Pedestrian Egress Behavior During Classroom Evacuation: A Simulation Approach

Masria Mustafa, Zanariah Abd Rahman, Mohamad Noor Faiz Mohamad Najid and Yasmin Ashaari

Abstract Pedestrians evacuation is a multi-agent system which composed of pedestrians with interaction. Usually, special flow of pedestrians' evacuation occurs in emergency situation such as in case of fire. Interactions between pedestrians become more complicated, when all pedestrians moving towards a bottleneck area. The objective of this study was to examine the egress behavior of pedestrians during panic situation in a classroom environment. The results revealed that the pedestrians behave aggressively in order to evacuate themselves from the bottleneck area and different number of exit in the classroom gives different route choice during the evacuation process.

Keywords Evacuation · Bottleneck · Pedestrians simulation · SimWalk

1 Introduction

An increasing amount of literature is devoted to discuss about the pedestrians movement pattern in indoor or outdoor environment. A better understanding of human behavior is the key to plan to manage the pedestrians flow. In order to

M. Mustafa (✉) · Y. Ashaari
Lecturer, Faculty of Civil Engineering, Universiti Teknologi MARA,
40450 Shah Alam, Selangor, Malaysia
e-mail: masria@salam.uitm.edu.my

Z. A. Rahman
PhD Student, Faculty of Civil Engineering, Universiti Teknologi MARA,
40450 Shah Alam, Selangor, Malaysia

M. N. F. M. Najid
Undergraduate Student, Faculty of Civil Engineering, Universiti Teknologi MARA,
40450 Shah Alam, Selangor, Malaysia

R. Hassan et al. (eds.), *InCIEC 2013*, DOI: 10.1007/978-981-4585-02-6_37,

determine the pedestrians' behavior some parameters should be measured such as walking speed, spatial use and person counts [1].

Panic refers to pedestrians' behavior during an emergency situation. Panic is defined by breakdown of ordered, cooperative behavior of individuals due to anxious reactions. Often, panic is characterized by attempted escape of many individuals from a real evacuation process, which may end up in interaction of people in a group [2]. An example of emergency situation is when a building is on fire and pedestrians compete to save themselves through the exit area. High density of pedestrians made the situation become worst which can contribute to pedestrians' accident. In some emergency cases, if the person is not sure the best thing to do at that time, there is a tendency of them to show a herding behavior. Herding behavior as in [3] is defined as "go with the flow" or "follow the other pedestrians".

The initial hypothesis for this study is pedestrians' behavior during a building evacuation which can be determined by analyzing their walking speed. There are different factors affecting the walking speeds of pedestrians as in [4], such as the personal characteristics of pedestrians like age, gender, weight, height and breadth.

The particular problem of pedestrians' behavior during classroom evacuation was found to be important. This study will benefit the users to evacuate the building especially for non-familiar users of the building where often with visiting purposes.

2 Emergencies and Evacuation

Evacuation planning involves constructing plans for rapid movement of people from an emergency affected area. However, these plans are actually constructed only to prepare for emergency, before more information is available about the actual threat. The same evacuation plans are to be used regardless of the origin of hazard and location of people, which might render them unsafe. However, recent new technology of pedestrians' simulation gives advantages to plan an evacuation with more complicated simulated scenarios with different characteristic.

The emergency evacuation processes are affected by many uncertain factors. The factors for real evacuation are traffic accidents, number of deaths from the hazard and number of injuries caused by the evacuation [5]. For trial evacuation, some people are spontaneously evacuated before being told to do so. However, some people refused to be evacuated because they have already know it is only a trial version. In addition, people stated that the alerting method, pedestrians' cooperation and well trained emergency responders contribute to the efficiency and effectiveness of the evacuation process.

In case of emergency, the movement of a pedestrian is more straightforward than in the general cases [3]. The movement of commuters in a railway station for example is more complicated because they choose the route to reach their destination which is usually guided by signboard or map. However, in case of a

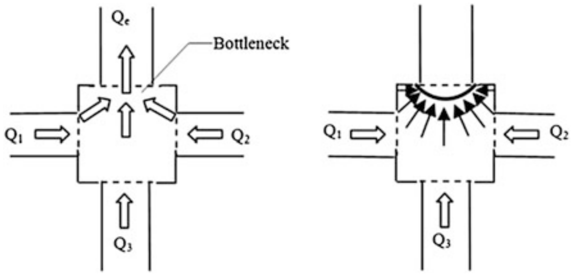


Fig. 1 Bottleneck situation as in [6]

building evacuation, the aims and routes used are known and usually the same; i.e.: the exit way. That is why pedestrians' movement in an emergency case is more straightforward than general cases.

In an emergency situation, pedestrians from any areas or angle who rushed to an exit way would block the pedestrians movement and increase pedestrians density. Therefore, a formation of an arch shape blockings at exit bottlenecks, which instantaneously causes a cease in evacuation flow will occur. When the arches break, the pedestrians will suddenly leave just like avalanche bunches. More seriously, this phenomenon can cause psychological panic that could lead to more dangerous situation. For example, a pedestrian stampede which is one of the most disastrous forms that often leading to fatalities as people are trampled [2]. Figure 1 shows the example of pedestrians' movement in bottleneck situation where in an emergency situation, crowd route from any areas rushing to an exit would block the crowd movement and increase crowd density and then form an arch shape blockings at exit bottlenecks, which instantaneously causes a cease in evacuation flow. When the arches break, pedestrians will suddenly leave just like avalanche bunches. More seriously, this phenomenon can cause people psychological panic that could cause dangerous situation like a crowd stampede which is one of the most disastrous forms that often leading to fatalities as people are trampled [6].

A well-developed skill in assessing a complex traffic situation and being able to choose and execute an appropriate response are an essential key for a safe pedestrians' behavior [7]. A model for pedestrians flow and pedestrian dynamics are based from a series of force which include will forces (the desire of the pedestrian to reach a place at a certain time), pedestrian collision avoidance forces, obstacle or wall avoidance forces, pedestrian contact forces and obstacle or wall contact forces. The forces are the results from internal and external forces. The forces are considered as follows:

1. Internal forces: will force, pedestrian collision, obstacle or wall avoidance forces.
2. External forces: pedestrian contact forces, obstacle or wall contact forces.

When the pedestrians' motion is accurately predicted, it can be used to assess the possibility of safety hazard and operational performance at the event for example in the cinemas or conference center where many people are gathered [8].

Pedestrians' behavior was investigated during the emergency evacuation at Shuangjing Station in Beijing. The result from the evacuation capacity model shows that 8,942 people can be evacuated within 6 min under emergency. It was found that the critically affected elements during the emergency evacuation process were the characteristic of the evacuees, the evacuation facilities and the evacuation organization and management [9].

An evacuation of pedestrians in a transit terminal such as subway station was studied where an agent-based model was used for the evacuation process. The effective evacuation time considered the effect from the density of the occupant and the width of the exit door and automatic fare gates. It was found that the evacuation time becomes longer with the increasing of the occupants' densities and different occupant densities correspond to a different critical exit width. The automatic gates however played the roles of making the evacuation process more orderly [10].

In this study, the focus was on pedestrians' evacuation in case of fire in a building. Pedestrians' evacuation means the method and solution for the pedestrians to move from a danger area to a safer area. Whilst, it means that pedestrians must move using the correct route to ensure their safety.

3 Pedestrian Simulation Model

Modeling a wide range of pedestrians behavior is not simple and some model developed from discrete choice and social force can be used to describe how pedestrian deviate from their free flow behavior due to the presence of other pedestrian [11]. There are several types of Microscopic Pedestrian Simulation Model (MPSM) and to be exact are the Benefit Cost Cellular Model, Magnetic Force Model, Queuing Network Model, Cellular Automata Model and Social Force Model. Many simulation models have been designed and available in the market. Each simulation package has its characteristics and advantages. Some of the examples include AnyLogic, Arena, PanicSim, Exudox, Legion, ProModel, PedGo, Simul8 and KanbaraSim. The pedestrian simulation software has been used widely as a tool in managing the operational and strategies of pedestrians' movement. Social Force Model (SFM), for example has been widely used by simulation software where SimWalk software (developed by Savannah Simulation AG Switzerland) was used as a test bed of this study uses SFM as its fundamental equation to determine the path of the pedestrian [12].

The greatest advantage of the SFM which differentiate it from other MPSM model is the ability in representing the communication between pedestrian in more realistic way. For this distinction, most researchers considered SFM as the representative model for the environmental phenomena that are triggered by the interaction among pedestrians such as congestion. SimWalk is capable to design the pedestrians walking areas and simulating the movement of pedestrians through the shortest route in order to reach destination after evading all the obstacles [12].

There are two types of SimWalk which are SimWalk Pro and SimWalk Transport. SimWalk Pro is use to analyze the safety evaluation of stations, airports, sports stadium, building, etc. while SimWalk Transport is use more on to stimulate and analyze the passenger movements in trains, metro and bus station. Besides, SimWalk can also help to optimize timetable, passenger transfer times and connections. Furthermore, by using this software, we can measure the effectiveness of a transportation system such as density, personal count such as exits or self-defined in space, walking speeds, travel times, space, pedestrians' trails as well as Level of Service (LOS).

4 Methodology and Data Collection

Generally, pedestrian modeling is divided into two different scales which are microscopic models and macroscopic models. In microscopic models, each pedestrian is represented separately as an individual agent and his/her behavior is explored independently. While in macroscopic models, pedestrians are analyzed in groups where it is generally described by mass densities, flow and average velocity [13]. In this study, the simulation method using SimWalk software is categorized as microscopic model that have different types of pedestrians with individual properties such as route selection. Figure 2 shows the example of SimWalk configuration.

SimWalk can be define as a flexible pedestrian simulation software focusing on evacuation, transportation and urban application and it is decision support software for traffic engineers, transit planners, architects and urban planners [14]. The software use a flexible model which allow users to define the density, agent flow, the range of speed for pedestrians, the level of service (LOS), time step and speed loss.

Video recording is a method used for collecting data in this study. Portable Vision Based Traffic Analyser (PVBTA), Video Based Traffic Analysis (TRAIS) and Semi-Automatic Video Analyser (SAVA) software were used for data extraction. Video recording has become common and suitable equipment for empirical pedestrians study. Automatic evaluation of pedestrians' trajectories could be the advantage, but video recording also has its limitations where some recording software such as TRAIS requires user to specify the starting and finishing points of pedestrians manually and the position of the camera should be at suitable place. It is often imply small areas of recording and oblique camera positions. The pedestrians could be hidden in the video in a huge pedestrians' crowd [15].

Data were obtained from a video recording during a trial fire drill that has been conducted in a building at Faculty of Civil Engineering, Universiti Teknologi MARA (UiTM). The fire drill started with the fire alarm and whistle to notify the students in the class that there is an emergency case. They have to move quickly to

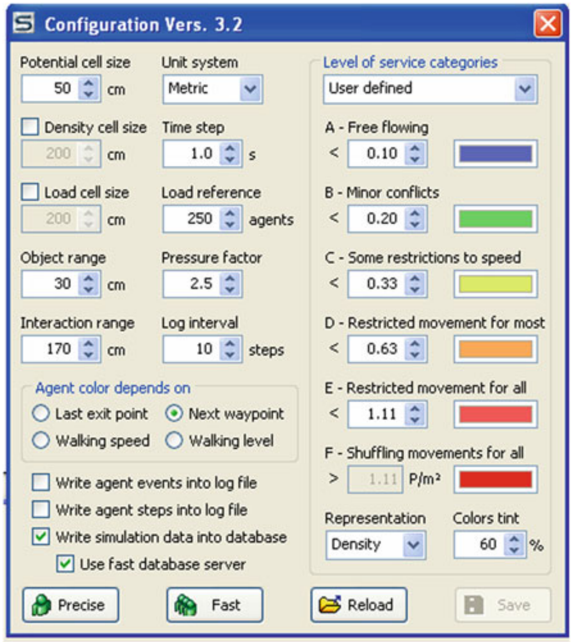


Fig. 2 Configuration in SimWalk

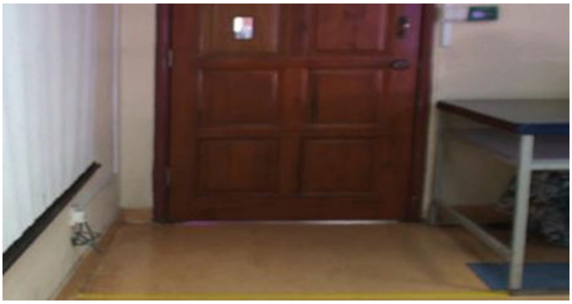


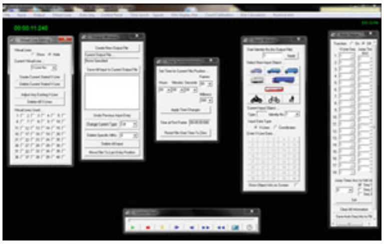
Fig. 3 Exit door in the classroom

a safe area by using stairs. When all people have left the building and reached the safe area, the evacuation process is considered finished.

PVBTA device had been placed in one of the classroom located at Level 8, Faculty of Civil Engineering, during a fire drill session. Figure 3 shows the exit door in the classroom and the use of a wide lens of the PVBTA enabled the camera to view the entire walking area in the classroom. During the trial, there were 35 students in the class. TRIAS or Video Based Traffic Analysis in Fig. 4 was used to specify the parameter needs in recording the video using PVBTA. SAVA in Fig. 5 is the software that provides a basis for analyzing traffic film data. The basic functionality of the program includes being able to forward the film one frame at a time using the media player controls, arrow keys or the mouse wheel.

Fig. 4 TRIAS

Fig. 5 SAVA



There is a pedestrian application in SAVA which can be used to extract the pedestrian's speed and counting the pedestrians. It was used as the data extraction tools for the video recorded. TRAIS is used only for the video recording with the specific parameters and then SAVA will take place to extract the pedestrians' data of the speed and person counts. After the data was extracted from SAVA, SimWalk was used to validate and simulate the data where some output can be measured such as route selection, walking speed and density.

5 Results and Discussions

5.1 Route Selection

Figure 6 shows the differences between pedestrians' trail during real time (video recording) and simulation. Figure 6a shows pedestrians at the left side of the classroom chosed to use the left lane to go to the exit door. Same goes to the pedestrians at the right side of the classroom. They chosed the right lane to make a move towards the exit door. For pedestrians in the middle row, some used the right lane and some used the left lane to walk to the exit door. On the other hand, in SimWalk simulation (Fig. 6b), the different trail for the pedestrians at the middle row could be seen. All of them used the right side lane to evacuate themselves. That could cause congestion at the right lane and more time will be taken by the pedestrians to reach the exit door. The pedestrians cannot overtake each other because the space is not enough.

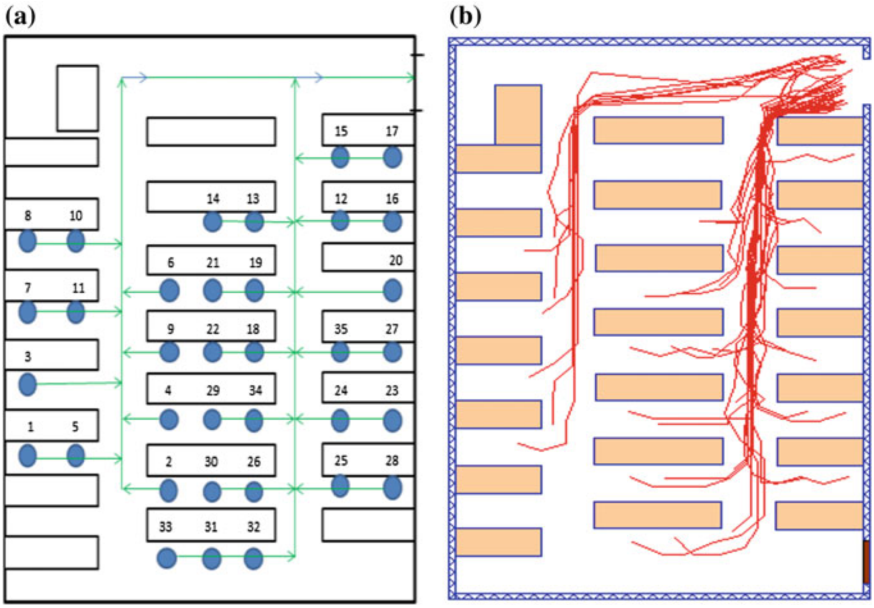


Fig. 6 Comparison of pedestrian's trail between **a** real (video recording) and **b** simulation

Figure 7 shows the pedestrians' trail in SimWalk software if only one door open and two doors open. There are many differences if we compare between these figures. Using only one door for evacuation, longer time was needed by the pedestrians to exit the classroom. The evacuation result when only one door was opened is 38s. When both doors are opened, 36s was needed by the pedestrians to leave the classroom.

Figure 7a also shows all pedestrians from the right row and the middle row used the right lane to go to the exit door while pedestrians at the left row of the classroom used the left lane to go to the exit door. The pedestrians from the two lanes will then meet at a point which was at the front lane. The pedestrians can choose to exit the classroom through the front or back door and make a better decision to choose their route to evacuate in a shorter time if any of the exits is congested.

5.2 Pedestrians' Density

Figure 8 shows the difference in maximum density between two situations in a classroom whether only one door open and both door open. Figure 8a (one door open) shows that there are four different colors covering the classroom area. Yellow color (>1.72P/m^2) shows a restricted movement for most pedestrians (LOS

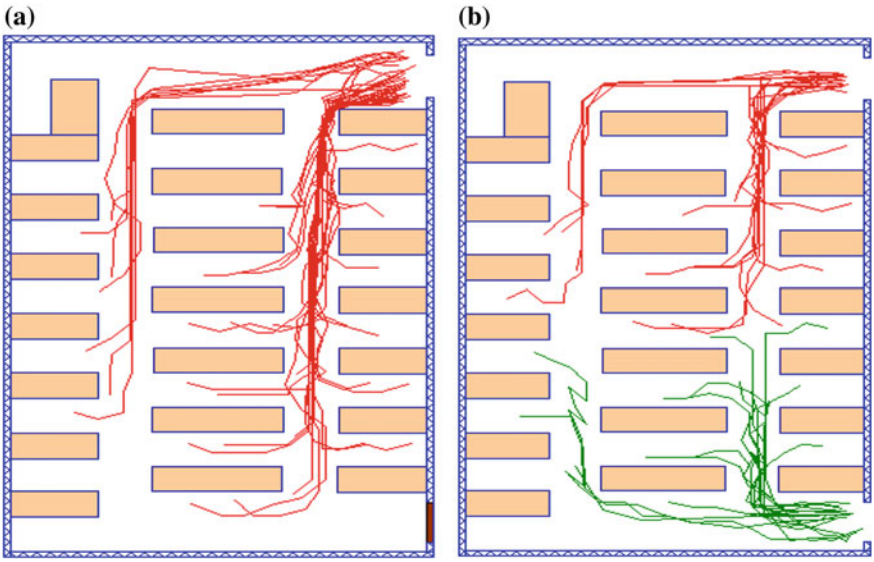


Fig. 7 Comparison of pedestrian's trail between **a** one door open and **b** two doors open in a classroom

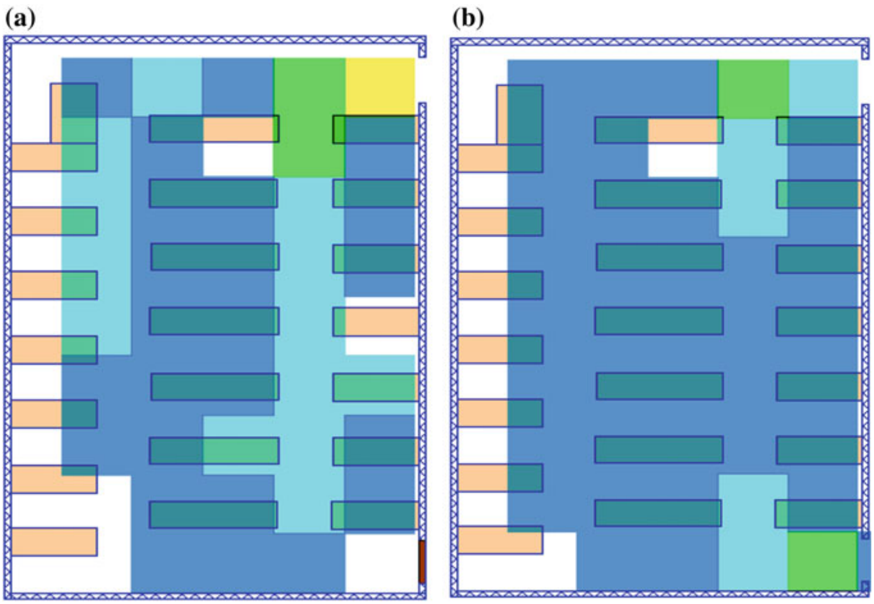


Fig. 8 Different maximum density between **a** one door open and **b** two doors open in a classroom

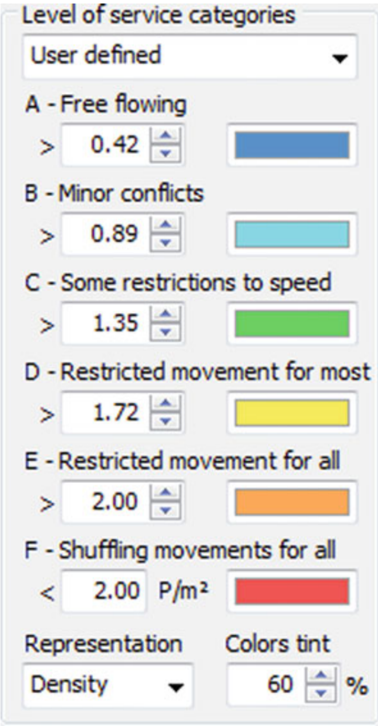


Fig. 9 Exit door in the classroom

D). In Fig. 8b, with both door open for exit, there is no restricted movement area. The blue color is the major color represented in both situations where it shows a free flow condition of pedestrian's movement (LOS A). Free flow movement can be found more frequently when two doors are open during the evacuation (Fig. 9).

5.3 Walking Speed

Figure 10 depicted the comparison of walking speed for each pedestrians between real (video recording) and simulation. It can be seen that in real evacuation, the speed has more variation as compared to the simulated one. In Fig. 10a, the highest speed of pedestrians is 0.92 m/s which is lower than the highest speed in Fig. 10b which is 1.23 m/s. The lowest speed of pedestrians in real (video recording) is 0.22 m/s as compared to 0.52 m/s as the lowest speed using simulation. Besides that, the average speed for real (video recording) is 0.40 and 0.63 m/s for simulation.

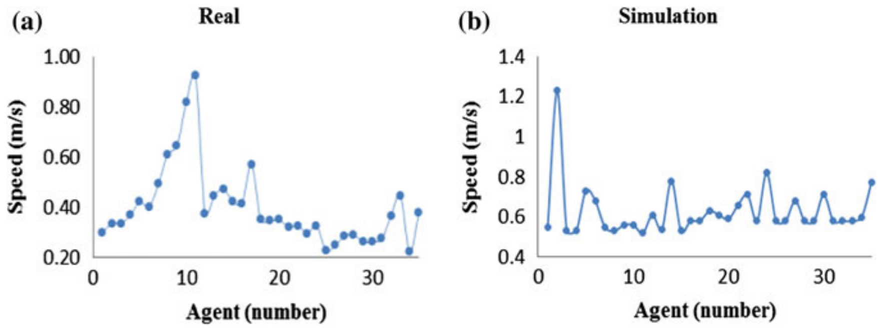


Fig. 10 Different of walking speed between **a** real (video recording) and **b** simulation

6 Conclusion and Recommendation

This study investigated the egress behavior during a classroom evacuation. The simulation approached used shows the variations in route selection when the people are on a panic situation. Door is the important function in any classroom that will be used as an exit way for the pedestrians to evacuate themselves. In this study, only one door was open when we observed the pedestrians using video recording. However, many scenarios can be created using simulation. It is recommended that both doors in every classroom are open to be used to ease and fasten the pedestrians' evacuation process. The simulation results have verified that the time taken for all pedestrians to exit when only one door was open is longer than both doors were open. A better use of exits door consists of more differentiated path with less congestion and reduced evacuation times is advisable.

This study has utilized one of the applications of SimWalk which are the pedestrians' trail and density in route selection during the evacuation process in classroom. In the future, studies involving realistic condition of pedestrians dynamic such as bottlenecks at the exit with variation dimension of door can be conducted.

Acknowledgments This study is funded by Universiti Teknologi MARA, Malaysia.

References

1. PED, in 6th International Conference on Pedestrian and Evacuation Dynamics, retrieved 30/11/12, from http://www.ped2012.org/
2. D. Helbing, A. Johansson, Pedestrian, Crowd and Evacuation Dynamics, in *Encyclopedia of Complexity and Systems Science,* pp. 6476–6495 (2009)
3. A. Schadschneider, W. Klingsch, H. Klüpfel, T. Kretz, C. Rogsch, A. Seyfried, Evacuation dynamics: empirical results, modeling and applications, in *Encyclopedia of Complexity and Systems Science*, pp. 3142–3176 (2008)

4. W. Daamen, S.P. Hoogendoorn, *Experimental Research of Pedestrian Walking Behavior*. Transportation Research Board annual meeting (National Academy Press, Washington DC, 2003), pp. 1–16
5. L.J. Dotson, J. Jones, D. Schneck, R. Sullivan, Identification and analysis of factors affecting emergency evacuations (2005), Nureg/CR-6864, vol. 1, retrieved 30/11/12, from http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6864/v1/
6. L. Huang, D. Liu, Y. Zhang, Dynamics-based stranded-crowd model for evacuation in building bottlenecks. Math. Probl. Eng. **2013**, 7 p (2013) (Article ID 364791)
7. J. Oxley, B. Fildes, E. Ihsen, J. Charlton, R. Day, Differences in traffic judgements between young and old adult pedestrians. Accid. Anal. Prev. **29**(6), 839–847 (1997)
8. R. Lohner, On the modeling of pedestrian motion. Appl. Math. Model. **34**(2), 366–382 (2010)
9. H. Cheng, X. Yang, Emergency evacuation capacity of subways station. Soc. Behav. Sci. **43**, 339–348 (2012)
10. W. Lei, A. Li, R. Gao, X. Hao, B. Deng, Simulation of pedestrians' evacuation in a huge transit terminal subway station. Phys. A: Stat. Mech. Appl. **391**(22), 5355–5365 (2012)
11. M.C. Campanella, S.P. Hoogendoorn, W. Dameen, Calibrating walker models: variations of parameter due to traffic regimes, in European Conference on Mathematical and Theoretical Biology (2011)
12. Z. Zainuddin, K. Thinakaran, I.M. Abu-Sulyman, Simulating the Circumambulation of the Ka'aba using SimWalk. Eur. J. Sci. Res. **38**(3), 454–464 (2009)
13. A.S. Sahaleh, M. Bierlaire, B. Farooq, A. Danalet, F.S. Hänseler, Scenario Analysis of Pedestrian Flow in Public Spaces, in *Proceeding of the 12th Swiss Transport Research Conference (STRC)*, Monte Verità, Ascona, Switzerland, May 2012
14. P. Stucki, Obstacles in Pedestrian Simulations, Department of Computer Sciences, Master Thesis, ETH Zurich, 2003
15. A. Johansson, D. Helbing, H.Z. Al-Abideen, S. Al-Bosta, *From Crowd Dynamics to Crowd Safety: A Video Based Analysis* (World Scientific Publishing Company (WPSC), 2008)