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Investigation of punctuality of local trains - the case of Oslo area

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Abstract

Norwegian railways experienced a steady decline in punctuality during the period 2007-2010. This paper briefly discusses the concept of train punctuality, influencing factors on punctuality, and investigates relationship between punctuality and weather factors on Norwegian railways by analysing data for the period 2007-2010. This study is particularly interested in data from the Oslo area, namely the section between Drammen and Eidsvoll, a stretch that has many travellers and affects all the train companies involved in the study. The analyses are based on data concerning punctuality and potential weather factors that are likely to influence punctuality. Data are studied on a weekly basis, and correlation and regression analyses are carried out. The results show that the influence of a harsh winter with extreme cold days on punctuality is strong and their correlation is statistically significant. The contribution of this paper lies within research on the empirical study of delay causes in the railway industry.

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Keywords: punctuality analysis; railway; influencing factors

1. Introduction

1.1. Punctuality

Punctuality is one of the main quality factors in the railways industry (Palmqvist et al. 2017, Parbo et al. 2013). A reliable service must be delivered in order to maintain the success and competitiveness of railway systems.

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Punctuality has a significant effect on the satisfaction of railway customers (Veiseth et al. 2011, Harris et al. 2016, Norheim and Ruud, 2011). Customers value the punctuality of railway services highly (Andersson, 2014, Coulombel and de Palma, 2014). They will revert to cars if the reliability of public transport, including the railways, is not satisfactory (Beirao and Cabral, 2007). Li et al. (2010) have found that travellers are keen to pay higher rates in exchange for more travel time punctuality.

According to Hansen (2001), punctuality is defined as the percentage of trains arriving or departing a specified point at a particular time. Olsson and Haugland (2004) define train punctuality as the associated deviation, majorly negative, from the defined timetable. In practice, this predefined time is different from country to country, and also for different types of transport services. In Norway, a train is considered punctual if it arrives at its destination with less than 4 minutes (3 minutes and 59 seconds) delay for local trains and less than 6 minutes (5 minutes and 59 seconds) delay for long distance trains.

1.2. Previous studies on influencing factors of delay and low punctuality

Olsson and Haugland (2004) performed a study on the Norwegian railways and found that the number of travellers, the load factor of the trains, and the departure punctuality were the factors with the strongest correlation to delays and punctuality. Jiang et al. (2010) studied the factors that may affect train punctuality for the Chinese high speed railways. They found that the main causes of train delays are attributed to locomotive/train factors, railway factors, and signal system factors. Ceder and Hassold (2015) studied the influencing factors for unreliability of the rail network in New Zealand. They identified that a heavy passenger load often causes increased dwell times, and is the main issue for delays in New Zealand.

There are few studies investigating the influence of weather factors on punctuality. Xia et al. (2013) highlighted how weather conditions such as snow, precipitation, wind and temperature can result in disturbances in infrastructure and affect performance of the train operator in the Dutch railway network. Ludvigsen and Klæboe (2014) described how 2010 winter weather caused very severe delays for rail transport in Norway, Sweden, Switzerland and Poland.

During the winter of 2009/2010, many problems occurred following the snowy and cold weather. Eleven countries experienced rolling stock problems ranging from coupler problem to trains picking up ballast which damaged underframe equipment. Amongst these countries, Norwegian trains experienced problems with the central coupling, heating, ventilation, and air conditioning systems and toilets freezing (Enno Wiebe, 2010). A problem often encountered by Norwegian freight operators is the wheel wearing during winter. For example, more than 2,000 wheels had to be reprofiled during winter 2010/2011 which represents more than one-fourth of all wheels. The reason why the wheels are wearing faster is the low temperature which increases the tensile stress on the steel. Sweden also experienced severe problems in 2009/2010 with an increase of 150% in cancelled trains. One of the major problems was the 30 tonne ice build-ups on the overhead wire from Göteborg to Stockholm (Enno Wiebe, 2010). The delays were double those of a normal winter, estimated to have a socio-economic cost of SEK 3 billion. An estimated investment of SEK 410 to 450 million would have decreased half of the delay, bringing it back to a normal winter situation (Szafránski, 2011, Andersson, 2010).

1.3. Norwegian railways and Variation in weather and punctuality: 2007-2010

It is important to study the Oslo area for rail traffic because a large number of trains transporting the majority of travellers run through the Oslo area, and the train traffic in most parts of the country are influenced by train traffic in the Oslo area. Several analyses focus on the section between Drammen and Eidsvoll, a line that has high number of trains and travellers and that affects all the train companies that are involved in the study. The line passes through Oslo airport Gardermoen and Oslo central station.

Fig. 1. (a) shows the average weekly punctuality allocated to local trains (operators NSB and Airport express trains) on Norwegian railways for the section between Drammen and Eidsvoll over the period 2007-2010. Fig. 1. (b) displays the number of days in a week with low temperature and Fig. 1. (c) shows the number of days in a week with high snowfall for for the period 2007 to 2010. As shown in Fig. 1. (a), there is a significant drop in the percentage of punctuality during the winters of 2007, 2009, and 2010, while the same pattern is not followed in 2008. The winter of 2010 is noticeable as having the largest decrease in punctuality compared to the other years.

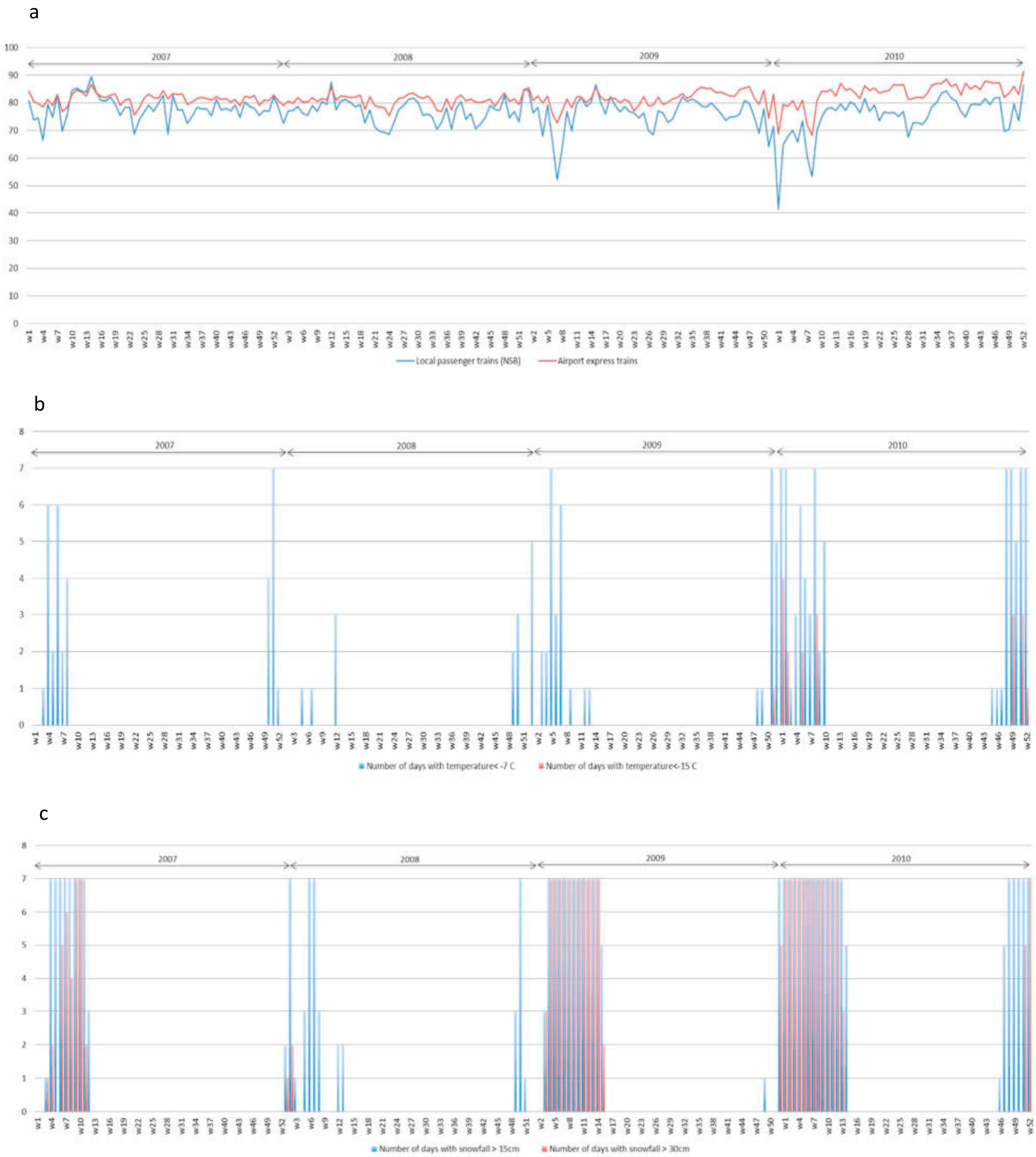

Fig. 1. (a) Punctuality per week for the Norwegian railway (section between Drammen and Eidsvoll) from 2007 to 2010; (b) Number of days with low temperature per week for Asker station (between Drammen and Eidsvoll) from 2007 to 2010; (c) Number of days with high snowfall per week for Asker weather station (between Drammen and Eidsvoll) from 2007 to 2010.

The simultaneous occurrence of a high number of extreme cold days, and low punctuality performance in some winters, may be an indication of the existence of a relationship between low temperature and low punctuality.

The main aim of this article is to investigate the effect of weather conditions on the performance of the Norwegian railway system.

2. Data

The data for this study were collected for the lines Drammen-Eidsvoll. The travel time for regional trains from Drammen to Oslo Central Station is 36 minutes, while the travel time from Oslo to Eidsvoll is 34 minutes. The majority of the line is on crowded double track (where formal capacity use is above 100% during peak hours). Data were studied on a weekly basis, and regression and correlation analyses were carried out.

The data used for the analyses can be categorized as:

- Aggregated punctuality or total number of arrival punctuality. This is a collocated measurement that shows the overall quality of the railway system delivery.
- Weather factors that may affect train traffic.

The analyses are based on data assumed to be relevant for delay and low punctuality, together with causes and potential explanatory factors. The punctuality data have been placed against the weather variables (explanatory factors) to uncover correlations and causes.

Table 1 illustrates the variables that are used for the analyses. The variables were selected due to their proven effect on punctuality (based on previous studies) as well as data availability. In this study punctuality is considered as a dependent variable and the assumed drivers of low punctuality (weather factors) are treated as independent variables.

Table 1. Overview of variables, punctuality and weather

Variable	Indicator name	Description of indicator	Unit	Data source
Punctuality	Local passenger train (NSB)	Weekly punctuality for local passenger trains	Percentage of trains arriving on time at final destination	Arrival time registrations
	Airport express train	Weekly punctuality for local passenger trains	Percentage of trains arriving on time at airport	Arrival time registrations
Weather	Temperature (< −7°C)	Days with temperature below −7 °C during one week	Number of days	Weather data
	Temperature (< −15°C)	Days with temperature below −15°C during one week	Number of days	Weather data
	Snow depth (> 15 cm)	Days with snow depth above 15 cm during one week	Number of days	Weather data
	Snow depth (> 30 cm)	Days with snow depth above 30 cm during one week	Number of days	Weather data

3. Results and discussion

We based our analyses on recognized statistical methods, primarily correlation and regression analyses, as shown in the following tables. We calculated the correlation coefficients (Pearson product-moment correlation coefficients) between the performance of the railway system expressed by punctuality and assumed drivers of low punctuality for the years 2007, 2008, 2009, and 2010. In the following, we will present the descriptive results for their relationships. It is expected that the drivers of low punctuality result in a reduction of the number of trains that arrive on time at their final destination, so punctuality and the drivers of low punctuality are expected to be related by negative correlation coefficients.

The relationship between punctuality and the number of days with a temperature below −7°C has been analysed. We found a correlation of −0.42 and −0.25 (significant at 0.000) for the local passenger and airport express trains, respectively. The correlation coefficient for each year separately was also calculated. For local passenger trains, we found correlation coefficients of −0.32 (significant at 0.02) for 2007, 0.21 (not significant (ns)) for 2008, −0.4 (significant at 0.000) for 2009, and −0.55 (significant at 0.000) for 2010. As shown in Table 2, a similar pattern of results with slightly different correlation coefficients was obtained for the airport express trains.

There is no week in winter 2007 and 2008, and only one week in 2009, with extremely low temperatures (below −15°C), while winter 2010 experienced 7 weeks with extreme cold temperature. Therefore, the correlation between low punctuality and number of days with temperatures below −15°C was only calculated for 2010. We found a correlation of −0.66 and −0.56 (significant at 0.000) for the local passenger and airport express trains, respectively. Results indicate that punctuality correlates very closely with the number of extreme cold days (temperature below −15°C) such that punctuality is reduced as the number of cold days increases.

In a similar way as the relationship between punctuality and number of days with low temperature was analysed, the correlation between punctuality and number of days with snow depth above 15 cm was calculated. A correlation (significant at 0.000) of −0.37 was found for local passenger trains for the whole period (2007 to 2010). Having calculated the correlation for each year separately, we found that the correlation was not statistically significant for the years 2007 (r=−0.05, ns) and 2008 (r=−0.02, ns). In 2009 and 2010, we obtained a partial correlation coefficient of −0.28 (significant at 0.04) and −0.46 (significant at 0.000), respectively. A similar pattern of results with slightly different correlation coefficients was found for the airport express trains.

Table 2. Pearson product-moment correlation coefficients (Pearson's r) between punctuality and considered weather factors. Correlation is significant at the 0.01 level or less for factors in bold font (two-tailed) and between 0.01 and 0.05 level (two-tailed) for factors in italic font. Coefficients not significant at the 0.05 level are marked in regular font.

		Temperature (< −7°C)	Temperature (< −15°C)	Snow depth (> 15 cm)	Snow depth (> 30 cm)
NSB	2007-2010	**−0.42**	**−0.46**	**−0.32**	**−0.37**
	2007	−0.32	-	−0.05	−0.02
	2008	0.21	-	−0.02	−0.1
	2009	**−0.4**	-	*−0.28*	*−0.3*
	2010	**−0.55**	**−0.66**	**−0.46**	**−0.53**
Airport Express	2007-2010	**−0.25**	**−0.28**	**−0.2**	**−0.3**
	2007	*−0.31*	-	0.16	−0.18
	2008	−0.24	-	−0.15	−0.12
	2009	**−0.34**	-	0.03	**−0.34**
	2010	**−0.47**	**−0.56**	**−0.46**	**−0.56**

Similarly, the relationship between punctuality and number of days with snow depth above 30 cm was analysed for the whole period (2007 to 2010). We found a significant correlation (significant at 0.000) of −0.37 and −0.3 for the local passenger and airport express trains, respectively. For both local passenger and airport express trains the correlation coefficients for the years 2007 and 2008 appeared to be small and not statistically significant. In 2009, we obtained a partial correlation coefficient of −0.3 (significant at 0.02) and −0.34 (significant at 0.01) for local passenger and airport express trains, respectively. In 2010, we found that punctuality and number of days (snow depth above 30 cm) were significantly correlated for both local passenger (r= 0.53, significant at 0.000) and airport express trains (r= 0.56, significant at 0.000).

To further study the relationship between punctuality (dependent variable) and assumed drivers of low punctuality (independent variables), regression models were developed for the overall period 2007-2010 and the year 2010.

Weather indicators, such as number of days with temperature less than −15°C and number of days with snow depth above 30 cm, which were found to have the strongest relationship with punctuality (according to correlation analysis) were selected to be used in the regression model. Table 3 summarizes results using multiple linear regression analysis.

The regression model of punctuality attributed to local passenger trains resulted in a significant correlation (regression fit) of 0.28 for the period 2007-2010. The fit of the regression models for airport express trains is slightly lower than that of the airport express trains (R^2 of 0.13).

The new regression model applying the identical set of independent variables for the year 2010 resulted in significant fits of 0.51 and 0.44 for local passenger and airport express trains, respectively. It was observed that low temperatures (number of days colder than −15°C and number of days with snow depth more than 30 cm) were significant in all models.

Table 3. Regression models for punctuality. Variables statistically significant at the 0,01-level are marked by a triple asterisk (***), variables statistically significant at the 0.05-level marked by a double asterisk (**).

		Constant	Weather		R^2 of model
			Temperature (< −15°C)	Snow depth (> 30 cm)	
Local passenger trains	2007-2010	77.4980 ***	−4.6632 ***	−0.5725 **	0.28
	2010	77.9930 ***	−4.3213 ***	−0.7536 **	0.51
Airport express trains	2007-2010	82.29391 ***	−1.46 ***	−0.278 **	0.13
	2010	85.2515 ***	−1.82 ***	−0.5609 **	0.44

The correlation and regression results in this study confirmed that punctuality has been negatively influenced during cold winters, as was the case for the winters of 2007, 2009, and 2010, while the punctuality during the winter of 2008 was not affected since it was a mild winter. This paper also found that there is a stronger correlation between weather factors and low punctuality during harsh winters with extreme cold days (temperature below −15°C and snow depth above 30 cm) compared to normal winters. It was also found that the relationship between low temperature and punctuality correlates to a higher degree than the relationship between snow depth and punctuality.

Considering extreme cold winters which have temperatures below −15°C or snow depth above 30 cm, we found the year 2010 (which had 7 weeks with average temperature > −15°C and 14 weeks with snow depth > 30 cm) was the coldest winter in the period 2007-2010. Based on the regression results in this study, we found that cold weather explains 51% of the variation in punctuality in 2010.

It is important to note that besides weather factors, there are other important factors that can influence the punctuality of trains. Since the occurrence of extreme weather is inevitable and railway systems are sensitive to weather conditions, the success and performance of train operators can be affected by harsh weather. It is necessary for operators in the railways industry to be aware of weather forecasts for extreme weather conditions, have an overall view of the situation, and put the required preparations into practice in order to tackle the negative influence of harsh weather conditions and prevent significant loss of punctuality. Possible actions might include frequent removal of snow and ice from the railway network, using electric heating for switches and crossings, and considering extra capacity for infrastructure managers to replace broken units and maintain the track, which is more vulnerable in cold temperature (Ludvigsen and Klaboe, 2014, Szafránski, 2011).

4. Conclusion

In this study, we investigated the relationship between weather factors (temperature and snow depth) and the punctuality of trains in the Oslo area. The correlation and regression results indicate that the influence of a harsh winter, with extreme cold days (with temperature below −15°C and snow depth above 30 cm), on punctuality is strong and they are significantly correlated. Therefore, it can be concluded that a severe winter is a key driver for low punctuality. It has been widely assumed that weather variables have a large impact on low punctuality, but this has been documented to a lesser extent scientifically.

For the further development of this research, we suggest investigating the relationship between weather and the accumulation of delay (referred to as the delay hour) which is also a measure of the quality of train services.

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References

Andersson, E., 2014. An economic evaluation of the Swedish prioritisation rule for conflict resolution in train traffic management. ProcediaSocial and Behavioral Sciences, 111, pp.634-644.

Andersson, T. (2010, June 15). Utredning Järnväg Vinter. Retrieved May 26, 2011, from Situationen för järnvägen under vintern 2009/10 - Trafikverket: http://www.trafikverket.se/PageFiles/32231/20100615_Utredning_jarnvag_vint er.pdf

Beirão, G. and Cabral, J.S., 2007. Understanding attitudes towards public transport and private car: A qualitative study. Transport policy, 14(6), pp.478-489.

Ceder, A.A. and Hassold, S., 2015. Applied analysis for improving rail-network operations. Journal of Rail Transport Planning & Management, 5(2), pp.50-63.

Coulombel, N. and De Palma, A., 2014. Variability of travel time, congestion, and the cost of travel. Mathematical Population Studies, 21(4), pp.220-242.

Jiang, W., Chen, X. and Zhong, Z., 2010. The impact of quality of services in Chinese train control system on train delays analysis. In Vehicular Technology Conference Fall (VTC 2010-Fall), 2010 IEEE 72nd (pp. 1-5). IEEE.

Enno Wiebe, L. F. (2010, October 20). Factsheet Snow and Ice. Retrieved April 21, 2011, from UIC Information Platform "Winter and Railways": http://www.uic.org/forms/IMG/pdf/001_factsheet_snow_and_ice.pdf

Hansen, I.A., 2001. Improving railway punctuality by automatic piloting. In Intelligent Transportation Systems, 2001. Proceedings. 2001 IEEE (pp. 792-797). IEEE.

Harris, N., Haugland, H., Olsson, N. and Veiseth, M. (2016), An introduction to Railway Operations Planning. London: A & N Harris.

Li, Z., Hensher, D.A. and Rose, J.M., 2010. Willingness to pay for travel time reliability in passenger transport: a review and some new empirical evidence. Transportation Research Part E: Logistics and Transportation Review, 46(3), pp.384-403.

Ludvigsen, J. and Klæboe, R., 2014. Extreme weather impacts on freight railways in Europe. Natural hazards, 70(1), pp.767-787.

Norheim, B., Ruud, A., 2011. The underestimated demand for public transport? Association For European Transport and Contributors 2011.

Olsson, N.O. and Haugland, H., 2004. Influencing factors on train punctuality—results from some Norwegian studies. Transport policy, 11(4), pp.387-397.

Palmqvist, C.W. Olsson, N.O.E, Hiselius, L (2017) et al., Delays for passenger trains on a regional railway line in southern Sweden. Int. J. Transp. Dev. Integr., 1(3), pp 421–431

Parbo, J., Nielsen, O.A., Landex, A. and Prato, C.G. (2013), Measuring Robustness, Reliability and punctuality within passenger railway transportation – a literature review, KGS Lyngby, Denmark: Technical University of Denmark.

Szafránski, Z. (2011, March 9), Winter and Railways - Study. Retrieved May 3, 2011, from UIC: http://www.uic.org/forms/IMG/pdf/500_uic_siafi_report__winter_and_railways .pdf

Veiseth, M., Hegglund, P.M., Wien, I., Olsson, N.O.E, Stokland, Ø (2011). Development of a punctuality improvement method. The TQM Journal;Vol. 23.(3) s. 268-283

Xia, Y., Van Ommeren, J.N., Rietveld, P. and Verhagen, W., 2013. Railway infrastructure disturbances and train operator performance: The role of weather. Transportation research part D: transport and environment, 18, pp.97-102.