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Pedestrian Movement at the Unpaid Concourse Area in KLCC Train Station

Nur Sabahiah Abdul Sukor[1*], Noorhazlinda Abdul Rahman[1], Munzilah Md Rohani[2], Kamarudin Ambak[2], Sitti Asmah Hassan[3]

[1]School of Civil Engineering
Universiti Sains Malaysia, 14300 Penang, MALAYSIA

[2]Faculty of Civil and Environmental Engineering
Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, MALAYSIA

[3]School of Civil Engineering
Universiti Teknologi Malaysia, 81310 Johor Bahru, MALAYSIA

*Corresponding author

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Abstract: This study investigates the pedestrian movement during three different peak hours by considering their walking speed and density at the unpaid concourse at a train station. The data for analyses; pedestrian hourly volume and pedestrian walking speed in this study was extracted from the CCTV video footage at the train station in KLCC. The findings show the walking speed at the study area can be considered as fast with the highest walking speed was 1.68m/s during the afternoon peak hour and the slowest walking speed was 0.98m/s during the morning peak hour. The study area was divided into several segments in order to simulate the pedestrian density by using VISWALK. Pedestrian density was highest during the evening peak hours. The study also found that the pedestrian tended to walk in oblique movement to avoid collision with other pedestrian in the crowd during the peak hours. The findings in this study give some insights for pedestrian crowd management in the train station to increase the pedestrian flow and may useful for emergency evacuation planning.

Keywords: Pedestrian walking speed, pedestrian crowd, pedestrian movement, VISWALK, train station

1. Introduction

The economic transition in Malaysia has started from 1970's, by focusing towards industrial sector which has driven the economic prosperity to a higher point. This rapid growth in economic had allowed Malaysia to be well-developed in the transportation sector, including the rapid transit networks. Kuala Lumpur, the capital city of Malaysia is now one of the cities that featured with modern and convenient rapid transit network in Asian countries, which is essential to serve the transportation demand for 1.79 million populations for 243 sq.km [1]. With the expansion of the transit train system, more and more facilities for the pedestrian were needed to be equipped in the train stations. This is including by providing the sufficient infrastructures and designs to ensure adequate and safe pedestrian spaces especially during the dense and crowded hours. At the same time, it is crucial to prepare the pedestrian infrastructures and facilities for the emergency conditions.

The increment number of pedestrians in the train station definitely will increase the space demand of the train station. The crowded station will create the uncomfortable feelings when the pedestrian needs to walk closer to each

*Corresponding author: cesabahiah@usm.my

other [2]. This will affect the movement pattern at the spaces inside the train station. Besides, it will possibly decrease the likeliness to use the public transport and the users may consider switching their mode of transport from public transit to car [3]. Hence, the poor quality of service should be avoided, and station should able to cater the high capacity of users [4].

This study is focusing on KLCC train station, which has highest ridership for Kelana Jaya Line. Each of the train station in Kelana Jaya Line has different design. In order to increase the vivaciousness of the KLCC train station, the train operator has created the unpaid concourse area to be lively with several entertainment activities such as busking and singing performance, that not disturbing the passing by passengers. There were also other activities such as buying tickets at ticketing machines and ticket counter, and also shopping at the shopping mall that attached to the train station building. In the future, this station is expected to receive more passengers as a linkage for the new transit line known as MRT Sungai Buloh - Serdang- Putrajaya Line (SSP Line) The underground transit station named KLCC East MRT station is expected to be completed on 2022 and will contribute to the increasing number of train passengers a the KLCC area [5].

This study is to understand the current behaviour of the pedestrian crowd at the concourse area of KLCC train especially at the peak hours. This paper is organized as follows. The following section reviews the previous studies on pedestrian in the crowded spaces. It will be followed by the explanation on data collection and simulation steps. Next, the results and findings from the analyses will be explained. Finally, conclusions are drawn and recommendations for future study are presented.

2. Pedestrian Movement

Pedestrian movement includes the walking speed, density and the behaviour of the pedestrian at the area of study. Pedestrian walking speed is defined as rate of motion in distance per unit time and it is a parameter that described how fast a pedestrian walk to complete a unit length of trip that usually represented in centimeter/second, meter/second or meter/minutes. The average of pedestrian walking was reported in between 1.5m/sec and 2m/sec [6]. As one of a fundamental parameter in pedestrian traffic flow, it will be a very important parameter that will be used in a simulation work.

Meanwhile, passageway and walkway in buildings (including unpaid area or paid area in the train station) are considered as the confined space with limited width. It was reported that the pedestrians mean speed walking was 1.36m/s at level passageway in a building [3]. A study about pedestrian walking speed at a 4.4m passageway in People's Square Station had divided the pedestrian into 22 groups and found that the average walking speed for each group was 1.31m/s. However, the pedestrian walking speed in the train station was reported to be different based on the condition and location [7]. For example, the pedestrians walk at a speed of 1.33m/s in an ordinary passageway meanwhile, the walking speed can reach 1.62m/s in the platform if they realised the arriving of the train. In a normal condition, the walking speed at the train platform was 1.49m/s which can also be considered as fast [8]

A more comprehensive study on pedestrian speed and flow had been done at walking facilities in Hong Kong [9]. In this study, pedestrian walking speed at indoor walkway in commercial areas and shopping areas with the effective width of 6.3m and 5.4m respectively, were observed. The results show that the walking speed at the commercial areas was higher than in the shopping areas. For the case of Kuala Lumpur, the pedestrian walking speed at non-signalised crosswalk was found to be 1.39m/s, meanwhile at signalised crosswalk the walking speed was 1.31m/s. [10]. It shows that the walking speed is affected by the environment and surrounding of walking.

Ease of movement or the pedestrian walkability is related to the interaction between each pedestrian. When pedestrians walk, they will always have interaction with the other pedestrians and that incurred interaction will always influence the behaviour and the walking direction of a pedestrian. The interaction between the pedestrian also occurs at the train stations.

It is believed that during the interaction between each pedestrian, there are three main effects which were follow effect, deterrent effect and rejection effect [11]. Follow effect was usually performed when a pedestrian follows another pedestrian who in front of them. Pedestrian were most likely to match their speed with a person who walked in front of them [12]. The deterrent effect was triggered when a pedestrian moved away to avoid collision with other pedestrian from opposite direction [13]. The third effect which was rejection effect shows that the pedestrians tended to change their walking direction when their path had been blocked by other pedestrians [14].

It was also suggested that a pedestrian may not only try to avoid collision with other pedestrians but also try to avoid collision with the surrounding and built environment such as walls and columns [15]. For example, pedestrian has repulsion force to wall at approximate 30cm from the wall border [13]. Meanwhile, it was also found that pedestrian keeps a distance of about 0.4m from the wall and had the tendency to walking too close to the wall [16]. The reason of pedestrians tends to keep a distance from the wall is mainly because of they to worry to get collided with the wall [17].

In addition, pedestrian walks differently in a crowded environment by preventing collision with other pedestrians in order to have a comfort walking speed [18]. This also explained the formation of walking in group in the pedestrian crowd. For example, in order to minimize the collision and interaction effect with other pedestrian who walked from difference direction, most of pedestrian were tended to follow the path used by the pedestrian in front of them [19].

Furthermore, in the crowded environment pedestrians were most likely to walk at the right side of the walkway in bidirectional flow Moussaid et al. [13].

3. Pedestrian Microsimulation

Simulation is needed to forecast the future scenario and lot of researches also depend simulation to study pedestrian crowd flow under different scenarios. There are few models that used to describe and predict the behaviour of pedestrian during walking, such as agent-based model, cellular automation model and social force model. Agent-based model is model that can be used to model the pedestrian movement behaviour. The outcomes from this model are depending and determined by the interactions between pedestrian [20]

In addition, agent-based model also being used in various simulation scenarios, such as simulation of pedestrian flow [21], [22], building evacuation [23], [24], evacuation in urban and urban outdoor scenario [25], [26] and other evacuation scenario such as concert venue [27].

Meanwhile, the theory of cellular automation model exists and has been studied for a long time [28]. In cellular automaton model, space is discretized into many small cells [29], [30]. These cells are usually filled with value of variables [31]. These cells also filled by a pedestrian and pedestrian may move to an adjacent cell at next discrete time step ($t \rightarrow t+1$). One of the advantages of this model is that the simple rule in this model allows high simulation speed [32].

Social force model is another simulation model that widely used by researchers to simulation the pedestrian traffic activities. The concept is, pedestrians rather walk in a situation where they are conformed with, instead of walking randomly, automatically and react according to their experiences for the best outcome [17]. In social force model, each agent in the model will have effects on all other agents, which resulted in the computational complexity and limit the model's ability to simulate a simulation contains many agents [33]. In other words, a pedestrian will act according to the environment or subjected to an external force. The social force model was then improved by enabling the simulation of panic situation [34]. Despite social-force model is a famed model, it does have some disadvantages and limitations It was found that this model may allow two pedestrians to overlap with each other or occupy the same location [35]. In order word, the pedestrian will walk through each other. In order to eliminate the possibility of the pedestrian to overlap with each other, the model was modified to create an impenetrable barrier between two pedestrians. It is also having some limitations, especially when describing the specific flow rate at different door width and the fundamental diagram. For this reason, the model was modified, and the simulation model shows the results that matched with experiment data under normal condition [36]. Beside the mentioned modification, there are researchers modified the model for a more realistic simulation [37]-[39]

Another simulation approach was proposed to keep the model as simple as it is but allows longer-range interactions, static and dynamic floor fields were introduced [40]. These floor fields affect and determine the probabilities of an object to transit of a from a cell to another cell [30]. Static floor field does not change with time, but dynamic floor field does. In fact, this model was generally acceptable as there are many simulations were simulated using this model [32], [41]-[46].

4. Data Extraction

A video footage from the CCTV that provided by the train operator was analysed. The time frame of morning peak hours (6.00 to 9.00 a.m), afternoon peak hours (12.00 to 2.00 p.m) and evening peak hours (5.00 to 8.00) were chosen for further investigation. The selection of the peak hours was based on the trend of the ridership during weekdays that provided by the train operator (Prasarana Malaysia Berhad). Therefore, the analysis was considering normal working days and no influence of holiday season. The data extraction from the CCTV was considering the concourse unpaid area which was used by the pedestrian and the train passengers either to access the shopping complex, offices and also the underground train platform. In order to extract the pedestrian volume and other related data, the video footage was played in the slow-speed for each 15s-time frame. Before further analysis, the pedestrian walking speeds in the study area also needed to be determined. In order to calculate the walking speed, the travel distances of each pedestrian were needed to be examined. The existence of fix-structures such as columns and ticketing machines were eliminated from the analysis, thus the video footage focused on the trapezoid area ($b1 = 8000$ cm, $b2 = 9800$ cm, $h = 6200$ cm) as shown in Fig. 1.

Next, the trapezoid area was divided into several enter and exit segments. The Right-Side (RS) area were equally divided into 4 segments (RA, RB, RC, RD) meanwhile the Left-Side (LS) area were divided to 3 equal segments (LA, LB, LC) as shown in Fig. 2. Meanwhile, the analyses of pedestrian walking speed were divided into two groups; the pedestrians who walked towards the left side (LS) and pedestrians who walked towards the right side (RS) by considering the estimated average distance as shown in Table 1. In order to get the walking speed, the duration for a pedestrian that walking from RS to LS or LS to RS was recorded and analyzed.

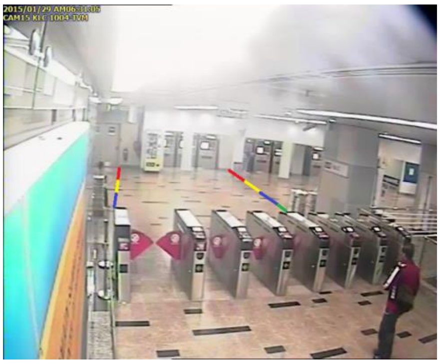

Fig. 1 – The dimension of the trapezoid area of the study.

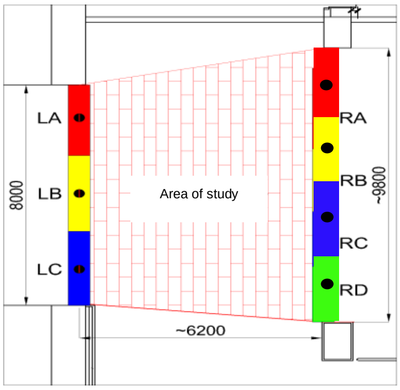

Fig. 2 – Exit and entrance segments at the area of study.

Table 1 – The distance for 12 selected paths.

		Length for Right Segments			
		RA	**RB**	**RC**	**RD**
Length for Left segments	**LA**	6.7m	7.1m	8.1m	9.1m
	LB	7.2m	6.7m	6.9m	7.5m
	LC	8.7m	7.4m	6.7m	6.7m

4.1 VISWALK Setting

In order to simulate the pedestrian density for morning, afternoon and evening peak hours at the study area, VISWALK which is microscopic pedestrian simulation software was used in this study. VISWALK is a pedestrian simulation software developed by PVT Group. This software simulates pedestrian based on Social Force Model (PVT VISWALK, n.d.). VISWALK as a standalone simulation software not only able to simulate pedestrian walking activities but also able to integrate into PTV Vissim. Unlike the other simulator, VISWALK can simulate the pedestrian to reach their destination by taking the shortest distance or the path that take the least time if there is present of crowd (Infographic: Pedestrian simulation - modelling dynamics, n.d)

There were several important data that needed to be extracted to be use in the VISWALK simulation in this study. Firstly, the total number of pedestrian and the hourly volume of pedestrian that walked across the area of study need to be determined. Based on the analysis of pedestrian volume during the peak hours, the hourly pedestrian volume data that used for the simulation were considered an hour of 7.50 to 8. 50a.m for the morning peak hour, 12.50 to 1.50p.m for the afternoon peak hour and 5.50 to 6.50p.m for the evening peak hour. Next, to perform the simulation, it is essential to verify and validate the model. Verification is a process to ensure the model predictions area in accordance with the theory and input specifications. Table 2 shows the verification results in this study.

In the table, “assigned” referred to the original pedestrian data from the analysis and was being assigned into VISWALK to simulate the pedestrian walking speed at path RC to LB for one-hour period. Simulation number one, two and three referred the simulation results obtained from the VISWALK. The t-test results show that the p value between assigned pedestrian walking speed and all three-simulated pedestrian walking speed were greater than 0.05. This indicated that the stimulated pedestrian walking speed and the assigned pedestrian walking speed has not significant different. This also represents that VISWALK was able to simulate the pedestrian walking characteristic that follows the assigned parameter.

Meanwhile, validation is a process to investigate the ability of the software to present the real-life scenario. Tables 3 and 4 show the comparison between simulated pedestrian walking speed and the actual pedestrian walking speed using two different settings. In this validation, two settings were used, which were 'default' and 'specified' setting. 'Default' setting refers to the setting that pre-existed in VISWALK while 'specified' setting refer to setting that was configured and defined by user. For each setting, the tests were run for three times.

Table 2 – The verification results for simulation models and original pedestrian data.

Simulation Number	Number of pedestrian	Pedestrian walking speed(m/s)		p value
		Mean	Difference	
Assigned	663	1.24	-	-
One	663	1.26	0.02006	0.122
Two	663	1.24	0.00235	0.854
Three	663	1.26	0.02101	0.100

Table 3 – Model walking speed and actual walking speed by using 'default' setting.

		Walking Speed (m/s)		
		Model	Actual	Diff %
Simulation 1	Toward Left	1.14451	1.24909	-8.37
	Toward Right	1.12857	1.29652	-12.95
Simulation 2	Toward Left	1.12921	1.24909	-9.60
	Toward Right	1.13397	1.29652	-12.54
Simulation 3	Toward Left	1.13374	1.24909	-9.23
	Toward Right	1.13353	1.29652	-12.57

Table 4 – Model walking speed and actual walking speed by using 'specified' setting.

		Walking Speed (m/s)		
		Model	Actual	Diff %
Simulation 1	Toward Left	1.27374	1.24909	1.97
	Toward Right	1.29696	1.29652	0.03
Simulation 2	Toward Left	1.24704	1.24909	-0.16
	Toward Right	1.30738	1.29652	0.84
Simulation 3	Toward Left	1.26618	1.24909	1.37
	Toward Right	1.29870	1.29652	0.17

The validation results show that pedestrian walking speeds with default setting in the model has higher different from the actual pedestrian walking speed compared to the specified setting. It showed up to 12.57% slowest than the actual pedestrian walking speed in Simulation 3. Meanwhile, the model for pedestrian walking speeds that used specified setting shows much closer results to the pedestrian walking speed. The results determine that it is needed to use 'specified' setting in the future simulation model in this study

Next, the area of simulation models needed to be set up. There were 3 segments on the left side of the study area that accommodated 8 paths, which were LA to RA; LA to RB; LA to RC and LA to RD and vice verca. Hence, 12 area settings were created on the left side of the study area. On the right side of the study area, another 12 areas were created as well as there were 4 segments and each point was shared by 3 paths, RA to LA; RA to LB; RA to LC and vice versa. The preparation for the pedestrian segments and points were as shown in Fig. 3. The important setting for the simulation is the pedestrian input, where the pedestrian volume and walking paths were needed to be set up as shown in Fig. 4. Each path consists of an entry and exit point for the pedestrian; therefore, 24 walking paths were defined. Then, the pedestrian walking speed on each path was setup in the speed distribution curve by considering the minimum and maximum pedestrian walking.

Fig. 5 shows the desired speed distribution curve that used for the simulation. Meanwhile, in order to determine the density, the concourse area was discretized into smaller 48 small boxes as shown in Fig. 6. These sections were used to obtain results for pedestrian density. The area of study was set as 8m(width) x 6.2m(long) where each small boxes are about 1m x 1.03m.

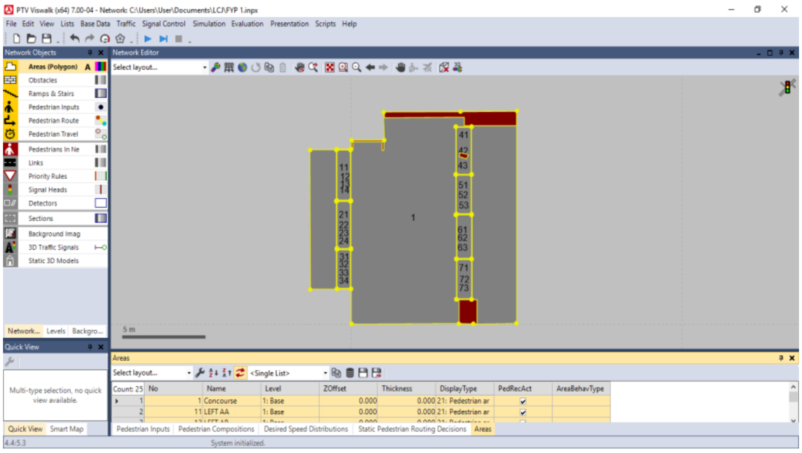

Fig. 3 – The setting for pedestrian areas and points in the VISWALK.

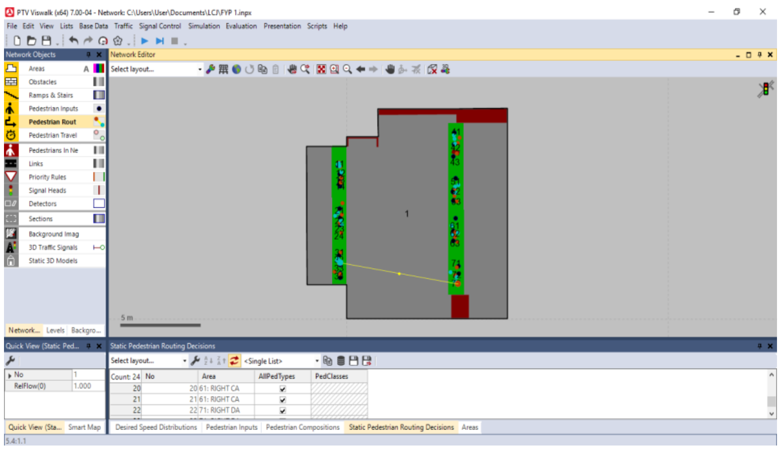

Fig. 4 – The setting for pedestrian walking path in the VISWALK.

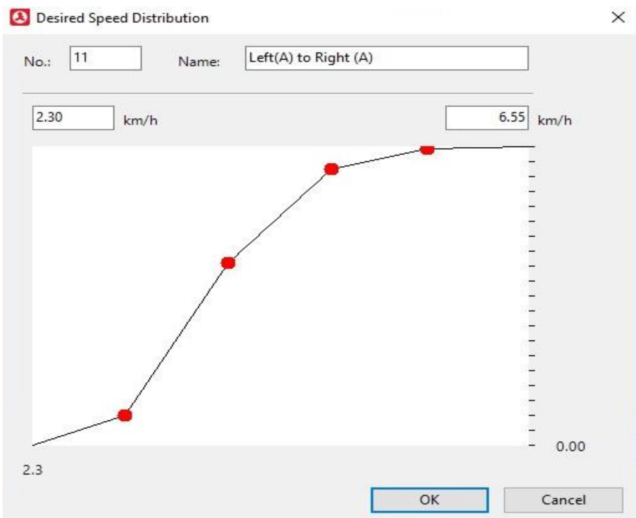

Fig. 5 – The example of speed distribution curve in VISWALK.

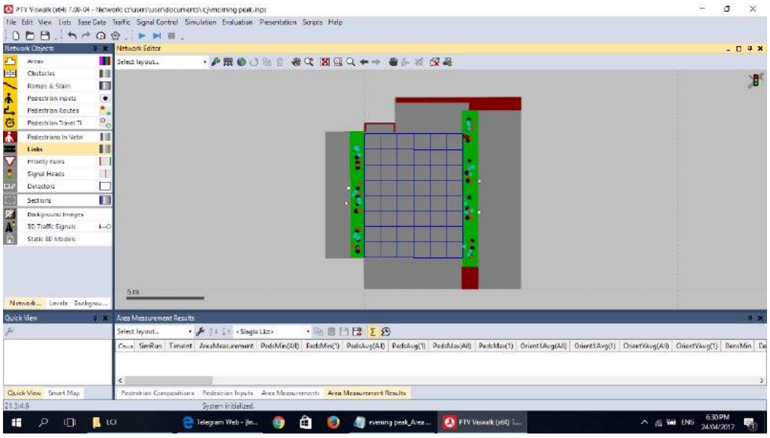

Fig. 6 – The area of study divided into small sections.

5. Results and Discussion

5.1 Pedestrian Volume

A total of 24,622 pedestrians were observed in this survey. During the morning peak hour, 3437 sets of pedestrian data were recorded. Fig. 7 shows the volume of pedestrian during the morning peak hour which also considering the hourly pedestrian volume and cumulative pedestrian volume. The results show that the volume for the pedestrian that crossing the area of study was fluctuated for every minute. The highest pedestrian volume was captured at 8.44 a.m with 64 pedestrians were recorded walking across the study area. In average, 30 pedestrians per minute were walking through the area of study during the morning peak hour survey. Meanwhile, based on the hourly pedestrian volume, the increasing and fluctuated pattern was started as early as 7. 00a.m and decreasing when it was nearly 9a.m. The highest number of pedestrians at hourly volume was 2255 pedestrians per hour recorded between 7. 50a.m to 8.50a.m.

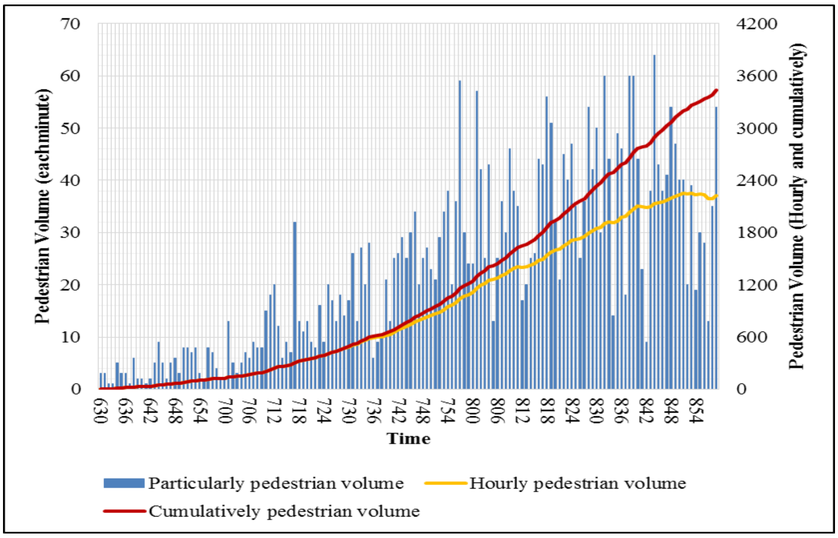

Fig. 7 – Pedestrian volume during morning peak hour.

Meanwhile, Fig. 8 shows the 5347 of pedestrian volume during the afternoon peak hour. The highest pedestrian volume per minute was recorded at 1. 07p.m with 79 pedestrians crossing the area of study. The average of 45 pedestrian per minute was recorded during the afternoon peak hour. In terms of hourly volume, the highest pedestrian volume recorded was from 12:50pm to 1:50pm with 3066 pedestrians per hour. The pedestrian volume that crossing the study area was higher compare to the morning peak hour. This situation is describing the lunch break where people tended to have their lunch and do some retail shopping in the shopping complexes nearby the area of study.

The pattern for the pedestrian volume at the study area during the evening peak hours is shown in Fig. 9. A total of 15858 pedestrian were using the study area during the evening peak where the numbers were 3 times higher than the pedestrian volume during the afternoon peak hours. The highest recorded pedestrian volume per minute was 161 pedestrians at 5.53pm. The lowest pedestrian volume per minute was 20 pedestrians at 6.34pm. It was found that the mean for pedestrian volume during the evening peak hour was 88.2 pedestrian per min. In term of hourly volume, a period from 5.52pm to 6.51pm recorded the highest hourly pedestrian volume. This situation explains that during the evening time, the area of study was crowded with the train passengers that want to go home after the working hours or those who would likely to do shop and dine at the nearby shopping complexes after the office hours. Table 5 shows the comparison of the pedestrian volume in the area of study between morning, afternoon and evening peak hours.

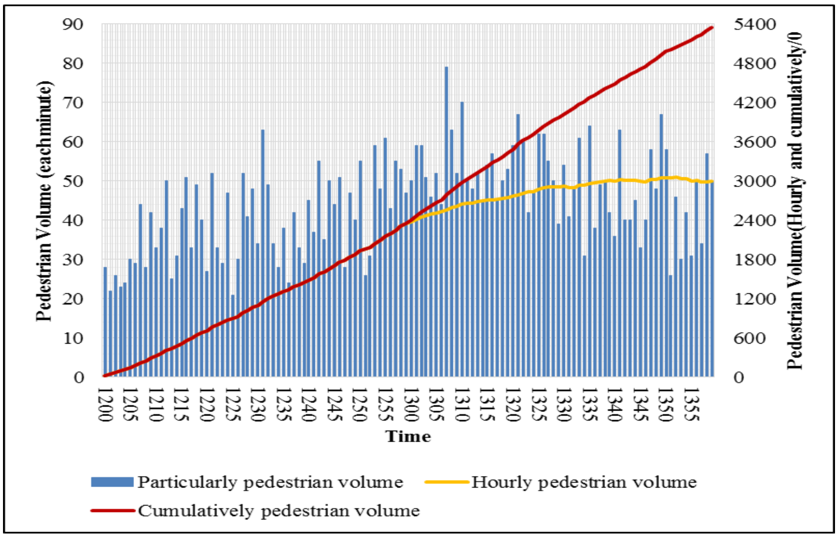

Fig. 8 – Pedestrian volume during afternoon peak hour.

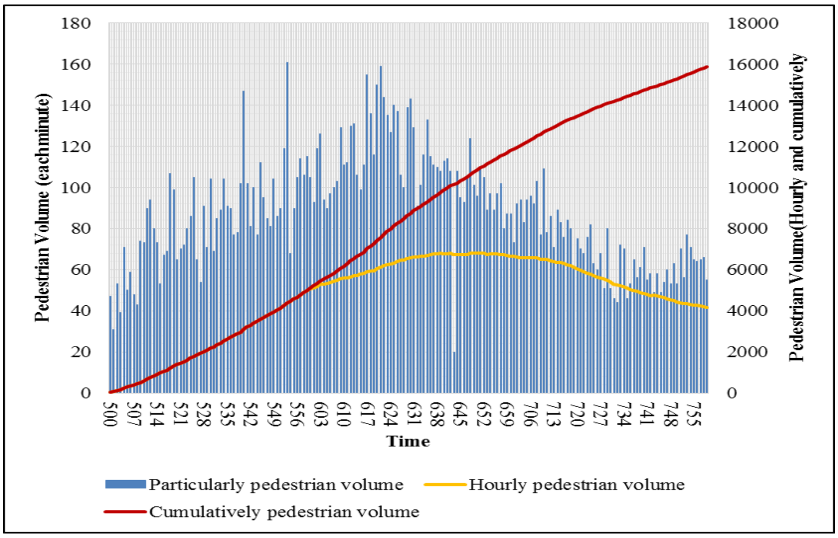

Fig. 9 – Pedestrian volume during evening peak hour.

Table 5 – Pedestrian volume comparison between morning, afternoon and evening peak hours.

	Morning peak hour	Afternoon peak hour	Evening peak hour
Total number of pedestrian volume	3439 pedestrians	5347 pedestrians	15872 pedestrians
Max ped/hour (duration)	2255 (7.52am to 8.51am)	3066 (12.53pm to 1.52pm)	6821 (5.52pm to 6.51pm)
Maximum ped/min	64	79	161
Mean ped/min	23	45	88
Minimum ped/min	1	20	20

5.2 Pedestrian Walking Speed for Maximum Hourly Volume

Table 6 shows the mean walking speed for three different peak hours based on 12 pedestrian routes in the study area. In terms of the morning peak hours, the results shows that the fastest average pedestrian walking speed for right to left side were paths RD to LA, RC to LA and RB to LC with 1.49m/s, 1.48m/s and 1.44m/s respectively. The slowest paths were RD to LA (0.98m/s), it was followed by RD to LC (1.18m/s) and RC to LC (1.12m/s). Meanwhile for the average walking speed from left to right, the path LA to RC recorded the fastest speed (1.52m/s). It was followed by LA to RD (1.46m/s) and LB to RC (1.38m/s). The slowest path was the pedestrian who walked at route LC to RD with 1.02m/s.

During the afternoon peak hours, the results show that the fastest path for the direction from right to left was RD to LA and RA to LC with 1.68m/s and 1.64m/s respectively. RA to LA and RC to LC were the slowest paths with average walking speed (1.18m/s). Meanwhile, for the path from left to right, LA to RD and LA to RC were amongst the fastest route (1.52m/s and 1.50m/s) compared to the slower routes which were LA to RA and LB to RA with 1.11m/s and 1.13m/s respectively.

For the evening peak hours, the results show that for the average pedestrian walking speed for right to left side, RD to LA recorded the fastest speed (1.47m/s), followed by RA to LC(1.45m/s) and RB to LC (1.34m/s). The slowest paths were RA to LA and RB to LA with 1.11m/s and 1.43m/s respectively. Meanwhile for the average walking speed from left to right, the route LA to RD recorded the fastest speed (1.56m/s). The slowest path was the pedestrian who walked at route LA to RA (1.10m/s).

Table 6 – Pedestrian average walking speed at different route choices.

Path	**Mean pedestrian walking speed (m/s)**			**Path**	**Mean pedestrian walking speed (m/s)**		
	Morning peak	**Afternoon peak**	**Evening peak**		**Morning peak**	**Afternoon peak**	**Evening peak**
Walking route: RS to LS (right to left)				**Walking route: LS to RS (left to right)**			
RAto LA	1.19	1.18	1.13	**LA to RA**	1.19	1.11	1.10
RA to LB	1.20	1.33	1.11	**LA to RB**	1.37	1.30	1.24
RA to LC	0.98	1.64	1.45	**LA to RC**	1.52	1.50	1.41
RB to LA	1.36	1.25	1.22	**LA to RD**	1.46	1.52	1.56
RB to LB	1.27	1.22	1.20	**LB to RA**	1.18	1.13	1.20
RB to LC	1.44	1.45	1.34	**LB to RB**	1.25	1.21	1.18
RC to LA	1.48	1.44	1.27	**LB to RC**	1.38	1.32	1.25
RC to LB	1.26	1.26	1.22	**LB to RD**	1.24	1.42	1.42
RC to LC	1.18	1.18	1.23	**LC to RA**	-	-	1.35
RD to LA	1.49	1.68	1.47	**LC to RB**	1.17	1.47	1.38
RD to LB	1.21	1.33	1.30	**LC to RC**	1.11	1.30	1.23
RD to LC	1.12	1.21	1.26	**LC to RD**	1.02	1.32	1.31

In general, the results show that there was a tendency for the pedestrian that walked in the oblique movement to have higher walking speed compare to those who walked in the straight direction. The oblique movement occurred maybe because of the pedestrian tendency to avoid the collision with the pedestrian that came from the straight direction. Thus, the side-step walking behaviour triggered them to walk faster to avoid the collision. For example, those who walked towards LA and LC tended to walk in the higher speed. Overall, the evening peak hours show the fastest speed at the area of study, followed by afternoon and morning peak hours.

5.3 Pedestrian Walking Speed for Maximum Hourly Volume

The pedestrian walking activities in the area of study during morning peak, afternoon peak and evening peak was simulated by using VISWALK. The pedestrian density results from the simulation then extracted and analyzed. The focus is to highlight the path toward LA, LB, LC, RB and RD. The proportion for pedestrian to use path towards at RA and RD were very small, therefore, these parts were less presented and the result in this section need to exclude the small part of RA and RD. Fig. 10 shows the pedestrian density at the study area during the morning peak hours. The results show 4 cycles of time in one-hour peak with each cycle has time interval of 15 minutes (7.50 to 8. 05a.m, 8.05 to 8. 20a.m, 8.20 to 8.35a.m and 8.35 to 8.50a.m). The darker areas show the higher density of pedestrian, meanwhile the lighter areas show less density. The results indicate that for the first 15 minutes, most of the pedestrian tended to walk across LA to RC or RC to LA. At the same time there was also crowded area near to LC. The pattern was continued for the next 15minutes and after that the pedestrian crowd were likely to be formed in the middle of the study area. The high density was formed in between of LA - LB and RB- RC. This result is concurrent with the results for average walking speed, where the pedestrian who walked crossing RC to LA or LA to RC would likely to have high walking speed. In shows that in the morning peak hour, the pedestrian crowd move in high walking speed but in the oblique direction because of the crowded area was formed in the middle of the area.

Meanwhile for the afternoon peak hour, most of the pedestrian crowd were likely occurred at the areas of LA to RB or RB to LA as shown in Fig. 11. The result shows that at the first 15 minutes of the afternoon peak the pedestrian density were also high in between RB and RC areas. Furthermore, the crowd was also formed near to LC and RC areas. The patterns were changed after 45 minutes, where the results show that the pedestrian crowd would likely to form in the middle of the study area and may reduce the likeliness to walk straight from LC to RC or RC to LC. However, it is assumed that route LA to RB and RB to LA still being preferred by the pedestrian. The average walking speed at these path routes were not too high or too slow.

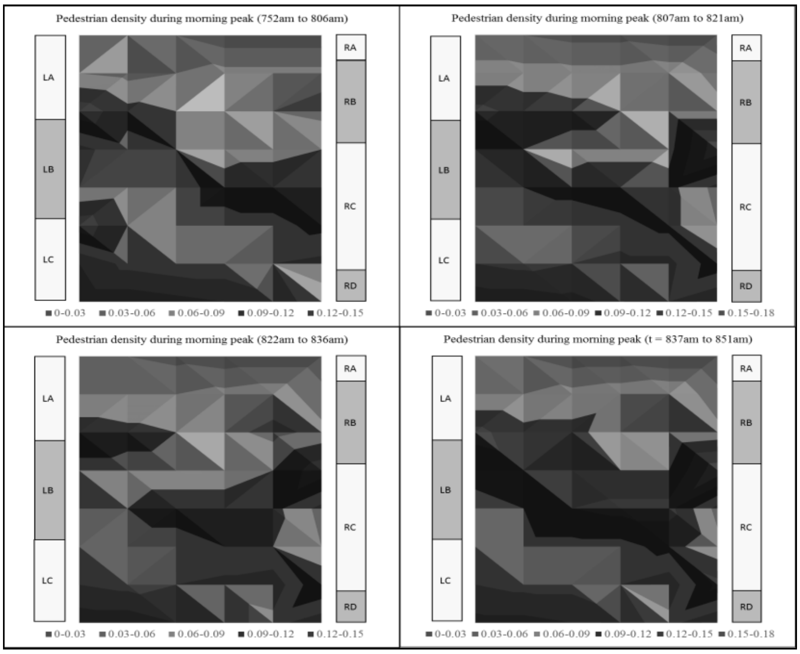

Fig. 10 – Pedestrian density (ped/m2) during morning peak hour.

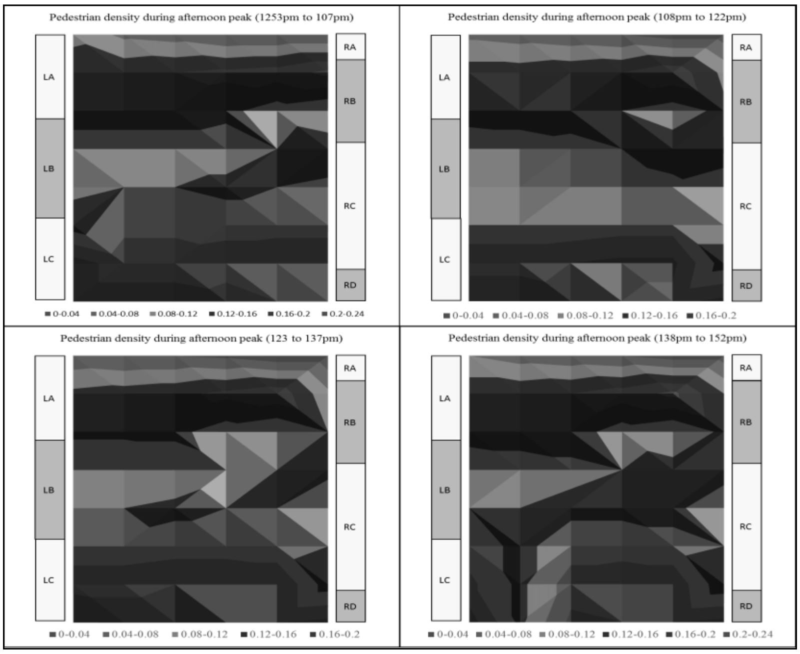

Fig. 11 – Pedestrian density (ped/m2) during afternoon peak hour.

In terms of evening peak hour, the results show that the pedestrian crowd tended to be occurred in the middle of the area of study. Fig. 12 shows that that LB area was the most crowded after the office hours ended. The results also show that the pedestrian would likely to walk in the straight directions either from LB to RB or LB to RC by considering the high density at these paths. The results indicate that during the evening peak hour, the likeliness for two different directions to be collided was higher compared with morning and afternoon peak hours. This situation could cause the pedestrian walking speed to be slow down in the middle of study area.

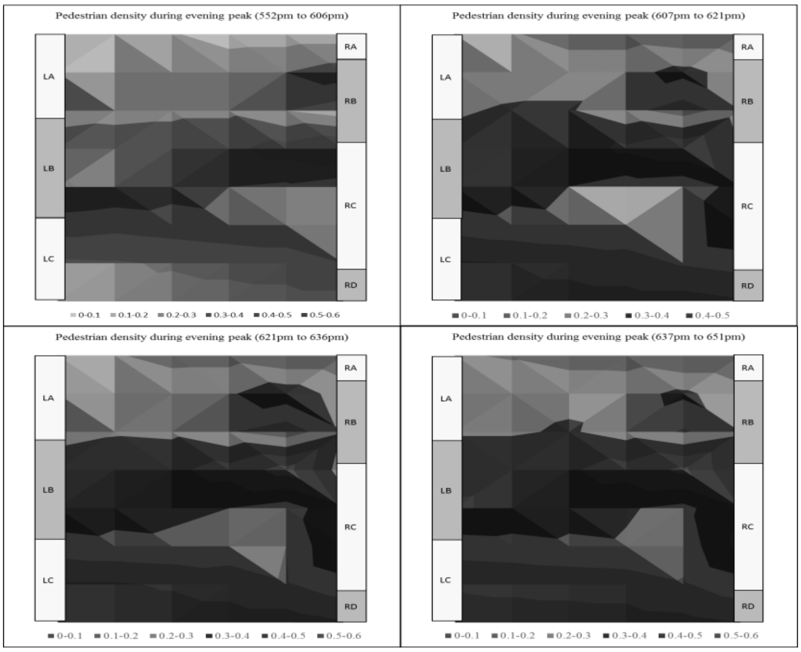

Fig. 12 – Pedestrian density(ped/m2) during evening peak hour.

6. Conclusion

In this study, the behaviour of pedestrian crowd at the train intersection was examined by focusing the walking speed and density for three different peak hours. It was found the numbers of pedestrian that crossing the study area was the highest during the evening peak hour. Therefore, the pedestrian density was also the highest in the evening peak hours especially in the middle of study area. The study found that the pedestrian tended to walk faster when they move in the oblique direction. This is because; they tended to step aside to avoid collision while walking in bi-directional flow. However, during the crowded environment, the oblique movement instigate those who move in straight direction to slow down their pace, thus it caused the pedestrian walking speed during evening peak hour was slower compare to the other peak hours.

It is interesting that there was different pattern of movements at the study area for three different peak hours. It confirmed that the self-organization phenomenon was performed based on the pedestrian density at the specific time. In terms of walking pattern, it was found that most of the pedestrian who came from the left side of the study area (from corridor) were came from point LA while pedestrian who came from right side of the study area, they exit the area of study through point LB. This was most likely influenced by the Malaysian driving pattern because vehicle in Malaysia are drove on the left side of the road.

In order to increase the pedestrian flow and walking speed in study area, it was suggested to install direction marking on the floor to avoid the bi-directional movement occurs during the peak hours. The marking is purposely to motivate the straight movement of walking pattern that could help to avoid the collision in the crowd. It is believed that the pedestrian at the study area could alter their movement paths according to the marking.

The findings from this study give some insights for future direction in designing the facilities to increase the pedestrian flow and emergency evacuation at the train station. In the future, it is suggested to focus on the formation of group behaviour in the area of study that maybe influences the walking speed. It is because the walking behaviour of pedestrian groups and the individual pedestrian are different either in low density or high density.

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