A Microsimulation Modeling of Pedestrian Characteristics in Bangkok Transit System Case Study

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Abstract: Although there are many international standards of walkway design, walking behaviors are different in each country/region. To determine the pedestrian characteristics the concept of the social force model, which is analogous to resolving forces in Newtonian mechanics was adopted. Behavioral data related to pedestrian walking speed were collected by using a digital camera at BTS (Bangkok Transit System) station and manually extracted needed factors like pedestrian speed, density and others. After completing the calibration and validation process using a VISSIM microsimulation technique, pedestrian walking speed is analyzed on the basis of density. The analysis shows that the walking speed of pedestrians is 75.07 m/min, which is slower than the U.S. pedestrians. It is also found that the walking speed and the body size directly affect the pedestrian flow rate. A similar traffic microsimulation model has also been applied to analyze the pedestrian capacity that is calibrated by adjusting pedestrian speed. Due to the smaller body size of Asians compared to Americans, the flow rate observed in this study is higher. In particular, the pedestrian capacities per one-meter width of uni-direction and bi-direction are 91 peds/m/min and 78 peds/m/min, respectively.

1 INTRODUCTION

Many in Bangkok has a formula "Walk-BTS-Walk" to avoid Bangkok's chronic traffic jam. It is just because of the rapid development of high-density residential communities around BTS (Bangkok Mass Transit System) stations and high-density shopping malls, offices, and commercial buildings located around that or other stations additionally BTS offers ease accessibility to airports and bus terminals. A survey study in Bangkok (Rastogi et al., 2003) has found that 62 % of passengers living near transit stations within 1 km prefer to walk. Similarly, in Mumbai, India (Pongprasert & Kubota, 2017) found that 85 % of passengers living near transit stations are comfortable to walk up to the distance of 1250 meters. Evidently, walking is one of the most economical and effective modes of transportation for short-distance trips, at the same time, a simple fact is that most journeys start or end with a walking trip. As Bangkok is a rapidly developing Metropolitan city, with increasing inward migration, there is a rise in traffic congestion problems. It has a population of more than 15 million people and has an increasing tendency each year. The increase in population is directly proportional to travel demand. And data from the Office of Transport and Traffic Policy and Planning in Thailand (OTP) indicates that more than half of all travel demand are using private vehicles.

The key solution is a sustainable transportation system that focuses on safety, eco-friendliness, and dependency reduction on limited resources. For example, a walking system will reduce the usage of private vehicle/motorcycle transportation. Therefore, proper and standardized walkway design system is necessary.

When it becomes necessary to provide, making decision on selecting an inappropriate concept can be costly to rectify. For example, to design a pedestrian facility, foreign criterion was adopted in Chinese metro stations without any further studies to understand the difference between Chinese and

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Westerners. This leads to a peerless connection between demand and capacity of pedestrians during rush hours in some Shanghai, China, metro stations. Such that designing effective and appropriate walking facilities that suit local pedestrian characteristics considered as a challenge by dense and regular passenger traffic. For example, a typical illustration is metro transfer stations. So consciously, to sidestep the issue, in-depth study of local pedestrian flow characteristics is compulsory (Ye et al., 2008).

Application of Western standards for pedestrian facility design in Asian countries is not always effective way to design and, in some cases, inappropriate, as every location is bound by its own unique set of environmental and physical constraints. As the study conducted by (Y Tanaboriboon, Record, & 1991) summarizes, in designing of pedestrian facilities walking speed parameter is of utmost importance. Therefore, more attention should be given to pedestrian facilities by doing studies on pedestrian flow characteristics and walking behavior to find the optimal design for pedestrian spaces. Hence, this study will explore the walking speed in Thailand by using the case study of BTS Sky Walk Bangna – BITEC. The traffic microsimulation model has been applied to analyze the pedestrian characteristics which are calibrated through adjusted pedestrian speed.

2 LITERATURE REVIEW

2.1 Pedestrian Walking Speed

The findings of the various studies show that Asian pedestrians walk slower compared to Western pedestrians as shown in Table 1. (Y Tanaboriboon & Guyano, 1991) conducted a study in Thailand and obtained a mean walking speed of 73 m/min, which is relatively comparable to the 74 m/min walking speed of Singaporean pedestrians (Yordphol Tanaboriboon et al., 1986) but significantly slower than the 81 m/min speed of the U.S. pedestrians (Fruin, 1971).

In the United States, study conducted by (Navin & Wheeler, 1969) in the University of Missouri, Columbia found students were walking at an average speed of 79 m/min. Similar study conducted in the United States by (Gupta, 1986) and yielded a result of slightly higher mean walking speed of 88 m/min.

In Asia, (Gupta, 1986) conducted a study in Delhi and found a mean pedestrian walking speed of 72 m/min. (Yu, 1993) found a mean pedestrian walking speed of 73 m/min in China. (Gerilla et al., 1995) found a mean pedestrian walking speed of 70.6 m/min in the Philippines.

In addition, (Fruin, 1971) also studied the distribution of free-flow pedestrian walking speeds at Port Authority of New York bus terminal and Pennsylvania Train Station. The results are shown in Figure 1.

Table 1: Mean walking speeds in various studies.

Region	City, Country	Mean Walking Speed (m/min)	Author
Asian	Bangkok, Thailand	73.0	Tanaboriboon and Guyano (1991)
	Singapore	74.0	Tanaboriboon et al. (1986)
	Delhi, India	72.0	Gupta (1986)
	China	73.0	Yu (1993)
	Metro Manila, Philippines	70.6	Gerilla (1995)
Western	New York, United States	81.0	Fruin (1971)
	Columbia, United States	79.0	Navin and Wheeler (1969)
	Pittsburgh, United States	88.0	Hoel (1968)

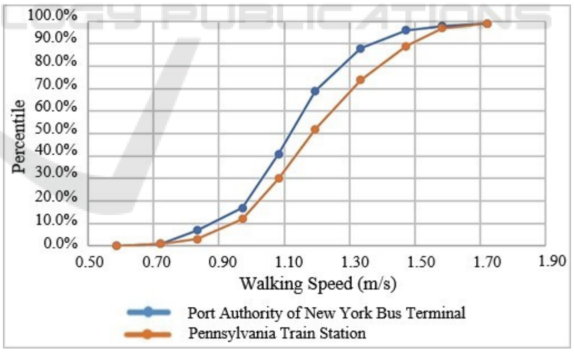

Figure 1: Speed distribution according to (Fruin, 1971).

2.2 Human Ellipse of Pedestrians

Human Ellipse (Body Ellipse) has a significant impact on pedestrian characteristics. According to (Y Tanaboriboon et al., 1991) study, Thai pedestrians walk slower than Western pedestrians, but Thai pedestrian capacity per 1-meter width is greater.

While designing a pedestrian facility, current practices adopt pedestrian space requirements mentioned in US-Highway Capacity Manual (HCM-

2010), which serves as the standard for developing a level of service criteria for a pedestrian facility design.

Dimensions of a pedestrian are bound to be different, when two different regions are compared. As per the study conducted by (Singh et al., 2016) concluded that compared to Western people Asians are generally shorter with relatively less broader shoulders as shown in Figure 2.

Singh, N., (Singh et al., 2016) studied Asian people and found Asian ellipse dimensions to be 0.3476m × 0.5082m (Body Depth × Shoulder Width) while the dimension provided by USHCM 2010 is 0.4572m × 0.6096m (Body Depth × Shoulder Width). Therefore, it was concluded that Asians have 23.97% relatively less body height and their shoulder are 16.63% less when compared to the Americans.

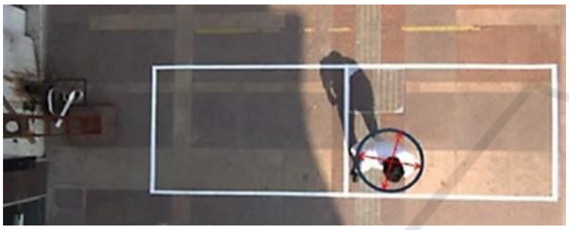

Figure 2: The study of Asian Ellipse dimensions (Singh et al., 2016).

Table 2: Average dimensions of pedestrians for different countries (Dynamics Ltd., 2005).

Population M = Male; F = Female		Width (cm)	Depth (cm)	Area in Rectangle (m^2)	Area in Ellipse (m^2)
France	M	51.50	28.00	0.14	0.11
	F	47.00	29.50	0.14	0.11
USA	M	51.50	29.00	0.15	0.12
	F	44.00	30.00	0.13	0.10
Great Britain	M	51.00	32.50	0.17	0.13
	F	43.50	30.50	0.13	0.10
India	M	45.50	23.50	0.11	0.09
	F	39.00	25.50	0.10	0.08
Japan	M	41.00	28.50	0.12	0.09
	F	42.50	23.50	0.10	0.08
Hong Kong	M	47.00	23.50	0.11	0.09
	F	43.50	27.00	0.12	0.09

3 METHODOLOGY

Figure 3 shows the framework employed for this study to estimate pedestrian characteristics, also shows intermediate steps of data collection methods, analysis, and an overview of validating the developed model.

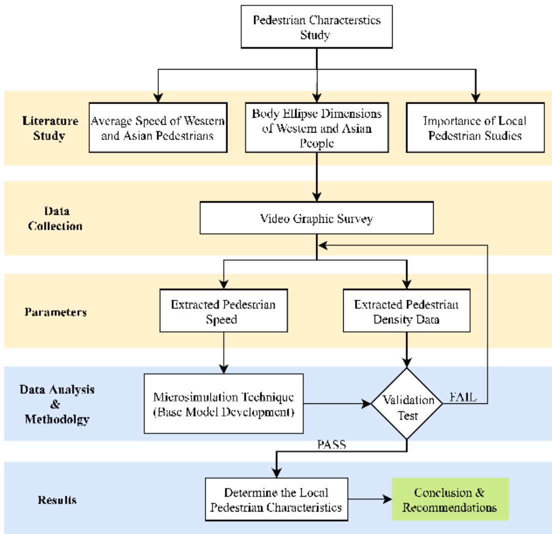

Figure 3: Research framework.

3.1 Data Collection

This study was conducted in Bangkok, Thailand. As this study required an area with higher pedestrian density to perform speed studies, so, BTS Sky Walk Bangna – BITEC as shown in Figure 4, was selected.

Pedestrians were timed manually over a measured length, and then their respective speeds were calculated. A portable video camera was used to collect all the data on pedestrian traffic. The camera was placed in a fixed position to obtain a view that encompassed all the selected study area. The surveys were conducted for 7 hours during peak and off-peak periods. Speed data for calibrating models and density data for validating model has been collected. In addition, the processed results of the walking speed are shown in Figure 5.

Figure 4: Site location.

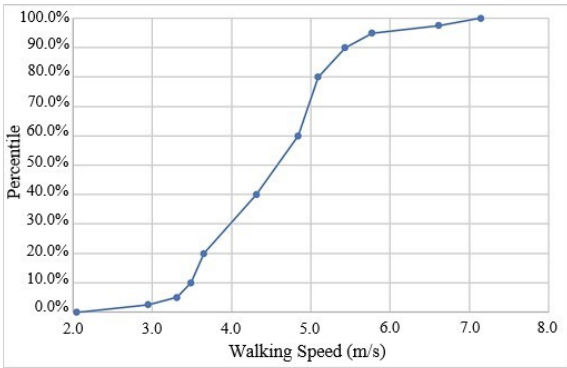

Figure 5: Results of walking speed (m/s=meter/second).

3.2 Pedestrian Simulation

This study used the traffic microsimulation modeling software for pedestrians, PTV Viswalk, to analyze the pedestrian capacity with Social Force Model theory (Helbing & Molnár, 1995).

Fundamental notion of Social Force Model is to model the elementary forces that influence motion of pedestrians (as shown in Figure 6), this modelling is analogous to how Newtonian mechanics is used to resolve forces acting on a physical object. Total force evaluated comprises of social, psychological, and physical forces, which eventually results in an entirely physical parameter acceleration of pedestrian.

The forces discussed above come into play due to the desire of pedestrians to reach a destination and these forces are the results of the influence of various factors such as obstacles, walls, other pedestrians etc., (PTV VISION, 2016). In the same way, pedestrian behavior can be categorized into three different levels as in (Hoogendoorn & Bovy, 2002):

- At strategic level of minutes to hours, a pedestrian plans his or her route and generates a list of stops/destinations.
- At tactical level of seconds to minutes, a pedestrian chooses the route between the destinations. Thereby he takes the network into account.
- At operational level of milliseconds to seconds, the pedestrian performs the actual movement to avoid oncoming pedestrians, navigates through a dense crowd, or simply continues the movement toward his/her destination.

The Social Force Model encompasses both operational and tactical levels of pedestrian behavior. Therefore, this study discusses the aspects of the strategic level of pedestrian behavior using factors such as pedestrian volume and pedestrian speed.

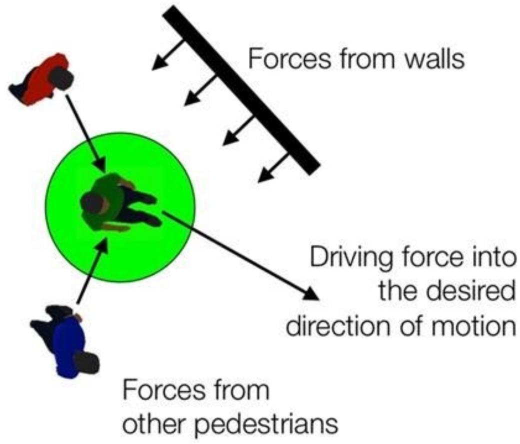

Figure 6: Social Force Model (Helbing and Molnár, 1995).

Among all the other microscopic pedestrian model SFM has the ability to model all the interactions and tends to be more realistic when reproducing the pedestrian walking environments (Helbing et al., 2005). Also, SFM has been considered by a majority of researchers (Teknomo, 2016) -(Helbing et al., 2006) - (W & A, 2007) - (Lakoba et al., 2016) the reason being, social force model accurately captures most of the phenomenon resulting due to complex interactions between pedestrians compared to other similar models.

4 DATA ANALYSIS AND RESULTS

4.1 Calibration and Validation Process

The models were calibrated by adjusting two parameters. First is the desired walking speed collected from the site (shown in Figure 7), second is the Asian body ellipse (shown in Figure 8). In order to obtain a realistic pedestrian behavior, simulation run was visually validated and necessary adjustments were made accordingly, as shown and discussed in Figure 3.

For the output to be considered satisfactory the statistical GEH (Geoffrey E. Havers) equation value of output was constrained to a value of GEH < 5.0 for 85 % of all modeled volumes. Further, the summary of the validation process results is shown in Table 3.

$$\boldsymbol{GEH} = \sqrt{\frac{(E-V)^2}{\frac{(E+V)}{2}}} \quad (1)$$

Where E is the estimated traffic volume from the simulation model, V is the observed traffic volume.

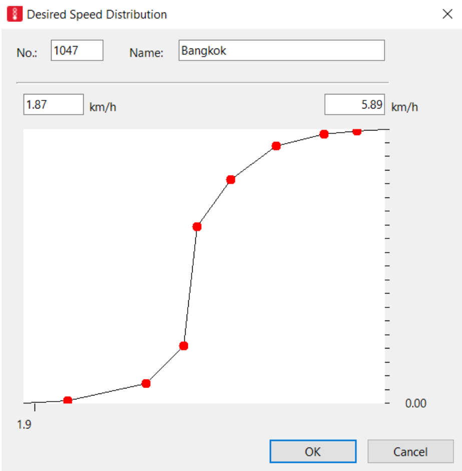

Figure 7: Calibration of walking speed in the traffic microsimulation model.

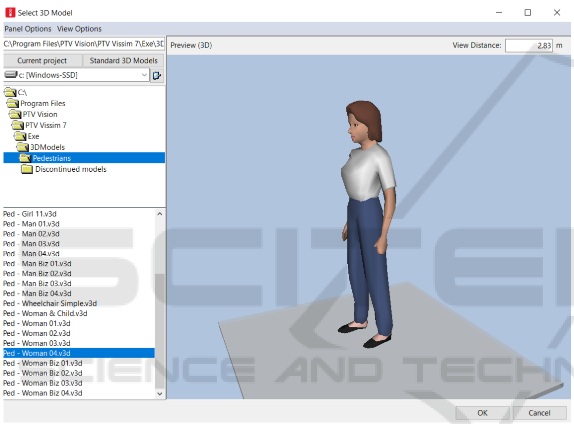

Figure 8: Calibration of Asian body ellipse in the traffic microsimulation model.

Table 3: Result of the Validation Process.

From	TO	Observed	Simulation	GEH
11:00	11:30	1,262	1,238	0.6788
11:30	12:00	1,184	1,170	0.4081
12:00	12:30	1,432	1,440	0.2111
12:30	13:00	1,231	1,215	0.4575
13:00	13:30	1,681	1,717	0.8734
13:30	14:00	1,701	1,723	0.5317
14:00	14:30	1,750	1,739	0.2634
14:30	15:00	896	908	0.3996
15:00	15:30	1,326	1,324	0.0549
15:30	16:00	1,291	1,289	0.0557
16:00	16:30	1,413	1,440	0.7149
16:30	17:00	2,313	2,320	0.1454
17:00	17:30	1,834	1,851	0.3960
17:30	18:00	1,672	1,702	0.7304
18:00	18:30	1,555	1,556	0.0254

4.2 Simulation Results and Pedestrian Flow Characteristics

After the model calibration, the analysis of pedestrian flow rates at various pedestrian densities were analyzed. For the analysis to provide greater resolution, pedestrian volumes from 1,000 pedestrians/hr to 30,000 pedestrians/hr with an increment of 1,000 pedestrians/hr were used.

It is noticed that the average pedestrian walking speed is evidently higher in U.S when compared to Asian walking speeds, which results in higher average flow rates. However, when pedestrian volumes near the walkway capacity as shown in Figure 10 and Figure 11 in terms of pedestrian density, the body size factor gains more importance. Hence, resulting in the maximum Thai Pedestrian flow rate being greater than U.S flow rates when nearing critical volumes.

Under the free flow conditions as shown in Figure 9, it is evident that a pedestrian is relatively free to decide on his/her walking speeds due to less obstructive forces, this scenario was also observed in simulation trials and it further validates the approach of modeling pedestrian behavior using social force model.

But when the pedestrian volume approaches the capacity, the flow rate of this study is relatively higher than US due to the smaller body size of Asians on average. In addition, when comparing between uni-directional and bi-directional walking, it is found that the capacities of the flow rate are different. The pedestrian flow rates of uni-directional and bi-directional walking are 91 peds/m/min and 78 peds/m/min, respectively. Figure 12 compares the variation observed between uni-directional and bi-directional pedestrian flows vs area module observed in this study and past studies, which indicates the model proposed in this study have the potential to be used to model the pedestrian behavior accurately.

Figure 9: PTV VISSIM 3D Animation (Low Density).

Figure 10: PTV VISSIM 3D Animation (High Density).

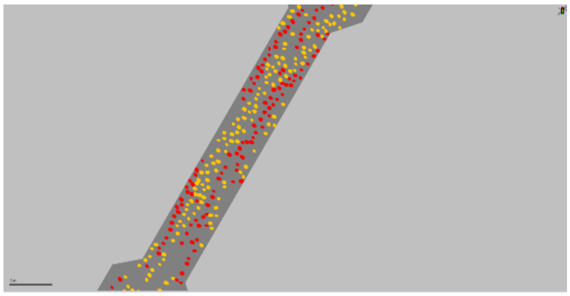

Figure 11: PTV VISSIM 2D Animation (High Density).

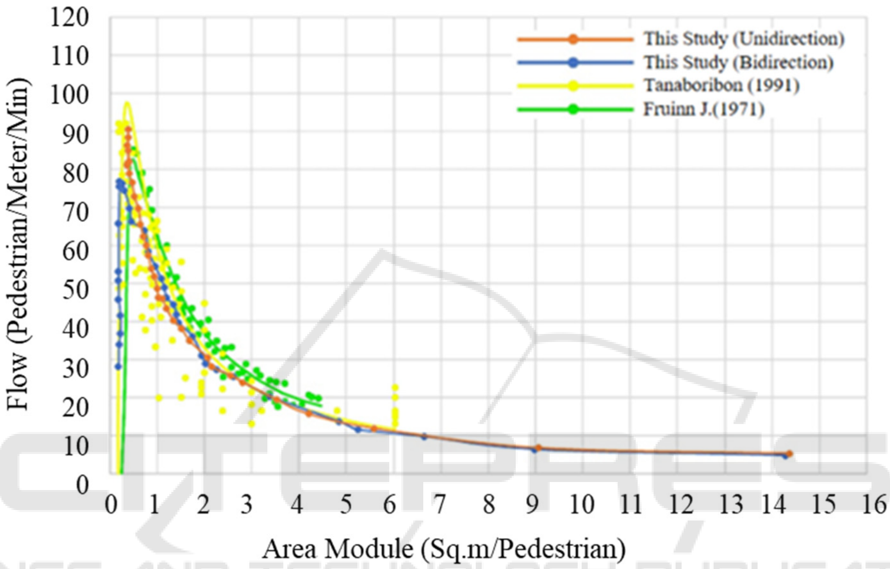

Figure 12: Pedestrian flow area module relationship.

5 CONCLUSION

The methodology of this study proves to be robust enough to model the pedestrian behaviors accurately, and the validation technique employed provides a measure to compare and validate the observed and simulated pedestrian volumes of the skywalk in Bangkok. The results of this case study demonstrates that Thai pedestrian walking speed is 75.07 m/min, which is higher than 73.0 m/min of the previous walking speed study results conducted in Bangkok in 1991 but still slower than U.S. pedestrian walking speed.

The pedestrian flow per one-meter width of uni-direction and bi-direction is 91 peds/m/min and 78 peds/m/min, respectively. It is also clearly indicated that a uni-directional walkway would provide a higher pedestrian flow rate than a bi-directional walkway.

In addition, the maximum Thai pedestrian flow rate obtained in this study is greater than the one obtained in the U.S. It could indicate that the Thai pedestrian body size is smaller than the U.S. Therefore, this study concludes that walking speed and body size significantly affect the pedestrian flow rate. Most importantly, the methodology and results of this study would provide useful information for better planning and robust design of pedestrian facilities in Bangkok. Similarly, the other cities with similar pedestrian flow characteristics could also adopt this methodology where walkways reach their capacities and the importance of body sizes comes into the foreground.

For future research, in addition to factors considered in this study, it would be essential to consider socio-economic factors like age, gender, occupation, etc. Also, a comparison of different types of pedestrian locations at midblock crosswalks, signalized and unsignalized crosswalks, and sidewalks would also be a great prospect for studying the pedestrian flow characteristics and behaviors using the proposed methodology.

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