger Load Data

In this paper, two main data sources are combined to analyse traveller punctuality. On the one hand, passenger load data from weekdays in September and October 2015 for regional trains on Mälarbanan is used (Jansson et al., 2017). This data includes occupancy and number of seats per train number and railway segment (between larger stations). Thus, from this data number of passengers on the train can be calculated. An example of the passenger load data is shown in Table 2.

Table 2: Example of passenger load data from Jansson et al. (2017). Occupancy and number of seats for trains from Västerås to Stockholm C weekdays in September 2015.

Train number	#Seats	Occupancy (%)			
		Västerås-Enköping	**Enköping - Bålsta**	**Bålsta - Sundbyberg**	**Sundbyberg - Stockholm**
707	239	32	57	61	59
783	293	47	69	73	69
781	395	41	50	50	50
787	387	61	72	74	70
791	243	27	30	29	28
795	300	39	44	42	38
797	277	39	41	37	33
799	243	35	35	32	29
767	244	11	11	10	10

Jansson et al. (2017) show that average passenger loads are highest in the morning and afternoon peak (but still below 80 percent of seating capacity at the highest) and that very low occupancy numbers often are the case for trains running in the late evening, see Figure 3 and Figure 4. For the line Västerås – Stockholm C there is a clear morning peak for occupancy, see Figure 3. In the other direction, Stockholm C – Västerås, the highest occupancy occurs in the afternoon peak, see Figure 4. The pattern in the two figures indicate a large share of commute travel to Stockholm.

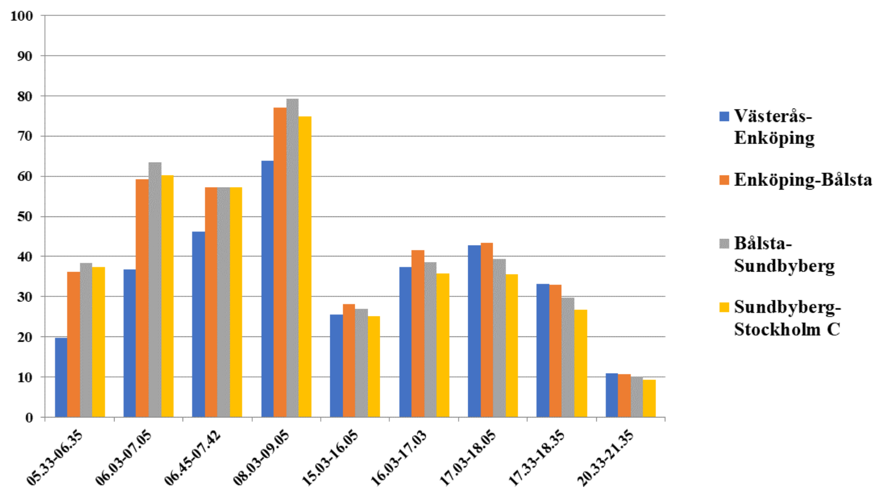

Figure 3: Occupancy (in per cent) for regional trains on weekdays from Västerås to Stockholm C, average values for September 2015, October 2015 and April 2016 (Jansson et al., 2017).

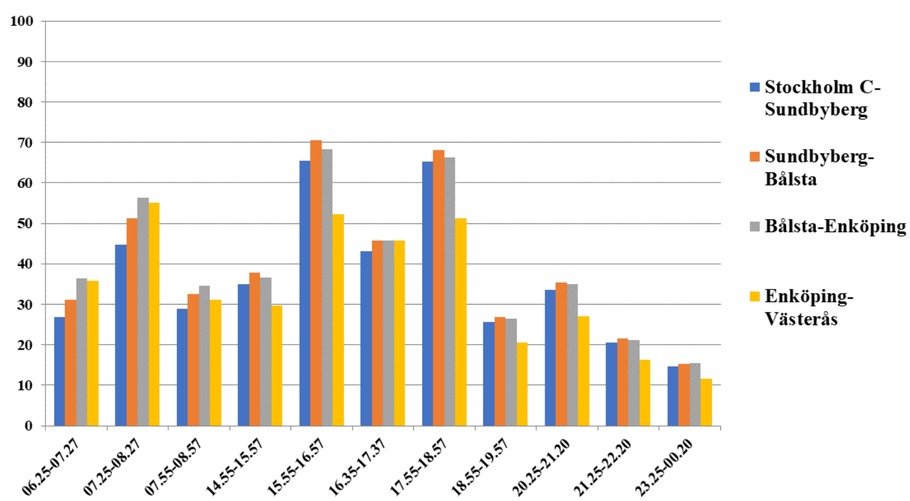

Figure 4: Occupancy for regional trains on weekdays from Stockholm C – Västerås, average values for September 2015, October 2015 and April 2016 (Jansson et al., 2017).

3.3 Punctuality Data

For the same time period (weekdays in September and October 2015) and the same train numbers, train delay data have been extracted from the Swedish delay database LUPP, in which deviations from the time table are recorded for all stations along the line.

Table 3 shows an example of train delay data from LUPP. Note that in LUPP time deviations are also given for stations in-between the major stations, but these have not been extracted here. Note also that time deviation from schedule can be negative. Small negative time deviations are quite common in the data, but few observations are more than 7 minutes early. Trains and travellers arriving early to the destination are in this paper considered to be punctual. The train in the example of Table 3 is not punctual, since it arrives to the destination Stockholm C 34 minutes late - it is even *significantly late* according to the definition in 3.1, since it is more than 30 minutes late.

Table 3: Example of train punctuality data for a train from Västerås to Stockholm C extracted from the LUPP database.

Date	Place	Train number	Arrival/ Departure	Planned time	Time deviation (min)
2015-09-01	Västerås	781	Departure	06:45	0
2015-09-01	Enköping	781	Arrival	06:58	1
2015-09-01	Enköping	781	Departure	06:59	1
2015-09-01	Bålsta	781	Departure	07:09	0
2015-09-01	Sundbyberg	781	Departure	07:31	34
2015-09-01	Stockholm C	781	Arrival	07:38	34

There are in total 1343 observations of train journeys in the format of Table 3 for which time deviation at the destination is given. Each of these observations are matched to passenger load data for the corresponding train number and measurement month. Most observations are from September 2015, with 436 observations from October 2015. After combining punctuality and passenger load data, the data contains around 220 000 traveller journeys, which implies an average of 164 passengers per train.

3.4 Result Quantities

Table 4 lists the result quantities and shows how they are calculated. Note that result quantities are only calculated for the destination of the train using passenger loads from the last section of the journey and time deviation at the destination. Passenger load data and time deviation for earlier sections of the journey are not used in calculations and are only included here for completeness.

Table 4: Result quantities and how they are calculated.

Result Quantity	Calculation	Unit
Share of punctual trains	Number of punctual trains / total number of trains for the geographic relation under study	%
Share of punctual travellers	Number of punctual travellers / total number of travellers for the geographic relation under study	%
Share of significantly late trains	Number of significantly late trains / total number of trains for the geographic relation under study	%
Share of significantly late travellers	Number of significantly late travellers / total number of travellers for the geographic relation under study	%

4 Results

The results of the analysis from a traveller perspective is presented in this chapter. First, we note that train punctuality for the regional trains on Mälarbanan studied in this paper is on average 90.5% when looking at the two different railway lines in both directions. This figure is somewhat higher, but similar to the punctuality of 89.9% for all regional trains in Sweden during 2015 presented in Table 1. Thus, it appears that the studied observations are representative of regional trains in Sweden, or at least do not deviate too much when it comes to punctuality.

4.1 Traveller Punctuality Compared to Train Punctuality

Figure 5 shows that, for regional lines running on Mälarbanan, traveller punctuality is somewhat lower than train punctuality. Average traveller punctuality is 88.8% compared to 90.5% for train punctuality. This suggests that trains are not much more delayed at times when many passengers travel. As indicated in Table 1, trains travelling longer are more often delayed. The same pattern can be found in the results of this paper, where the share of punctual trains is lower for Hallsberg-Stockholm compared to Västerås-Stockholm (which is a shorter distance as can be seen in Figure 1).

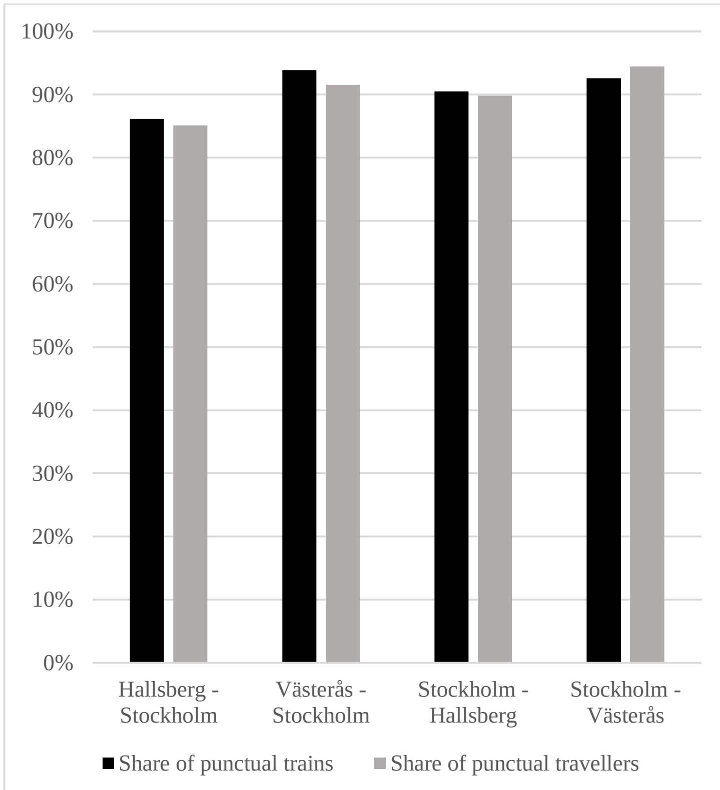

Figure 5: Share of punctual travellers compared to the share of punctual trains for regional train lines on Mälarbanan.

4.2 Significantly Late Travellers Compared to Significantly Late Trains

Figure 6 shows a comparison of significantly late travellers and trains. Here, the figures differ somewhat more between travellers and trains compared to the measurements of punctuality above. The share of significantly late travellers is substantially larger than the share of significantly late trains for the relation Västerås-Stockholm (2.9% compared to 1.5%), but on the other hand, the opposite is true for the relation Stockholm-Västerås, which has a higher share of significantly late trains than travellers (2.0% compared to 1.2%). Looking at an overall average this evens out the differences between travellers and trains and the average share of significantly late is 1.8% for travellers compared to 1.7% for trains.

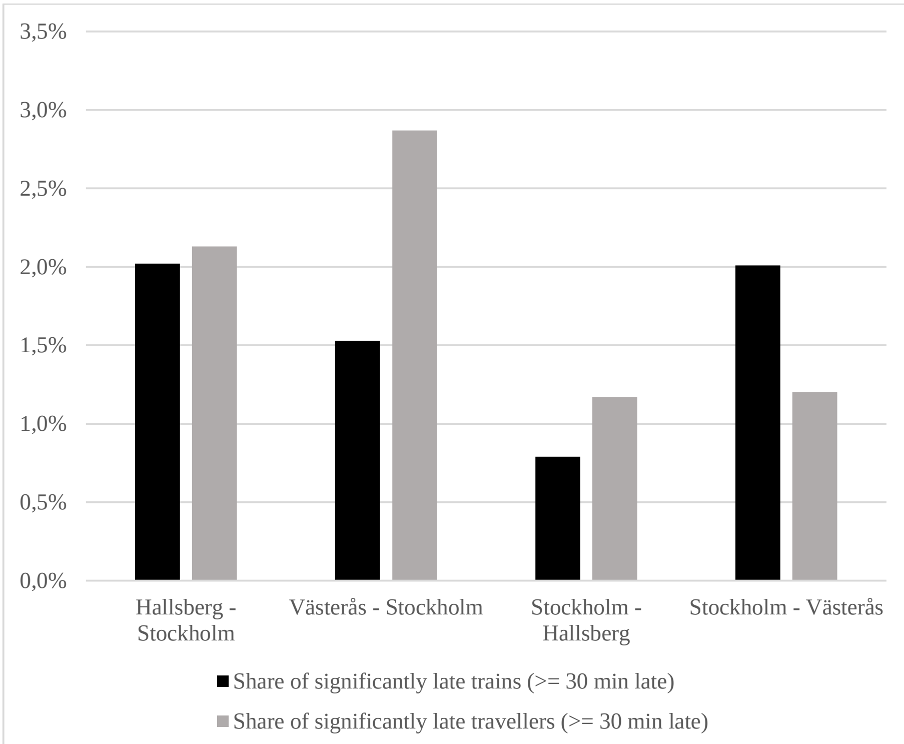

Figure 6: Share of significantly late travellers compared to share of significantly late trains for regional lines on Mälarbanan.

A deeper analysis of the data reveals that, for the relation Västerås to Stockholm, the significantly late trains are trains running in the morning peak, i.e. when occupancy rates are the highest and most people travel (see also Figure 3). Therefore, a larger share of travellers is affected. This is in line with the hypothesis made in the introduction. However, when analysing the opposite direction – Stockholm to Västerås – it is not primarily the trains running in the afternoon peak that are significantly late. On the contrary, the significantly late trains mainly depart from Stockholm C in the early morning peak. Figure 4 shows that occupancy rates for the early morning peak are rather low in this direction of travel (around 30%). Therefore, the share of significantly late trains is higher than the share of significantly late travellers in this case. One possible interpretation of these results could be that congestion/delays at the large station Stockholm C in the morning peak affects trains in both directions even though occupancy rates are much higher in the inbound direction.

There are more useful interpretations to be made from the analysis of significantly late travellers. First, it is notable that the share of significantly late travellers is not negligible. Out of 220 000 travellers in the data, around 4 000 (1.8%) are significantly late when arriving at the train's destination. Second, Figure 6 shows that the variation between relations is larger for significantly late travellers compared to traveller punctuality.

5 Discussion

If delays are mainly driven by boarding and alighting times policy implications will be different than if it is external factors or dense train movements that drive delays. Punctuality is however rarely associated with passenger numbers and consequently the impact it has on passengers has not been measured.

This study indicates that for regional trains in the Hallsberg-Västerås-Stockholm corridor in Sweden, trains do not seem to be much more delayed at times when many passengers travel. Train punctuality is thus a good measure of traveller punctuality in this case (not accounting for travellers that travel further with connecting trains). This result suggests that high passenger numbers and subsequent longer boarding and alighting times are not the main cause of delays for the context under study. Rather indications from the JBS (2018) study are that external factors, such as infrastructure or signal system failures; or knock-on delays due to dense train movements (with not as densely loaded trains in this case) could be possible causes of delays.

If it is external factors and/or dense train movements that is the main cause of delays, then reducing number of trains in the network (maybe combined with lengthening of trains and platforms) could be beneficial. Improved timetable planning and improved processes for operational traffic (decision support, improved information about rolling stock, improved interaction between infrastructure manager and railway undertaking etc.) are also effective measures to increase punctuality. Long railway lines will have increased probability of being disturbed if external factors occur evenly spread along the railway network. Data shows that punctuality is lower for long-distance trains, especially high-speed long-distance trains. In a railway network, such as the Swedish network, with many single tracks and a mix of trains with different speeds, it is quite common that high-speed trains get stuck behind a slower train. Changing operation rules to prioritize the faster train could be beneficial in this situation.

Furthermore, results of this paper suggest that it is important to monitor the share of significantly late travellers. The share of significantly late travellers and trains differ more compared to traveller and train punctuality. It is therefore important to bear in mind that even if only a small share of trains is significantly late, the share of travellers might be substantially larger. It is also important to note that the share of significantly late travellers is not negligible, at least not for regional trains in Sweden. A delay of more than half an hour imposes great trouble for travellers and reduces traveller trust in the railway, which will have a negative impact on the railway market share. This suggests that significantly late travellers/trains should be monitored and more in focus of future measures to decrease railway delays.

This paper examines the hypothesis that trains in peak carry more passengers and are more hit by delays and that therefore passengers on average experience more delays than trains. We find only small differences between the shares of trains and travellers that are delayed. We find some indications of uneven distribution of delays, both with respect to train types and time of day. Our assessment is that there is a need for further analysis of both the causes for delays and the time and geographical patterns of delays to examine the evenness of these distributions. Are the likelihoods of being hit by delay even per train kilometre and track kilometre?

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