Journal of Engineering and Applied Sciences 12 (Special Issue 5): 6958-6963, 2017
ISSN: 1816-949X

Analysis of Pedestrian Walking Velocity by using Human Behavior Simulator (HBS)

[1]Muhammad Salleh Abustan, [1]Mohd. Firdaus Mohamad Ali, [2]Noorhazlinda A. Rahman,
[3]Hitoshi Gotoh, [3]Eiji Harada, [1]Siti Hidayah Abu Talib and [1]Syarifah Intan Najla Syed Hashim
[1]Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia,
86400 Parit Raja, Batu Pahat, Johor, Malaysia
[2]School of Civil Engineering, Universiti Sains Malaysia, Engineering Campus,
14300 Nibong Tebal, Penang, Malaysia
[3]Department of Civil and Earth Resources Engineering, Kyoto University,
Katsura Campus, 615-8584 Kyoto, Japan

Abstract: Our understanding of crowd movements has rapidly improved over the course of the last decades. This study shows that the empirical research has not kept up with the pace of the simulation studies. Based on a large-scale of literature review, this study proposes a conceptual model describing the movements of individuals within a crowd. The model features the relationships between the macroscopic flow variables and characteristics of the pedestrians their physiologic environment and the surrounding infrastructure in which they reside. Moreover, walking velocity is one of the factors that affect the movement of every pedestrian with the difference of gender, age, culture and their physical abilities. Trajectory sets of basic data were gathered during the observation among independently pedestrian at one of the most regularly used crosswalk by pedestrians in Penang, Malaysia and the data sets have been analyzed. The results show that the data analysis has proven that the walking velocity is different among every human with the difference in terms of physical and psychological factors.

Key words: Walking, velocity, pedestrian, gender, age, Human Behavior Simulator (HBS)

INTRODUCTION

Walking is a basis daily Physical Activity (PA) and it is an important healthy behavior that can significantly enhance the quality of healthy lifestyle in reducing morbidity and mortality (Fortes *et al*., 2013; Murtagh *et al*., 2015). Every human being has different level of walking velocity and it is one of the indications that interpret the physical behavior. It can be defined as a statistical distribution that considers several factors such as age, gender, culture, physical abilities and etc. (Cao *et al*., 2016; Ferenchak, 2016; Ghani *et al*., 2016; Helbing *et al*., 2000). Walking velocity is defined as the velocity of a pedestrian that capable to walk without the obstruction by other pedestrians or the existence of bottlenecks throughout the pathway. The study of walking velocity distribution plays an important role in the accomplishment of many kinds of models about pedestrian walking velocity such as evacuation models, pedestrian behavior models and traffic flow models that lead to the achievement of realistic modeling development. Therefore, this study is purposely implemented to describe the determination of Malaysian average walking velocity measurement in detail and the walking velocity was classically defined and there are some important terms are useful for performing the simulation.

The independently walking pedestrians were chosen to determine the average walking velocity. Basic data on walking velocity by the chosen pedestrians were gathered by on-site video-based observational recording. There are some factors affecting the walking velocity of pedestrians such as age, gender, culture, environmental conditions, etc., during the observation. The applied concept in measuring the walking velocity was referred to the pedestrian trajectories and from which the walking force is happening.

Equilibrium and average walking velocity: Velocity is defined as a vector which is the change of displacement

Corresponding Author: Muhammad Salleh Abustan, Faculty of Civil and Environmental Engineering,
Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia

rate in physical quantity for a particular element. In this research, the rate of change of pedestrian's movement with the certain time interval is considered as the walking velocity. In the present study, it is assumed that each pedestrian is walking with the specific equilibrium velocity and this concept has been applied in this research. Moreover, when a pedestrian is losing velocity he/she will uniformly increase the step constantly until reaching the equilibrium velocity.

The number of density of pedestrian is influencing the equilibrium walking velocity that has the upper bound of velocity for particular types of human. It is essential to consider the factors of age and gender of the average walking velocity of pedestrian for calculating the equilibrium walking velocity. In summary, the equilibrium walking velocity can be defined as a function of the average walking velocity and density of pedestrian in the perception domain, if the pedestrian perception domain is taken into account:

$$u_{limit} = u_{hi} - \gamma \times c \quad (1)$$

Where:

u_{limit} = The specific equilibrium walking velocity
u_{hi} = Average walking velocity of pedestrian
γ = Parameter for the attenuation effect due to congested condition in the designated area
c = The number of density of pedestrian in the designated area (perception domain). In respect to the density of pedestrian (**c**)

The direct definition is used as stated below which is the ratio of the number of pedestrian (N) in the perceptual domain of the area (A):

$$c = N/A \quad (2)$$

In the measurement of velocity, the value of the average walking velocity can be obtained from the on-site video recording of the independently walking pedestrian. The consideration of age and gender of the pedestrian is important in measuring the average walking velocity. Hence, the determination of pedestrian average walking velocity is described thoroughly in the next study.

MATERIALS AND METHODS

This study is explaining about the steps involved starting from the data collection until the data analysis. The observation of pedestrians took place in Penang, Malaysia and the pedestrian's trajectories were recorded by using a camera and the video had been analyzed by using software that is necessary in this study. Hence, further description of methodologies is presented in the following subsections.

Site selection and crossing observation setup: The observation of pedestrian crosswalk was conducted in Penang, Malaysia at one of the commonly used crosswalk. The video recorder was placed on the top angle view to get better observation for recording the characteristics of pedestrian's movement from their respective starting point to the end point of the crossroad. The observation area of pedestrian movement is shown in Fig. 1 where the total dimensions of the crosswalk are in 12.6 m length and 4.6 m width. Peak hours from 1.00-2.00 p.m. were considered as the best time for observing the pedestrians traffic across the crosswalk in three different days and that made the observation has been done in total of 3 and 1 h each day.

The measurement of average walking velocity: Human behavior simulator was plugged into the software of the Autodesk® MAYA® to analyze the video recorder that contained the data of the observation of the independently walking pedestrian at a crosswalk. Hence, the video format was converted from the format of (avi) to the sequence of image (JPEG) by using the software of the Adobe® after effects CS4 for every 0.5 sec gap. Afterward, the following procedures conclude the determination of pedestrian positions and the sequence images were imported into the software of the Autodesk® MAYA®. The processes of importing sequence of images into the software Autodesk® MAYA® are as:

- The new camera was created by selecting create> cameras>camera. Then, camera 1 will be created and appeared at once (Fig. 2a)
- Next, panels>perspective is clicked. Hence, the viewpoint of the camera 1 is selected and it will become the perspective view as shown in Fig. 2b
- Then, the camerashape 1 tab is selected from the attribute of the camera 1. In the environment section from the selected menu, the create button is clicked and the image plane 1 will be instantly installed
- Image plane attributes is selected in image plane 1 and to select the sequence images of pedestrian movement, the image name button is clicked. Then, click check in use image sequence (Fig. 2c)

Scale adjustment processes are as follow: the rectangular polygon is drawn according to the dimension of crosswalk with the ratio 1:1 scale between reality and the Autodesk® MAYA® (from the top view).

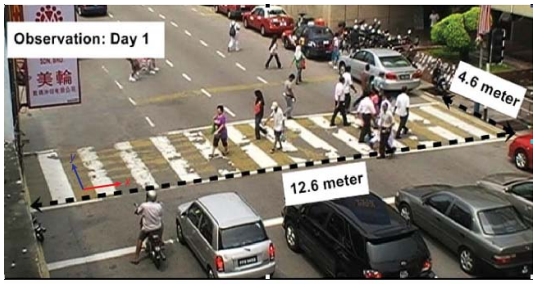
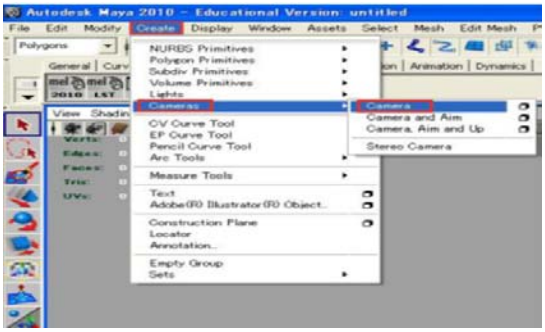
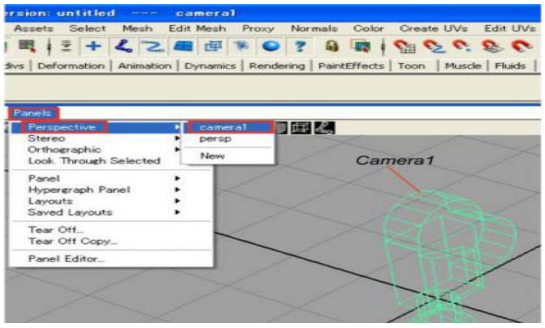


Fig. 1: Pedestrians crossing the road

(a)



(b)



(c)

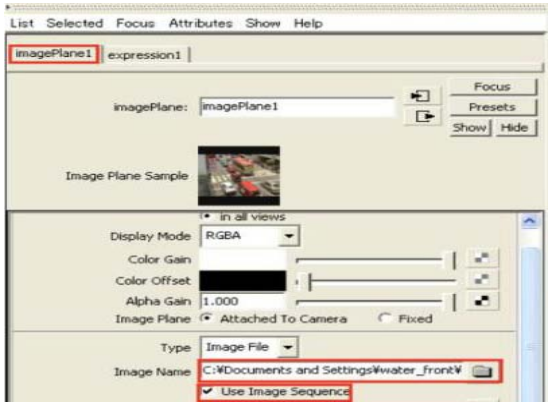


Fig. 2: a) Create the new camera; b) change the perspective view to look through camera 1 and c) Import the sequence images

The position of camera1 view is adjusted to fit with the rectangular polygon drawn in step 2 (i). The procedure is shown in Fig. 3. After completing the position adjustment of the rectangular polygon inside the sequence images, the channel box is clicked to lock the position of camera 1. Then, for maintaining the position, the coordinate of camera1 is selected and locked.

Ascertain position of the pedestrian: EP curve tool is used to determine the pedestrians position and their heads are used as the reference to locate the coordinate. The "mark" is executed and the time slides are moved. The track lines are selected (Fig. 3) after completing the tracking of pedestrian route. Then, the wall menu is selected from the human behavior simulator and the button of output cylinder is clicked as shown in Fig. 3. Finally, the coordinate is recorded in detail within the 0.5 sec time gap.

Hence, the changes of pedestrian coordinate is recorded in the ".txt" file in which it allows the determination of walking velocity. The following formula describes the velocity of pedestrian moving through a displacement (s) with a time interval (t) and it describes the entire movement of pedestrian:

$$v = s \tag{3}$$

Regularly, masking tape is used as the mark to capture longitudinal pedestrian behavior and this is to examine the walking velocity of pedestrians at the walking facilities such as sidewalk or crosswalk. However, the pedestrian traffic flow is normally interrupted especially during the peak time (Fig. 4).

Occasionally, the pedestrians will slow down their walking velocity in order to avoid collisions with other pedestrians and they tend to change direction or stop for a while and for this case, the movement of pedestrian is not in the straight line. Therefore, the predetermined longitudinal distance is incompatible with the actual distance of pedestrian's route. The equation below is then modified in order to solve the problem at disputed point:

$$v = \lim_{\Delta t \to 0} \left[s(t + \Delta t) - s(t) \right] / \Delta t = ds/dt \tag{4}$$

This equation has been used to find the value of walking velocity among Malaysian citizens in which the velocity vector v of the pedestrian has position s(t) at the time t and s(t+Δt) at the time t+Δt is the derivative of distance with respect to time. As explained earlier, the route of pedestrian is specified for every 0.5 sec in order

to minimize the displacement error. The time interval is fixed with the value of 0.5 sec while the distance displacement is variable. Other than that, the age approximation and gender of each pedestrian are also considered in this walking velocity data analysis. During the age approximation, the pedestrian's age is estimated by observing the walking attribute and their attire because it is the best judgment for each pedestrian for detailed analysis.

Fig. 3: The rectangular polygon drawn in accordance to the ratio of actual dimension to fit with the sequence image in scale adjusted process

Fig. 4: a) The track of pedestrian route is selected and b) After selecting the route of pedestrian, the button output cylinder is clicked to obtain the coordinate x- and y-axis in each 0.5 sec

RESULTS AND DISCUSSION

Analysis of Malaysian pedestrian walking velocity: This research had been implemented with the focus of main objective in finding out the value of average walking velocity among Malaysian pedestrian. Some differences of the average walking velocity are highlighted in this discussion in relation to both age and gender of pedestrian. The average of walking velocity was extracted from the implemented observation of independently walking pedestrian during pass through the chosen crosswalk area. Data of average, standard deviation and range of pedestrian walking velocity are presented in Table 1-5 in unit of meter per sec for children, adult and

Table 1: Average walking velocity for the male adult group (10-39 years)

				Range	
Varibles	N	Average	SD (m/sec)	Low	High
Day 1	170	1.40	0.13	0.93	1.63
Day 2	110	1.39	0.16	0.87	1.73
Day 3	76	1.35	0.19	0.88	1.69
Average	-	1.38	0.16	-	-
Total	337	-	-	-	-

Table 2: Average walking velocity for the male senior adult group (40-69 years)

				Range	
Varibles	N	Average	SD (m/sec)	Low	High
Day 1	57	1.16	0.15	0.79	1.46
Day 2	81	1.10	0.13	0.88	1.40
Day 3	37	1.14	0.18	0.85	1.52
Average	-	1.14	0.15	-	-
Total	175	-	-	-	-

Table 3: Average walking velocity for the female adult group (10-39 years)

				Range	
Varibles	N	Average	SD (m/sec)	Low	High
Day 1	171	1.19	0.14	0.94	1.58
Day 2	125	1.19	0.15	0.93	1.66
Day 3	55	1.22	0.17	0.95	1.65
Average	-	1.20	0.15	-	-
Total	351	-	-	-	-

Table 4: Average walking velocity for the female senior adult group (40-69 years)

				Range	
Varibles	N	Average	SD (m/sec)	Low	High
Day 1	50	1.09	0.12	0.78	1.29
Day 2	58	1.03	0.10	0.78	1.27
Day 3	23	1.02	0.16	0.80	1.53
Average	-	1.04	0.13	-	-
Total	139	-	-	-	-

Table 5: Average walking velocity for the children group (5-9 years)

				Range	
Varibles	N	Average	SD (m/sec)	Low	High
Day 1	25	1.06	0.11	0.91	1.30
Day 2	35	1.02	0.17	0.72	1.34
Day 3	30	1.08	0.16	0.80	1.40
Average	-	1.06	0.15	-	-
Total	90	-	-	-	-

Table 6: Overall of average walking velocity for Malaysian pedestrian

Varibles	N	Average	SD (m/sec)
L10-39	337	1.35	0.16
L40-69	175	1.14	0.15
P10-39	351	1.20	0.15
P40-69	139	1.04	0.13
Children	90	1.06	0.15
Average	-	1.16	0.15
Total	1092	-	-

Table 7: List of pedestrian average walking velocity (m/sec) for different countries (Ferenchak, 2016; Kiyono *et al*., 1998)

Continent	Pedestrian average walking velocity (m/sec)
Asia	
Japan	1.12
Saudi Arabia	1.08
India	1.20
China	1.20
Bangladesh	1.20
Thailand	1.22
Singapore	1.23
Sri Lanka	1.25
Europe	
England	1.47
Austria	1.54
North America	
USA	1.47
USA	1.35
Canada	1.40

senior adult for three different days during the peak time of 1.00-2.00 p.m. There were 1,092 pedestrians were observed in total.

From the results as presented in Table 1-5, the male adult pedestrian has the highest average walking velocity with 1.38 m/sec while the female senior adult has the lowest value with 1.04 m/sec. Moreover, the average walking velocity of the male senior adult is 1.14 m/sec which are 0.24 m/sec slower compare to male adult. Female adult pedestrian is 1.20 m/sec and that is 0.16 m/sec faster compare to the senior female adult while children are 1.06 m/sec. These values show the reduction of the walking velocity rate in comparison on the adult group to senior adult group which is nearly identical for both male and female. Besides, the standard deviation for each group was estimated at the lower average value and it represents the acceptance of data consistency. Hence, the value of 1.16 m/sec is the overall average walking velocity from the conducted observation as shown in Table 6 and 7.

CONCLUSION

In general, the average walking velocity is influenced by the factors of the environmental and cultural elements. Furthermore, the average walking velocity will be affected by the individual gender, age, personal disabilities and trip purposes with regards to the particular country. Hence, the list of average walking velocity in different countries is shown in Table 7. From Table 7, it is obvious that Asians have smaller value of walking velocity compared to the people in the continent of North America and Europe and this would be due to the difference in terms of physical characteristics. Moreover, the socio-economic activities also will give significant influences at the particular continent and this has been proven by Rahman *et al*. (2012) and Gotoh *et al*. (2004, 2009, 2012) as shown in Table 7.

By referring to Table 7, it can be concluded that Malaysian walk slower compared to the other countries in Asia and the value (1.16 m/sec) is also the lowest value among countries in Asia continent. However, the difference among Malaysia and the nearest neighbor like Singapore (1.23 m/sec) and Thailand (1.22 m/sec) are not far different because of the physical characteristics that are approximately similar.

In conclusion, there are limitations occur in this research study and the first one is the chosen location should affect the value of walking velocity and that can possibly be influenced by the pedestrians background. Secondly, the time factors must be put in consideration because it is possible that the walking velocity will be different during weekends compare to weekdays and/or during peak hours compare to non-peak hours. Furthermore, the quality and the location of video recorder can influence the recording in terms of the age of pedestrians and also the walking pattern among them. This is because good quality of video recording is helpful in recognizing the pedestrians physically and it will be easier to do the observation by locating the video recorder on top of selected site for this kind of experiment. Besides, in-depth information for this study can be gained by adding more video recorders.

This research study is important because the obtained data of walking velocity is necessary and beneficial for the safety purpose when designing a building or infrastructure. By referring to the value of Malaysian walking velocity (1.16 m/sec), it can be said that the value is quite similar with other Asian countries especially the nearest neighbor as aforementioned. Thus, the acquired data from the experiment of Malaysian walking velocity will be useful in the pedestrian numerical studies or any related research in the future.

ACKNOWLEDGEMENT

This study is fully supported by the Fundamental Research Grant Scheme (FRGS) Vot 1526 granted by the Ministry of Higher Education (MOHE) of Malaysia.

REFERENCES

Cao, S., J. Zhang, D. Salden, J. Ma and C.A. Shi *et al*., 2016. Pedestrian dynamics in single-file movement of crowd with different age compositions. Phys. Rev., 94: 1-1.

Ferenchak, N.N., 2016. Pedestrian age and gender in relation to crossing behavior at midblock crossings in India. J. Traffic Trans. Eng., 3: 345-351.

Fortes, C., S. Mastroeni, A. Sperati, R. Pacifici and P. Zuccaro, *et al*., 2013. Walking four times weekly for at least 15min is associated with longevity in a cohort of very elderly people. Maturitas, 74: 246-251.

Ghani, F., J.N. Rachele, S. Washington and G. Turrell, 2016. Gender and age differences in walking for transport and recreation: Are the relationships the same in all neighborhoods?. Preventive Med. Rep., 4: 75-80.

Gotoh, H., E. Harada and E. Andoh, 2012. Simulation of pedestrian contra-flow by multi-agent DEM model with self-evasive action model. Saf. Sci., 50: 326-332.

Gotoh, H., E. Harada and K. Ohniwa, 2009. Numerical simulation of coastal town planning against tsunami by DEM-base human behavior simulator. Proceedings of the 19th International Conference on Offshore and Polar Engineering, July 21-26, 2009, International Society of Offshore and Polar Engineers, Osaka, Japan, pp: 1248-1252.

Gotoh, H., E. Harada, Y. Kubo and T. Sakai, 2004. Particle-system model of the behavior of crowd in Tsunami flood refuge. Ann. J. Coastal Eng. JSCE., 51: 1261-1265, (In Japanase).

Helbing, D., I. Farkas and T. Vicsek, 2000. Simulating dynamical features of escape panic. Nature, 407: 487-490.

Kiyono, J., F. Miura and H. Yagi, 1998. Simulation of evacuation behavior in a disaster by distinct element method. Proc. Jpn. Soc. Civil Eng. Ronbunshu, 1998: 365-378.

Murtagh, E.M., L. Nichols, M.A. Mohammed, R. Holder and A.M. Nevill *et al*., 2015. The effect of walking on risk factors for cardiovascular disease: An updated systematic review and meta-analysis of randomised control trials. Preventive Med., 72: 34-43.

Rahman, K., N.A. Ghani, A.A. Kamil and A. Mustafa, 2012. Analysis of pedestrian free flow walking speed in a least developing country: a factorial design study. Res. J. Appl. Sci. Eng. Technol., 4: 4299-4304.