Infrastructure's influence on rail punctuality

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Abstract

This paper focuses on the possibilities for root cause analyzes of delays and estimation of effects of delay-causing incidents by linking infrastructure data and operational data. Such information could be used to prioritize improvement and maintenance activities and to quantify the effects of improvement measures. We have analysed and compared data from two infrastructure databases and one punctuality database in Norway. Linking of data between the databases should theoretically and technically be possible but our analyses have shown that this is challenging. To make linking of information possible we recommend the railway industry to develop a general code-system for all three databases that directly ties the information together.
Keywords: punctuality, delay, railway, infrastructure, data quality, root cause identification.

1 Introduction

Punctuality is highly valued by railway customers and is claimed to be the number one factor determining railway service quality in most countries [1]. Hence, most railway companies set punctuality targets for their services. However, punctuality statistics show that the actual level of punctuality lies below the targets for many rail services (see for example [2]), and should thus be subject to improvement efforts. Veiseth and Bititci [3] have compared best practice of performance measurement with measurement of punctuality in Norway, Sweden and Scotland. They conclude there is need for more focus on processes and factors that influence punctuality in the improvement work. They also recommend the railway industry to link measurements of punctuality with other management and data systems to make the measurement system more balanced and complete.

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Traditionally, improvement work in the railway industry has been based on practical experience [4]. Such experience is valuable and necessary, but it is also important to base improvement work on facts and structured data analyses [5]. One of the most well-known models for quality improvement is the "Deming-circle" which consists of four steps: plan, do, check and act [6]. This model requires information about what causes the situation one seeks to improve and information about weather the chosen improvement measures actually give the expected and desired effects.

Norwegian punctuality statistics show that about 20- 30% of the total delay minutes are caused by infrastructure faults, which are distributed between three main categories: the track, the signal system, and the power supply system [7]. We assumed that by identifying root causes of infrastructure faults and estimating the effects of these faults, we would enable railway organisations to improve punctuality by systematically prioritizing improvement and maintenance activities. In Norway, these data are not readily available in one single database. Thus, we sought to improve data quality through linking of data from a punctuality database with corresponding information from two infrastructure databases. We here use a wide understanding of data quality that includes dimension of utility in the data for users. We expand on this connotation below.

The purpose of this paper is to present and discuss our approach to creating this link. We start with a discussion of punctuality and delay causes. Based on this we propose a way to improve quality of punctuality data by linking operational (punctuality) data and infrastructure data. To explore the opportunities for creating such a link we have analysed and compared data from three databases in the Norwegian railways: one punctuality database and two infrastructure databases. We have also discussed how the databases' design needs to be developed to achieve automatic linking of information between the data sources.

2 Punctuality and delay causes

In the railway industry, punctuality is a measure of the operations' reliability and performance. Rudnicki [8] defines punctuality as "that a predefined vehicle arrives, departs, or passes a predefined point at a predefined time". Thus, punctuality is related to delays which are the deviations between the actual and predefined departure or arrival time for a train [9].

Punctuality is usually measured as the percentage of trains that arrive on time at their final destinations. Trains are defined as not-punctual if they are delayed more than a predefined time limit. The size of the time limit typically varies between 1-30 minutes and depends on the type of trains (e.g. local trains, Inter City trains and freight trains). Trains' delay minutes/hours is another indicator related to punctuality. Causes of delays are usually registered manually according to a set of codes [3].

Rietveld et al [10] use the term unreliability when discussing deviations from the official timetable. They also list a number of different definitions of reliability (or punctuality) including: (1) the probability that a train arrives x minutes late, (2) the mean difference between the expected arrival and the scheduled arrival time and (3) the standard deviation of arrival times. Noland and Polak [11] use travel time variability as a measurement of the uncertainty of trip journey times in transportation, which for railway traffic include delays, early arrivals and cancellations. Their definition of variability is related to the distribution of arrival times for a train, not related to the scheduled arrival time. For example, if a train consistently arrives the same amount of minutes behind schedule every day, the variability is low, while the train from a conventional point of view would be considered as delayed and non-punctual.

Delays can be categorized as primary or secondary delays, used in the meaning that secondary delays are delays caused by other delayed trains, while primary delays are delays caused by direct influence on the train [12]. Gibson et al [13] use the term exogenous delays in the same meaning as primary delays, while their reactionary delays are similar to the term secondary delays, but with more emphasis on the interaction between different train operators. Similarly, Carey [14] distinguishes between exogenous delays and knock-on delays. Exogenous delays are here similar to primary delays in that they are due to events such as failure of infrastructure equipment and delays in passengers boarding or alighting. Knock-on delays are the equivalent of secondary delays and are due to exogenous delays and the interdependence in the schedule.

Data quality often refers to the extent to which data satisfy the users' requirements or are suitable for a given process [15]. Redman [16] defines data-quality as:

"Data are of high quality if they are fit for their indented uses in operations, decision making and planning. Data are fit for use if they are free of defects and possess desired features"

This definition emphasises that data quality is about data free of defects and that they should be suitable for its use. Based on this definition we conclude that punctuality data of good quality can be characterised by: (1) Data with little error and (2) Data that satisfies the users' needs.

2.1 Improvement of punctuality and use of punctuality data

When it comes to improvement of punctuality there are especially two sets of data which can be used for this purpose: registrations of delays and registrations of what causes the delays. In most countries there has been a development the last decades when it comes to the first set of data. More and more of the registrations are now collected automatically through the infrastructure signal systems and stored in databases. This has resulted in a larger volume and improved reliability of data.

The second set of data, the delay cause registrations, are registered manually. In several countries there is disagreement about the accuracy and completeness of these registrations [3, 17]. An important aspect is that the personnel that do the registration neither have full access to information about the root causes of the delays nor have they enough time to investigate the root causes closer, especially not in hectic periods. One result is that the cause category “miscellaneous” often is one of the largest in many punctuality statistics [2, 4].

2.2 Delay causes and infrastructure faults

Punctuality statistics show that infrastructure faults are a major source for delayed trains. Table 1 shows how the total amount of delay hours registered in Norway in 2005 are distributed between the three main cause categories: infrastructure, operators and miscellaneous and accidents. It shows that more than 4000 delay hours was caused by infrastructure conditions, which is about 30 % of the total amount of delay hours. This number can be split into five subcategories: track, signal (includes safety and communications systems), power supply, planned work and blocked tracks, as shown in Table 2. This paper focuses on infrastructure faults, and we define infrastructure faults as “faults related to the track, the signal, safety and communication system and the power supply system”.

Table 1: Delay hours registered in Norway in 2005 distributed on main cause categories (source: Jernbanverket [7]).

Cause category	Delay hours
Infrastructure	4118 hours
Operators	5280 hours
Miscellaneous and accidents	4728 hours

Table 2: Infrastructure related delay hours registered in Norway in 2005 distributed to cause categories (source: Jernbaneverket [7]).

Cause category	Delay hours
Track	552 hours
Signal	1911 hours
Power supply	624 hours
Planned work	753 hours
Blocked track	278 hours

3 Increase the quality of punctuality data by linking operational and infrastructure data

Different strategies can be followed to improve the quality of punctuality data. One could be to improve the accuracy of the delay causes registrations. Veiseth and Bititci [3] suggest that one way to achieve more accurate registrations could be to make the registration system more transparent, to motivate and train the people that record and register the information and to develop indicators that measure the quality of these data.

Another way to improve the quality of punctuality data could be to use additional data sources, e.g. put together information from different databases. The definition of data quality states that an important element is that the data should be suitable for its users [16]. Important users of punctuality data are personnel and projects that try to improve punctuality. We therefore argue that quality of punctuality data will increase if we manage to increase the possibilities of root-cause analyses and make estimation of the operational effects of these causes possible. Infrastructure databases include detailed information about reported delay-causing incidents and information about components and faults history. By linking this information with operational data from punctuality databases it should be possible to identify root causes of delays and to estimate effects of delay-causing incidents, as shown in Figure 1.

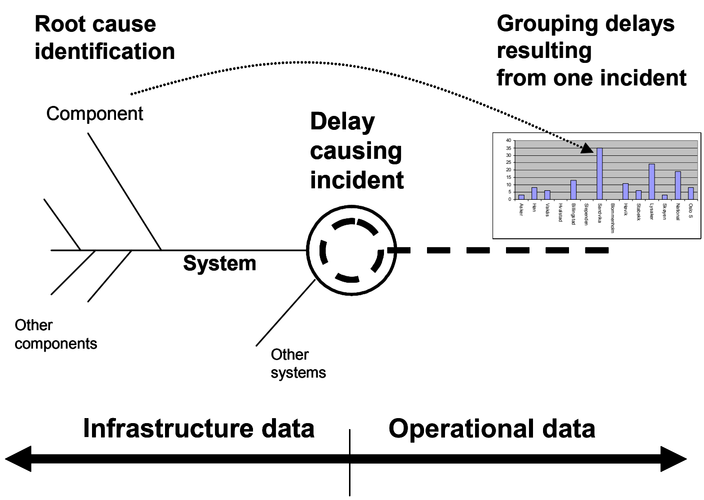

Figure 1: Root cause identification of delay-causing incidents and estimation of effects by linking infrastructure data and operational data.

In Norway, two databases are used to store information about infrastructure faults and one database is used to store punctuality data. The three databases and the type of information they contain are described below.

3.1 Punctuality database (TIOS)

TIOS means: “traffic-information and follow-up system”. TIOS collects information regarding delays at numerous locations along the lines and stores this in a database. The delays causes are manual registered directly into the database. The intention is that for all trains that become more than four minutes delayed between to registration points (e.g. between two station), the delays causes are registered by a set of codes. The following information can be found in TIOS regarding delay causes: Cause code, date, train number, station, cancelled (yes/no), delay minutes and comments.

3.2 Rail infrastructure data (Banedata)

Banedata is an extensive system for information regarding the infrastructure. It includes information about all equipments and components to support activities such as maintenance planning. It also includes information about incidents related to the infrastructure, for example infrastructure faults. All registered incidents are connected to specific equipment or components. Key-data from Banedata includes all registered faults distributed to the different lines. You also find information about whether the incident affected the train traffic. The following information can be found in Banedata related to delay causes: Description and classification of incident, object, location, time, period the incident affected the train traffic and action carried out.

3.3 Rail messages centre (BMS)

BMS contains systemized data of all reported messages of incidents regarding the infrastructure. The type of information in BMS is therefore similar to the data in Banedata, but because BMS does not have to attach the incidents to specific equipment or components, more incidents are registered here compared to Banedata. BMS also records whether the reported incidents affected the train traffic. The following information can be found in BMS which is related to delay causes: Description and classification of incident reported, type of object and responsible unit, location, time, affected the train traffic (yes/no), status and priority and action carried out.

4 Methods and findings

In our study we have explored avenues towards obtaining a data set that includes data on both root causes of infrastructure faults and estimates of effects of selected infrastructure faults. We have done this through two different approaches:

1. Explore possibilities for attributing delay-causing incidents to different lines and part of lines by using TIOS data.
2. Compared number of registrations and match of data from the three databases described above for specific lines and period of times.

Based on these efforts, we discuss possibilities for automatic linking of punctuality and infrastructure data in Norway.

4.1 Attributing delay-causing incidents to different lines and part of lines

Because TIOS contains information about where a delay has occurred represented by name of stations, it is possible to distribute the delay hours for a line to different parts of the line. The delays registered at a station means that the delay has occurred at the station or between the station and the previous measure point. For some of the registered delay causes it is possible, through the comment field in the TIOS data-base, to check if the delay-causing incidents are located at the same section of the line as where the delay is registered, or if it is located somewhere else.

We chose to explore possibilities for attributing delay-causing incidents to different lines and part of lines at three specific stations the Oslo – Asker line (one of the busiest railway sections in Norway): Høn, Oslo and Sandvika. Using data from the time period 01.06.2005 to 31.05.2006, we compared the number of delay causes registered at the given station with the number of these delay causes that for sure did not occurred at this station or between the station and the previous measure point. The result is presented in Table 3.

Table 3: Comparison between the number of delay causes registered at given stations and delay causes that for sure occurred other places. Data from 01.06.2005 to 31.05.2006 (source: TIOS database [18]).

Cause category	**Station**	**Delay causes registered (number)**	**Delay causes actually occurred other places (number)**
Signal	Høn	96	45
Track	Oslo	319	83
Power supply	Sandvika	92	47

Based on the results presented in table 3, we conclude that several of the delay causes registered at a specific station have not actually occurred at this station or between the station and the previously measure point. It is therefore not possible to only use data from the TIOS database to distribute delay causes to different sections of a line. For some of the registrations it is possible to find out where the delay cause occurred through the information in the comment field, but not for all. This is because a comment is missing for many of the registered delay causes and the comments that do exist do not always contain information about location. Furthermore, the comment-filed is text-based which means one has to go trough the data manually and make subjective judgments.

4.2 Number of registrations and match of data

To compare the number of registrations and match of data in the three databases we analysed data from one week, for two different railway lines: The Asker-Oslo line (local trains, Inter City and long distant trains) and the Bergen line from Hoenefoss to Bergen (long distant trains). By manually merging data from three databases based on location, time and delay causes we counted number of registrations and match of data.

In both cases, we did not find a good match of data in the three databases and we found a mismatch between numbers of registered faults in the two infrastructure databases. The results indicate that the registrations in BMS, and especially Banedata, are insufficient.

5 Discussion: automatic linking of information between the three databases

Linking information automatically between the three data sources should be possible because the data systems are meant to register information about the same incidents. In addition, all the three databases hold information about time and location and if the incidents affected the train traffic or not. It should therefore also be possible to link the information, technically. Yet, our analyses have demonstrated that this is challenging. There are especially two main-reasons for this:

The first reason is that delay causes registered in TIOS are not always registered at the location where they occurred but where the effect of the delay causes occurred (where the delay occurred). For some of the registrations it is possible through the comment field to check where the delay cause occurred. But this information is text based which means it is difficult to use it for automatic linking of information. Furthermore, many of the registered delay causes lack a descriptive comment and not all comments include information about location. The second reason is that the registrations in BMS, and especially Banedata, seem to be insufficient. Many of the delay causes registered in TIOS cannot be found in the two other databases, especially when it comes to delays caused by signal and track faults.

Registrations in the three databases are made for different purposes and this affects the possibilities for data analysis across the systems. Both of the infrastructure systems provide a time window from when a fault is registered, until it is repaired, and a location. TIOS, being a traffic operational system, is based on individual trains and train paths. For major infrastructure faults, most delays for trains passing a fault location in the time period the fault is present is likely to be derived from that particular incident. Allocating delays to different minor faults during a "normal bad day" requires a significant amount of manual work at best, and is not possible at worst. In all cases, grouping secondary delays together and assigning them to one particular primary delay must presently be done manually.

To achieve automatic linking, one possibility is to develop a general code-system for all three databases that directly ties the information together. It could be designed in such a way that each infrastructure fault reported in BMS was given a unique number, where the same number is used when the fault is registered in Banedata. If the personnel that do the registrations of delay causes in TIOS are given access to this information, they could use the same codes when they register the delay causes. In addition, the completeness of registrations in BMS and Banedata has to improve if linking of information should be possible.

6 Conclusion

This paper gives input to how it could be possible to identify root causes for delays, caused by infrastructure faults, and to estimate the effects of these faults by linking information from several data sources. In our study we have analysed data systems used in the Norwegian railways, but the findings may also be useful for railway industries in other countries, because most railway administrations maintain registrations of train delays as well as registrations of infrastructure faults. Linking of information between the punctuality database and the infrastructure databases should be possible, technically, but our analyses have demonstrated that this is challenging. This is due to that delay-causes registered in the punctuality database are not always registered at the location where they occurred but often where the effect of the delay-cause occurred. Another reason is that the registrations in the infrastructure databases seam to be insufficient. To achieve automatic linking of information between the data sources we recommend the railway industry to develop a general code-system for all three databases that directly ties the information together.

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