Safety Science 91 (2017) 40–48

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

Likely behaviours of passengers under emergency evacuation in train station

Nirajan Shiwakoti [a,*], Richard Tay [b], Peter Stasinopoulos [a], Peter Jarrod Woolley [a]

[a] School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, Carlton, Victoria 3053, Australia
[b] School of Business, IT & Logistics, RMIT University, Melbourne, Victoria 3000, Australia

ARTICLE INFO

Article history:
Received 18 March 2016
Received in revised form 26 May 2016
Accepted 20 July 2016

Keywords:
Pedestrians
Underground train station
Safety
Crowd dynamics
Gender differences
Route choice

ABSTRACT

This paper explores the likely behaviours of train passengers in an emergency evacuation and examines four crucial theoretical issues on the passengers' evacuation, including reactive vs. proactive behaviours, cooperative vs. competitive behaviours, symmetry breaking, and route/exit choice.

A survey of 1134 train passengers shows that respondents are not homogeneous in their likely behaviours. Overall, they are more likely to be reactive (e.g., wait for instruction from station staff) than proactive (e.g., move to exit) in an emergency situation. We also find that people are more likely to be cooperative (e.g., helping other people) than competitive (e.g., push other passengers). Although passengers are likely to show herding or symmetry breaking behaviour (e.g., following other passengers) than symmetric behaviour (e.g., choose least crowded exit), the degree of symmetry breaking behaviour is not as high as assumed in previous mathematical models. They are also unlikely to use escalators, lifts and train tunnels in their exit/route choice during an emergency escape. In terms of demographic differences in behaviours, results from the ordered logit models demonstrate that there are significant differences in the evacuation behaviours between males and females but not among the different age groups.

Besides providing valuable information for developing mathematical models intended to simulate passengers' evacuation in a train station, our findings can assist managers of emergency response in developing appropriate strategies and training, and in designing solutions and education campaigns for effective evacuation.

1. Introduction

1.1. Background and rationale

Suburban railways and subway systems are important contributors to the movement of people in many of the world's large cities. For example, the New York Grand Terminal serves on average 200,000 passengers per day while Flinders Street Station in Melbourne, Australia, serves an average of 100,000 passengers daily but with significantly higher crowds during special events and unexpected service disruptions (Davies, 2008; Pender et al., 2013). These transport hubs pose a significant challenge in the management and security of a large volume of passengers in a confined and complex space (Johnson, 2008; Zhang et al., 2008; Leurent, 2011; Pel et al., 2014; Kim et al., 2015).

In particular, passenger crowd behaviours and safety under emergency situation in train stations are important challenges for transit agencies around the world (Proulx and Sime, 1991; Drury et al., 2009; Fridolf et al., 2013). Several natural or man-made disasters in major train stations in the past have prompted the mass evacuation of passengers, resulting in fatalities and injuries. One of the key reasons for the inefficient evacuation in those disasters has been identified as the lack of understanding of the likely behaviour of people under emergency conditions (Fridolf et al., 2013).

Existing studies on passenger crowd evacuation have focused mainly on the development of mathematical models, simulations, controlled laboratory experiments, evacuation drills, and socio-psychological studies of documented crowd disasters (Daamen, 2004; Shiwakoti et al., 2008, 2011, 2014; Asano et al., 2009; Dias et al., 2012; Fridolf et al., 2013; Shi et al., 2015). However, it is difficult to replicate emergency situations in controlled laboratory experiments due to ethical and safety concerns that will then have a negative consequence on the development and verification of mathematical models intended to simulate emergency evacuation. Therefore, most mathematical models are tested with crowd

* Corresponding author.
E-mail address: nirajan.shiwakoti@rmit.edu.au (N. Shiwakoti).

http://dx.doi.org/10.1016/j.ssci.2016.07.017
0925-7535/

movement under normal conditions to identify congested areas and level of service for major public infrastructure.

The prediction of crowd behaviours under emergency condition has mostly been inspected and verified visually through computer graphics (Shiwakoti et al., 2008; Duives et al., 2013; Kalakou and Moura, 2014; Shi et al., 2015). Without verification with complementary data on emergency situation, it is difficult to gauge the reliability of these mathematical models. On the other hand, most socio-psychological studies have examined crowd behaviours qualitatively based on limited information on previous crowd disasters. Such methods are unable to provide the quantitative information on crowd behaviour under emergency conditions that is important to develop the appropriate mathematical models and simulations.

It is important to note that the understanding of human behaviour under emergency situation is not limited only to major transport infrastructures but also extends to the evacuation of buildings, and the safety and security of people at major events. Thus, theories on human behaviour under emergency situations can have a wide range of applications (Fridolf et al., 2013). Although an evacuation in a train station and a building evacuation may share some similarities, there are also differences that need to be considered during the design and operation phases of a station. Therefore, the understanding of passengers' behaviours in an emergency situation in a complex environment like a train station demands specific attention.

1.2. Objective and scope of study

This paper aims to examine the likely behaviours of passengers in transit hubs under emergency evacuation via a questionnaire survey at a major train station in Melbourne, Australia. Although questionnaire survey has been popular in transport mode choice analysis, we are not aware of any behavioural study that has examined the likely behaviour of passengers during emergency evacuation at train stations. Hence, this study is the first of its kind in the field and will provide valuable insights to supplement and extend the knowledge in evacuation modelling and simulations.

Moreover, to our knowledge, there is no previous study that has examined the different types of likely behaviour of passengers during an evacuation in a train station. More specifically, we examine four commonly debated issues in evacuation; namely, proactive vs. reactive; competitive vs. cooperative; symmetry vs. symmetry breaking; and route choice. Hence, this paper will contribute significantly to advancing knowledge on passenger's behaviour under emergency conditions in a train station.

In addition, we examine any differences in the likely behaviours between male and female passengers as well as investigate any differences among passengers from different age groups. These demographic differences in likely behaviours of passengers during an evacuation will provide valuable insights to assist in future evacuation planning and modelling, especially at venues and during events that have a higher concentration of a specific demographic segment.

2. Literature review

There are existing pedestrian crowd simulation models, both micro and macro, that are being used mostly to understand the crowd dynamics under normal conditions and to identify the congested location or level of service in major public infrastructures (Shiwakoti et al., 2008; Duives et al., 2013). There are also models that are being used to simulate human crowd evacuation in buildings, train stations or open events (Kang, 2007; Klüpfel, 2007; Pelechano and Malkawi, 2008; Shi et al., 2012; Fridolf et al., 2014). However, there is still a strong need for better empirical data, specifically under emergency situation, to develop a more reliable evacuation model (Helbing et al., 2002; Shiwakoti and Sarvi, 2013; Shi et al., 2015).

To provide empirical data for model validation, evacuation exercises in buildings (Olsson and Regan, 2001; Ko et al., 2007; Kretz, 2007) and passenger vessels (Galea and Galparsoro, 1994; Fridolf et al., 2013) have been carried out by some researchers. These exercises have enabled researchers to observe evacuation times, response times of the occupants and occupants' movements. Likewise, controlled laboratory walking experiments of pedestrians egress through a bottleneck or in a corridor, and experiments on multi-direction crowd movement have been also conducted to understand the flow rate and speed effects at bottleneck points (Daamen, 2004; Helbing et al., 2005; Kretz, 2007; Asano et al., 2009; Zhang et al., 2011; Shiwakoti et al., 2015).

However, such evacuation exercises and laboratory experiments are performed with a small number of participants under normal conditions as researchers cannot replicate real emergency conditions due to safety and ethical reasons. Some studies have conducted surveys of passengers in train stations to examine mainly the operational aspects, such as safety issues due to crowding and riding behaviour, dwell time, and pre-evacuation times (Zhao et al., 2009; Li et al., 2011; Wan et al., 2015; Kim et al., 2015). Recent study by Shiwakoti et al. (2016) has looked into the passengers' understanding and rating of the location of emergency exit signs, emergency buttons, evacuation maps and the assembly area through a primary survey at an underground train station. Studies on human behavioural models for emergency situations have also been conducted by sociologists over many years. These studies focused on the psychological aspect of crowd behaviour like cooperation or competitive behaviour under emergency conditions. Although the socio-psychological theories may explain why an individual becomes competitive or co-operative, these theories do not estimate the likelihood of different passenger behaviours quantitatively to provide the pertinent data needed to optimise existing evacuation models and operational plans.

To summarise, due to its complexity, rare and hazardous nature, the existing theoretical, empirical, survey and socio-psychological studies on emergency evacuation have all examined only some critical aspects of the problem but with some limitations. More research using different approaches is needed to complement and supplement the existing research and advance our understanding of this critical issue.

Nevertheless, through the detailed review of the literature, it is observed that there are several recurring debates and uncertainties regarding the likely strategies and behaviours of people under emergency conditions, which can be classified into four major categories discussed below.

2.1. Reactive vs. proactive

A detailed literature review on documented case studies of real evacuation in underground transportation systems revealed that different people might be more reactive or more proactive during different emergency situations (Fridolf et al., 2013). In some cases, people took a reactive approach by not responding to emergency situation even when the emergency alarm went off and evacuated only when the instructions were provided over the public address (PA) system or when they received directions from station staff. Most people also did not use the emergency call buttons. In other cases, rather than waiting for instructions, people were proactive and moved to exits quickly and also used the emergency call buttons once they were aware of the emergency situation. The proactive approach of passengers has been observed not only in underground transportation but also in aircraft evacuation as