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Risk assessment model for railway passengers on crowded platforms

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Abstract

The purpose of this study is to develop a risk assessment measure allowing us to understand the safety of railway station platforms. We estimated the number of accidents on a platform, which is influenced by the design, equipment, and users of a station. Sixteen factors were defined, such as the platform design and passenger movement. A Poisson regression model was estimated from an accident and station database containing 142 platforms from 47 stations in Japan. The results show that the number of accidents is related to the length of the narrow part of a platform, the width of the gap between the platform and train, platform curving, passenger flow crossing, number of trains passing and stopping, and audio and visual announcements concerning approaching trains. We expect that this result will allow railway companies to identify weaknesses in station safety and set priorities for investments in safety. Furthermore, administrative authorities can evaluate the safety performances of railway companies, and consider subsidies for investments in safety.

Keywords: Platform accident; Poisson regression; Urban passengers rail; Platform design

1. Introduction

Rail is safer than many other methods of transport. However, passengers on train platforms sometimes face risks of colliding with a moving train. Passengers who wish to move around a crowded platform may be fearful when they have to walk close to the platform edge. Many railway companies have been attempting to decrease the number of passengers walking on platform edges. However, so far their efforts have not succeeded at crowded urban stations (Fig. 1).

According to a transportation safety white paper (Cabinet Office (2012)), in 2011 there were 431 accidents that involved a person being struck by a train in Japan, and these accidents resulted in 196 deaths. Of those 431 accidents, 208 (resulting in 29 fatalities) involved falls from a platform and subsequent injury or death as a result of collision with a train. Therefore, to evaluate the safety and security of the Japanese railway system, it is necessary to focus our attention on stations. Specifically, we should examine station design (platform width, platform shape, presence of narrow parts, etc.), station equipment (automatic platform gates, warning devices for approaching trains, etc.),

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train operation (operation frequency, train speed, etc.) and users (crowding, passenger movement and behavior, etc.). These factors are related to falls from the platform onto the track. Even if they do not result in an accident, such falls cause fear and anxiety for the people involved.

We should invest in passenger safety by installing platform gates and other devices to alert them to approaching trains. However, investing in these devices involves considerably costs. Because it is worthwhile for railway companies to understand the priorities for investment considering risks on the platform, the purpose of this study is to provide a risk assessment that allows a comparison among locations on a railway platform by estimating the number of passengers walking near the platform edge. Thus, safety investments for each platform in a station can be prioritized.

Fig. 1. Crowded urban platforms.

The UK Rail Safety and Standards Board (RSSB) released a guidance document that aids railway companies in identifying safety performance indicators (SPIs) that reveal the most appropriate operations for them and ensure their continued effectiveness. It provides an overview and background for the SPIs, and also detailed step-by-step guidance on how to develop and manage SPIs. However, the document does not set out to prescribe SPIs (Rail Safety and Standards Board, 2011). Fielding (1992) examined three programs, including federal triennial reviews that monitor compliance with planning and grant requirements. However, safety was one of the seven considered dimensions, and was not discussed in detail. Kecklund et al. (2001) also discussed safety issues, focusing particularly on the working environment for train drivers. Nelson et al. (2012) mentioned the safety of level boarding. Most commuter railways in Japan enable passengers to board trains at the same level as the platform, without a stairway. Some articles, including the Transit Cooperative Research Program (2013), Cothen et al. (2015), and Muttram (2003), have already discussed rail safety. However, these were related to regulatory procedures and policy issues. Tennyson (1998) analyzed data from the National Transit Database from 1993 to 1995, to review the relative safety of rail. According to this work, automated guideways lead to no grade-crossing accidents, but lead to a higher rate of station accidents. Light rail has less formal stations, so it would have fewer recorded station accidents. Commuter rail involves many more kilometers per passenger, which can reduce the frequency of station accidents per passenger-kilometer.

2. Data

2.1. Platform accident database

An anonymous railway company provided data on a total of 352 platform accidents for one year on all the company lines. This database contains the items shown in Table 1. These are the accidents reported by the station staff on platforms. The accidents are classified into four types: falling, falling into gaps, missteps, and others. Falling is defined as passengers falling from the platform onto the railway surface when there is no train, whereas falling into gaps is defined as passengers falling into the gap between the train and the platform. Missteps means that passengers step off the platform edge or their feet slip when boarding or alighting from a train. Other types of accidents include touching a running train.

Table 1. Available items from platform accident database

Group	Item
When	Date, Day of the week, Time
Where	Line, Station, Platform number, Train number, Door number, Gap
What	Types of accidents: Falling, Falling gaps, Missteps, and Others.
Who	Gender, Age, Visually impaired, Wheelchair, Other disability
Why	Drunken, Sickness, Smartphone use, Reading book, Trouble with other passenger

2.2. Summary of accidents

Fig. 2 shows the number of accidents classified by accident type and summarized by month. The total number of accidents decreases in the summer, and is highest in October followed by December. Although there are variations depending on month, most accidents occurs because of missteps, followed by falling. The occurrences of falling into gaps and others are relatively lower. When we examine at the classification of accident types in October, we can see that only missteps have been reported considerably more than in other months. Prior to aggregating the data, we predicted that there would be many accidents in December owing to the year-end party season and in April at the beginning of the new fiscal year. In December, passengers can be under the influence of alcohol owing to the many year-end parties. In April, many new passengers are unfamiliar with railways because many people begin to commute to new companies and schools. However, although the number of accidents in December is high it is not the highest. We discussed with the railway company why many missteps are reported in October, but the reason is unclear.

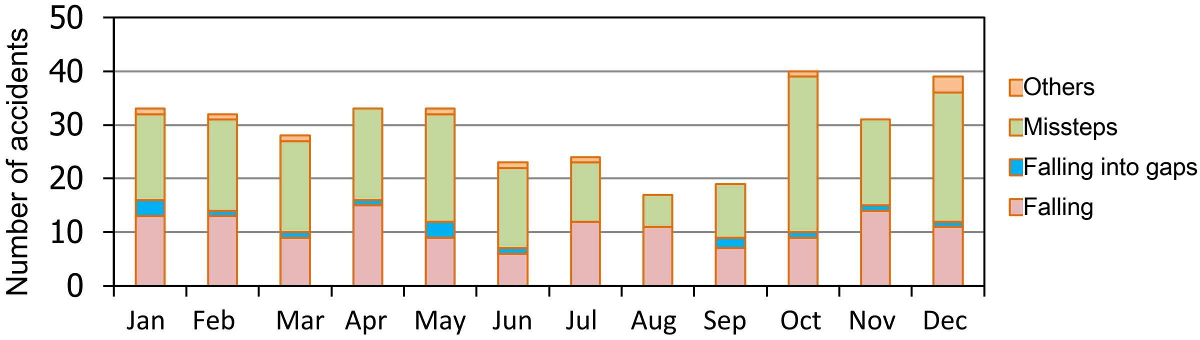

Fig. 2. Number of accidents classified by type and month.

Accidents classified by type and summarized by the day of the week are presented in Fig. 3. The number of accidents is highest on Friday, followed by Monday. Falling accidents occur frequently on Fridays, Saturdays, and Sundays. The total number of cases is small on Sunday, but the number of falling accidents is higher than on weekdays. This is caused by passengers being inebriated rather than falling because of crowds caused by a commuting rush. Misstep accidents occur frequently on Mondays and Fridays, but not on Saturdays and Sundays. Crowded trains and platforms cause passengers to step off platform edges or to slip when boarding or alighting from trains.

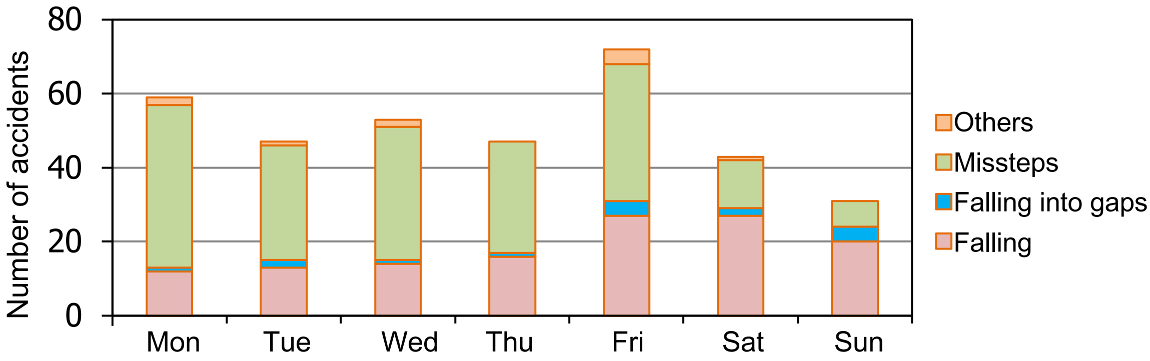

Fig. 3. Number of accidents classified by day of the week.

3. Risk assessment model for rail passengers on crowded platforms

3.1. Modeling the number of passenger accidents

Although the number of accidents on the platform appears to be strongly correlated with the number of passengers, there are other factors concerning type of platform. It is very interesting to model the relationship between the number of accidents and the platform characteristics. We carried out our own on-site survey to collect such characteristics, and estimated a model to predict the number of accidents using platform factors. The model shows which factors of a platform increase the risk. Furthermore, railway companies can evaluate the extent to which risk is reduced when they improve their platforms. Thus, this model is useful for enhancing platform safety.

3.2. Selection of evaluation factors

a) Focusing on platform safety

This research focused on safety in cases of accidental falling, missteps of passengers from platforms, and minor collisions between trains and passengers on station platforms. Evaluation factors were applied from a list presented in a previous study, Yamada et al. (2014). It is necessary to keep in mind that there is a significant risk around stairs and escalators. Passengers may fall on stairs or get their shoe stuck on an escalator. If stairs and escalators are crowded, then the problems will increase. However, we do not consider that factor in this article, because accidents related to stairs and escalators are not directly related to trains. This must be examined separately as a problem of pedestrian behavior or mechanical risks rather than platform safety.

b) Selection of evaluation factors

Accidental falls from the platform and minor collisions between trains and passengers on platforms are likely to occur under several conditions that depend on the design and environment of a platform and the passenger profile. From the list of all common evaluation factors presented in the previous research, we selected several factors considering their contributions to platform safety.

An emphasis was placed on the selection of evaluation factors that facilitate and simplify the evaluation procedure for railway companies. This was achieved through a discussion with railway companies and general passengers. The principles of selection were to allow evaluation in a quantitative manner, to use observable items from on-site surveys or existing statistics, to collect the data easily, to manage the number of factors, and to help in comparing one station to others. We concluded that there were four major factors, comprising the platform design, passenger flow, train operation, and passenger profile. Each major factor encompasses between three and five minor factors (Fig. 4). The categorization based on the concepts and evaluation factors was presented in the previous section.

Major factors	Minor factors
Platform structure	(1)-(5)
Passenger flow	(6)-(9)
Train operation	(10)-(13)
Passenger profile	(14)-(16)

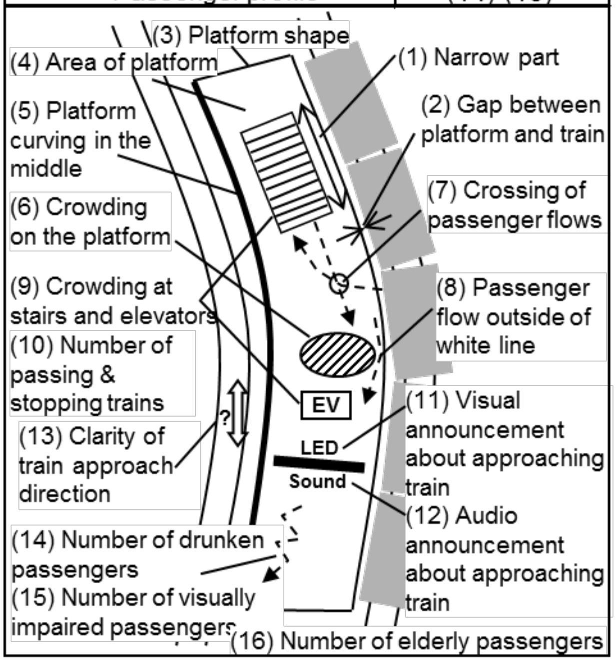

Fig. 4. Safety evaluation factors.

3.3 On-site survey to measure evaluation factors

a) Selection of stations and platforms

There are about 300 platforms on the lines of the considered railway companies. Accidents in the database occurred on 110 platforms among these. Because it is difficult to investigate all stations in detail, it is necessary to select stations to survey. The selection method is described as follows. First, we selected 41 stations, which are the top 30 stations in terms of the number of either accidents or passengers. In order to avoid selecting only the major stations where risks are recognized, six other intermediate stations were added. These intermediate stations have different designs and lines from the others. We surveyed 142 platforms of 47 stations.

b) On-site survey

A field survey was conducted in August 2015. The investigator visited the platforms and observed the safety factors from (1) to (13) in Table 2. The investigator paced the platforms or used a ruler to measure the lengths for

(1), (2), (4), and (8). He observed the platforms to record (3), (5), (7), and (9) - (13). The number of daily passengers for (6) was calculated from statistics listed in companies' websites and the metropolitan transit census. The number of facilities for (15) was counted manually on the map around the stations. The safety factors of (14) and (16) were not used in this research, because appropriate data were not available.

Table 2 Safety evaluation factors and their definitions

Safety Factors	Definition
Platform design	
(1) Length of narrow part	Length of a narrow part [m]
(2) Width of gap between platform and train	Width of gap between train and platform [cm]
(3) Platform shape	Island-type or not
(4) Area of platform	Usable platform area per number of tracks [m^2]
(5) Platform curving in the middle	Straight line, concave curve, or convex curve
Passengers flow	
(6) Crowding on platform	Number of daily passengers / area of platform
(7) Passenger flow crossing	Number of crossing points of passenger flows
(8) Passenger flow outside white line	Platform length over which safety fences are not built
(9) Crowding at stairs and elevators	Number of escalators and elevators
Train operations	
(10) Number of trains passing and stopping	Number of trains passing and stopping
(11) Visual announcements of approaching trains	Number of LEDs warning of approaching trains
(12) Audio announcements of approaching trains	Number of approach announcements, melody, and arrival announcement
(13) Clarity of indicators of train approach direction	The direction of approaching trains is always the same or not
Passenger profile	
(14) Number of drunken passengers	(Not used in this research)
(15) Number of visually impaired passengers	Number of facilities for visually impaired person near the station
(16) Number of elderly passengers	(Not used in this research)

3.4. Poisson regression

Poisson regression is applied assuming the number of accidents on the platform is explained by safety factors. Poisson regression is a generalized linear model form of regression analysis used to model counting data, e.g., the number of occurring traffic accidents or earthquakes. It is assumed the response variable follows a Poisson distribution, and that the logarithm of its expected value can be modeled by a linear combination of unknown parameters.

Some variables, such as the number of passengers, crowding on a platform, and clarity of the indicators of the train approach direction were introduced or deleted from Table 2 for modeling purposes. The number of passengers was introduced instead of crowding on a platform, which was calculated as the number of daily passengers over the area of a platform, to avoid multicollinearity. The clarity of indicators of the train approach direction was deleted for this regression analysis, because it has the same value for each of the 142 platforms for the 47 stations.

We estimated the model using all explanatory variables (Model 1 of Table 3), and then we estimated it again by excluding the variables that were not statistically significant (Models 2 and 3). Model 3 only has statistically significant coefficients. Although Model 1 had many variables that were not statistically significant, it achieved the lowest AIC (Akaike's information criteria) value, and exhibited the best fit for the data.

Table 3 Parameter estimates by Poisson regression

Explanatory Variables	Model 1	Model 2	Model 3
Intercept	-3.320 ***	-2.657 ***	-2.976***
Log (number of passengers)	0.104	-----	-----
Length of narrow part	0.013 **	-0.0005	-----
Width of gap between platform and train	0.137 ***	0.112 ***	0.118 ***
Platform shape is not island-type	0.156	-----	-----
Area of platform	-0.0003	-----	-----
Platform curving is straight	0.783 ***	0.644 ***	0.695 ***
Platform curving is convex curve	0.920 ***	0.810 ***	0.835 ***
Passenger flow crossing	0.007 ***	0.004 ***	0.003 ***
Passenger flow outside white line	-0.0002	-----	-----
Crowding at stairs and elevators	-0.307 **	-0.076	-----
Number of trains passing and stopping	0.004 **	0.004 ***	0.004 ***
Visual announcement of approaching train	0.287	0.239 *	0.216 *
Audio announcement of approaching train	-0.849 ***	-0.421 **	-0.422 **
Number of visually impaired passengers	-0.338 **	-0.057	-----
Goodness of Fit			
AIC	383.69	525.41	524.31

3.5. Discussion

Model 1 shows which safety factors affect the number of platform accidents more strongly. When explanatory variables have positive and statistically significant coefficients this means that they increase the number of platform accidents. These are interpreted as follows:

- A longer length for the narrow part causes passengers to walk at the platform edge with a higher risk.
- The possibility of passengers falling into the gap is higher when the gap between the platform and train is wider.
- Waiting passengers on a straight or convex curved platform are less likely to see and notice incoming trains than those on a concave curved platform.
- Passenger flow crossing represents the number of crossing points of passenger flows on the platform. When there are more crossing points, passenger flows on the platform conflict more. This increases the risk of passenger collisions and can lead to more accidents.
- The number of trains passing and stopping refers to the frequency of train services on the platform. When trains arrive more frequently, the number of accidents increases.
- There are variables that have negative and statistically significant coefficients, which decrease the number of accidents. These are interpreted as follows:
- The availability of audio announcements for approaching trains helps waiting passengers to notice the arrival of a train.
- The coefficient of crowding at stairs and elevators and the number of visually impaired passengers were expected to be positive. However, the estimates give negative values. We cannot find any reason for this.
- Some factors, including the number of passengers, platform shape, area of platform, passenger flow outside the white line, and visual announcements of approaching trains are not statistically significant, whereas the signs are the same as hypothesized.

4. Conclusion

We developed a risk assessment model for train passengers on a crowded platform. The risk here refers to the number of platform accidents, such as by falling from the platform onto the railway surface, falling into the gap between a train and the platform, and missteps in which passengers step off of the platform edge or their foot slips when boarding or alighting from a train.

The estimated model reflects passenger behavior on a crowded platform, and reveals that the risk increases as the length of the narrow part of a platform increases, and/or when the gap between the platform and the train is wider. This indicates that passengers tend to walk close to the edge when they want to walk a short distance to avoid the crowd, and so the possibility of passengers falling into the gap between the train and the platform also becomes higher. The shape of the platform, conflicts of passenger flows, and the number of trains passing and stopping also affect the accident risk.

These results will enable transit operators and station designers to compare how many accidents will occur before and after a safety investment is installed on a platform. It can also help to decide the contents of a safety investment by considering the current condition of each railway platform.

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