Crowded Railway Stations and Train Compartments to Watch

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1. Introduction

Mass transit in Hong Kong has over 4 million passengers every day [1]. A large proportion of local citizens use this means of transport to travel between residential complexes and workplaces. Visitors from 49 mainland cities under the Individual Visit Scheme use it also since 2003 [2]. The railway stations and train compartments are then crowded with passengers most of the time. Further, many incidents happened recently in the local subway system that made the situation of crowded stations and train compartments even worse [3]. Over 70,000 passengers were affected up to 2011 as reported by the Principal Author [4]. Consequently, members of Legislative Council are very concerned with crowdedness in train compartments. A legislator said that he had to wait for 10 trains at an interchange station for transit [5]. Normal evacuation in a crowded station would take a long time. Emergency evacuation would be very difficult to control.

In addition, passengers frequently carry large amounts of baggage and goods into the station in recent years. Many mainland visitors even bring trolleys and large suitcases. The type and fire loads of such baggage and goods are not known. It is doubtful whether the dynamic smoke extraction systems in stations are able to perform its functions effectively and efficiently. Large suitcases and trolleys will not only occupy more spaces but will also impede the efficiency of evacuation in the event of fire or other emergencies. The situation will be aggravated when passengers gather at the station exit gates after leaving the train compartment.

The behaviour of commuters in the event of fire is difficult to be predicted. Despite the provision of broadcasting system, directional and exit signage, it is uncertain whether people will escape in the directions as planned.

In general, partial evacuation is adopted in railway stations depending on the magnitude of the fire. If a fire occurs at the platform level, passengers will be directed to evacuate upwards to the concourse level. If a fire breaks out on the concourse, commuters will be evacuated from the fire zone to the adjacent zone on the same level. It is assumed that smoke in the fire zone will be completely extracted by the dynamic smoke extraction system. However, as mentioned earlier, it is difficult to predict the behaviour of commuters in the event of fire or other emergencies.

In principle, the concourse level is designed mainly for entrance and exit while the platform level is solely for embarking or debarking from the train. Therefore, it was presumed 30 years ago that the things carried by passengers into station and train compartments are mainly personal belongings or hand-carrying bags. The fire load and fire size should be small. As mentioned earlier, more baggage is now being carried by passengers into the stations, lifting both the fire load and design fire size. Such change should not be neglected and continuous review is necessary for fire safety.

2. Timeline Analysis

As reported before [6-8], timeline analysis has been applied to determine fire safety provisions through performance-based design for many large-scale constructions that have difficulties to comply with the prescriptive fire safety codes. Both the Available Safe Egress Time (ASET) and the Required Safe Egress Time (RSET) are estimated and compared.

Small fire scenarios of only up to 5 MW were used in large halls in subway stations to obtain longer ASET. RSET was not estimated under crowded conditions to give small values of evacuation time. The 'safety margin' was only taken as a small percentage of RSET. As a realistic fire might have much higher heat release rate, a smaller value of ASET will be resulted. Therefore, a higher 'safety margin' of multiples of ASET should be provided in new projects to cater for uncertainties.

A two-level [9,10] railway station was used to illustrate the problems encountered using timeline analysis. Fire simulations were carried out to predict the ASET under low design fires. When using Computational Fluid Dynamics (CFD), the tenability due to smoke toxicity included only carbon monoxide. Evacuation simulations were conducted to predict the RSET under low passenger loadings.

The railway station was 120 m long, with two platforms of widths 18 m and 9 m respectively. There were two tracks along platform 1 with two stairs connected to outside. One track was built on the side of platform 2. The floor areas of platform 1 and platform 2 were 5400 m^2 and 6000 m^2 respectively. There was only one exit in this station on platform 2, as shown in

Fig. 1. There were two passenger accesses on the second level connecting platform 1 and platform 2. Passengers on platform 1 must use the accesses to reach the station.

Passengers may carry large amounts of luggage in some stations. The tests used bigger fires due to greater air supply by natural ventilation system in the station. Two fire sizes of 5 MW and 25 MW representing different types of fire were chosen to assess the effect of fire size on ASET.

Timeline analysis on the stairs of platform 1 was carried out, with its ASET and RSET shown in Fig. 2. Under normal circumstances, subway stations are designed to accommodate only 720 persons. Most scenarios are located in the safe region of the ASET-RSET curve. However, for a heavy occupant loading of 0.5 m^2/person or 2 person/m^2 (the figure was 6 persons/m^2 in a train car), 7280 persons would stay in the station. Full evacuation would take a long time, therefore RSET is longer than ASET even under a small fire. As no smoke barriers were placed between the fire sources and stairs, smoke would quickly spread to the nearest stairs even in a very small fire.

Although the above analysis illustrates that some remote places and exits give long ASET, passengers must be guided to move instantly in case of fire. There are great variations in capabilities and physical conditions of passengers involved in a fire [6]. Passengers will not move to the designated exit like robots in a real fire. It may be difficult to upgrade hardware provisions in existing stations, so fire safety management must be enhanced in existing stations. The fire safety plan should be worked out carefully for large, crowded and deep underground stations.

Fire safety management must be enhanced in existing projects with low safety margin, long ASET based on small fire scenarios and short RSET with low design occupant loading. Such application is urgently needed in crowded areas of subway stations without adequate fire safety provisions.

3. Way Forward

The train compartments and stations of most existing railway lines were designed in the 1980s and 1990s to hold a maximum of 6 persons/m^2 or 0.167 m^2/person. For new projects, fire scenarios with higher heat release rates should be applied to derive reasonable values of ASET including fractional effective dose (FED) [11]. Higher ‘safety margin’ of multiples of ASET should be provided to cater for uncertainties. Effort was made to mitigate the problem of crowdedness, such as by strengthening passenger flow management, purchasing new trains and increasing train frequency. However, these actions might not improve the efficiency of evacuation. A comprehensive review on how to enhance the efficiency of evacuation and tenable condition for evacuation of the existing railway lines should be conducted. As it would take time to implement long-term measures, immediate action should be carried out as soon as possible to ensure that the design fire scenario and passenger loading match with the performance-based design report. For existing subway stations, immediate actions to take [12] are:

- For stations with ASET much larger than RSET, say slope of 2 as in Fig. 2, no upgrading works are needed.

- For stations with ASET close to RSET, the amount of combustibles carried by passengers should be limited and the management ought to implement emergency evacuation scheme to match better with those ‘robotic motions’ [6] assumed in the simulations. This practice must be implemented immediately in crowded areas such as public transport interchanges and deep underground subway stations without adequate fire safety provisions.

- Stations with ASET shorter than RSET should be considered to closing or at least enhancing better management even under normal operation.

In response to lawmakers on alleviating the crowdedness of stations and train compartments, the local subway system has already taken some actions [13]:

- Better passenger flow management;
- Purchasing more new train cars;
- Replacing signalling systems;
- Ensuring the timely completion of new railways;
- Increasing train frequency; and
- Exploring the feasibility of removing some seats from overcrowded train compartments.

The carrying capacity of trains has increased [14] with the fare concession scheme launched [15] to encourage some commuters to take their subway rides during non-peak hours. Effectiveness of these actions should be watched.

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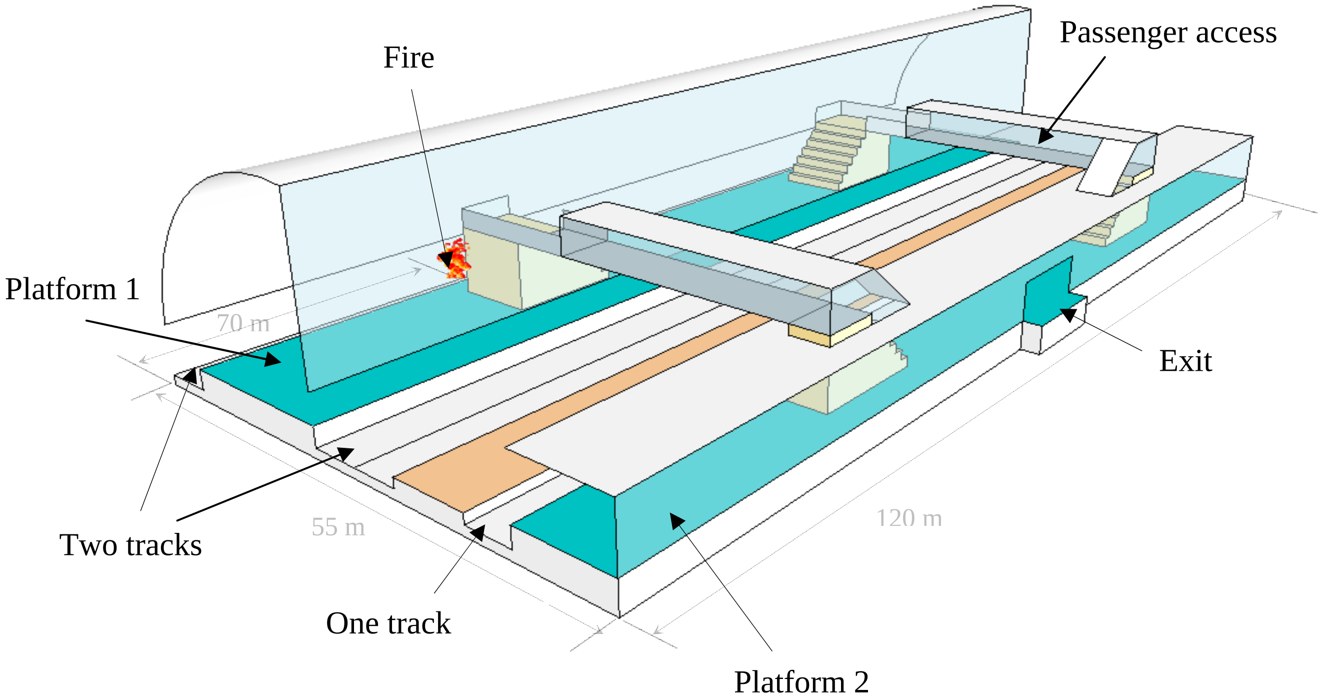

Fig. 1: Geometry of the railway station (Qu and Chow 2013)

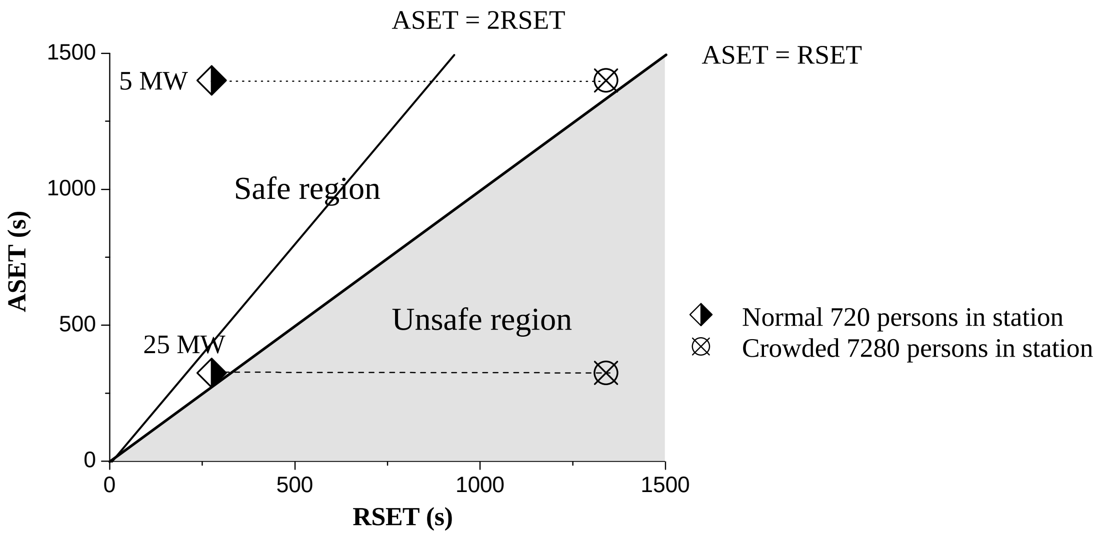

Fig. 2: Timeline Analysis of ASET and RSET for Platform 1 (Qu and Chow 2013)