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# A study on pedestrian choice between stairway and escalator in the transfer station based on floor field cellular automata

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## HIGHLIGHTS

- Pedestrian choice between stairway and escalator is studied.
- Random utility theory is used and a logit-based model is proposed.
- Parameters like familiarity, walking disutility, and time pressure are proposed.
- Counting rule based on the Large Number Law is proposed.
- Sensitivity analysis on the three parameters is done to show the choice distributions.

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## ABSTRACT

Stairway and escalator are the main transfer facilities in the station where pedestrians make choices between them. A good understanding of pedestrian choices is helpful to raise the efficiency of transfer stations and lower the probability of disasters, such as stamps caused by congestion. This paper studies the choice behavior of pedestrians using random utility theory and floor field cellular automata. Among the factors influencing pedestrian choices, there are non-quantitative ones and quantitative ones. Thus, a method combining qualitative description and quantitative description is adopted. Subsequently, a logit model is presented to mimic the choice behaviors of pedestrians. In this model, there are three new important parameters, including familiarity, walking disutility, and time pressure. By using micro-simulation, a sensitivity analysis for these parameters is conducted. Besides, a counting rule based on the Large Number Law is presented to count the real data in transfer stations in Shanghai. After comparing the sensitivity analysis results and measurement data, several reference values of the three important parameters are obtained in un-congested and congested situations respectively.



## 1. Introduction

Walking is essential for pedestrian movement in densely populated cities in the world such as Hong Kong and Shanghai, especially in Mass Transit Railway (MTR) transfer stations. During the peak hours, there are massive pedestrian flows and vertical transfer facilities like stairways and escalators are bottlenecks in MTR, which are the focus of this paper. Paying no special attention to crowd of pedestrians there can lower the efficiencies and even cause serious disasters, such as stamps. Therefore, knowledge of pedestrian's demand is valuable in the planning and design of the facilities.

Study on pedestrian movement starts from the VAKH of USSR in 1937 and has a history of more than 60 years in Pretechenskii and Milinski (1969) [1]. Since then, a number of models have been proposed and lots of software packages, based on these models, have been developed and commercialized.

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Models of pedestrian simulation can be divided into two categories, the macroscopic ones and microscopic ones. In the 1970s, Henderson [2] presented the earliest macroscopic model for pedestrian flow, which analyzed pedestrian flow in analogy to fluid. Hughes (2002) [3] established a two-dimensional macroscopic model to simulate pedestrian flow and obtained the fundamental diagram. Besides, Yinhua Xia et al. (2009) [4] and Dogbe (2010) [5] also obtained the similar result. As for the microscopic models, there exist social force model, cellular automata model and some related improved models. The social force model, first proposed by Helbing and Mornar (1995) [6], took pedestrians as self-driving particles. Movements of pedestrians are decided by self-driving force, repulsive forces from other pedestrians and obstacles. Later, Helbing et al. (2001, 2005, 2007) [7–9] improved this model from different aspects. Blue et al. (1997) [10] first used the cellar automata model to mimic pedestrian movements and then Blue and Adler simulated unidirectional flow, bidirectional flow (2001) [11] and four-way flow (2000) [12].

Although the above-mentioned models can simulate pedestrian flow well, they ignore the analysis of pedestrian behavior more or less. However, recent studies on pedestrian route choice and collision avoidance fill this void. For example, Hoogendoorn and Bovy (2004) [13] studied pedestrian route choice based on the utility theory under uncertainty and solved this problem with dynamic programming. Antonini et al. (2006) [14] proposed the pedestrian discrete choice model, which included movement direction and movement speed. The final utility was decided by expected direction, expected speed, actual location, actual speed, and so on. The model is verified with measurement data. Guo and Huang (2011) [15] formulated the route choice behavior of pedestrians in evacuation in closed areas with internal obstacles. The route choice is determined by the potential of discrete space with effective factors, such as route distance, pedestrian congestion and route capacity. Pedestrian's collision appears when two or more pedestrians move to the same location at the same time interval because of the irregular characteristics of pedestrian movement. Besides the former rule-based collision avoidance [10–12], Karamouzas et al. (2009) [16] presented a new local method for collision avoidance based on collision prediction, which reproduced emergent behavior like lane formation observed in real crowds. Asano et al. (2009) [17] mimicked the collision avoidance based on pure strategy Nash equilibrium and solved it by the augment allocation algorithm. Asano et al. (2010) [18] integrated pedestrian route choice and collision avoidance based on their paper in 2009 [17].

Some studies have been made on the pedestrian choice between stairway and escalator. Cheung and Lam (1998) [19] investigated pedestrian behavior during a choice between stairway and escalator with data from six MTR stations in Hong Kong and calibrated the travel time on the vertical facilities. Some other researchers who are not from traffic engineering also did some related research [20–24]. Webb et al. (2011) [20] investigated whether individuals mimic the stair/escalator choices of preceding pedestrians. Webb et al. (2011) [21] investigated the poster/banner on the pedestrian choice between stairway and escalator. Eves et al. (2008) [22] modeled the effects of speed of leaving the station and stair width on the choice of the stairs or escalator. Eves et al. (2009) [23] reported pedestrian responsiveness to an intervention on the choice of stairways and escalators. Olander et al. (2011) [24] tested whether contextual factors may affect the stair/escalator choice, such as the impact of escalator availability.

Based on the existing models, this paper proposes a logit-based model to mimic the pedestrian choice between stairway and escalator. Three important parameters are presented, which are familiarity, walking disutility, and time pressure and a sensitivity analysis on these parameters is done after a micro-simulation using floor field cellular automata. During the sensitivity analysis, one parameter is fixed according to the questionnaire stated below and the other two change to find out the pedestrian's choice probability distribution for the escalator in congested and un-congested situation respectively. The simultaneous change of the three parameters for the choice probability distribution for the escalator will be one of our further study directions. Finally, the reference values of these three parameters are given according to the comparison between the simulation result and real data collected in a transfer station of Shanghai.

Compared to the former models, the model of this paper is a new one shown as follows. Firstly, influencing factors on the pedestrian choice are summarized and classified into qualitative ones and quantitative ones. Our logit-based model is proposed according to the quantitative factors. Secondly, three parameters are presented and a sensitivity analysis on these parameters is done after micro-simulation. This is the first appearance in the analysis of pedestrian's choice between stairway and escalator as far as we know. Finally, the reference values of these parameters are given according to the comparison between the simulation result and real data collected in a transfer station of Shanghai.

The remainder is organized as follows. Section 2 analyzes the influencing factors on the pedestrian choice between stairway and escalator. The model is developed in Section 3 and in Section 4, simulation and the sensitivity analysis are done. Some conclusions are obtained in Section 5.

## 2. Influencing factors on the pedestrian choice

The pedestrian choice between stairway and escalator is a complex process and can be influenced by lots of factors, such as consciousness, travel time, pleasantness or comfort, trip purpose and safety in Ref. [13], physical characteristics of the study area, age and gender in Ref. [25] and availability and occupancy in Ref. [24]. Besides, the speed of escalator and fear of using escalator also can be the influencing factors. However, the study object is the choice of coming pedestrians between stairway and escalator during peak hour. Therefore, influencing factors in this paper are divided into three categories according to the following assumptions and the proposed model in this paper.