Train delays due to trackwork in Sweden

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Abstract

Only well-maintained railway systems can function without severe interruptions. However, maintenance activities can themselves cause train delays if they conflict with train movements. Trackwork refers to maintenance performed on a railway track. This study aims to investigate the effect of trackwork on train delays in Sweden. It presents a logistic regression analysis based on more than 225,000 planned trackwork and 25,600,000 train movements during 2017. The results show that trains that pass through trackwork on single-track segments were on average 44% more likely to be delayed than those that do not. The corresponding value for double-track segments was 25%, and the weighted average was an increased risk of 31%. With the number of trackwork set to increase over the coming years, these results highlight the importance of improved scheduling and performance of trackwork to reduce the conflicts between trackwork and train movements.

Keywords

Trackwork, Railway maintenance, Train delay, Track type

1 Introduction

Punctuality is a key contributor to the competitiveness of railways (Olsson and Haugland, 2004; Jovanovic et al., 2017). Train delays impact the quality of service to both passengers and freight operators (Nyström, 2008; Palmqvist et al., 2017; Olsson, 2020; Corman, 2020). A growing literature is devoted to exploring the causes of train delays (e.g. Olsson and Haugland, 2004; Jiang et al., 2010; van der Kooij et al., 2017; Palmqvist, 2019). Ceder and Hassold (2015) classified causes of delay as train fault, infrastructure fault, maintenance (servicing or trackwork), staff error, network control measures, incidents, and other delay causes. Delay estimation techniques were developed for single and double-track infrastructure segments, where travel time delay was a function of the operating parameters (Murali et al., 2010; Meng and Zhou, 2011). Some parameters included in delay prediction models are distance covered, train length, running time margins, railway capacity and passenger loads (Olsson and Haugland, 2004). Infrastructure failures and speed reductions are also associated with delays (Harris, 2013), as are some weather conditions (Xia et al., 2013; Palmqvist et al., 2017; Zakeri and Olsson, 2018).

Supporting railway reliability is essential because more traffic is expected to be shifted toward railways (EC, 2010). As traffic increases, so does the wear of railway infrastructure components, creating the need for maintenance. Stenström et al. (2016) predict exponential growth in railway maintenance as the frequency of trains increases. Trackwork often leads to capacity restrictions for train traffic, through track closures, speed reductions and single-track operation (van der Kooij et al., 2017; Peterson et al., 2019). This often creates a need to adapt paths for trackwork through train timetable rescheduling, which is not always done (Peterson et al., 2019). The capacity restrictions and unadjusted train timetables can lead to unpunctual trains (Olsson and Haugland, 2004). Therefore, substantial research has been conducted in the field of maintenance optimisation and planning to cope with existing traffic (Famurewa et al., 2015; Liden, 2016; Albrecht et al., 2013; Budai et al., 2004). Although a lack of maintenance and its relation to railway operational reliability has been discussed (Økland et al., 2013; Trafikverket, 2015a; Trafikverket, 2015b; Trafikverket, 2016; Arenas et el., 2018), fewer studies have investigated the effects of maintenance activities on train delays.

This study aims to quantify the extent to which trackwork affects train delays. We use one year of data from Sweden covering more than 225,000 planned trackwork and more than 25,600,00 train movements from across the whole country during the year of 2017. The main hypothesis is that if a train moves over a section where there is ongoing trackwork, the risk of being delayed will increase.

2 Trackwork in Sweden

The total length of railway infrastructure in Sweden is approximately 15,500 km. Trafikverket (the Swedish Transport Administration) manages the infrastructure and is responsible for around 14,200 kilometres of tracks, 4,000 railway bridges, 150 tunnels, and close to 11,500 switches (Trafikverket, 2020). The maintenance of this infrastructure is delegated through contracts to five major maintenance companies and more than 1,000 subcontractors. According to existing regulations, maintenance contractors must perform operational planning and apply for capacity on the railway (RailNetEurope, 2017). The application period starts 12 weeks before the day of track maintenance; the last application is to be sent no later than four weeks before maintenance performance. All approved applications are recorded in the track utilisation plan. When the capacity for trackwork is booked, it may conflict with already scheduled train operations (Forsgren, 2013) if it has not already been coordinated during the annual capacity allocation process.

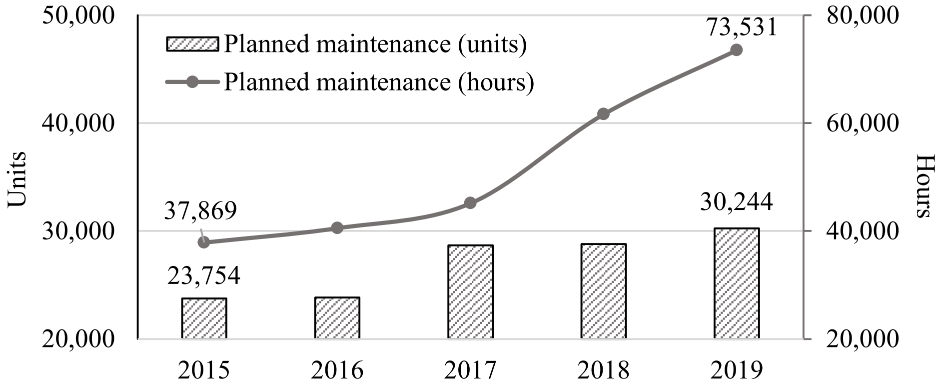

Figure 1: Planned track maintenance in Sweden (with data obtained from Trafikverket). The number of annual maintenance activities planned are shown as bars (with units on the left vertical axis); hours planned for maintenance are shown as a line (with units on the right vertical axis).

The number of planned railway track maintenance hours in Sweden has almost doubled since 2015. As shown in Figure 1, starting from 2017, planned maintenance activities in the track utilisation plan gradually increased while assigned hours for maintenance activities have increased drastically. This implies that maintenance activities have become more time-consuming over the last couple of years, which leads to more conflicts with train operations.

3 Overview of data

In this study, we analysed train punctuality and trackwork datasets covering the Swedish railway network in 2017. The trackwork records were extracted from the track utilisation plan, which specifies roughly 225,000 scheduled trackwork with their associated times, locations, and traffic restriction.

The train punctuality data was extracted from an internal Swedish Transport Administration database. The data contained information about the scheduled departure/arrival time and actual departure/arrival time to each station on the assigned train path, with a time-resolution of one minute. In addition, each train route had an identification number, train type, and information about the infrastructure (single or double-track). The selected data contained about 25,600,000 train movements.

In this study, we analyse how train delay increase is associated with trackwork. Train type and train entry status to the analysed track segment are the control factors; other factors affecting the train delay are out of the scope of this study. Track type and time period are controlling variables for the trackwork relevant to this study's context.

Figure 2 summarises the characteristics of analysed train movements along the investigated infrastructure segments. A quarter of the train movements analysed, 23%, experienced a delay increase through the route, whereas 77% did not. Delay increase was calculated as the difference between the arrival delay at the end of a segment and the departure delay at the beginning of a segment. Scheduled trackwork overlapped with about 1% of the train movements, whereas 99% of the movements did not pass through scheduled trackwork (see subsection 4). 60% of the train movements happened on double-track (or more), while 40% on single-track. Our sample was composed of 79% passenger trains and 21% freight trains. Importantly, 29% of the train movements in our sample were ahead of schedule, which means they *should slow down* to return to the schedule. Slowing down relative to the schedule will be detected as an increase in delay. Thus, it needs to be controlled explicitly so that its effect does not spill over into the estimate regarding the effect of trackwork.

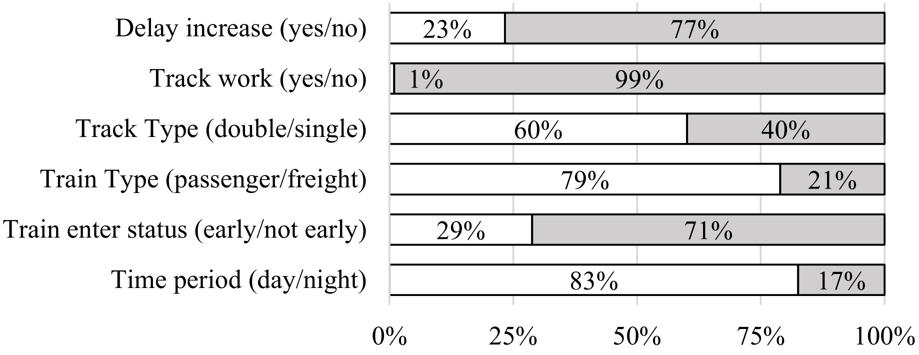

Figure 2: Characteristics of the analysed sample of train movements

Finally, 83% of the movements occurred in the daytime and 17% at night. Night-time was defined according to the labour act of Sweden (SFS, 1982) as the period between 22.00 and 06.00.

4 Matching trackwork and train movements

In the track utilisation plan, the trackwork location is specified by the unique signal numbers on the track segment between two assigned stations (S_1 and S_n in Figure 3). On each track segment studied, S_1 and S_n stations represent the start and end stations of trackwork (Figure 3). In total, 3,218 unique track segments were identified from the track utilisation plan for 2017, with one to nine stations in between. Frequently these track segments overlapped one another, as illustrated in Figure 4. Therefore, overlapping track segments were joined into one for eliminating duplicates in the analysed data ($S_{3.1}$ $S_{3.n}$ in Figure 4).

In the train punctuality dataset, the train passage was defined by the sequence of stations on the train route, which is a more detailed geographical representation than in the trackwork dataset (Figure 3). To merge two datasets by location on railway track segments, we identified each unique train passage from the train punctuality dataset between S3.1 and S3.n stations in the train route. Each analysed train on its route passes over more than one track segment ($S_{3.1}$ $S_{3.n}$ in Figure 4). Combining the 25,600,000 trains with the 3,318 track segments thus resulted in a total of 40,764,253 train passages. Then we identified the train passages which occurred during the scheduled trackwork. The hypothesis is that such overlap with scheduled trackwork would increase the probability of train delay.

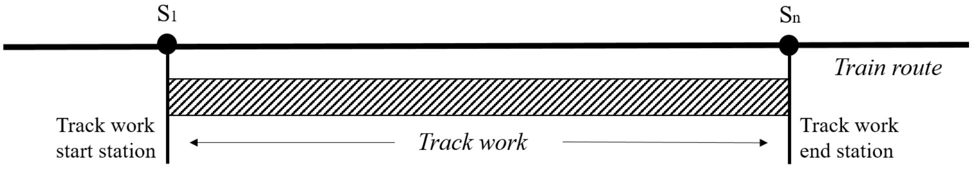

Figure 3: Railway track segment where trackwork happens between stations S_1 and S_n

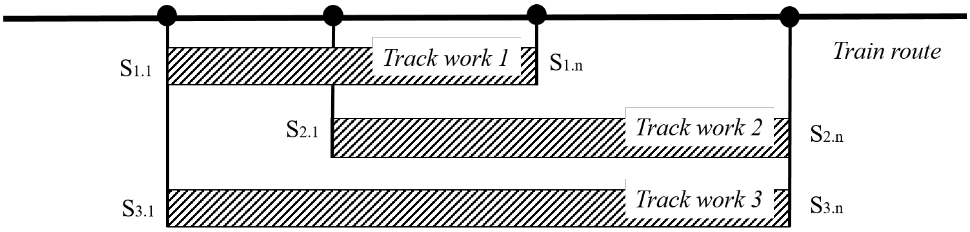

Figure 4: Two overlapping track segments joined into one ($S_{3.1}$ $S_{3.n}$)

5 Analysis and results

We used multiple logistic regression models to analyse the relationship between train delay and trackwork, controlled by the set of independent categorical variables (see Table 1). The regression coefficients were estimated using the maximum likelihood method, implementation of which was provided by the command *glm* (Generalised Linear Model) in R, a free software environment for statistical computing. The statistical significance of each individual regression coefficient was tested using the Wald chi-square statistic test.

The regression results presented in Table 1 show that each explanatory variable in the analysed model has a statistically significant effect on delay increase. It should be noted that an odds ratio greater than 1 indicates variable's positive correlation with the likelihood of a delay increase. Delay increase is positively correlated to track work activities and to the train passing on a single track line. At the same time, delay increase is negatively correlated to passenger trains and to trains not departing early from the first station in the studied line segment. The time period of train passage has a marginal impact on increases in delays.

For ease of interpretation, we have also expressed the coefficients in terms of relative risk of train delay increase (Table 1). Relative risk was defined as the ratio of the risk (or probability) of something happening (such as a train being delayed) in one circumstance (such as the train passing by trackwork) divided by the ratio of the risk (or probability) of the event in another circumstance (such as the train *not* passing by trackwork).

5.1 Main model to identify the effects of trackwork

The regression results presented in Table 1 show that delay increase was *more likely* to occur when the train passed through trackwork. The relative risk of delay increase was 31% higher when trains passed through the track segment with scheduled trackwork. Delay increase was more common for freight trains rather than passenger trains, on single rather than double-track segments, during day than night-time. If the train was ahead of schedule, it was more likely to have a delay increase (which can be explained by the driver slowing down the speed of the train to return to the timetable).

Table 1: Summary of the multiple logistic regression, where the dependent variable is delay increase (yes=1; no=0)

Coefficients	**Estimate** ***	**Odds ratio**	**CI 95%** Lower	Upper	**Relative risk**
(Intercept)	-0.592	0.553	0.552	0.554	
Trackwork (yes=1; no=0)	0.370	1.448	1.438	1.458	1.31
Train type (passenger=1; freight=0)	-0.234	0.791	0.790	0.793	0.84
Track type (single=1; double=0)	0.116	1.123	1.121	1.124	1.09
Train departure status (not early=1; early=0)	-0.689	0.502	0.501	0.503	0.60
Time period (night=1; day=0)	-0.046	0.955	0.953	0.957	0.96

Note: ***$p < 0.0001$

Area under the curve: 0.608

Table 2: Relative risks of delays on single and double-track

Predictors	**Relative risk of delays on**	
	Single-track	**Double-track**
Trackwork (yes/no)	1.44	1.25
Train type (freight/passenger)	1.21	1.19
Train departure status (early/not early)	1.57	1.74
Time period (day/night)	1.04	1.03

5.2 Does the track type matter?

We investigated how the relation of trackwork to the train delays is different if trackwork is performed on the single track rather than on double-track segments. The analysed dataset was spit into two, classified by the track segment type. We estimated two multiple logistic regression models tor single and double-track cases analogous to the one presented in Table 1. Table 2 displays the relative risk measured for both the single and double-track models.

As Table 2 shows, train passing scheduled trackwork has a higher risk to delay on the single-track track segment than on the double-track segment. Delays were 44% more likely to occur if a train passed through scheduled trackwork on a single-track and 25% more likely if it passed by one on a double track. We also saw that trains ahead of schedule were more likely to slow down to come back to schedule on double-track rather than single-track segments. Other than this, there were no major effects from separating the number of tracks, and we have found no other interaction effects between the variables of a similar magnitude.

6 Conclusion

In this paper, we have investigated the extent to which scheduled trackwork affects the risk of train delays. Trackwork has increased significantly over the last few years in Sweden, which led to more operational restrictions for train traffic. We have found that, on average, trains that pass by scheduled trackwork were 31% more likely to be delayed. This is a weighted average across both single and double-track segments. Looking at each of these separately, we saw that the increased risk was 44% on single-track and 25% on double-track segments. Thus, planning trackwork, particular attention must thus be paid to single-track segments. Furthermore, trackwork is likely to increase further as train traffic volume grows. This paper underlines the importance of improving the planning and performance of trackwork and minimising their conflicts with train operations.

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