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PEDESTRIAN FLOW CHARACTERISTICS IN KHULNA METROPOLITAN CITY, BANGLADESH

Md. Imran Nazir*, Sajal Kumar Adhikary, Quazi Sazzad Hossain and Syed Ashik Ali

Department of Civil Engineering, Khulna University of Engineering & Technology, Khulna-9203, Bangladesh

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ABSTRACT

This paper deals with the findings of pedestrian flow characteristics on walkways in Khulna Metropolitan City, Bangladesh. Data were collected from three locations by using a digital camera and were analyzed by using the statistical software SPSSv11.5. The mean walking speed of the pedestrian in Khulna city is 51.67 m/min (2.83 ft/sec.). This speed is slower than that of Asian and American counterpart. The collected data were used to develop the speed-flow-density relationship of pedestrian. The free-flow speed of pedestrians was observed to be 64.14 m/min., which is lower than that of Singapore, Britain and United States. Moreover, pedestrian characteristics from various cities in the world were compared. The results of this study can be used in the field of research and considered as a resource for those developing pedestrian models in practice. It is expected that the results will be highly useful in the planning and design of pedestrian networks for efficient, adequate and safer movement of the pedestrians.

Keywords: *Density, Flow, Pedestrian, Speed, Walkways*

1. INTRODUCTION

Walking is the most efficient and effective mode of transportation to reach a short destination directly or after using other modes. The walking speed of pedestrians is prime importance in a study of function, design and provision of pedestrian facilities. Walking speeds are governed not only by the width of the facility but also by age and gender. The age was judged from the face value of the pedestrian (Laxman et al., 2010). Therefore, the importance of pedestrian movements is globally understood and cannot be neglected. Large proportion of sidewalk users' needs the provision of walk facilities such as exclusive walkways or footpaths on the road for their safe movement. Pedestrians walk differently on different types of walking facilities.

The research works on pedestrians flow characteristics were started from about four decades ago. Available literatures suggest that numerous studies on pedestrians flow characteristics have been carried out based on different existing consitions in different cities in Asia and other parts of the world (Oeding, 1963; Hoel, 1968; Older, 1968; Navin and Wheeler, 1969; Polus et al., 1983; Tanboriboon et al., 1986; Koushki, 1988; Koushki and Ali, 1993; Victor, 1989; Morrel et al., 1991; Tanaboriboon and Guyano, 1991; Thompson and Heydon, 1991; Arasan et al., 1994; Tanaboriboon and Jing, 1994; Gerilla, 1995; Lam et al., 1995; Poei et al., 1995; Thambiah et al., 2004; Rastogi et al., 2008; Laxman et al., 2010). Oeding (1963) indicated that the speed-flow relationships for different types of pedestrians are different. However, Fruin (1971) reported that different speed-flow relationships were established for different types of pedestrian facilities. A comprehensive review of Asian pedestrian characteristics can be found in the study conducted by Morrall et al. (1991), in which a comparison of the pedestrian characteristics in Canadian and Asian cities was made. The study suggested that for Asian countries, such as India, Sri Lanka, and China, the pedestrian planning should be based on local pedestrian characteristics rather than those from cities with dissimilar cultures. The pedestrian flow characteristics in Hong Kong were carried out in another research work by Lam et al. (1995). In that study, the walking speed-pedestrian flow relationships for indoor and outdoor walkways were investigated. The speed-density-flow models developed for Hong Kong are similar to those developed for Singapore.

A comprehensive review of different models for pedestrian facilities around the world has been conducted. Almost all of them conclude that there is a fundamental requirement for studying the characteristics of pedestrians and developing a pedestrian model for road network improvement purposes in any developing city. Since Khulna Metropolitan City (KMC) is rapidly developing due to its geographical importance in Bangladesh, advanced research on pedestrian flow characteristics is an urgent requirement for improving its transportation and road network facilities. However, in order to develop pedestrian planning standards for Khulna city, it is required to conduct study on local pedestrian characteristics. The main objectives of this study are to analyse the

* Corresponding author : imran.nazir06@gmail.com

pedestrian flow characteristics and develops corresponding models in KMC area. The results of this study will be useful in the planning and design of pedestrian networks in Khulna city and can be applied to other cities.

2. METHODOLOGY

This study was conducted in the Khulna Metropolitan City (KMC), Bangladesh. KMC is the third largest city of Bangladesh with a population of about 1.4 million and a land area of only 45.65 km2 (BBS, 2007). The rapid developments of Khulna city as well as the increase of population have put pressure on the pedestrian network. To conduct the speed studies in the concentrated areas, three walkways along the main streets (i.e. Day Night College Road, K.D. Ghosh Road and Khan-A-Sabur Road) were selected. Pedestrians were manually timed over the measured test length and speeds were then measured.

A photographic technique was applied to collect data for the study on speed, flow and density relationships which were introduced by Thompson and Heydon (1991). A digital video camera was used to record the situation at the selected observation sites of known length. From the recordings, suitable time intervals were chosen to measure the walking speed, density and flow. The walking speeds of pedestrians were manually extracted from the recorded videos. The accuracy of time for the speed measurement was about 0.1 sec. The time taken by a pedestrian to traverse the test length was measured from the recording. The density was obtained by counting the number of pedestrians within the boundaries of the observation site. The flow was obtained by counting the number of pedestrians passing the centre line of the observation site within the time interval.

3. RESULTS AND DISCUSSIONS

As mentioned before, there were total three observation sites, one in the Day Night College Road (DNCR) at Daulatpur and other two in the K.D. Ghosh Road (KDGR) and Khan-A-Sabur Road (KSR) of Khulna Sadar. The details of each location are shown in Table 1.

Table 1 Detail of Study Locations

Location ID	Observation Sites	Width (m)	Length (m)
I	Day Night College Road (DNCR) (Walkway at the side of Century Super Market)	1.37	6.10
II	K.D. Ghosh Road (KDGR) (Walkway beside Hadit Park)	1.22	5.49
III	Khan-A-Sabur Road (KSR) (Walkway at the side of Jalil Tower)	1.27	3.56

The observed walking speed for the various types of pedestrian facilities in walkways were obtained from the video recording surveys and tabulated in Table 2.

Table 2 Results of the Walking Speed Study

Characteristics		Pedestrians				
		Men	**Women**	**Adult**	**Young**	**Elderly**
Mean walking speed (m/min)		52.63	49.29	52.83	51.07	47.67
Standard deviation		5.57	5.83	5.75	4.63	5.25
Range	High	68.90	63.00	68.90	61.10	56.60
	Low	40.10	39.00	40.10	43.20	39.00
Sample size		367	148	332	102	81

It is seen in Table 2 that the mean free-flow walking speed of these pedestrians was found to be 51.67 m/min. For a further breakdown by gender, it was found that the Khulna city's males generally walked faster than the females. The mean free-flow walking speeds are 52.63 m/min. 49.29 m/min. for males and females, respectively. The observed mean free-flow walking speed of Khulna City's pedestrians is comparatively slower than the Asian and American counterpart. The mean walking speeds for adult and young pedestrians were found to be 52.83 m/min. and 51.07 m/min. respectively. The elderly, however, were found to have a lower walking speed

47.67m/min. It is noted here that the term elderly is used subjectively. Any pedestrian who appeared to be over 60 years old was termed elderly. Table 3 shows the comparison of pedestrian walking speeds. It is noticed that the Asian and American pedestrians were found to have free-flow walking speed ranging from 73 m/min. to 74 m/min. and 79 m/min. to 88 m/min., respectively.

Table 3 Comparison of pedestrian walking speeds in different studies

City, Country	Mean Speed (m/min)	Author(s)
(a) American and European Countries		
Pittsburgh, United States	88.0	Hoel (1968)
London, England	79.0	Older (1968)
Columbia, United States	79.0	Navin and Wheeler (1969)
New York, United States	81.0	Fruin (1971)
Paris, France	87.6	Kamino (1980)
(b) Asian Countries		
Fukuoka, Japan	81.0	Kamino (1980)
Koori-cho, Fukushima, Japan	69.6	Kamino (1980)
Osaka, Japan	90.0	Kamino (1980)
Tokyo, Japan	93.6	Kamino (1980)
Haifa, Israel	79.0	Polus et al. (1983)
Delhi, India	72.0	Gupta (1986)
Roorkee, India	84.0	Laxman et al. (2010)
Madras, India	72.0	Victor (1989)
Singapore	74.0	Tanaboriboon et al. (1986)
Riyadh, Saudi Arabia	65.0	Koushki (1988)
Yogyakarta, Indonesia	52.0	Poei et al. (1995)
Bangkok, Thailand	73.0	Tanaboriboon and Guyano (1991)
Kuwait city, Kuwait	71.0	Koushki and Ali (1993)
Shanghai, China	72.0	Yu (1993)
Tiruchirapalli, India	74.0	Arasan et al. (1994)
Metro Manila, Philippines	70.6	Gerilla (1995)

The pedestrian data were analyzed by using the statistical software SPSSv11.5. The values of pedestrian flow, pedestrian speed, pedestrian density and pedestrian area module were computed at each study location. Curves were plotted between speed and density, speed and flow, flow and density and flow and area module. These are presented in Figure 1 to Figure 3. For all locations, the analysis was done for one direction. The scattered plot of data points suggested a straight line relation between pedestrian speed and density; quadratic relationship between pedestrian flow and density, and pedestrian speed and flow; and polynomial relationship between pedestrian flow and area module.

The general relationships used for the analysis of pedestrian flow characteristics were developed based on single-regime approach and are described as follows:

Pedestrian speed (μ) and density (k): $\mu = a - b \times k$ (1)

Pedestrian flow (q) and density (k): $q = a \times k - b \times k^2$ (2)

Pedestrian speed (μ) and flow (q): $q = \mu(a - \mu)/b$ (3)

Pedestrian flow (q) and module (M): $q = \frac{a}{M} - \frac{b}{M^2}$ (4)

Where, speed (μ) in m/min, density (k) in ped/m^2, flow (q) in ped/m/min and Area module (M) in m^2/ped

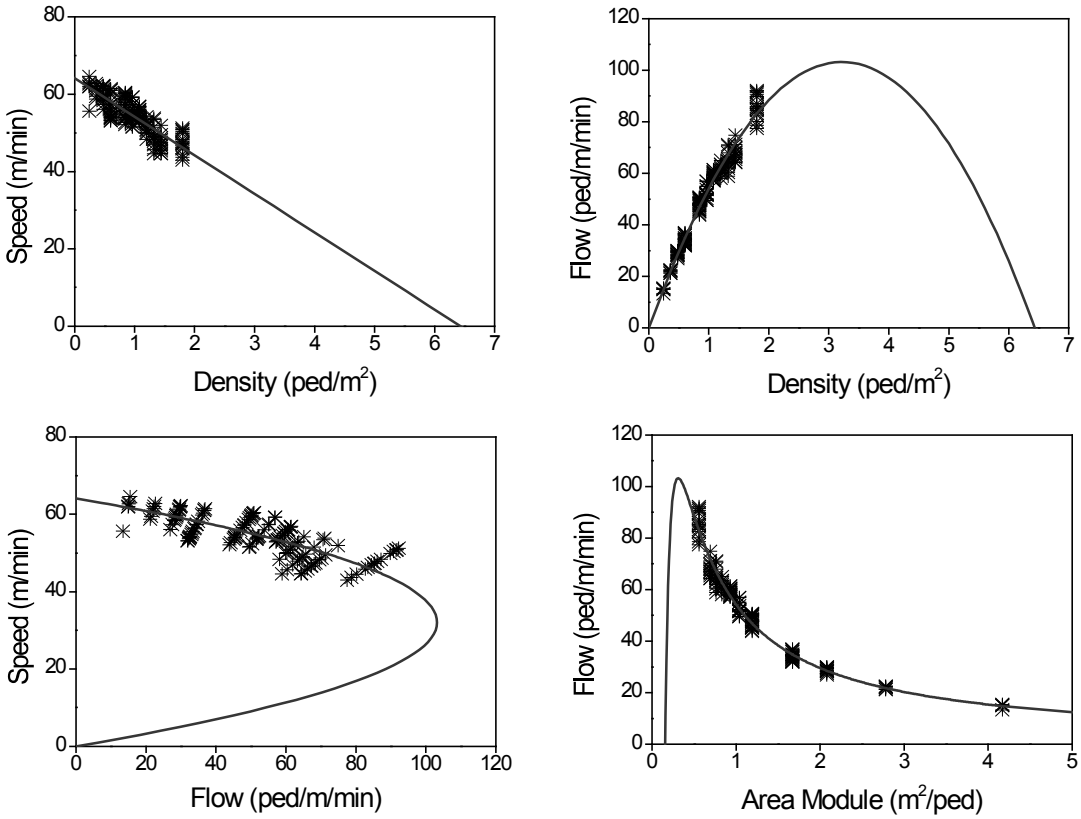

Figure 1 Pedestrian flow characteristics in Day Night College Road

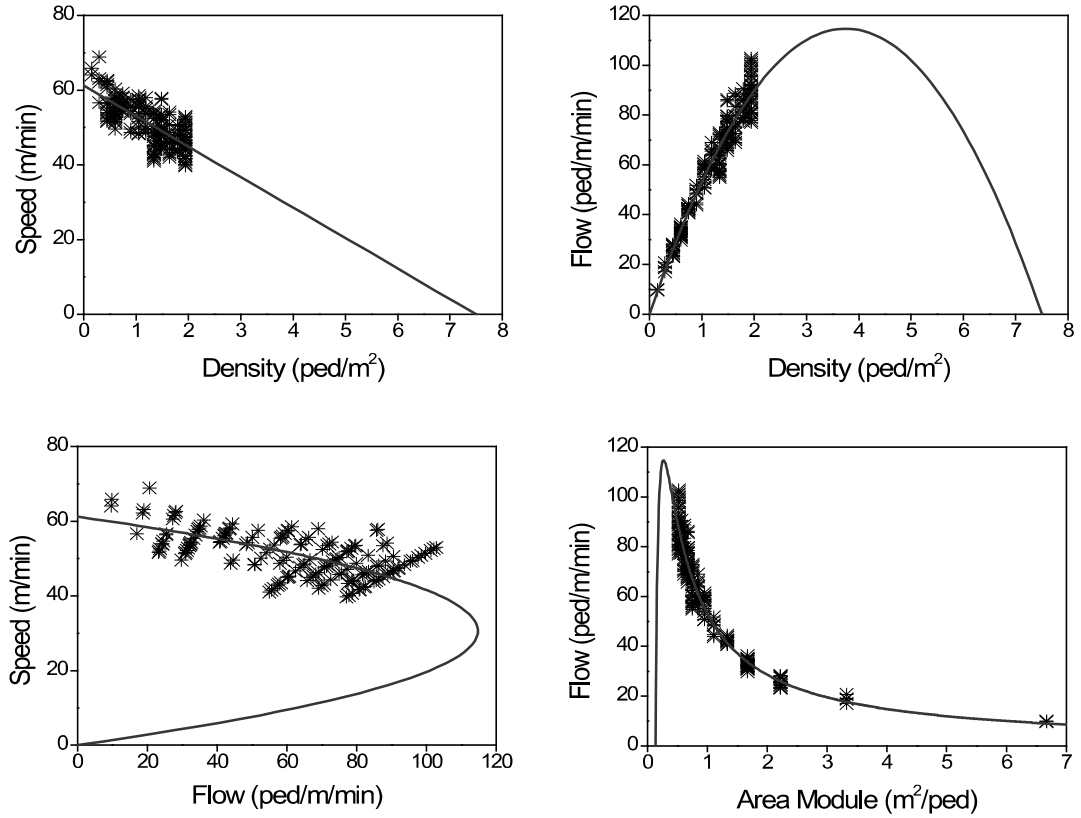

Figure 2 Pedestrian flow characteristics in K.D. Ghosh Road

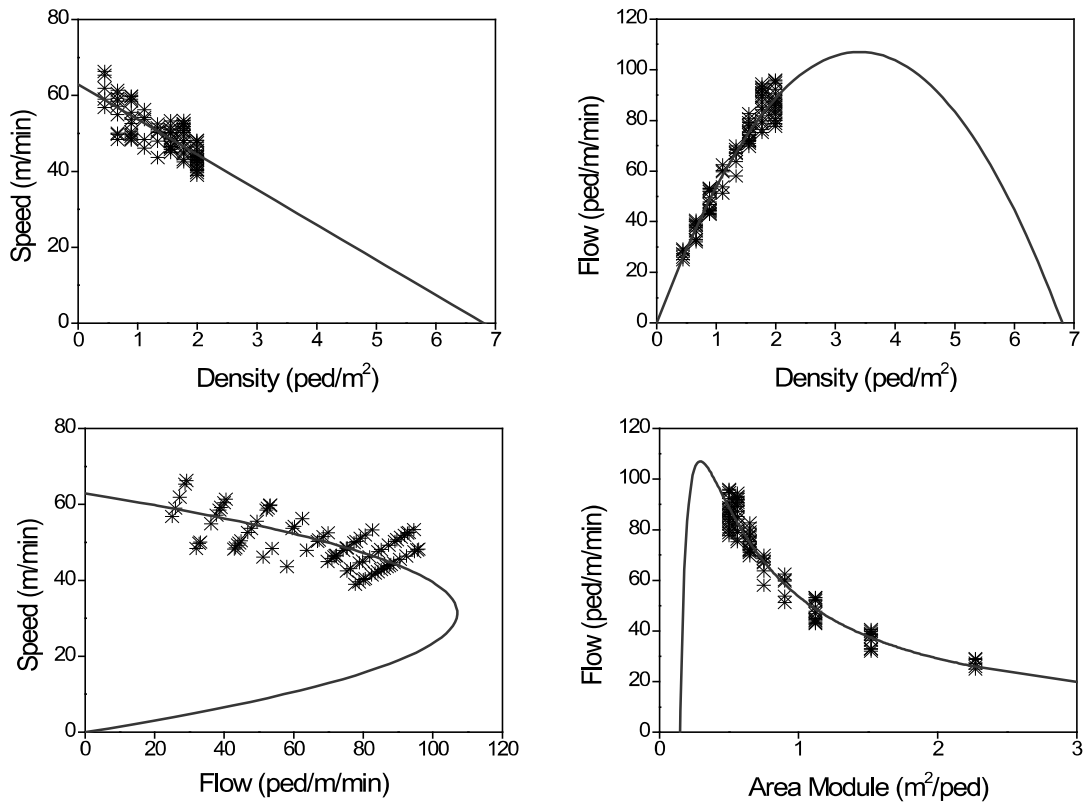

Figure 3 Pedestrian flow characteristics in Khan-A-Sabur Road

The relationships obtained from the analysis of data are presented in Table 4. The important flow characteristics estimated from the above relationships are given in Table 5. It is seen in Table 4 that the correlation coefficient R^2 varies between 0.33 and 0.97. These represent from fair to good fits to the data. It also suggests that instead of single-regime models, two to three-regime models might give better R^2 value. In the absence of extensive data these are not attempted in the present study.

Table 4 Relationship Developed between Different Pedestrian Flow Characteristics

Location ID	Site Location	Relationship	Model Equation	R^2 value
I	Day Night College Road (Walkway at the side of Century Super Market)	Speed-density	$\mu = 64.14 - 9.97k$	0.72
		Flow-density	$q = 64.14k - 9.97k^2$	0.97
		Flow-speed	$q = \mu(64.14 - \mu)/9.97$	0.58
		Flow-space	$q = 64.14/M - 9.97/M^2$	0.75
II	K.D. Ghosh Road (Walkway beside Hadit Park)	Speed-density	$\mu = 61.19 - 8.16k$	0.54
		Flow-density	$q = 61.19k - 8.16k^2$	0.94
		Flow-speed	$q = \mu(61.19 - \mu)/8.16$	0.33
		Flow-space	$q = 61.19/M - 8.16/M^2$	0.61
III	Khan-A-Sabur Road (Walkway at the side of Jalil Tower)	Speed-density	$\mu = 62.89 - 9.24k$	0.62
		Flow-density	$q = 62.89k - 9.24k^2$	0.94
		Flow-speed	$q = \mu(62.89 - \mu)/9.24$	0.40
		Flow-space	$q = 62.89/M - 9.24/M^2$	0.84

The mathematical relationships obtained in the present study are similar to those reported by Tanaboriboon et al. (1986) for the United States. The free-flow pedestrian speeds were found more than 60 m/min. at all of the three locations. These speeds are highest at Location I (64.14 m/min.). This location has highest width of the carriageway (1.37m) and the pedestrian face little frictions at this location. In case of Location II and III, the friction due to parked vehicles is present. Due to high pedestrian flow, many pedestrians use carriageway. The friction imposed by motorized vehicles is higher at Location III as compared to the Location I and II. This has resulted in a reduction in speed at location II (61.19 m/min.) and III (62.89 m/min.) compared to Location I.

Table 5 Pedestrian Flow Characteristics at Different Study Locations

Location ID	Free-flow speed (μ_f), m/min	Jam density (k_j), ped/m^2	Maximum flow rate (q_{max}), ped/m/min	Area module (M) (m^2/ped.)	
				At q_{max}	Minimum
I	64.14	6.43	102.87	0.31	0.16
II	61.19	7.50	114.71	0.27	0.13
III	62.89	6.81	107.00	0.30	0.15

It is seen in Table 5 that the maximum density was observed at Location II, 7.50 ped/m^2 or 50 pedestrian in an area of 7 m^2. The minimum density was observed as 6.43 ped/m^2 at location I. It may be due to the level of frictions on roads and the roadway width. The higher level of friction and lesser roadway width make the pedestrians to use restricted road space, thus resulting in higher density. The maximum and minimum flow rates were observed as 114.71 ped./m/min or 6883 ped./h and 102.87 ped./m/min. or 6172 ped./h. It is highest at location II and lowest at location I. Flow rate is lowest at location I due to open area and pedestrian freedom to use the space. The minimum area module was observed between 0.13 to 0.16 m^2/ped. and the area module at maximum flow rate was found between 0.27 and 0.31 m^2/ped. The comparison of different flow characteristics is shown in Table 6.

Table 6 Comparison of Pedestrian Flow Characteistics From Different Studies

Source	Country	Type	Free-flow speed μ_f, (m/min)	Traffic jam density k_j, (ped./m^2)	Maximum flow rate (q_{max}), ped/m/min
Oeding (1963)	Germany	Mixed	89.9	3.98	89.10
Older (1968)	Britain	Shoppers	78.64	3.89	76.54
Navin and Wheeler (1969)	United States	Students	97.6	2.70	65.79
Tanaboriboon et al. (1986)	Singapore	Mixed	73.9	4.83	89.24
Fruin (1971)	United States	Commuter	81.4	3.99	81.2
Yu (1993)	China	Mixed	75.45	5.10	95.97
Gerilla (1995)	Philippines	Mixed	83.23	3.60	74.94

It is seen in Table 6 that the free-flow speed computed in this study are lower than those observed in Germany, Britain, United States, Singapore, China and Philippines. The maximum density (7.50 ped./m^2) observed in this study is higher than the observed density in Germany, Britain, United States, Singapore, China and Philippines. The maximum flow rate observed in this study (114.71 ped./m/min) is higher than the above study mentioned in Table 6. Therefore, we can conclude that, Bangladeshi pedestrians require less personal space than others study.

4. CONCLUSIONS

This study aims to investigate the pedestrian flow characteristics in the walkways of Khulna city. The results indicate that the pedestrian of Khulna city has a slower walking speed than that of the American and other Asian cities. However, the maximum flow rate obtained in this study is higher than that obtained in the Asian and Western counties. This study also shows that the characteristics of the location have effect on the pedestrian flow characteristics. The relationships developed between different flow parameters i.e. speed, flow, density and area module are observed to be satisfactory. There is need to re-examine these relationships based on two-or three-regime models. The free-flow speeds of this study were found lower than the Asian and Western countries. The observed free-flow speed and densities are found proportional to each other. The increase in road friction also increases the jam density. Thus, the findings of this study will be useful to design efficient, adequate and safer pedestrian facilities.

REFERENCES

Arasan, V. T., Rengaraju, V. R. and Rao, K. V. K.: Characteristics of trips by foot and bicycle modes in Indian city, Journal of Transportation Engineering, Vol. 120(2), 283-294, 1994.

BBS (Bangladesh Bureau of Statistics).: Bangladesh Population Sensus-2001: Planning Division, Ministry of Planning, Government of the People's Republic of Bangladesh, 2007.

Fruin, J.J.: Pedestrian Planning and Design, Metropolitan Association of Urban Designers and Environmental Planners, Inc., New York, 1971.

Gerilla, G. P.: Proposed level of service standards for walkways in Metro Manila, Journal of Eastern Asia Society of Transportation Studies, Vol. 1(3), 1041–1060, 1995.

Hoel, L.A.: Pedestrian travel rates in central business district, Traffic Engineering, Vol. 39(4), 10-13, 1968.

Kamino, K.: People's movement and town design, Shôkokusha, Japan, 1980.

Koushki, P.A. and Ali, S.Y.: Pedestrian characteristics and the promotion of walking in Kuwait City Center, Transportation Research Record, Vol. 1396, 30-33, 1993.

Koushki, P.A.: Walking characteristics in Central Riyadh, Saudi Arabia, Journal of Transportation Engineering, Vol. 114(6), 735-744, 1988.

Lam, W.H.K., Morrall, J.F., and Ho, H.: Pedestrian flow characteristics in Hong Kong, Transportation Research Record, 1487, Transportation Research Board, Washington, D.C., 56-62, 1995.

Laxman, K.K., Rastogi, R. and Chandra, S.: Pedestrian Flow Characteristics in Mixed Traffic Conditions, Journal of Urban Planning and Development, Vol. 136(1), 23-33, 2010.

Morrall, J.F., Ratnayake, L.L., and Seneviatne, P.N.: Comparison of central business district pedestrian characteristics in Canada and Sri Lanka, Transportation Research Record, 1294, Transportation Research Board, Washington, D.C., 57-61, 1991.

Navin, F.P.D., and Wheeler, .J.: Pedestrian flow characteristics, Traffic Engineering and Control, Vol. 39(9), 30-36, 1969.

Oeding, D.: Verkehrsbelastung und dimensionierung von gehwegen and anderen anlagen des fussgangerverkehrs (Congestion and dimensioning of sidewalks and other pedestrian facilities of transport), Vol. 22, Strassenbau und Stasserverkehrstechnik, Bonn, Germany, 1963.

Older, S.J.: Movement of pedestrians on footways in shopping streets, Traffic Engineering and Control, Vol. 10(4), 160-163, 1968.

Poei, E. P., Hanzawa, Y. and Koyama, S.: Pedestrian flow analysis at Yogyakarta, Indonesia. Journal of Japan Society of Civil Engineers, Vol. 18(1), 131-134, 1995.

Polus, A., Schoer, J.L. and Ushpiz, A.: Pedestrian flow and level of service, Journal of Transportation Engineering, Vol. 109(1), 46-56, 1983.

SPSS Inc.: SPSS Base 11.5 Application Guide, U.S.A, 2003.

Tanaboriboon, Y. and Jing, Q.: Chinese pedestrians and their walking characteristics: case study in Beijing, Transportation Research Record, Vol. 1441, 16-26, 1994.

Tanaboriboon, Y. and Guyano, J.A.: Analysis of pedestrian movements in Bangkok, Transportation Research Record, Vol. 1294, 52-56, 1991.

Tanaboriboon, Y., Hwa, S.S. and Cho, C.H.: Pedestrian characteristics study in Singapore, Journal of Transportation Engineering, ASCE, Vol. 112(3), 229-235, 1986.

Thambiah, M., Adachi, T., Hagiwara, T., Kagaya, S. and Ken'etsu, U.: A study on evaluation of pedestrian level of service on sidewalks and crosswalks using conjoint analysis, Journal of Infrastructure Planning, JSCE, Vol. 21(3), 727-735, 2004.

Thompson, S. J., and Heydon, S.: Improving pedestrian conspicuity by use of a promontory, Traffic Eng. Control, 32(7-8), 370-371, 1991.

Victor, D.J.: Pedestrian traffic management in Indian cities, Proc. of the 5th World Conference on Transportation Research, Yokohama, Japan, 1989.

Yu, M. F.: Level of service design standards for non-motorized transport in Shanghai, China, M.Eng. Thesis, Transportation Engineering (TRE), School of Engineering and Technology (SET), Asian Institute of Technology (AIT), Bangkok, Thailand, 1993.