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ScienceDirect

Procedia Engineering 135 (2016) 207 – 216

Procedia Engineering

www.elsevier.com/locate/procedia

Experimental study on choice behavior of pedestrians during building evacuation

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Abstract

Understanding human behavior in emergency evacuation is a significant issue for layout optimization, crowd management and rescue. In this study, we conducted a series of controlled experiments to study choice behavior of pedestrians considering environment factors (e.g. occupant initial distribution, auditory information, and building layout). We found it was non-symmetrical for pedestrians' exit selection and aisle selection in the room. And there was a strong positive relation between intermediate exit choice and destination choice. Pedestrians' final destinations had significantly effects on evacuation route and intermediate facilities usage. When the final destination was uncertain, the factor of building layout performed more effect than occupant initial distribution. Pedestrian psychology, following the crowd, had a major influence on pedestrians' exit stairs selection, especially when pedestrians were in non-limited visual field environment. Bifurcation point, where a row of pedestrians split into two streams with diametrically opposite movement directions, was a quite biased away from the side of exit. The conclusions are expected to provide valuable advice for crowd management and optimization design such as aisle-seating layout.

Peer-review under responsibility of the organizing committee of ICPFFPE 2015

Keywords: building evacuation, choice behavior, aisle, bifurcation point.

1. Introduction

Considerable attention has been paid to the topic of human behavior in evacuation caused by fires, since many serious fatalities in fire occur. This fascinating field involves a wide range of disciplines such as building design, safety engineering, crowd management, physics, psychology, sociology, and computer science etc. In the past few decades, a great many of experimental studies have been performed to either understand human behavior and pedestrian mobility, or collect empirical data in term of evacuation time, pre-movement time, speed, density or flow for the calibration and validation of evacuation models. Meanwhile, a variety of simulation models, such as social force model, cellular automata model, lattice gas model, multi-agent model and network model, have been developed. For a review concerning simulation models, the reader can refer to [1-3]. A detailed discussion of these models is beyond the scope of this paper.

Based on different experimental subjects as well as different methods of data collection, experiment methods can be divided into five categories: field observation [4-6], evacuation drill [7-13], controlled experiment [14-24], experiment based on animals [25-28] and data-collection in real emergency [29-33]. There is its own field of application and shortcomings for each kind of method. Nowadays, due to the well operability of experiments as well as the reliability and accuracy of results, the method of controlled experiment has been widely used.

The evacuation route selection of pedestrians, for example, exit selection as well as other facilities selection (e.g., stairs, aisles, escalators and lifts), not only affects the successful probabilities of individual safety evacuation, but also takes effect

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Peer-review under responsibility of the organizing committee of ICPFFPE 2015
doi:10.1016/j.proeng.2016.01.110

on crowd evacuation efficiency. Three factors, route characteristics (e.g., distance, capacity of route, movement quality of route), environment information (e.g., visibility, evacuation indicator, sound message) and pedestrian characteristics (e.g., experience, personality, role), are acknowledged to have an impact on travel-path decisions of pedestrians. Cheung and Lam [34] studied the behavior of pedestrian in choosing between escalators and stairways in MTR stations during peak hours focusing on the influence of relative delay. Helbing [35] indicated the phenomenon of nonsymmetrical choice of exits due to herding behavior in panic situation. Furthermore, Altshuler et al [25] demonstrated this phenomenon by means of conducting laboratory experiments using ants. Unfortunately, the rooms were empty in the above studies, and it is not clearly whether nonsymmetrical or not when evacuating from a multi-obstacle room such as classroom.

Evacuation from room with obstacles has also been studied by means of experiments, simulations or a combination of both. Helbing et al [36] and Liu et al [37] analyzed the distribution of pedestrians' evacuation times as a function of their initial positions using experimental and modeling methods. Guo et al [38] use experimental and modeling methods to investigate pedestrians' evacuation route choice in classroom under conditions of both good and zero visibility. Papinigis et al [39] estimated the egress time from the theatre hall based on FDS+Evac program. However, the above studies are all single stage evacuation. There are no internal exits in the evacuation route of pedestrians, the room exits are regarded as final exits. In reality, evacuations from buildings are normally multi-stage since pedestrians will pass through many facilities for leaving a building. And we believe that the choice of transitional facilities is affected by not only the prior factors such as initial pedestrian distribution and internal layout, but also such factors as final destination.

An interesting phenomenon in pedestrian dynamics is kin behavior [40] performing by particular groups, such as family members, friends and classmates. The members usually gather together firstly before evacuation, sometimes even go back to the dangerous area to find or help other members. In general, the performance of particular group will bring negative influences to other pedestrians, for example, moving together or going back will get in other occupants' way, which does reduce the whole evacuation efficiency. Yang et al [40] proposed a cellular automata model to simulate the kin behavior of particular group. Qiu and Hu [41] developed an agent-based crowd simulation system to model the structure aspect of different groups in pedestrian crowds. Two group structures, intra-group structure and inter-group relationships were considered. In addition, Zhao et al [42] simulated sub-group behavior in sports stadium based on agent technology. Ji and Gao [43] explored a crowd evacuation model based on A* Algorithm to simulate the dynamic grouping phenomena with each group having a leader and some followers guided by the leader. Unfortunately, the information with respect to the performance of particular groups in reality with different size, population composition, or initial position, is still limited.

The remainder of this paper proceeds as follows: Section 2 describes the details of the experimental setup. Section 3 covers the experimental results and discussion. Finally, a brief summary including the conclusions and a discussion of future research work is presented in section 4.

2. Experiments

We conducted a series of experiments participated by university students to explore typical choice behavior of pedestrians in building evacuation. 102 students (87 males and 15 females), with age ranging from 18 to 24, took part in the experiments as evacuees.

2.1. Building layout

The group of experiments was carried out in a teaching building illustrated schematically in Figure 1. The evacuation route fell into three successive parts, classroom, passage and alternative stairs. In the classroom, one latitudinal aisle leading to Exit A, and four longitudinal aisles divided all 144 seats into 9 rows and 16 columns as shown in Figure 2. Two identical exits, Exit A and Exit B, with widths of 1.2m, were located in the east wall. Additionally, in Figure 2, it illustrates two types of occupant initial distribution which we used in the experiments, even distribution and non-even distribution.

The passage was 3.4m width and 64.6m length, and both of its ends leaded to exit stairs. The classrooms were located at one side of the passage, and the chosen experimental classroom was a little closer to Exit Stairs A. It was a distance of 19.7m from classroom Exit A to Exit Stairs A, and 31.5m from classroom Exit B to Exit Stairs B.

Stairs A was 2.10m wide and the individual step measured 14.5cm rise and 28cm tread depth. There were two identical flights connected by a mid landing, with the size of 2.30m×4.70m. Each flight consisted of 14 steps. Stairs B was 2.70m wide and the individual step measured 14.5cm rise and 28cm tread depth. There were totally 28 steps interrupted by 2 mid landings (11 steps between upper floor and upper landing, 6 steps between two landings and 11 steps between lower landing and lower floor). The dimensions of upper landing and lower landing were 2.57m×2.75m, 2.6m×2.75m, respectively.

At each end of the passage, an alarm was positioned to give auditory information representing of exit stairs status (open or closed). What needs to be emphasized is that the alarm information was not always in accordance with the status of exit