RISK ASSESSMENT FOR PASSENGERS ON STATION PLATFORMS: A QUANTITATIVE APPROACH

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Abstract

The time spent by passengers on the station platforms, including boarding and alighting processes, is a phase of the rail travel where accidents concentrate. Therefore, systematic analyses and robust methodologies to assess the risks in these phases are a priority to ensure the safety integrity of the railway system. The key aspects are the elements that play a role in generating hazards. Analyses and methodologies should be able to consider the large variety of infrastructural and traffic conditions to reach a quantitative risk assessment and pondering them. The paper describes the preliminary results of an ongoing research, developed in cooperation with the Infrastructure Manager RFI, specifically focused on these aspects. The inputs of the study are the various accessibility systems of the passengers to the platforms, rules and standards for their design, operational rules, mainly concerning maximum speed in stations, composition of trains, dwell times, etc. The research activities carried out include: 1) to study the state of the assets to identify common standards and infrastructure-specific elements (in terms of typology and accessibility) at network level; 2) to qualify the platforms in terms of number of served tracks, calling passenger services, passing through trains; 3) to analyse the accidents database from the stochastic viewpoint to identify recurrent locations, periods, causal factors; 4) to correlate accidents with single or groups of infrastructural and operational features; 5) to elaborate a specific risk analysis methodology; 6) to apply the elaborated risk analysis to a set of sampling stations for tuning and validating the methodology. As soon as the methodology has been setup, the application is focused on the expected results: A) to apply widely and systematically it at network level to rank the stations and the single platforms according to the risk level; B) to identify corrective actions, such as morphological, technological, operational measures.

Keywords: railway, stations, safety

1 Introduction

The infrastructure managers must frequently tackle the hazards generated on the platforms and the consequences of accidental events involving passengers, both during the boarding and alighting operations, as well as during waiting, e.g., as a consequence of a train passing nearby. The work focuses on the identification of the priority of the interventions to improve the functionality and the safety of the station platforms by means of the defintion of integrated risk indexes. They consider the criteria fixed by the normatives concerning:

- Infrastructures: geometrical-architectural features of the platforms;
- Vehicles: typologies of services, geometrical features and speed performances;
- Operation: use of station tracks and services thereby available.

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2 State-of-the-art

The specific problem tackled in the present paper is not extensively considered in the literature, though some important results have been considered for the present research. Johannson ad Peterson (2024) [1] considered the rail platform allocation problem to ensure reliable interchanges. Padovan et al. (2023) [2] focused their research on improving safety management in railway stations through a simulation-based approach. Popovic et al. (2023) [3] developed a formal analysis to assess satety of passengers in various stations. Küpper M. and Seyfried (2020) [4] studied the use of the space in the stations according to trajectories of passengers flows. Dancing Gilbert et al. (2019) [5] propose the introduction of safety grill to prevent the accidental fall down in the stations. Sasamoto and Momomoto (1995) [6] proposed the introduction of physical obstacles to prevent accidental and volunteer intrusions of passengers on the track. Parkinson (2019) [7] proposed intelligent visual systems to detect eccessive crowdiness on the platform. Hwang et al. (2010) [8] proposed the use of laser radar sensors to estimate the level of crowdiness on the platforms. Mizuno and Tukuda [9] analysed the specific exigences of visually impaired persons. Finally, Terabe et al. (2019) [10] open the doors to the present work, by setting up a risk assessment model for passengers standing on the plaforms.

3 Methodological approach

3.1 Preliminary analyses

From the state-of-the-art and the check of significance of accident database, which show insufficient number and description of the events, arose the need to identify new indicators, based on the movements of the passengers along the platforms while waiting for arriving trains or alighting from arrived trains.

The possible itineraries of these movements to/from exits, stairs, escalators, lifts are rarely linear, due to deviations caused by the presence of other passengers on the platforms, as well as fixed obstacles located along the longitudinal axis of the platform.

The passengers are forced to get closer to the yellow safety line or finally beyond it depending on their number and the obstacles on the platform that reduces the net area available for passengers' flows. This could be a pre-condition to hazards, particularly in combination with trains running along nearby tracks. These considerations bring to the hypotheses and the assumptions described in the next paragraphs.

3.2 Hypotheses and assumptions

3.2.1 Global Risk factor G

The analyses above allowed at identifying the risk as the combination of two factors: 1) the probability to have one train moving along the aside track (trains' presence factor T), 2) the density of persons on the platform (P) factor. Therefore, the Global Risk Factor is:

$$G = T \cdot P \tag{1}$$

Where:

P – is the ratio between the estimated number of passengers using the station in the reference time and the numbers of persons that could use it according to the available net surface of the platforms,

T – is the proability that one train is moving along the tracks aside the platforms.

3.2.2 Sigle platform and equivalent platform

The database of passengers attending the stations are normally available at global level and must be disaggregated with reference to days and platforms to arrive to estimate the average density on the platforms. This is performed by using the definiton of equivalent platform characterized by a representative equivalent area:

$$A_{Me} = \sum_{i=0}^{n} \left(a_i \times n_i \right) \tag{2}$$

Where:
A_{Me} – Equivalent platform area,
a_i – Net platform area of i platform = total area – areas occupied by steps, escalators, and lifts,
n_i – number of trains calling the tracks nearby the I platform.

On this basis, it is possible to calculate the estimated density (passengers/A_{Me}). This value can be calculated for each platform.
In case of platforms laying aside a single track the value of the equivalent area is considered globally, differently (two tracks), the value is divided by two to consider the possible homogeneous distibution of the passengers on the plaform itself.

3.2.3 Passengers' density factor

The passengers' density factor P will be correspondingly calculated as:

$$P = \frac{n_{\frac{pax}{day} total}}{N_{\frac{pax}{day} \text{ equivalent platform}}} \tag{3}$$

Where:
$n_{\frac{pax}{day} total}$ – estimated daily number of passengers using the concerned station,
$N_{\frac{pax}{day} \text{ equivalent platform}}$ – estimated daily number of passengers using the equivalent platform considered.

3.2.4 Train's presence factor

The train's presence factor T is defined to calculate the probability to have trains calling the tracks aside each platform in the reference time TR.

$$T = \sum \frac{n_1 \cdot t_1}{TR} + \sum \frac{n_2 \cdot t_2}{TR} \tag{4}$$

Where:
n_1, n_2 – number of trains calling the tracks aside the concerned platform,
t_1, t_2 – time spent by trains n_1, n_2 moving along the concerned tracks,
TR – reference time selected for the analysis.

3.2.5 Categories of trains and passengers' flows

The trains can be differentiated by categories characterized in terms of called stations, carrying capacity, dynamic performances (acceleration, max speed and deceleration).

In the case study have been considered 3 categories:
- Eurostar (EUR), grouping the high-speed trains typologies,
- Regional (REG), grouping the high-capacity trains typologies,
- Freight, grouping trains not operating passengers' services.

These groups relate to a maximum speed and maximum unbalanced transversal acceleration. To calculate the average number of passengers boarding and alighting has been assumed that the products of number of trains and passengers (boarded + alighted), according to:

$$(n_{REG} \cdot X_{REG}) + (n_{EUR} \cdot X_{EUR}) = N_{DAY} \tag{5}$$

Where:
$n_{EUR,}\ n_{REG}$ – number of high-speed and high-capacity trains calling the stations,
$\mathbf{X}_{\mathbf{EUR},}\ \mathbf{X}_{\mathbf{REG}}$ – time spent by trains $n_{EUR,}\ n_{REG}$ moving along the concerned tracks,
X_{DAY} – daily average number of boarding and alighting passengers,
TR – reference time selected for the analysis.

Considering the different capacity of the trains, has been also define the equivalent coefficient:

$$C_E = \frac{X_{EUR}}{X_{REG}} \tag{6}$$

From (5) and (6) we can obtain:

$$(n_{REG} \cdot X_{REG}) + (n_{EUR} \cdot C_E \cdot X_{EUR}) = N_{DAY} \tag{7}$$

$$X_{REG} = \frac{N_{DAY}}{\left(n_{REG} + n_{EUR} \cdot C_E\right)} \tag{8}$$

3.3 Model for indicators calculation

The structure of the model to calculate the indivìcators above includes the following phases:
- Acquisition of data about train running in a station in a day,
- Elaboration of data to identify, per ecah train, the platform, the track, the direction, and if it stops or pass the station,
- Ordering the data above according to platform, track, stop/pass condition and category of the trains,
- Elaboration of ordered data to associate the platforms to the corresponding tracks,
- Cross elaboration of point 3 and point 4 data to define the number of trains stopping or passing on each track,
- Elaborazione of quality indicators of acquired data to assess the significativeness of the indicators calculated by formulas (1), (3) and (4),
- Calculation of the weighted average length of the equivalent platforms,
- Calculation of weighted average speed, considering the platforms in both directions,
- Calculation of the net platform areas,
- Elaboration of formulas (3) and (4) for the calculation of Global Risk factor G of the station by formula (1).

The same procedure is used to calculate the Global Risk factor of each platform. In this case the calculation of the number of passengers per each platform in the TR is by formulas (6) and (8).

3.4 Ranking of stations and platforms

The application of the model to a sampling set of stations brought to obtain for them the values of the Global Risk factor G for the entire station (equivalent platform) and for the single platforms (phase 10 in section 3.3).
On this basis, two separate rankings, from the biggest to the smallest values, are available for stations and platforms and can be combined with respective data quality indicators (phase 6 in section 3.3). They will allow at developing a further ranking according to the quality of the input data used for the calculations.
The entire methodology has been tested by comparing the resulting rankings and the statistics on accidents happened in about twenty years (standardized accident database).
The accidents are fortunately rare, which does not allow a statistical demonstration of the effectiveness of the methodology. Nevertheless, a certain alignment between rankings and location and typologies of hazards has been detected: 3 accidents in the top-20 resulting stations.

4 Corrective actions for the improvement of the safety

The ranking resulting from the application of the model will be used for the prioritization of the corrective actions identified as the most appropriate to mitigate the arising risks. To increase the level of the safety in crowdy stations and platforms, the emerging measure is the use of intelligent video-cameras, which, thanks to a specific software, can:

- Measure (count) the number of objects (persons and obstacles) on platforms or parts of them,
- Detect the density of the persons in the concerned areas,
- Detect the presence of persons in potentially dangerous areas interdicted to public,
- Notify the detected hazards by activating vocal messages,
- Produce time-based reports with statistics on key information, such as the overpass of pre-fixed maximum persons density level in specific periods or at the arrival/departure of specific trains.

The setting of the system would allow at detecting specific typologies of objects in specific areas and at calculating the corresponding detected densities. Further measures, adoptable according to the typology of the passengers are the following:

- Insertion of a luminous barrier nearby the yellow tactile safety line, activated as soon as a train is arriving (to pass or to stop) on the nearby track.
- Re-introduction of the ringing bell activated to announce trains' arrival in addition to the audio announcements.

5 Conclusions

As we anticipated in the state-of-the-art, the specific problem was not extensively considered in the literature. Some results from other studies have been considered for the present research but a model for the classification of platforms and stations (equivalent platforms) has been originally built by the authors and presented in the paper. It included a systematic stepwise approach and its comparison with the corresponding accident database. The results are promising because in 3 stations in the list of the first 20 stations ranked as most critical by the application of the methodology happened severe accidents to passengers in the last years. Nevertheless, systematic statistical analyses cannot provide any robust confirmation feedback due to the fortunate rarity of the accidents themselves.

Moreover, due the complexity of the problem and the variety of parameters affecting the mechanism that generate the accidents, limitations of the study exist and further research developments to better overcome them will include:

- the extension of the analyses to the entire set of stations managed by Rete Ferroviaria Italiana (RFI),
- the implementation of an economic analysis to assess life-cycle costs of the identified promising mitigating measures,
- the identification of infrastructural mitigating measures to be translated into recommendations for the design of new stations.

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