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Analysis of pedestrian walking characteristics at vertical facilities in underground train station

Nur Sabahiah Abdul Sukor[1,2], Farah Hanin Mohd Nain[1], Irwina Ismail[1] and Mohd Ashraf Mohamad Ismail[1,2]
[1] School of Civil Engineering, Engineering Campus, Universiti Sains Malaysia, 14300 Nibong Tebal, Pulau Pinang, Malaysia
[2] Senior Lecturer, School of Civil Engineering, Universiti Sains Malaysia

E-mail: cesabahiah@usm.my

Abstract. Kuala Lumpur is the national capital of Malaysia as well as the center of attraction for people looking for jobs. Thus, in the future people will tend to use public transport including the Light Rail Transit (LRT) more often than driving their vehicle. This is especially so due to critical traffic congestion on the road especially during peak hours. The increasing population in Kuala Lumpur could lead the LRT stations to become more crowded form day to day due to excessive demand. Due to this problem, the facilities provided will not be enough and suitable to cater the space demand. Unfortunately, the limited study was done regarding the pedestrian spaces and facilities at underground LRT in Malaysia. Thus, this paper aims to establish the fundamental understanding of pedestrian behavior at vertical facilities in underground train station.

1. Introduction

The study of pedestrian movement is important in order to facilitate the pedestrian with comfort and safe environment. The previous study in Malaysia figured out that the mean walking speed for the pedestrian at signalized and non-signalised crosswalk is 1.39 m/s and 1.31 m/s respectively [1]. Meanwhile, the average free flow speed and the estimated jam density for the pedestrians on the sidewalk in Dhaka, Bangladesh are 1.2m/sec and 3.32peds/m² respectively [2]. However, less study reported on the pedestrian movement and their characteristics in underground spaces in Kuala Lumpur. Also, usually during the peak hour, there is a huge volume of the pedestrian using underground spaces and the facilities provided might be limited in the future if the demand for the pedestrian spaces increases.

Therefore, to provide comfort and safest facilities, the pedestrian walking facilities supposed to be designed in such a way that they can be used conveniently and be easily assembled, built and installed with no confusion involved in the process of their usage [3]. The analysis of pedestrian travel time, free flow speed, speed, flow, density and the capacity of facilities are required to provide the best and pleasant facilities for the pedestrian. One of the methods to determine all of these elements is through a video camera survey to gather the detail of walking characteristics of the pedestrian [4,5]. This survey can record all of the movement of the pedestrian in the facilities including the stairways and escalators. In addition, to understand the pedestrian behavior and their characteristics at the underground train station, the analysis on pedestrian travel time is important. Travel time refers to the amount of time required to travel from one point to another point [6]. The estimated travel time on different walking facilities such as stairway and escalator will be helpful in designing the size of the facility required that suitable for the demand and the walking characteristics of the pedestrian.

2. Methods

A video survey was held on 27th to 29th January 2015 in KLCC LRT station during the peak hours and non-peak hours to investigate the pedestrian walking speed-density-flow. The aim of this survey is to collect pedestrian travel time, flows, density on the stairway and escalators. The physical dimensions of the vertical facilities such as length and width of the stairway and escalator were also determined. A survey plan for data collection at KLCC LRT station is illustrated in Figure 1. The figure shows the location of the video cameras that used to collect the data. All of the video cameras were synchronized to determine the exact entry and exit time of the chosen pedestrian.

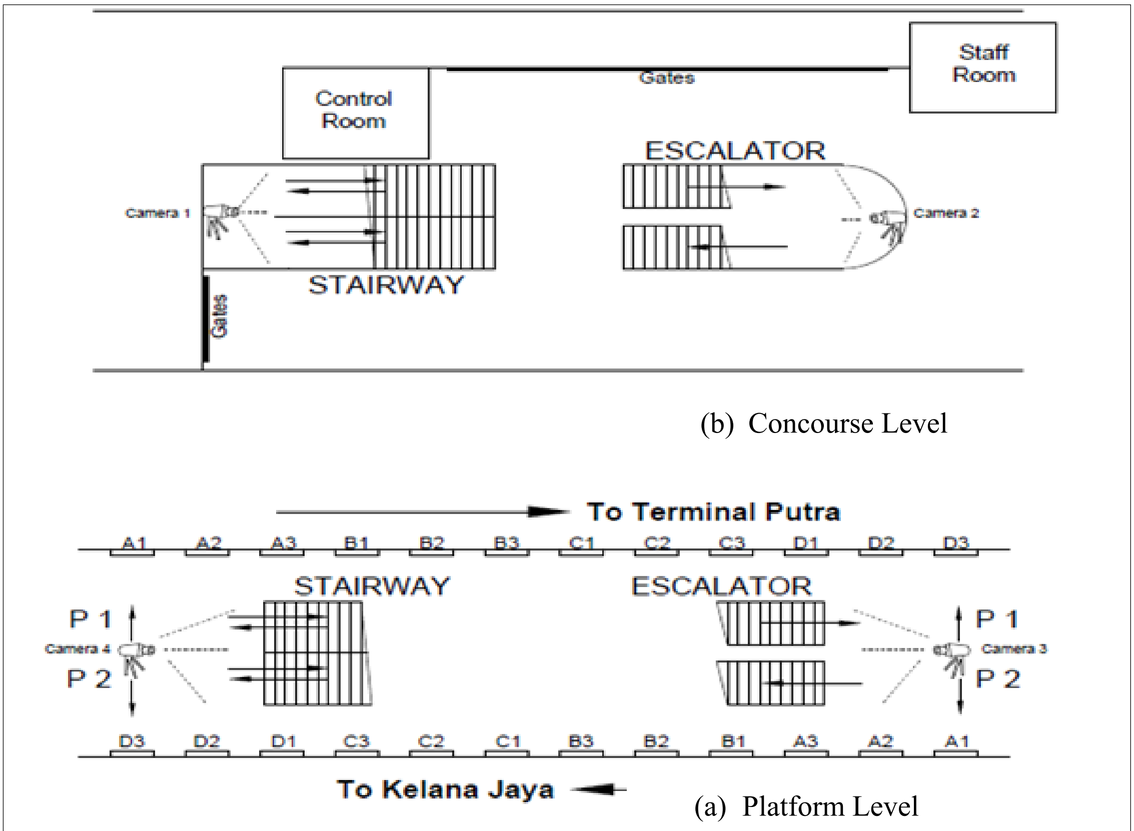


Figure 1. Location of video cameras for data collection at KLCC LRT Station.

Then, data analysis was carried out to extract the required data from the recording by using media player. This method has its advantage as it can be repeated and the data can be reviewed. Moreover, pedestrian manual counting was also done during the video camera surveys for calibration purpose.

Three parameters of pedestrian behavior such as flow, speed, and density, were extracted manually by playing the video recordings on a computer screen. The two hours video recording was divided into 15-minutes intervals. Due to the limitation of images in the video camera recording, 3-s intervals and 23-s for the stairway and escalator facilities respectively was adopted because most of the people could finish walking the distance of the observed length. In this study, pedestrian flow was determined by counting the numbers of the pedestrian passing a line of sight across the width of the facilities. For stairway, the number counted is the total number of pedestrian for both ascending and descending directions and then divided by 3-s and the width of a facility to obtain the flow rate. For escalator, the number counted is the total number of pedestrian for both ascending and descending directions and then divided by 23-s and the width of a facility. The flow rate was expressed as ped/s/m.

To obtained the pedestrian density, the number of pedestrians occupying the observed area for 3-s was counted and then divided by the observed area. The density was expressed as ped/m². Speed can be obtained by taking the travel time of pedestrian who traversed the observed length. The average travel time of the three random pedestrians who walk following the crowd is taken. The speed was computed as the observed length of facilities divided by the travel time and expressed as m/s. Moreover, a random pedestrian was chosen during the non-peak hour to obtain their time travel along the facility. The data of the pedestrian travel time was obtained using manual counting during the video camera surveys.

3. Results and Discussion

Figure 2 shows the total number of pedestrian per hour at the KLCC LRT Station for the three days of the survey. Observation time for pedestrian counting from the video camera recording based on the peak hour obtained from the graph below. The physical characteristics of the facilities are shown in table 1.

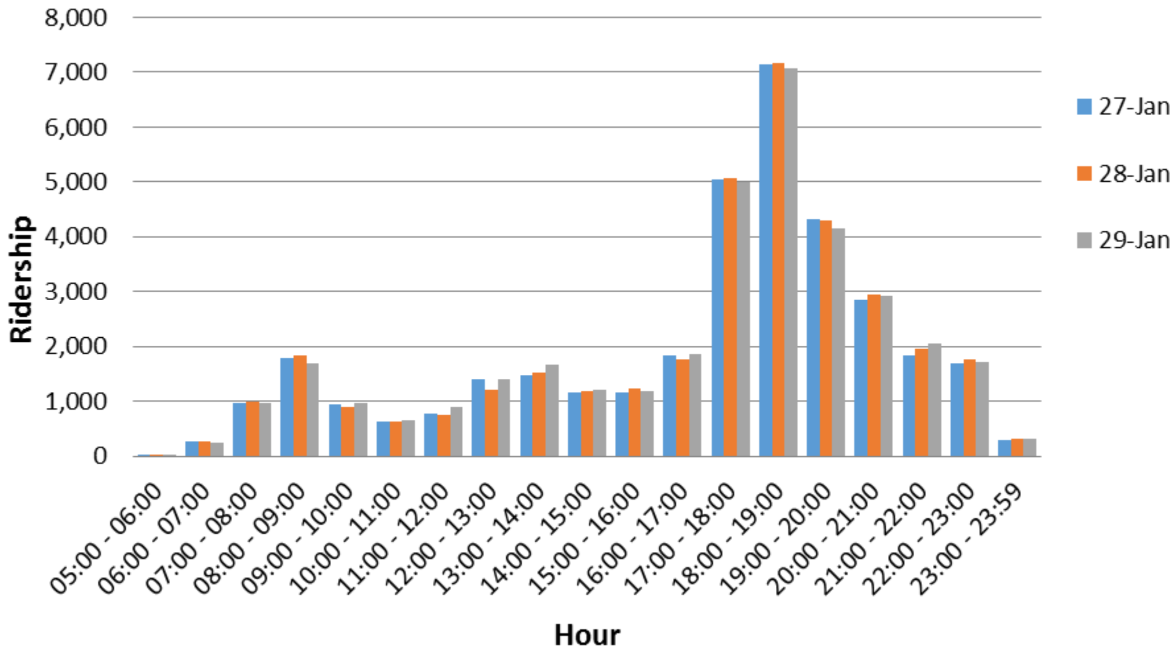


Figure 2. KLCC hourly station ridership.

Table 1. Observation times and physical characteristics of vertical facilities.

Walking Facility	Observation Time	Physical Characteristics				
		Width, mm	Length Observed, mm	Grade, °	Tread width, mm	Step Riser Height, mm
Stairway	7.30 a.m. – 9.30 a.m.	3810	12962	/	299	162
Escalator	12.00 p.m. – 2.00 p.m. 5.30 p.m. – 7.30 p.m.	1150	13900	30	/	/

3.1. Pedestrian free flow speed

From the data obtained, the free flow speed in descending direction is higher than ascending direction for stairway and escalator (Table 2). Ascending direction refers to flow from platform level to the concourse level, whereas descending direction refers to flow from concourse level to platform level. This phenomenon occurred because pedestrian needs more effort to travel in ascending direction compare to descending direction. At stairway, pedestrian walks more freely with their desired speed when traveling from concourse level to platform level. They tend to increase their walking speed at the facilities when the train has arrived at the station.

Table 2. Pedestrian free flow speed at stairway and escalator.

Free Flow Walking Speed (m/s)			
Stairway		Escalator	
Ascending	Descending	Ascending	Descending
0.806	0.965	0.755	0.786

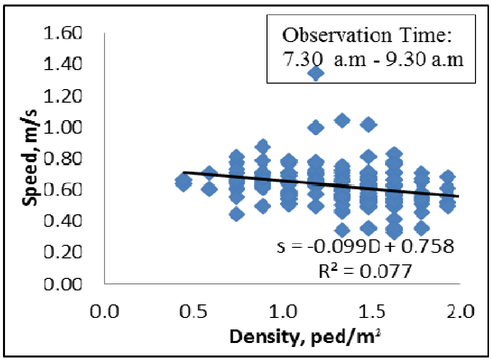
A similar situation occurred at the escalator where the pedestrian-only increase their walking speed when the train arrived. Due to less flow of pedestrian at the escalator, pedestrian tends to control their walking speed, and they were walking at the escalator, and their speed was affected by the escalator velocity which is 0.5 m/s. It was shown in Table 2 that the pedestrian walked at the escalator as the average walking speed were 0.755m/s and 0.786 for ascending and descending direction respectively.

3.2. Speed-Flow-Density Relationship at Stairway

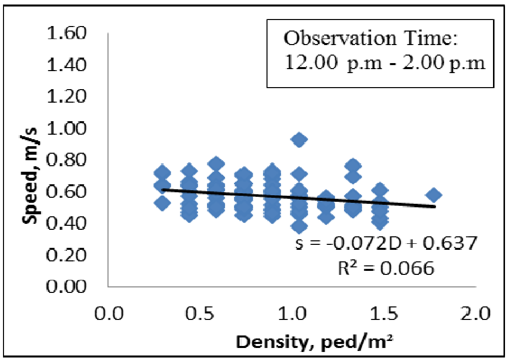
The scatter plots of pedestrian speed-density at the stairway for the different time of peak hours, including (a) morning peak, (b) noon peak and (c) evening peak hour can be seen in Figure 3. It shows that the speed is decreased as the increase of the density in the facility. Most of the pedestrian at Figure 3(a) walks at speed below 1 m/s differ with the pedestrian at Figure 3(c) because they walk in a different direction. Pedestrian at Figure 3(a) walks in ascending direction (platform level to concourse level) whereas Figure 3(c) walks at descending direction (concourse level to platform level). Thus, pedestrian in Figure 3(a) need more effort to walk upward compare to Figure 3(c).

Apart from that, pedestrian in Figure 3(b) tends to walk more slowly compare to Figure 3(a) and Figure 3(c). This phenomenon may be due to the time pressure that cause the pedestrian in Figure 3(a) and Figure 3(c) to walk at high speed such as in a rush going to the office or meeting whereas the lower speed at Figure 3(b) due to the less important walk purpose such as going out for lunch or shopping.

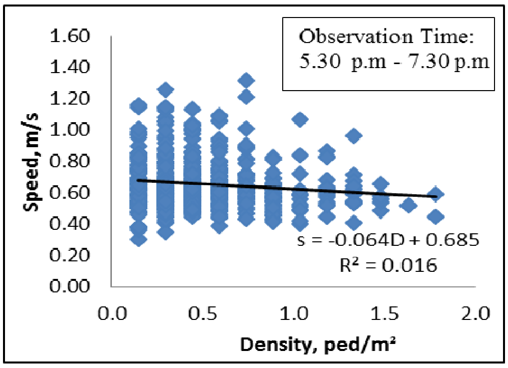
Figure 4 indicates the relationship of pedestrian flow-density at the stairway for the different time of peak hours including morning, noon and evening peak hour. The scatter plots of pedestrian flow-density for stairways are plotted as shown in Figure 4 below for three different peak hours, including (a) morning peak, (b) noon peak and (c) evening peak. Before the pedestrian density increases to a critical value, the variation of flow between Figure 4(a) and 4(b) is almost the same. At the same density, Figure 4(c) gives less value of flow due to the increased conflicts among pedestrian especially during the arriving of the train. There is less conflict occurred in Figure 4(c) because of most of the pedestrian walk in ascending direction and only a few in descending direction.



(a) Morning Peak

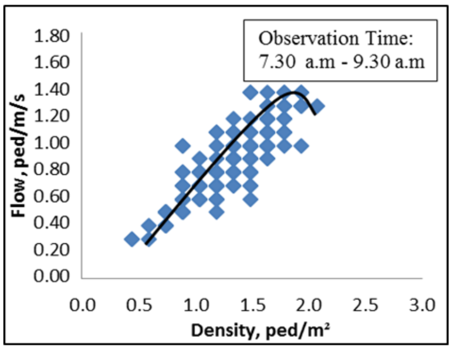


(b) Noon Peak

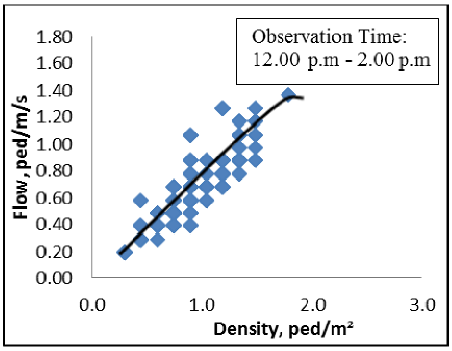


(c) Evening Peak

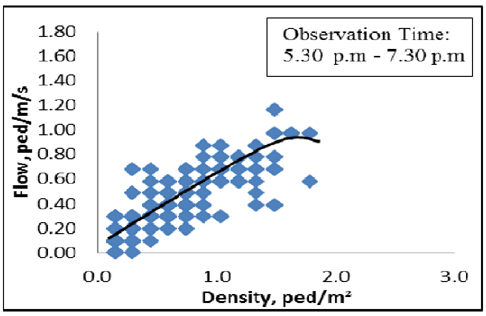
Figure 3. Scatter plots of pedestrian speed-density at the stairway.



(a) Morning Peak



(b) Noon Peak



(c) Evening Peak

Figure 4. Scatter plots of pedestrian flow-density at the stairway.

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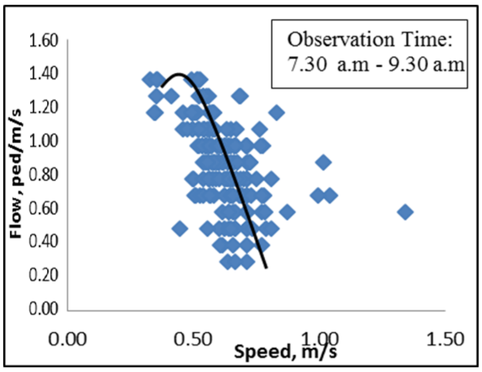
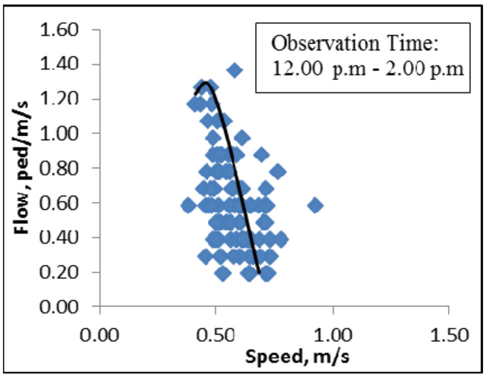
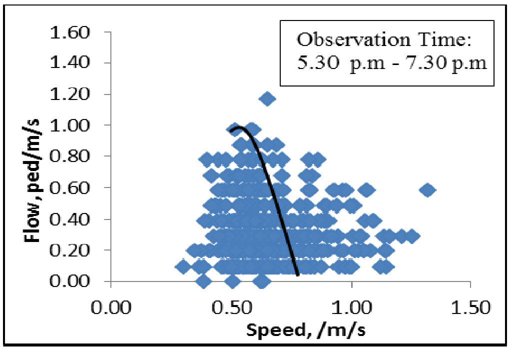
Moreover, as it was shown in Figure 5, the graph of pedestrian speed-flow relationship at stairway is illustrated. The highest pedestrian flow on morning and evening peak is 1.4 ped/m/s, whereas, on morning peak, the flow was below 1.2 peds/m/s. Pedestrian walking speed that obtained in Figure 5(a) and Figure 5(b) was below 1.0 m/s. The walking speed was lower because of most of the pedestrian travel in an ascending direction. When the pedestrian arrived at the station, the conflict will occur because the walking speed of the major flow from ascending direction was affected by the pedestrian from the opposite direction. At evening peak, most of the pedestrian was travel at the range speed of 0.5 – 1.7 m/s. High speed obtained due to less conflict occurred during evening peak because of most of the pedestrian travel in descending direction with less conflict with the pedestrian in the opposite direction. This phenomenon occurred because, through the observation, high demands in descending direction due to the most of the pedestrian were the workers that used the train after office hour.



(a) Morning Peak



(b) Noon Peak



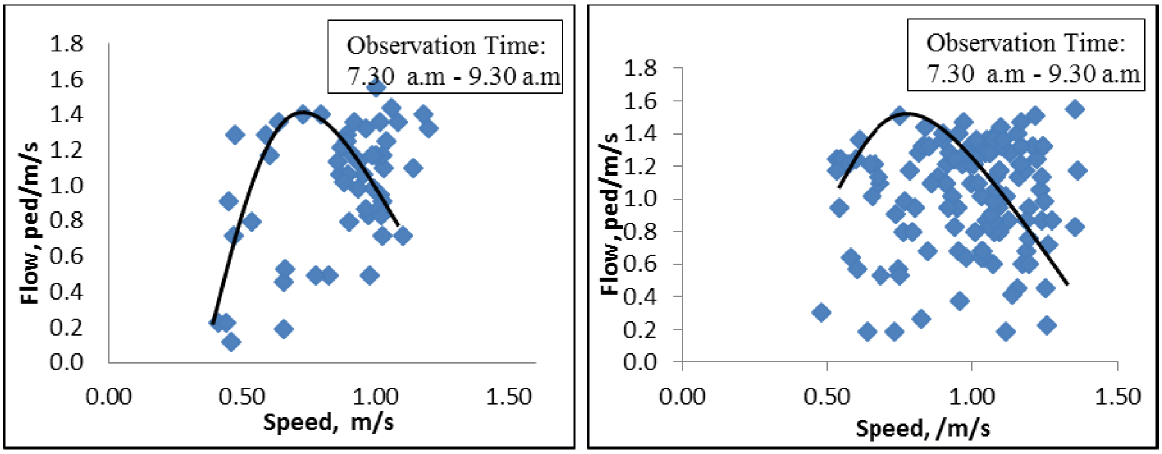
(c) Evening Peak

Figure 5. Scatter plots of pedestrian speed-flow at the stairway.

3.3. Speed-Flow-Density Relationship at Escalator

The scatter plots of speed-flow relationship in escalator from three different peak hours are displayed in Figure 6. Since the escalator on morning peak only operating in ascending direction, it can be compared that pedestrian who has chosen the right side escalator will travel at range speed of 0.5 – 1.7 m/s which higher than left side of an escalator.

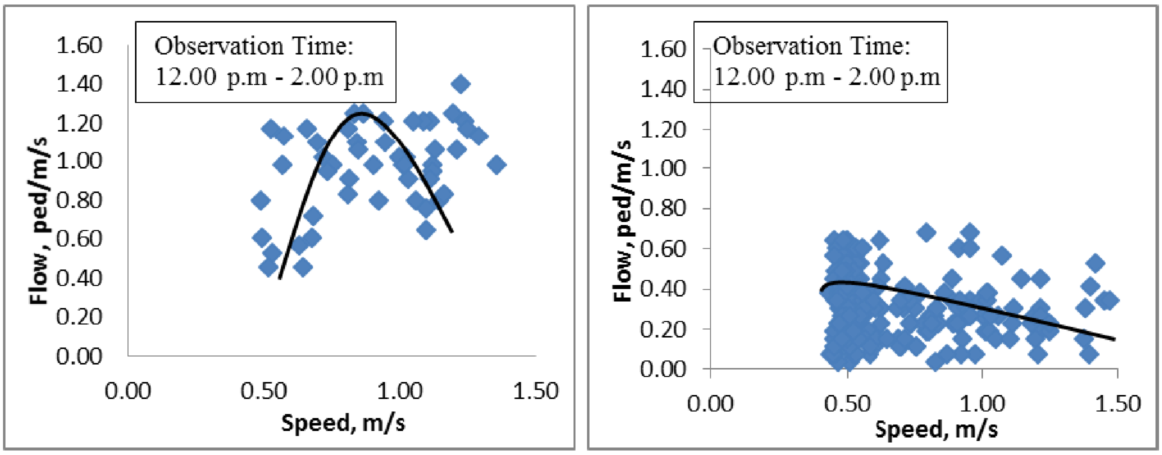
In addition, based on the observation, the preferable side of the escalator will be affected by the position of the arriving train. The pedestrian will choose the nearer escalator and based on the graph below, the travel speed of the pedestrian was not affected by the flow of the facility. This happens because based on the observation, the flow on the escalator will be split into two: pedestrian who following the escalator velocity will stay on the left side and pedestrian can travel with their desire speed will travel along the right side. To get the variation of the scatters plot for the escalator, the observation for pedestrian speed based on the pedestrian travel time from the right side.



(a) Left Side (b) Right Side

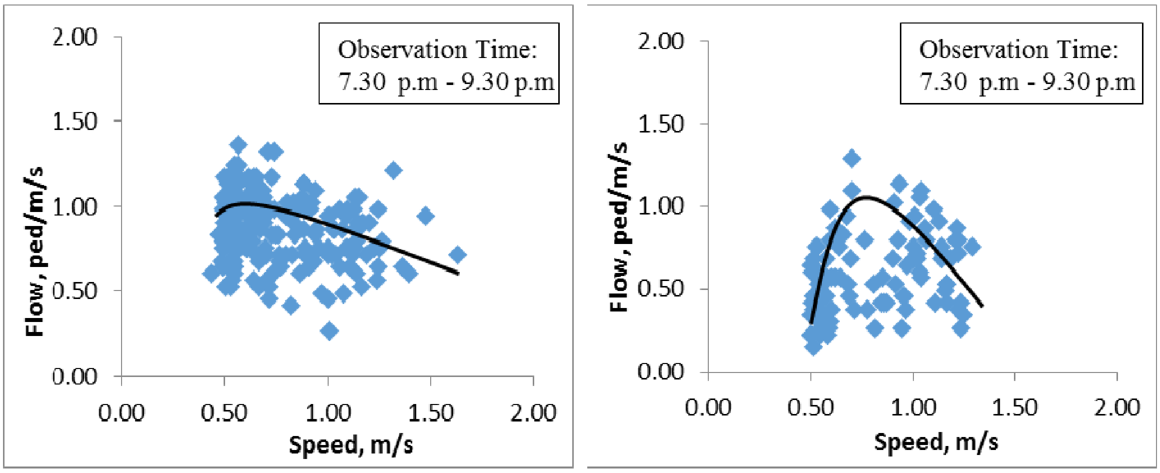
Figure 6. Scatter plots of pedestrian speed-flow for ascending escalator.

In Figure 7 the scatter plots for speed-flow density in escalator for both directions during noon peak and evening peak respectively are presented. During noon peak, the pedestrian flow in Figure 7(a) was 0.8 m/s which is lower compared to pedestrian flow in Figure 7(b). This is because lower demand observed during noon peak, whereas the high flow observed in Figure 7(a) due to the pedestrian flow in ascending direction that arrives at the station. The highest value of noon peak and evening peak are 0.7 ped/m/s and 1.4 ped/m/s respectively. High flow obtained in Figure 8(b) compared to the flow in Figure 8(a) because of the high demand occurred in the evening peak. The high flow was observed during evening peak due to the end time of office hour. Most of the people are heading back home. In addition, from the observation during the video camera survey, it is found that pedestrian in descending direction will increase their walking speed during the arriving of the train.



(a) Ascending Direction (b) Descending Direction

Figure 7. Scatter plots of pedestrian speed-flow for noon peak escalator.



(a) Ascending Direction (b) Descending Direction

Figure 8. Scatter plots of pedestrian speed-flow for evening peak escalator.

4. Conclusion

Pedestrian walking characteristics in KLCC Station were different between morning, noon and evening peak. During morning and evening peak, pedestrian tends to walk at high speed compared to noon peak. This is because they were in a rush hour for the important purpose such as going to the office. This is different with the noon peak as the pedestrian more relax and travel with their desire speed with fewer obstacles from another pedestrian. In stairway, pedestrian in minor flow will have to decrease they walking speed or to stop at one point when high flow is coming from the opposite direction. In addition, as the pedestrian density increase, the movement of the faster pedestrian is likely to be impeded by the slower pedestrian. This phenomenon occurred for both facilities. Though the scope of this study is limited, the survey result can still be a reference for the future study on pedestrian flow, especially in Malaysia. The result from this study can be useful for evacuation planning in underground spaces. Furthermore, it is believed that the study on pedestrian walking facilities will be beneficial for future planning of design facilities.

Acknowledgement

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