Analysis of Driving Performance Data Considering the Characteristics of Railway Stations

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Abstract. Here, we aim to investigate the relationship between characteristics of railway stations and errors in train stop positions. Hence, two kinds of logistic regression analysis were conducted with two different objective variables: train stations with or without the occurrence of delays in braking manipulations and stations with or without the occurrence of misrecognition of stop positions. The explanatory variables included velocities near stations, braking manipulations, and features of the stations. Logistic regression analysis revealed that the delay in braking manipulations was significantly associated with the ratio of the maximum brake notch and the mean of velocities at 200 m before train stops. The delay in braking manipulations occurred frequently at stations where the train velocities when approaching the stations were high and the maximum brake notch was frequently used. Logistic regression analysis further revealed that the misrecognition of stop positions was significantly associated with the existence of a stop sign for four or six vehicles and where there were many stopping velocity patterns. A stop sign before a stop position and decreasing train velocity for a caution signal caused the misrecognition of stop positions.

Keywords: Driving performance data · Characteristics of railway stations · Delay in braking manipulations · Misrecognition of stop positions · Logistic regression analysis

1 Introduction

Driving performance data from railway vehicles are often saved in data-recording devices. These data can be used to analyze accidents, prevent human error, and improve crew skills. In addition, several studies have been conducted with data describing the driving performance of railway drivers.

Sakashita et al. [1] analyzed more than 20 elements of driving performance data from approximately 100 drivers recorded over six months. Their study used the following evaluation indices related to braking operations for stopping a train at a station: (1) duration of strong braking (seven notches) used when stopping, (2) number of

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additional brakes stronger than three notches used when stopping, (3) amount of brake notch changes used when stopping, (4) number of times the coasting position was used when stopping, and (5) train speeds at a fixed point (five seconds before the train stops). It was demonstrated that the use of strong braking (1) and many brake notch changes (3) strongly influenced whether the drivers experienced train position errors when stopping at stations. Moreover, it was found that the train speed at a fixed point five seconds before the train stopped varied widely prior to the occurrence of an error. Marumo et al. [2] analyzed braking manipulations of railway drivers in a driving simulator to estimate the mental conditions of the drivers. The results showed that the relationship between the velocity deviation and the braking manipulations is an appropriate indicator of abnormal driving behavior. In another study, Marumo et al. [3] analyzed braking manipulations when stopping at stations and found that simultaneously performing secondary tasks was associated with significantly greater variance in operation of the brake handle. We also previously analyzed driving performance data to investigate how brake manipulations are related to train stop position errors at a station [4]. In our previous logistic regression analysis, the objective variable was whether or not the railway drivers had experienced train stop position errors.

Despite these studies of factors influencing the driving performance of railway drivers, the relationship between characteristics of railway stations and the occurrence of train stop position errors at stations has not been studied in depth. Therefore, the aim of this study is to investigate how railway station characteristics are related to the train stop position errors.

2 Methods

2.1 Analysis Data

Data concerning driving operations (i.e., distance, velocity, and brake notches) when stopping at railway stations were extracted from driving performance data recorded by railway vehicles in Japan over three years. The sampling rate was 1 Hz, and the number of stops at 81 total stations was approximately 1.3 million. A total of 118 railway drivers aged 25 to 61 years (mean age, 33 years; standard deviation (SD), nine years) participated in the current study. The driving experience of the participants ranged from 0 to 29 years (mean, seven years; SD, seven years).

2.2 Classification of Train Stop Position Errors

Eighty-nine train stop position errors at stations were analyzed. The reasons for the errors were divided into two factors: a delay in braking manipulations or a misrecognition of stop positions. The number of delays in braking manipulations was 29, and the number of misrecognitions of stop positions was 60.

2.3 Evaluation Indices and Analysis Method

Evaluation indices for railway station characteristics were the number of stop signs; the existence of stop signs for four vehicles, six vehicles, eight vehicles, or ten vehicles; the number of stopping velocity patterns; and the slopes near stations. In reference to the previous study [1], evaluation indices for driving performance data at each station were as follows: train velocity of 20 m before the train stop, train velocity of 200 m before the train stop, the ratio of using maximum brake notches, the ratio of using additional brake notches, and the number of switching brake notches.

A logistic regression analysis was conducted to identify the influence of the characteristics of railway stations on the occurrence of a train stop position error at a station. Two kinds of objective variables were analyzed: stations with or without the occurrence of delays in braking manipulations and stations with or without the occurrence of misrecognitions of stop positions. The explanatory variables included the station characteristics evaluation indices and the driving performance data at each station.

3 Results

3.1 Delays in Braking Manipulations

Table 1 shows the results of the logistic regression analysis; the objective variable was a station with or without the occurrence of a delay in braking manipulations. Variance-inflation factors (VIFs) were calculated to evaluate the multicollinearity of this study. Generally, a possibility of multicollinearity exists if the maximum VIF is above 10 or the average VIF is considerably more than one [5]. In this case, the maximum VIF among the explanatory variables used in this study was 1.35; thus, it was concluded that multicollinearity was not an issue for this analysis.

A p value < 0.05 indicates that the occurrence of a train stop position error at a railway station is significantly associated with the explanatory variable. The occurrence of delays in braking manipulations was significantly associated with the ratio of using maximum brake notches and mean of velocities at 200 m before the train stop.

Furthermore, evaluating the odds ratios revealed that when other variables do not change, the possibility of delays in braking manipulations increases by 7.62 times when the ratio of using maximum brake notches increases by 1%; similarly, it increases by 1.32 times when the mean of velocities at 200 m before the train stop increases by 1 km/h.

Standardized partial regression coefficients were determined as shown in Table 1. The absolute value of the standardized partial regression coefficient was directly proportional to the influence of the explanatory variable. Thus, the mean of velocities at 200 m before the train stop influenced the possibility of delays in braking manipulations more strongly.

Table 1. Logistic regression analysis with delays in braking manipulations as the objective variable

Explanatory variables	Standardized partial regression coefficient	Odds ratio	*p* value
Ratio of using maximum brake notch	0.78	7.62	$p < 0.05$
Mean of velocities at 200 m before the train stop	1.30	1.32	$p < 0.05$

3.2 Misrecognitions of Stop Positions

Table 2 shows the results of the logistic regression analysis with the objective variable as a station with or without the occurrence of misrecognition of stop positions. In this case, the maximum VIF among the explanatory variables used in this study was 1.97; thus, it was concluded that multicollinearity was not an issue for this analysis.

The *p* values revealed that the occurrence of misrecognitions of stop positions was significantly associated with the existence of a stop sign for four or six vehicles and with the number of stopping velocity patterns.

Furthermore, evaluating the odds ratios revealed that when other variables do not change, the possibility of misrecognitions of stop positions increases by 8.50 times when a stop sign for four vehicles exists and 3.88 times with a stop sign for six vehicles. Moreover, when other variables remain unchanged, the possibility of misrecognitions of stop positions increases by 2.09 times when the number of stopping velocity patterns increases by one pattern.

Standardized partial regression coefficients revealed that among these three variables, the existence of a stop sign for four vehicles had the largest influence on the possibility of misrecognitions of stop positions.

Table 2. Logistic regression analysis with misrecognitions of stop positions as the objective variable

Explanatory variables	Standardized partial regression coefficient	Odds ratio	*p* value
Existence of a stop sign for four vehicles	1.06	8.50	$p < 0.05$
Existence of a stop sign for six vehicles	0.68	3.88	$p < 0.05$
Number of stopping velocity patterns	0.53	2.09	$p < 0.05$

4 Discussion

Logistic regression analysis performed herein revealed that the delays in braking manipulations were significantly associated with the ratio of maximum brake notch and the mean of velocities at 200 m before the train stop. Delays in braking manipulations occurred frequently at stations where the train velocities approaching the stations were high and the maximum brake notch was frequently used. In hearings after delays in braking manipulations occurred, several railway drivers stated that when they braked, the velocity did not decrease as they expected. High velocities at 200 m before the train stop required strong braking to stop the train at the stop position. It is thought that when the velocity at 200 m before the train stop is high and the braking effect is weak, a delay in braking manipulations occurs.

The misrecognitions of stop positions were significantly associated with the existence of a stop sign for four or six vehicles and the number of stopping velocity patterns. In hearings after misrecognitions of stop positions occurred, several railway drivers stated that they mistakenly stopped at the nearest stop sign because passengers lined up at the stop sign for four or six vehicles. If drivers drove railway vehicles more than six, they have to stop trains at more far stop sign. It is therefore possible that a stop sign before a stop position causes the misrecognitions of stop positions. In the same hearings, several railway drivers stated that they misrecognized stop positions because they decreased train velocity for a caution signal aspect and released the brake. Releasing the brake confused drivers to stop trains near or far. Thus, velocity slowing patterns may contribute to the misrecognitions of stop positions.

It is thought that picking up stations that require special attention and sharing them with drivers decreases the possibility of train stop position errors. Further study is required to examine the influence of differences in the features of adjacent stations.

5 Conclusion

In this study, logistic regression analysis on train stop position error was conducted to investigate the relationship between characteristics of railway stations and train stop position errors at stations. Two kinds of objective variables were analyzed: stations with or without the occurrence of delays in braking manipulations and stations with or without the occurrence of misrecognitions of stop positions. The occurrence of delays in braking manipulations was significantly associated with the ratio of using maximum brake notch and mean of velocities at 200 m before the train stop. Delays in braking manipulations occurred frequently at stations where the train velocities approaching the stations were high and the maximum brake notch was frequently used. The occurrence of the misrecognitions of stop positions was significantly associated with the existence of a stop sign for four or six vehicles and the number of stopping velocity patterns. A stop sign before a stop position and decreasing train velocity for a caution signal aspect caused the misrecognitions of stop positions.

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