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ANALYSING THE SIMULATION MODEL OF RISK PERCEPTION BASED OF THE PEDESTRIAN BEHAVIOUR AT UNDERGROUND STATION IN MALAYSIA: A FRAMEWORK PAPER

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ABSTRACT

Pedestrian behaviour study has become a popular topic in transportation and planning conferences where many papers connected to the topic had been published. In Malaysia, studies on the effect of egress facilities, especially at the underground train stations towards the pedestrian movement during emergency evacuation have been given little attention. In order to assist the stakeholder in public transportation division, two shortcomings in the safety aspect of evacuation have been identified. Firstly, the pedestrians' demand on egress facilities is excessive and could cause severe congestion during peak hours. Next, up to this date, Malaysian Government is yet to establish their very own standard or specification and manuals for emergency evacuation. Instead, they use internationally recognized NFPA 130 standards to construct underground space and facilities for pedestrian. The objective of this study is to identify the factor that influences pedestrians' behaviour and to explain the framework used for analysing the simulation of risk perception based on it. Site observation and video recording of the passengers' movement and standing at the platform during peak hour is used as measurement and data collection of this study. Next, questionnaires are used to identify passengers' route choice in the event of emergency. *Viswalk* software tool is used to simulate the people's movement in virtual environment before being validated using Emergency Response Plan (ERP). Significantly, this study will contribute new knowledge in managing passenger crowd during emergency situation towards rail industry in Malaysia (LRT, MRT) as well as academicians.

Keywords: pedestrian behaviour, emergency evacuation, underground station.

INTRODUCTION

Pedestrian behaviour study has become a popular topic in previous transportation and planning conferences in which a number of papers discussing the topic have been presented. Among the presented papers, attention has been given on critical infrastructure at high rise building at a different mass event such as sports game or religious celebration. This event can create a problem of comfort, safety and dangerous scenarios. At the same time, it will generate a crowd, which can make an individual easily suffocate, crushed or trampled to death.

By definition, crowd management is an effective planning based from previous experience where it is limited to the event that have already happened and incompetent to cover future scenarios (Davidich and Koster (2012)). Thus, the role of mathematical model and simulation tools come into play. They are able to assist in predicting and planning crowd mass event and evacuation.

In Malaysia, little attention is given on the study on the effect of egress facilities, especially at the underground train stations towards the pedestrian movement during the emergency evacuation. There are several applications to examine the safety aspects such as design of the critical infrastructures and simulation on optimization of public transport operation to predict of pedestrian's dynamics in evacuation studies.

Therefore, it is important to understand the fundamental of pedestrian dynamics for all these applications since the flow of crowds and the individual behaviour of person with crowds are highly complex (Davidich *et al*., 2013). The simulation and prediction model of pedestrian dynamics are very useful and can be put in a wide spectrum of various applications.

In order to assist stakeholders involved in the public transportation division, especially in a case of safety analysis in the aspect of evacuation studies a few problems have been identified.

Firstly, the passengers' walking speed and selection to egress underground stations depend on behaviour or characteristic of the pedestrian themselves and egress facilities design. During peak hours, pedestrians' demand on egress facilities is always excessive and could cause severe congestion especially at the bottleneck entry of egress facilities. Therefore, the understanding of the pedestrian demands on the vertical egress facilities is needed to improve the planning and design of the egress environment and the emergency evacuation plan for the pedestrian.

Next, Malaysian Government is still referring to the specifications and manuals of the emergency evacuation from other countries such as NFPA 130 to develop underground spaces for pedestrian. This code has been used as guidelines to design the underground facilities. Chen *et al.* (2004) claimed that NFPA 130 considers the emergency evacuation time starts immediately at the break of emergency without considering the pedestrians that unfamiliar with the environment. Therefore, it is needed to analyse and simulate the evacuation, emergency time, referring to Malaysia's environment and compare with several worldwide specifications and manuals for emergency evacuation.

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On top of that, up to this date, rail operators in Malaysia do not have their own standard Emergency Guideline Response (ERP). Furthermore, the calibration with ERP needs to be updated as the last calibration has been done in years ago.

Based on the argument above, the objective of this paper is to identify the factors that influence pedestrian behaviour and to explain the framework for analysing the simulation of risk perception based on it.

FACTORS INFLUENCING PEDESTRIAN BEHAVIOR

Pedestrian movement is affected by a number of factors such as gradients or roughness of surface (Older, 1968), indoor or outdoor walkway (Lam *et al*., 1995), available space (Fruin, 1970), width of walking facilities (Mitchell and MacGregor, 2001), riser height of stairways (Tanaboriboon and Guyano, 1991) and type of walking facilities (Morrall *et al*., 1991; Smith, 1995). The understanding of the factors affecting the pedestrian movement is important not only to provide the comfortable pedestrian facilities, but also in order to plan the most operational egress facilities during the evacuation process, either in normal or emergency situations.

Therefore, it is also a need to understand the pedestrian walking speed to provide the appropriate walking facilities. Pedestrian desired walking speed or pedestrian free flow desired speed is the speed that the pedestrian can walk without hindered by any obstacles (Daamen and Hoogendoom, 2006). This speed is reported to be different among the pedestrian from different countries and regions (Rahman *et al*, 2012). It is also different among the different types of facilities such as stairways or escalators where the facilities also may have their own design criteria (Ye *et al*, 2008). It is also supported by Chandra and Bhart (2013) study that figured out the pedestrian speed is different for different locations and gender.

In 90's the study on pedestrian flow characteristics started to focus on the differences between the pedestrian in Asian and Western countries (Morrall *et al,* 1991; Seneviratne and Morrall, 1985). With the construction of underground train stations, especially in highly populated cities, more study on the relationship between walking facilities for pedestrian underground movement is needed especially focusing on stairs and escalators. These two types of facilities were found to play as important role during the evacuation process. It is because the code of design at underground pedestrian facilities was differently designed for different countries and regions (Wang et.al, 2012).

PREVIOUS WORK

A number of studies have found that the fundamental relationship of speed-flow relationship, including the travel time could be useful elements for the simulation tools for designing and improving the pedestrian facilities (Rahman *et al,* 2012). Ye *et al* (2008) had developed the pedestrian speed flow relationship for several walking facilities by considering the pedestrian flow at four different types of walking facilities (including stairways) at Shanghai metro stations. They figured out that the pedestrian capacity and flow of the stairways were affected by high constraint of locomotion ability. It means that the pedestrian need more energy and greater concentration while walking on the stairways. These factors were suggested to be considered for evacuation process plan for the underground train stations.

Another example by Jiang *et al* (2009) found that width of staircase has an influence to maximum upstairs walking speed and pedestrian flow. It is concluded that the evacuation simulation software can be applied for safety design with appropriate tuning on the key parameters such as pedestrian flow, speed and density through field tests. Pedestrian behaviour under emergency conditions is used to provide a valuable tool to assist planners and managers of emergency responses to analyse and assess safety precautions for those situations.

There are two types of study on pedestrian modelling and simulation one is macroscopic (focusing on crowd) and the other one is microscopic (focusing on individual). Most studies preferred macroscopic model which relate to the flow, density and speed passenger movement.

Daamen (2004) come out an outline on the speed versus flow relationship for pedestrians as proposed by several researchers based on empirical observations. Macroscopic model (SimPed) were used in this study to present a passenger flows in the underground public transport facilities. It is analogous with the simulation study by Daly *et al* (1991) that used PEDROUTE simulation tool for London Underground Limited where it also required the relationship between flow and travel time to estimate the pedestrian flows and delays during the evacuation process at London Underground train stations. The study also focused on the pedestrian characteristics while walking, ascending and descending on the stairways and escalators.

Table-1. List of selected previous study for underground pedestrian system.

Country	City	Underground Pedestrian System
Canada	Edmonton, AB	"Pedway", connecting buildings and LRT stations of the downtown core
	Montreal, QC	"RESO", 32 km, covering more than 41 city blocks (Besner 2007, p. 1)
	Toronto, ON	"PATH", 6 blocks wide, 10 blocks long, 27 km (Belanger 2007, p. 272)
	Vancouver, BC	Over 3 city blocks, connecting 2 shopping malls, 200 stores and three stations
	Winnipeg, MB	Connecting commercial office, office towers and downtown traffic
United States	Atlanta, GA	"Underground", covering 6 city blocks
	Chicago, IL	"Pedway", covering 40 city blocks ($8km^2$), connecting 50 buildings (Wang and Liang 2010, p. 96)
	Dallas, TX	"Dallas Pedestrian Network" (Zhu et al. 2007, p. 14), covering 36 city blocks by 15 bridges and 26 tunnels (Lassar 1988; Terranova 2009, p. 18)
	Houston, TX	4.5 km (Tong 2005; Zhu et al. 2007, p. 14)
	New York, NY	Locating at Rockefeller Centre in Manhattan, covering 10 city blocks (Tong 2005; Zhu et al. 2007, p. 14)
	Oklahoma City, OK	1.2 km, underground systems and skywalk systems covering 20 city blocks, connecting 30 buildings (Wang and Chen 2010, p. 42)
	Philadelphia, PA	Several underground concourses in Centre City connecting subway stations
Hong Kong	Hong Kong	Underground networks connecting buildings and shopping malls to Central Station (Yang et al. 2008)
Japan	Tokyo	6km, containing 141 shops, connecting 51 buildings (Guan and Yang 2001, p. 33)
China	Beijing	Locating at western area of Zhongguancun (Chen and Wang 2005, p. 24)
	Harbin	250,000 m^2, several underground shopping streets interconnected (Zhu et al. 2007, p. 20)
	Nanjing	Locating in Xinjiekou, connecting department stores, subway stations and shops
	Shanghai	People's Square containing 10,000 m^2 underground commercial spaces, connecting underground parking and subways (Geng 2005, p. 39)
Russia	Moscow	"Perekhod", Connecting commercial centers with kiosks, shops, buskers, pharmacies, often used as meeting places during winter times (Charlton 2010, p. 56)

MATERIAL AND METHOD

Parameter

The parameter of this study is show in Table-2.

Table-2. The parameter and definition.

Parameter	Definition
Passenger capacity	Movement of passenger depend on the size of the platform/station which reflected to passenger traffic flow
Time	The acceleration and velocity of the passenger to escape from platform/ station
Direction	The route choice of passenger based on distance, area, and surface.

Method

Site observation and video recording of the passenger moving and standing at the platform will be used as measurement and data collection of this study. The observation will commence during peak hour at the critical area. Questionnaires are distributed to passengers to identify their route choice during emergency situation.

A number of video cameras will be installed at several locations (Figure-1 and Figure-2) to acquire as accurate data as possible. The obtained video will then being verified with CCTV recording from rail operator.

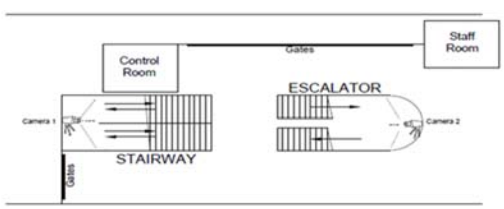

Figure-1. Camera location at concourse area.

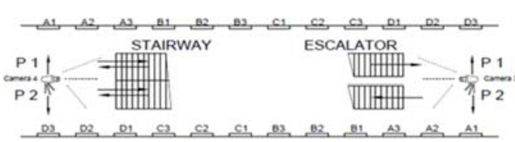

Figure-2. Camera location at platform area.

In virtual environment, *Viswalk* software will be used to simulate passengers' walking behaviour in free space, inside the building and in the event of mass gathering. The simulation result will then being validated with ERP.

FUTURE WORK

Towards the end of this study, the academic and industry, especially for rail operators in Malaysia (LRT, MRT) who have underground station will shared and received a good knowledge especially during the emergency situation. It will help the operator to manage the passenger crowd evacuate from the platform.

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