© Universiti Tun Hussein Onn Malaysia Publisher's Office

IJIE

Journal homepage: http://penerbit.uthm.edu.my/ojs/index.php/ijie
ISSN : 2229-838X e-ISSN : 2600-7916

The International Journal of Integrated Engineering

Evaluation of Pedestrian Walking Speed in Rail Transit Terminal

Nur Hanis Kasehyani[1], Noorhazlinda Abd Rahman[1,*], Nur Sabahiah Abdul Sukor[1], Herni Halim[1], Herda Yati Katman[2], Muhammad Salleh Abustan[3]

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

[2]College of Engineering
Universiti Tenaga Nasional, 4300 Kajang, Selangor, MALAYSIA

[3]Faculty of Civil and Environmental Engineering
Universiti Tun Hussien Onn Malaysia, 86400 Parit Raja, Johor, MALAYSIA

*Corresponding Author

DOI: https://doi.org/10.30880/ijie.2019.11.09.003
Received 05 February 2019; Accepted 17 September 2019; Available online 30 December 2019

Abstract: Current trend shows an exponential increase in rail traffic passenger volume, causing more attention must be paid to the crowd safety in rail transit terminal (RTT). In Malaysia, Kuala Lumpur Sentral Station (KLSS) is the largest transit terminal and as of 2017, the commuters at KLSS have reached 180,000. With this substantial number of commuters, walking might be difficult especially during peak hours. Hence, a better understanding of crowd dynamics is the key to plan and manage the pedestrians' flow in RTT. One of important crowd attributes that crucial to be quantified specifically is walking speed. While walking speed has been studied in general, such analysis specific to RTT commuters is still lacking. In this contribution, the main objective is to evaluate the walking speed of the commuters in KLSS by considering different pedestrians walking categories, like normal walking, walking with luggage and walking while looking at the gadget in hand. Data gathering was conducted by video footage during peak hours (morning, afternoon and evening) for four consecutive days. Total of 26 videos with 10 minutes duration were recorded and each video was analyzed using Autodesk Maya (2016) software with Human Behavior Simulator (HBS) plug-in. As the preliminary findings, the average walking speed of 393 pedestrians was 1.4 m/s. The average walking speed for normal walking female pedestrians was 1.46 m/s (morning), 1.34 m/s (afternoon), and 1.36 m/s (evening) and for normal walking male pedestrians was 1.38 m/s (morning), 1.44 m/s (afternoon), and 1.39 m/s (evening). Meanwhile, the average walking speed of male walking with luggage was 1.24 m/s (morning), 1.38 m/s (afternoon) and 1.38 m/s (evening) and for female walking with luggage was 1.14 m/s (morning), 1.27 m/s (afternoon) and 1.38 m/s (evening). Furthermore, the average walking speed of male walking with gadget was 1.01 m/s (morning), 1.41 m/s (afternoon) and 1.40 m/s (evening) and for female walking with gadget was 1.04 m/s (morning), 1.38 m/s (afternoon) and 1.32 m/s (evening). Male walking speed is higher compare to female in all three categories with 1.4%, 5.6% and 2.4% different in average walking speed for normal walking, walking with luggage and walking with gadget, respectively.

Keywords: Crowd dynamics, walking speed, rail transit terminal, Kuala Lumpur Sentral Station

*Corresponding author: celindarahman@usm.my

1. Introduction

Road transportation problems such as congestion make rail transit system one of the best choices of transportation alternatives. According to [1] there are 118 cities from 43 countries worldwide that provide rail transit services as one of the best choices to solve road traffic congestion. Kuala Lumpur, the national capital of Malaysia also provides transit facility called Kuala Lumpur Sentral Station (KLSS) that can cater up to 180,000 users daily [2]. Walking activities in the transit terminal might be difficult especially during peak hours due to the huge varieties of rail services provided at KLSS including Monorail, Keretapi Tanah Melayu (KTM), Light Rail Transit (LRT), Express Rail Line (ERL) and Mass Rapid Transit (MRT). Since current trend shows increasing demand in public transport usage especially rail transport services, studying the crowd dynamic such as walking speed will provide understanding on pedestrian interaction in the available spaces. Determining the walking speed will provide efficient information in planning of public transport infrastructure and evaluation of operation processes.

Pedestrians walk based on purpose and the environment of the walkway contribute to different value of walking speed [3]. There are many factors affecting the walking speed of human. In context of normal walking pedestrian at train station, past studies [4,5] have reported that gender, age, familiarity, and direction attributes are some of the factors that affect pedestrian walking speed with proved that 95% is true. Meanwhile, pedestrians walk with luggage tend to walk slower compare to normal walking pedestrian [6] and gives most obvious impact on pedestrian walking speed [7]. Gadget such as smartphone have change the way of communicate, navigate, work, and entertain ourselves [8] but there is no study on the effect of walking while using gadget at rail transit terminal.

This study focuses on evaluating pedestrians walking speed of pedestrians in three different categories of walking which are normal walking, walking while carrying luggage and walking while using gadget, particularly at rail transit terminal. The pedestrians are considered to use transit terminal as transit from home to workplace or travel destination and meal place. This study aims to evaluate the average walking speed of pedestrians in rail transit terminal with respect to those three categories of walking and compare the result obtained from the previous study.

2. Analysis Methodology

The work was divided into two phases as shown in Fig. 1. In Phase 1 Data Gathering: the raw data were obtained by field observations and video recording at KLSS. In Phase 2 Data Analysis: three stages involved as shown in Fig. 2.

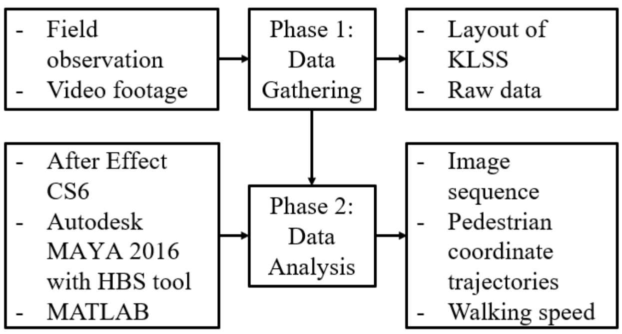


Fig. 1 – Work phases to determine walking speed

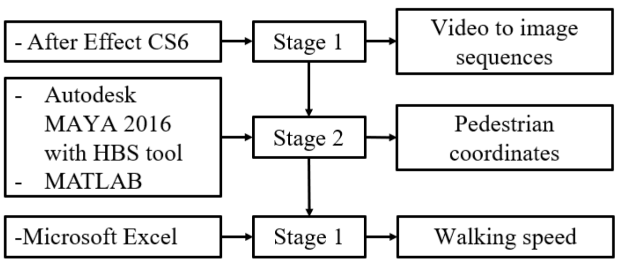


Fig. 2 – Stages involved in data analysis

2.1 Phase 1 Data Gathering

In Phase 1, software such as After Effect CS6 and Autodesk MAYA 2016 with HBS plug-in were used to integrate the raw data to analytical data. The video recording was conducted at selected open space in KLSS which is at Level 1 Transit Concourse as shown in Fig. 3. The videos recording was conducted in three sessions morning, afternoon and evening with two hours' time frame 7.00 am to 9.00 am, 12.30 pm to 2.30 pm and 5.00 pm to 7.00 pm. For every time frame, several videos were recorded with 10 minutes duration. With a total of 26 videos recording with 10 minutes duration that consist of 9, 10 and 7 videos recording for morning, afternoon and evening session were chosen to be evaluate in Phase 2.

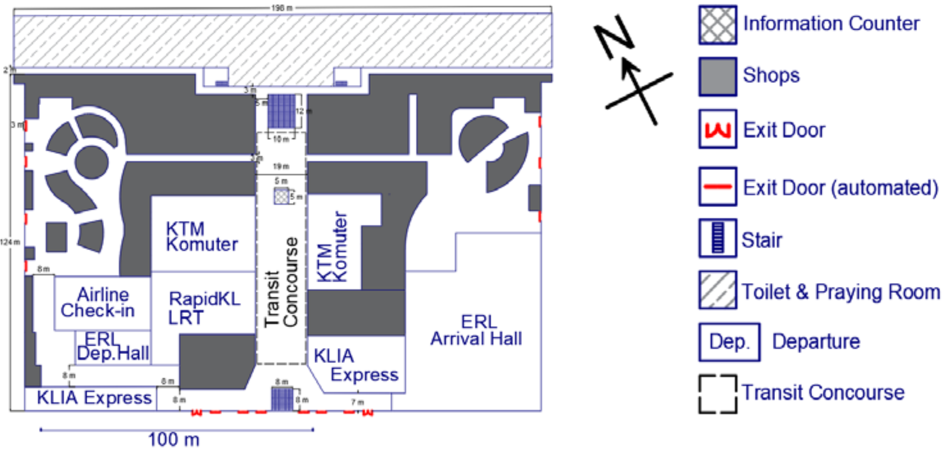


Fig. 3 – KLSS Level 1 floor map

2.2 Phase 2 Data Analysis

In Phase 2, the analysis was conducted in stages as shown in Fig. 2. The first stage involved the use of After Effect CS6 software, where the chosen videos were converted into image sequences with the rates of 25 frames per seconds (fps). 10 minutes video duration will produce a total of 15 000 images. Those images were review and several image sequences consist of 125 to 200 images were chosen to be proceed to stage 2.

In second stage, the image sequences were imported into Autodesk MAYA 2016 with HBS plug-in to track pedestrian trajectories. Before tracking pedestrian trajectories, a trap with 509 cm X 1018 cm dimension were drawn to represent the selected open space with edges labeled A, B, C and D at Level 1 Transit Concourse as shown in Fig. 4. The trap edges were determined according to the Transit Concourse flooring tiles. Selected pedestrian was then tracked within the trap to get its trajectories coordinates. Fig. 5 shown the pedestrian trajectories represent by dots and Fig. 6 shown three column of numbers represent the sample coordinated (x,y,z) of pedestrian trajectories.

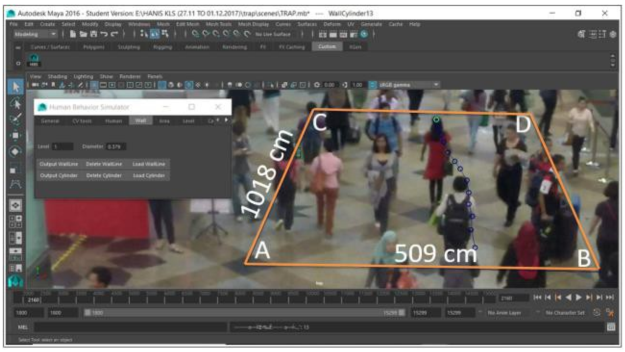


Fig. 4 – Snapshot of trap that represent selected open space

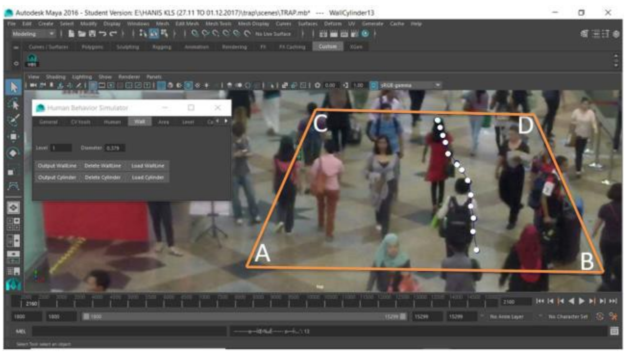


Fig. 5 – Snapshot of tracking pedestrian trajectories

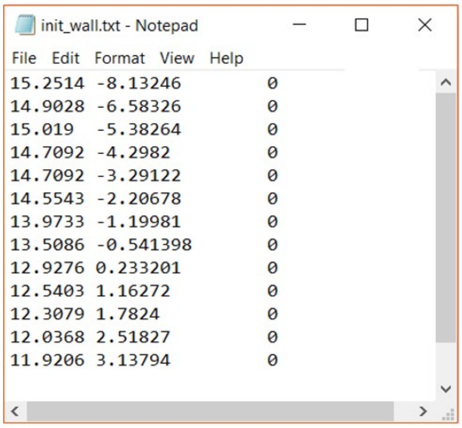


Fig. 6 – Sample coordinates of pedestrian movements

```
ImageCoordinates =
[AXi AYi; BXi BYi; CXi CYi; DXi DYi];
RealCoordinates =
[AXr AYr; BXr BYr; CXr CYr; DXr DYr];
T =
cp2tform(ImageCoordinates,RealCoor
dinates,'projective')
ImageMeasurePoint = [Xi Yi];
RealMeasurePoint =
tformfwd(T,ImageMeasurePoint)
```

Fig. 7 – Command used to transform image coordinates to real world coordinates in MATLAB

However, the coordinates of pedestrian trajectories were in image coordinates from perspective views. Real world coordinates are needed to proceed to the third stage of the analysis. Perspective transformation using MATLAB software with following command as shown in Fig. 7 were used to transform the image coordinates to real world coordinates. Those command were written in the "Editor" box as shown in Fig. 8 The ImageCoordinates and RealCoordinates is the coordinates of edge in the image view and real-world view as shown in Fig. 10. The ImageMeasurePoint is the coordinate of pedestrian trajectories. The RealMeasurePoint is the real-world coordinates of pedestrian trajectories after going through perspective transformation using MATLAB. The ImageCoordinates can be determine using Autodesk MAYA 2016 with HBS plug-in and RealCoordinates is fixed where (A_{xr} , A_{yr}), (B_{xr} , B_{yr}), (C_{xr} , C_{yr}) and (D_{xr} , D_{yr}) is (0 , 0), (509 , 0), (0 , 1018) and (509 , 1018). All those matrixes will be shown in the "Workplace" box in MATHLAB as shown in Fig. 9. Fig. 11 shows the real-world sample coordinate of pedestrian trajectories after perspective transformation.

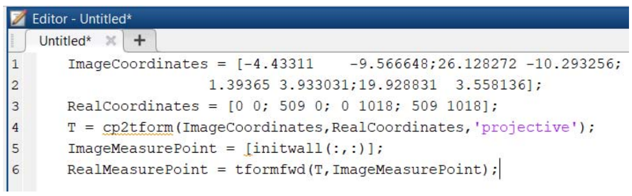


Fig. 8 – Editor box in MATLAB

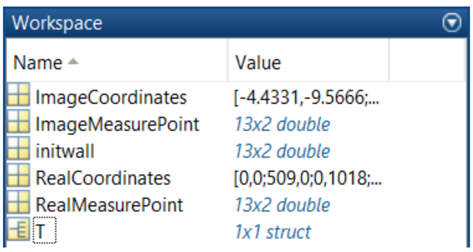


Fig. 9 – Workplace box in MATLAB

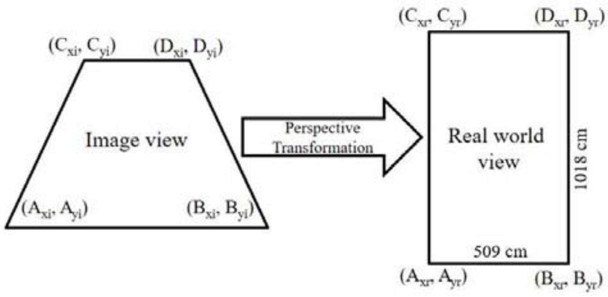
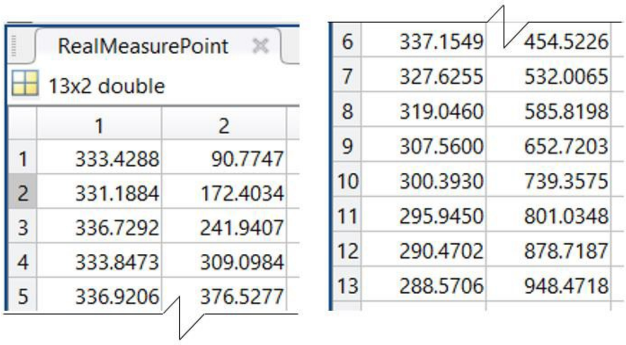


Fig. 10 – Perspective transformation of image view to real world


RealMeasurePoint

13x2 double

	1	2
1	333.4288	90.7747
2	331.1884	172.4034
3	336.7292	241.9407
4	333.8473	309.0984
5	336.9206	376.5277
6	337.1549	454.5226
7	327.6255	532.0065
8	319.0460	585.8198
9	307.5600	652.7203
10	300.3930	739.3575
11	295.9450	801.0348
12	290.4702	878.7187
13	288.5706	948.4718

Fig. 11 – Real world sample coordinates after perspective transformation

The third stage was the analyzing stage by using the coordinates of pedestrian movements (in stage 2) to determine the walking speed of pedestrian. In this stage, the pedestrians were divided into three categories of walking; normal walking, walking while carrying luggage and walking while using gadget. Pedestrians were chosen at random with several condition include pedestrian must walk without stopping and sudden turning. Following equation were used to determine pedestrian speed:

$$\bar{v} = \frac{\sqrt{\left(X_{r_n} - X_{r_{n-1}}\right)^2 + \left(Y_{r_n} - Y_{r_{n-1}}\right)^2}}{t_{n-1} - t_n} \tag{1}$$

where $\bar{v}$ is the speed; X_{r_n} and Y_{r_n} is the pedestrian x and y real world coordinate at n frame; $X_{r_{n-1}}$ and $Y_{r_{n-1}}$ is the pedestrian x and y real world coordinate at $n-1$ frame; t_n is time at n frame and t_{n-1} is time at frame.

3. Results and Discussion

Results that were obtained from this study are shown in Table 1 to Table 6 and Fig. 12 to Fig. 20. The average walking speed for normal walking, carrying luggage, and using gadget were 1.4 m/s, 1.3 m/s and 1.26 m/s respectively as shown in Fig. 19.

3.1 Normal Walking Pedestrian

Normal walking pedestrians were described as the pedestrian walking without holding anything that can cause distraction. The number of pedestrian (NOP) in KLSS during the afternoon session almost double for both male and female compare to other session as shown in Table 1 and Table 2 because there are variety of restaurant operated during lunch. Most of the officers work from the nearby offices will choose KLSS as their stop center for lunch.

Table 1 and Table 2 show the average walking speed, and standard deviation, σ for normal walking male and female. Meanwhile, Fig. 12 and Fig. 13 shows the minimum, average and maximum walking speed of normal male and female. The walking speed of normal walking male can reach up to 1.54 m/s while female is 1.49 m/s respectively as shown in Fig. 12 and Fig. 13. Although there were only 3.3% different in average walking speed between male and female, the maximum walking speed of male is 3.2% higher than maximum walking speed of female. This is because according to past studies [3], [9] the different in height, body shape and attire effect the pedestrian walking speed.

Table 1 – Average walking speed of normal male pedestrian

Session	NOP	$\bar{v}$ (m/s)	σ (m/s)
Morning	1	1.38	0.
Afternoon	5	1.44	0.
Evening	3	1.39	0.
Average	-	1.41	0.
Tot	1	-	-

*NOP – number of pedestrian; $\bar{v}$ – speed; σ – standard

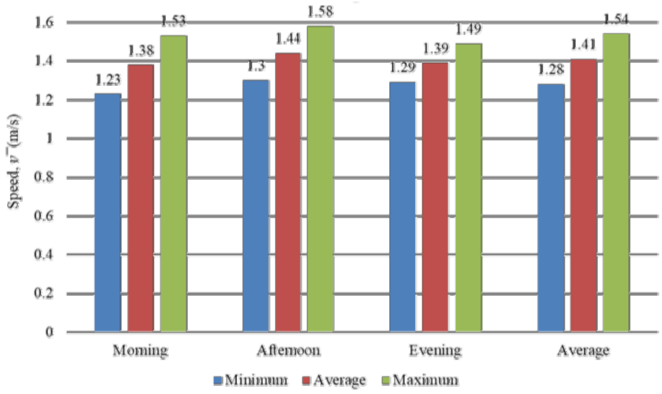


Fig. 12 – Minimum, average and maximum walking speed of normal male pedestrian

Bohari et al. [4] did study the pedestrian movement in transit station at Masjid Jamek LRT Station at Kuala Lumpur, Malaysia. The walking speed of male and female pedestrian was recorded in between 0.54 m/s to 1.55 m/s and 0.49 m/s to 1.46 m/s respectively. The results obtained also indicate that male pedestrians walk faster compare to female pedestrians. Study conducted at mass rapid transit (MRT) station in Singapore by Yeo and He [9] highlighted that walking speed of male are higher compare to female with 4.6%. Ali et al. [3] evaluate pedestrians walking speed at bus terminal area and the result shows that about 3% higher in speed for male compare to female pedestrian. Besides, Young [10] studied the pedestrian walking speed of pedestrian walking on moving walkways at airport terminals found that the average walking speed is 1.04 m/s with standard deviation of 0.46 m/s.

Table 2 – Average walking speed of normal female pedestrian

Session	NOP	$\bar{v}$ (m/s)	σ (m/s)
Morning	2	1.46	0.
Afternoon	5	1.34	0.
Evening	3	1.36	0.
Average	-	1.39	0.
Tot	1	-	-

*NOP – number of pedestrian; $\bar{v}$ – speed; σ – standard

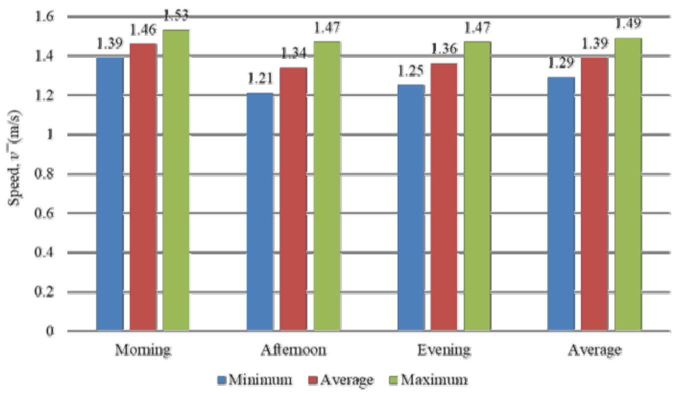


Fig. 13 – Minimum, average and maximum walking speed of normal female pedestrian

3.2 Pedestrian Walking while Carrying Luggage

Pedestrian walking while carrying luggage were described as pedestrian walking while holding heavy items with their hands. Table 3 and Table 4 shows the average walking speed of male and female while carrying luggage which were 1.33 m/s and 1.26 m/s, respectively. There was reduction in the average walking speed compare to the pedestrian without luggage (normal pedestrian) for male and female by 6% and 10%, respectively. Female pedestrian walking speed reduces more from normal walking to walking while carrying luggage compare to male due to the strength restriction. On average, male is stronger than female due to the different in muscle amount which is more in male compare to female.

Table 3 – Average walking speed of male pedestrian while carrying luggage

Session	NOP	$\bar{v}$ (m/s)	σ (m/s)
Morning	1	1.24	0.
Afternoon	1	1.38	0.
Evening	1	1.38	0.
Average	-	1.33	0.
Tot	3	-	-

*NOP – number of pedestrian; $\bar{v}$ – speed; σ – standard

Table 4 – Average walking speed of female pedestrian while carrying luggage

Session	NOP	$\bar{v}$ (m/s)	σ (m/s)
Morning	1	1.14	0.
Afternoon	1	1.27	0.
Evening	1	1.38	0.
Average	-	1.26	0.
Tot	4	-	-

*NOP – number of pedestrian; $\bar{v}$ – speed; σ – standard

Fig. 14 and Fig. 15 shows the minimum, average and maximum walking speed of male and female pedestrian while carrying luggage. The lowest walking speed of male and female pedestrian while carrying luggage is 1.01 m/s and 0.99 m/s respectively as shown in Fig. 14 and Fig. 15. Meanwhile, the highest walking speed of pedestrian while carrying luggage is 1.52 m/s for both male and female. The highest walking speed of male pedestrian while carrying luggage was recorded in the afternoon session but, for female, it is recorded on evening session.

Patra and Ravishankar [5] reported that pedestrian at Secunderabad Railway Station, India reduces its walking speed by 23% and 15% for male and female pedestrian that walk with luggage. Zhao and Liang [7] studied the effect of pedestrian walking with luggage on walking speed at Guangzhou Metro Line 1, China reported that there is about 10% decrease in walking speed for overall pedestrian that walk with luggage compare to without luggage. Pedestrians who walk with luggage reduce their walking speed compare to without luggage by 4% and 9% for male and female pedestrian. It was also reported that size and weight of the luggage contribute to the reduction factors on walking speed.

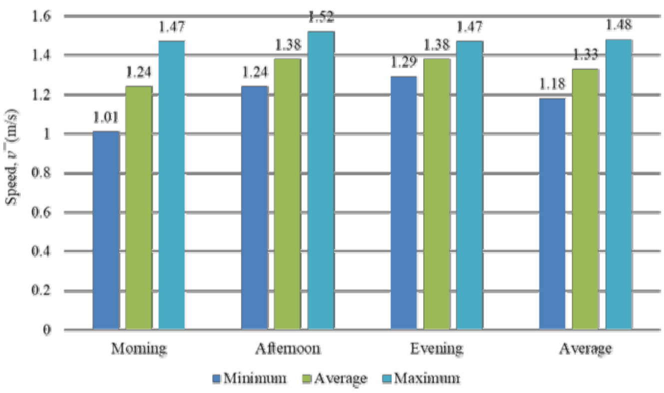


Fig. 14 – Minimum, average and maximum walking speed of male pedestrian while carrying luggage

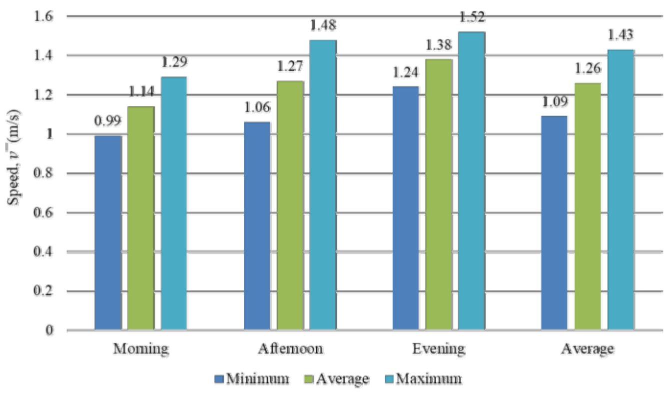


Fig. 15 – Minimum, average and maximum walking speed of female pedestrian while carrying luggage

3.3 Pedestrian Walking while Using Gadget

Pedestrian walking while using gadget were described as pedestrian walking while using smartphone, tablet, portable media players etc. Table 5 and Table 6 shows the average walking speed of male and female walking with gadget which were 1.27 m/s and 1.24 m/s, respectively. There were 11% and 12% decreasing in average walking speed compare to male and female pedestrian without gadget (normal pedestrian). Meanwhile, there were 5% and 2% decrease in average walking speed compare to male and female pedestrian while carrying luggage.

Table 5 – Average walking speed of male pedestrian with gadget

Session	NOP	$\overline{v}$ (m/s)	σ (m/s)
Morning	1	1.01	0.
Afternoon	1	1.41	0.
Evening	1	1.40	0.
Average	-	1.27	0.
Tot	3	-	-

*NOP – number of pedestrian; $\overline{v}$ – speed; σ – standard

Table 6 - Average walking speed of female pedestrian with gadget

Session	NOP	$\overline{v}$ (m/s)	σ (m/s)
Morning	1	1.04	0.
Afternoon	1	1.38	0.
Evening	1	1.32	0.
Average	-	1.24	0.
Tot	4	-	-

*NOP – number of pedestrian; $\overline{v}$ – speed; σ – standard

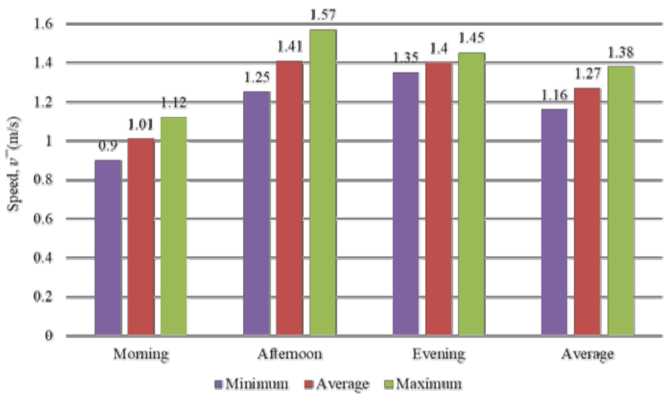


Fig. 16 - Minimum, average and maximum walking speed of male pedestrian while using gadget

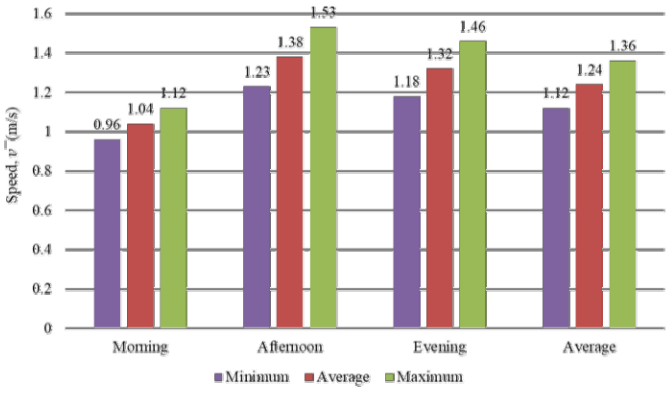


Fig. 17 – Minimum, average and maximum walking speed of female pedestrian while using gadget

Fig. 16 and Fig. 17 show the minimum, average and maximum walking speed of male and female pedestrian while using gadget. The lowest walking speed of male and female pedestrian while using gadget is 0.90 m/s and 0.96 m/s respectively which is both in morning session as shown in Fig. 16 and Fig. 17. Meanwhile, the highest walking speed of male and female pedestrian while using gadget is 1.57 m/s and 1.53 m/s respectively which is both in afternoon session. The afternoon session recorded the highest walking speed for both male and female because they need to move quickly during lunch break.

3.4 Average Walking Speed

Fig. 18 and Fig. 19 shows the average walking speed, for pedestrian for three various categories of walking (normal walking, with luggage and with gadget) for male and female on three different session (morning, afternoon and evening). From Fig. 18, the highest average walking speed recorded was in the afternoon session of normal walking male with 1.44 m/s. The afternoon session shows the highest average walking speed for all three categories in Fig. 7. This is because, most of the officer having their lunch hours from 1.00 pm to 2.00 pm. Due to time restriction, most male pedestrian tends to walk faster compare to the morning and evening session. As for male pedestrian with luggage, the train schedule from KLSS to KLIA 2 were limited as this session is not the peak hour session for the KLIA 2 services. With four trains by KLIA Transit and three trains by KLIA Express, pedestrian need to walk faster to catch up with the limited train numbers. Meanwhile, 1.46 m/s was the highest average walking speed recorded from Fig. 19. Female tend to have more energy in the morning compare to male with different in 6% increase in walking speed.

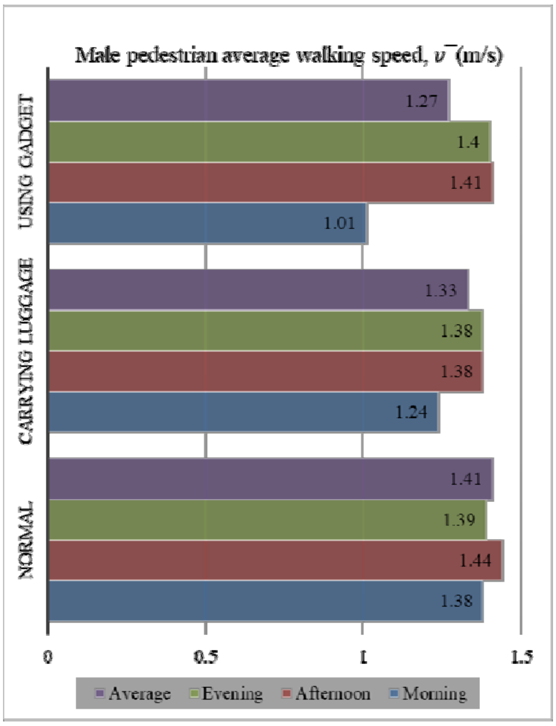


Fig. 18 – Male pedestrian average walking speed

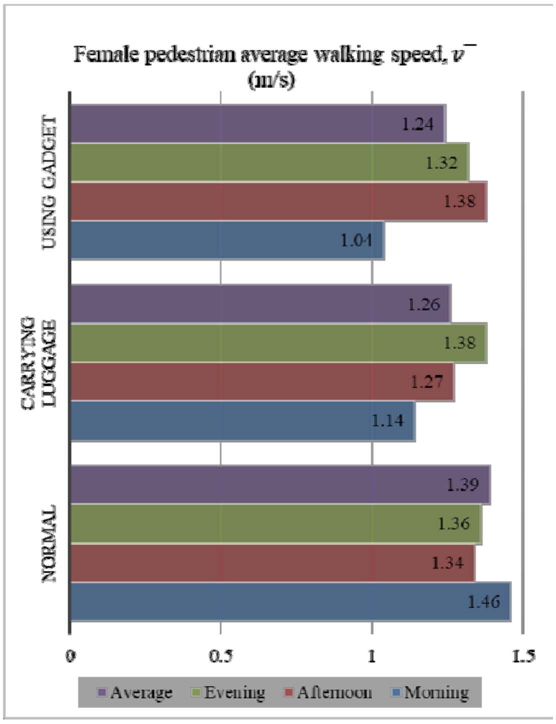


Fig. 19 – Female pedestrian average walking speed

The average walking speed of pedestrian varies according to places and the pedestrian itself because each place has different surrounding and environment, familiarity, physiques and direction. For this study, Fig. 20 shows the result of the average walking speed of pedestrian at transit terminal area. The result shows that there was reduction of pedestrian average walking speed between male and female of normal walking, walking while carrying luggage and walking while using gadget with 1.4%, 5.6% and 2.4% decreases. There are huge different up to 5.6% can be seen between male and female walking while carrying luggage. Female physical is considered smaller compare to male, this make female walking while carrying luggage walk slower than male due to extra weight that they need to carry. Male and female who walk while using gadget in hand tend to walk slower compare to other categories. While the eyes fixed to the gadget screen, movement are limited due to sight limitation. Pedestrian who walk while using gadget tend to be more sensitive and caution while walking and reduce the walking speed.

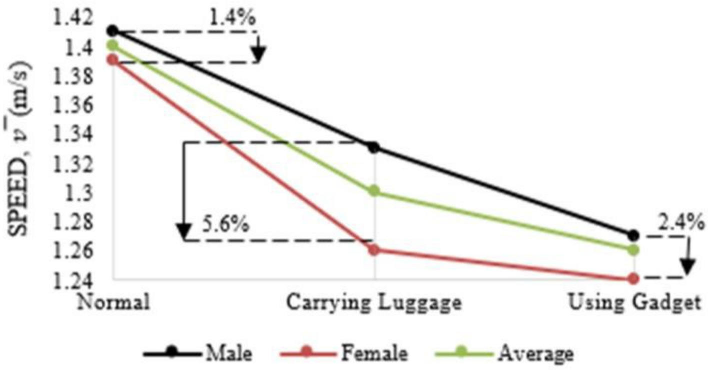


Fig. 20 – Average walking speed for normal walking, with luggage and with gadget

4. Conclusion

The findings reveal from the average walking speed demonstrate that female pedestrian walks slower compare to male pedestrian in each category. Normal pedestrian, pedestrian walking while carrying luggage and pedestrian walking while using gadget had the walking speed of 1.40 m/s, 1.30 m/s and 1.26 m/s respectively. The obtained result has proven that pedestrian with gadget walk slower followed by pedestrian with luggage and normal pedestrian. Noway, smart phone is a must for everyone to own it. Not only for communication, but also information seeking, schedule arranging, reminding, and leisure time activities such as online gaming and e-book reading. Besides, travelling seem to be a lot easier when traveler can choose their mode of travel from one transportation hub. People nowadays prefer to travel using public transport due to cheaper rate and easier excess. Therefore, the effect of carrying luggage and using gadget while walking at rail transit terminal need further study to understand the crowd dynamic and provide efficient information in planning of public transport infrastructure and evaluation of operation processes.

Acknowledgement

This research is supported by Minister of Higher Education, Malaysia, under the Fundamental Research Grant Scheme, (ref. No. FRGS/1/2017/TK08/USM/02/1). The authors also would like to acknowledge School of Civil Engineering, Universiti Sains Malaysia.

References

[1] Cheng, H., and Yang, X. (2012). Emergency Evacuation Capacity of Subway Stations. Procedia - Social and Behavioral Sciences, 43, 339-348.

[2] Nair, V. (2017). Working hard to serve commuters. The Star Online. Retrieved from https://www.thestar.com.my/metro/community/2017/05/23/working-hard-to-serve-commuters-mrcb-plans-to-improve-kl-sentral-to-better-handle-the-180000-passeng/.

[3] Ali, M. F. M., Abustan, M. S., Talib, S. H. A., Abustan, I., Rahman, N. A., and Gotoh, H. (2018). A Case Study on the Walking Speed of Pedestrian at the Bus Terminal Area. E3S Web of Conferences 34, 01023.

[4] Bohari, Z. A., Bachok, S., and Osman, M. M. (2016). Simulating the Pedestrian Movement in the Public Transport Infrastructure. Procedia - Social and Behavioral Sciences, 222, 791-799.

[5] Patra, M., Sala, E., and Ravishankar, K. V. R. (2017). Evaluation of pedestrian flow characteristics across different facilities inside a railway station. Transportation Research Procedia, 25(Supplement C), 4763-4770.

[6] Gupta, A., Singh, B., and Pundir, N. (2017). Effect of Gradient on Pedestrian Flow Characteristics Under Mixed Flow Conditions. Transportation Research Procedia, 25(Supplement C), 4720-4732.

[7] Zhao, Z., and Liang, D. (2016). Pedestrian Flow Characteristic of Metro Station along with the Mall. Procedia Engineering, 135(Supplement C), 602-606.
[8] Duke, E., and Montag, C. (2017). Smartphone addiction, daily interruptions and self-reported productivity. Addictive Behaviors Reports, 6, 90-95.
[9] Yeo, S. K., and He, Y. (2009). Commuter characteristics in mass rapid transit stations in Singapore. Fire Safety Journal, 44(2), 183-191.
[10] Young, S. (1999). Evaluation of Pedestrian Walking Speeds in Airports Terminals. Transportation Research Record: Transportation Research Board, 1674, 20-26.