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Passenger distribution modelling at the subway platform based on ant colony optimization algorithm

Xiaoxia Yang[a], Hairong Dong[a,*], Xiuming Yao[b]

[a] State Key Laboratory of Rail Traffic Control and Safety, Beijing Jiaotong University, Beijing 100044, China
[b] School of Electronic and Information Engineering, Beijing Jiaotong University, Beijing 100044, China

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ABSTRACT

In the subway platform, not all passengers distribute randomly but gather in the waiting areas, especially when a train is coming. During emergency evacuations, passengers' initial distribution may play a significant role in affecting the escape efficiency. In this paper, a passenger distribution modelling method is proposed to predict such waiting area choice processes based on ant colony optimization (ACO) algorithm, which is really a complicated job due to many influence factors. The model considers the distance to the target waiting area, the length of queues, the physical length of waiting areas and the train schedule as four main influence factors. Specially, a modification of the passenger's impatience factor in the famous social force model (SFM), better reflecting the change of psychological states with an arrival of a train, is presented. The field data collected at the Xuanwumen subway platform is utilized for the model calibration and validation. The ultimate simulation results demonstrate that passenger distributions based on ACO algorithm basically can reflect the field distribution and also the dynamic characteristics of waiting area choice processes. Impacts of passenger distributions on evacuation dynamics under fires are further studied based on the software FDS+Evac. The results indicate that passenger distribution does has little impact on evacuation efficiency when fires are not very large, while the evacuation will be affected significantly by passenger distributions once fires are large enough. This further indicates the necessity of studying the passenger distribution at the subway platform especially under emergencies.

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1. Introduction

In recent years, subway system has been developed vigorously around the world since it has the characteristics of energy saving, land saving, large volume, all-weather, no pollution, etc. According to an uncompleted statistic, over 40 counties with more than 100 cities have subway systems. Take Mainland China as an example, 24 cities have already had subway lines in operation up to February 2016 as Fig. 1 shows. Among which, the total mileage is 3,136.8 Km and the total number of subway stations is 2,014. Surely, subway plays a more and more important role in achieving rapid passenger transport, and thus it can further ease the traffic pressure in a city. Accordingly, the reliability and safety of the subway system is particularly worthy of our attentions. On January 26, 2016, fire occurred at Ginza subway station of Tokyo because of the combustion of unknown substance in the ventilation port of the station, smoke filled the entire station, and about 68,000

* Corresponding Author.
E-mail address: hrdong@bjtu.edu.cn (H. Dong).

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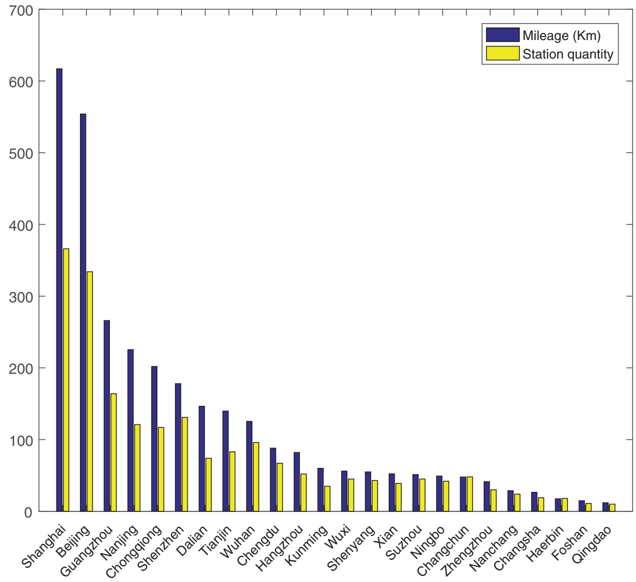

Fig. 1. Subway lines operated in Mainland China up to February 2016.

passengers were affected in the workday morning. On June 5, 2013, a subway station in Moscow city got fire due to the cable aging, which resulted in nearly 4500 passengers being evacuated and the injury of 52 passengers in hospital. In the management of a station, it is best to avoid the potential safety hazards caused by fire, terrorist attacks and other factors with the rapid development of subway systems. To keep pace with this demand, passenger distribution dynamics and also evacuation dynamics are two important research issues in the passenger traffic management for a subway station. Different passenger distributions in the station, for instance, may lead to different evacuation efficiencies, especially around the bottleneck places.

Platform, as an important part of a subway station, is the place for passenger transfer and waiting. Passenger distribution at a platform has a close relationship with the physical structure of the platform. Much research has already focused on studying passenger boarding and alighting processes occurring between the compartments of a train and the platform [32,37,53]. The effect of passenger traffic management in the boarding and alighting time at subway stations was determined by simulations and experiments in Ref. [34]. Holloway et al. presented the results from a series of experiments after testing the time required to board or alight a train across three different vertical step heights in Ref. [17]. The efficiency of the boarding and alighting behavior affects not only the activities of passengers at the platform but also the dwell time and the service level for passengers. Furthermore, there is an ongoing problem about passenger evacuation at subway stations after emergencies, and the most common solution is to develop contingency plans in advance. In order to keep pace with this demand, much research has been conducted, providing theoretical basis and directions to subway staff. Effects of occupant density, exit width and automatic fare gates on evacuation time are presented in details in Ref. [24] by numerical simulations of passenger evacuation from a huge transit terminal subway station. Zhang et al. further proposed a systematic simulation-based multi-attribute decision method to route planning for passenger evacuation in a subway station, and identified the length of evacuation route, evacuation time and passenger density having significant impacts on evacuation efficiency [51].

A common problem of above evacuation studies is that passengers were all set randomly at the initial time in the subway station, which may bring errors of evacuation results in the simulations. In addition, Kim et al. pointed out the unevenness of passenger distribution at the platform [20]. However, there is still no clear definition of passenger preference for a specific waiting area. As the requirement of lots of labor and time, few investigations have been conducted on the issue of passenger distribution prediction [41,42]. This paper, to the best of our knowledge, does not consider personal characteristics, but presents a new insight into the formation dynamic of passenger distribution at the subway platform before the open of train doors. It is worth mentioning that we mainly focus on the searching dynamic of passengers for the optimal waiting areas, this is an important research issue about which little work has been done, thereby forming the distribution dynamic at the platform during this searching process. Beyond that, we also investigated the boarding and alighting behaviors of passengers in Ref. [4] which had already been a hot research issue in recent years. According to Ref. [4], the distribution of passengers during the boarding and alighting process exhibits three types, namely clusters in front of train doors, queuing up into two lanes, and into three lanes, we refer the readers to Ref. [4] for more details.

So far, many pedestrian dynamic models have been established to simulate pedestrian motions [2,11,19,25,38,39], which can usually be divided into the continuous type and the discrete type [28]. The SFM is a typically continuous model, where

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