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A STUDY ON PEDESTRIAN CHARACTERISTICS IN KHULNA METROPOLITAN CITY, 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 at three locations by using a digital camera. The data were analyzed by using the statistical software SPSSv11.5. The mean walking speed of the pedestrian of Khulna city is 52.83 m/min (2.89 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 pedestrianis is observed to be 64.14 m/min. which is lower than the Singapore, Britain and United States.Moreover, pedestrian characteristics from various cities in the world are compared. The collected data and established relationships could be used as a basis for the development of more efficient, adequate and safer facilities for the pedestrians.

Keywords: Pedestrian, speed, flow, density, walkways

1. INTRODUCTION

Walking is the most efficient and effective mode of transportation for short trips. Walking is directly involved with using other modes. The importance of pedestrian movements is understood globally and cannot be overemphasized. Khulna Metropolitan City (KMC) is the 3rd largest city of Bangladesh with a population of about 1.4 million and a land area of only 45.65 km^2 (BBS, 2007). The rapid developments of Khulna city as well as the increase of population have put pressure on the pedestrian network. In order to identify the importance of the pedestrian mode, the pedestrian characteristics for various pedestrian facilities need to be investigated. In Khulna, little attention has been given to study on pedestrian behaviour and pedestrian flow characteristics. A review of different models for pedestrian facilities around the world was conducted. It was concluded that there was a fundamental need for studying the characteristics of Khulna City's pedestrians and developing a pedestrian model for road network improvement purposes.

The research works on pedestrians flow characteristics started about four decades ago. Oeding (1963) indicated that the speed/flow relationships for different types of pedestrians are different. Fruin (1971) also 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 Morrall et al. (1991) in which a comparison of the pedestrian characteristics in Canadian and Asian cities was made. Lam et al. (1995) studied the pedestrian flow characteristics in Hong Kong and investigated the walking speed/pedestrian flow relationships for indoor and outdoor walkways, signalized crosswalks as well as stairways in Mass Transit Railway (MTR). The speed-density-flow models developed for Hong Kong are similar to those developed for Singapore.

In order to develop pedestrian planning standards for Khulna city, it is required to conduct study on local pedestrian characteristics. The walking speed of pedestrians is the key factor for the design of pedestrian facilities. The objective of this paper is to develop the relationship between speed, flow and density for the pedestrians at walkways of urban areas in Khulna city. This result may be useful in the planning and design of pedestrian networks in Khulna and can be applied to other cities in Bangladesh.

2. DATA COLLECTION AND METHODOLOGY

This study was conducted in the Khulna Metropolitan City (KMC), Bangladesh. 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 a measured test length and speeds were then measured.

A photographic technique was used to collect data for the study on speed, flow, and density relationships. A digital video camera was used to record the situation at the observation sites. From the recordings, suitable time intervals were chosen to measure the walking speed, density and flow. 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	Combined	Young	Elderly
Mean walking speed (m/min)		53.52	50.77	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	41.40	40.10	43.20	39.00
Sample size		249	83	332	102	81

It is seen in Table 2 that the mean free-flow walking speed of these pedestrians was found to be 52.83 m/min. For a further breakdown by gender, it was found that the Khulna city's males generally walked faster than the females as their mean free-flow walking speeds are 53.52 m/min 50.77 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 young pedestrians were found to be 51.07 m/min. 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 pedestrian was 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

Speed	Asia		United States		
	Japan (Murata, 1978)	Singapore (Tanaboiboon et al, 1986)	Navin & Wheeler (1969)	Fruin (1971)	Hoel (1968)
Mean Walking Speed (m/min)	73.0	74.0	79.0	81.0	88.0

The pedestrian data were analyzed by using the statistical software SPSSv11.5. The values of pedestrian flows, pedestrian speeds, 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 are 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

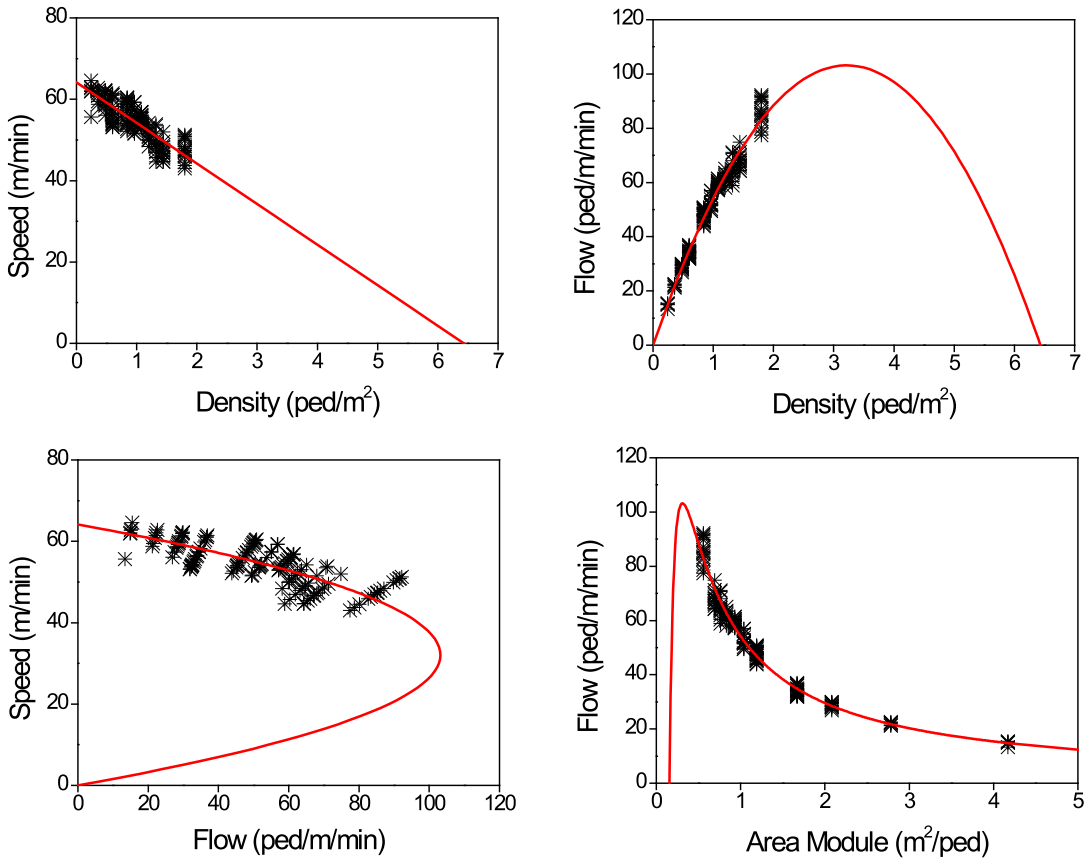

Figure 1: Pedestrian flow characteristics in Day Night College Road

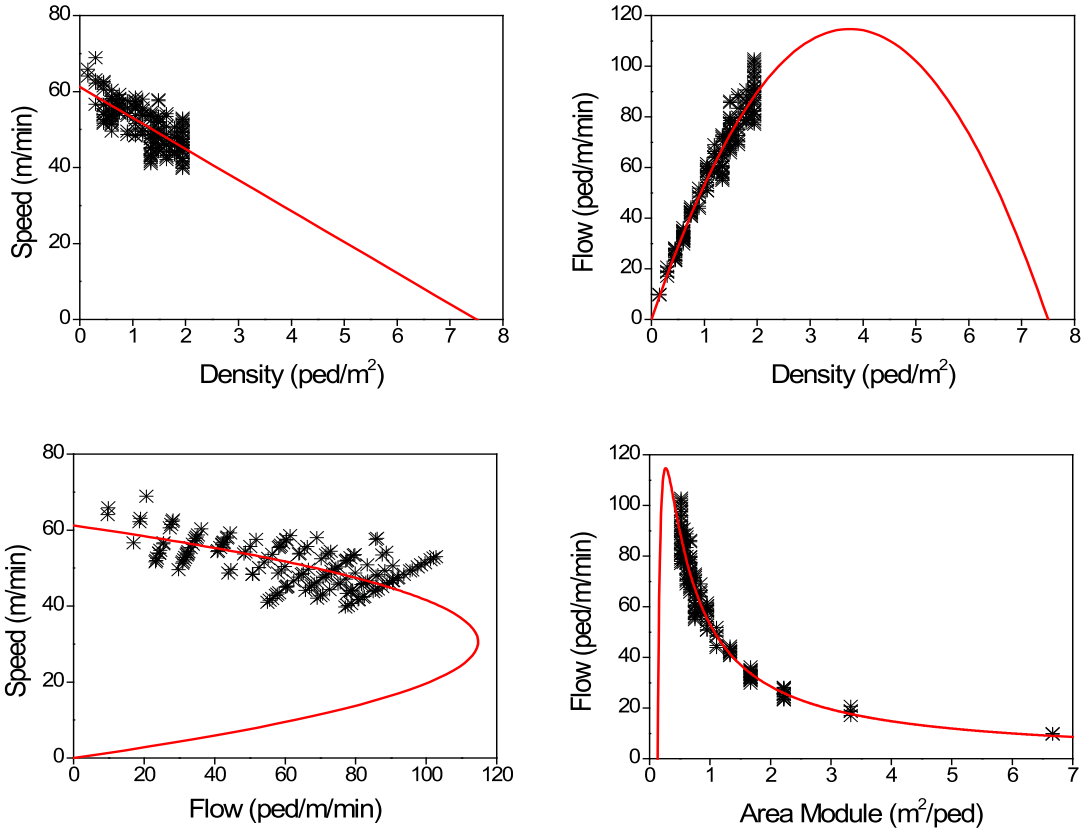

Figure 2: Pedestrian flow characteristics in K.D. Ghosh Road

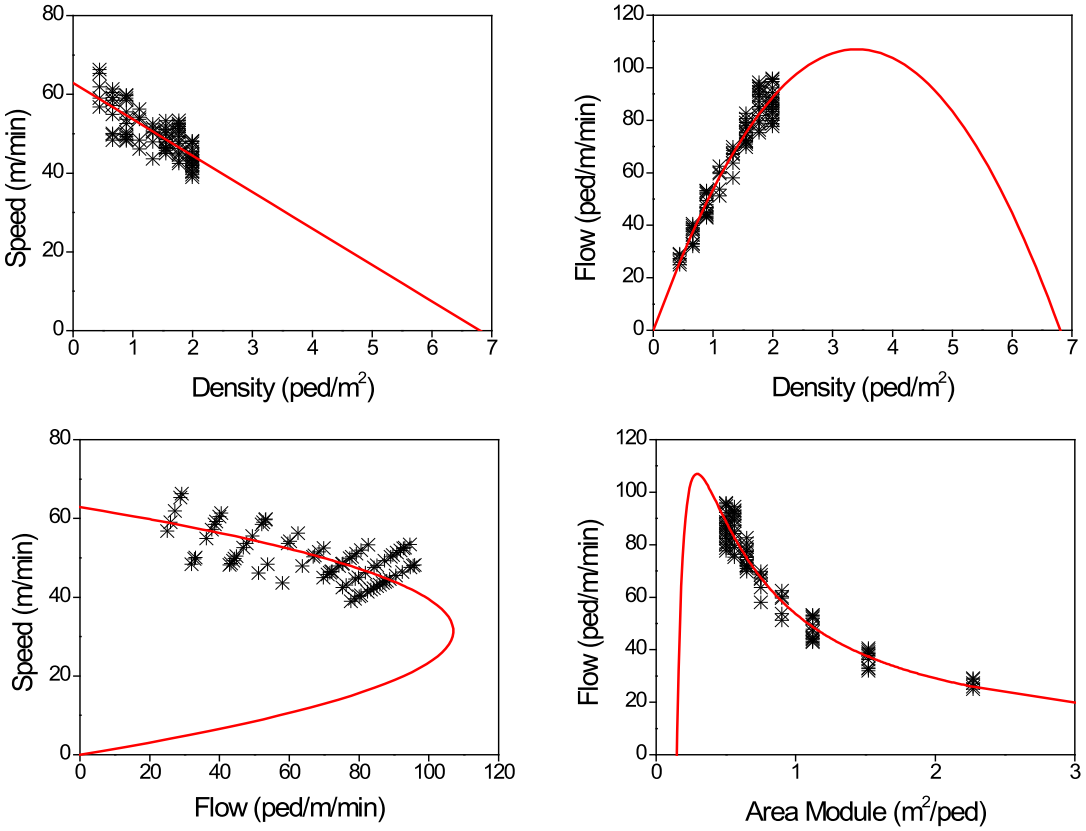

Figure 3: Pedestrian flow characteristics in Khan-A-Sabur Road

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 are found to be 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 the 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. 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 is 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	Free-flow speed μ_f (m/min)	Traffic jam density k_j (ped./m^2)	Maximum flow rate (q_{max}), ped/m/min
Older (1968)	Britain	78.64	3.89	78
Fruin (1971)	United States	81.40	3.99	81
Tanaboriboon et al. (1986)	Singapore	73.90	4.83	89

It is seen in Table 6 that the free-flow speed computed in this study are lower than those observed in Britain, United States and Singapore. The maximum density (7.50 ped./m^2)observed in this study is higher than the observed density in Britain, United States and Singapore. The maximum flow rate observed in this study (114.71 ped./m/min) is higher than that of Britain (78 ped./m/min), United States (81 ped./m/min) and Singapore (89 ped./m/min). Because, Bangladeshi pedestrians require less personal space than others study.

4. CONCLUSIONS

This paper aims to investigate the pedestrian flow characteristics in the walkways of Khulna city. The variations of pedestrians mean walking speed with respect to age and gender were also observed. The results indicate that the pedestrian of Khulna city has a slower walking speed than 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 to good. There is need to re-examine these relationships based on two-or three-regime models. The free-flow speeds of this study are 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 may be useful to the planners and designers to design efficient, adequate and safer pedestrian facilities.

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