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PEDESTRIAN FLOW CHARACTERISTICS AT WALKWAYS IN RAJSHAHI METROPOLITAN CITY OF BANGLADESH

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ABSTRACT

The walking speed of pedestrians are of prime importance in a study of function and design of pedestrian facilities. Pedestrians' speed depends on various characteristics such as age and gender of the pedestrian and width of the walkways. This paper deals with the findings of pedestrian flow characteristics on walkways in Rajshahi Metropolitan City, Bangladesh. Data were collected at three locations of walkways by using a digital camera. The data were analyzed by using the statistical software SPSSv16. The mean walking speed of the pedestrian of Rajshahi city is found 67 m/min (3.66 ft/sec.) at walkways. This speed is slower than that of Asian and American counterpart. The collected data were used to develop the speed-flow-density-space relationship of pedestrian. The maximum free-flow speed of pedestrianis is observed to be 85.26 m/min. which is higher 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 because every person walk sometimes in his/her every day journey. The importance of pedestrian movements is vital for economic development of city life. Rajshahi Metropolitan City (RMC) is one of the largest cities of Bangladesh. Population is increasing day by day in Rajshahi city as a result increased pedestrian's demand. The increase of population has put pressure on the pedestrian network. To identify the existing condition of the pedestrian mode, the pedestrian characteristics for various pedestrian facilities need to be investigated. Proper attention has been given to study on pedestrian behaviour and pedestrian flow characteristics for Rajshahi city. A review of different models for pedestrian facilities around the world was conducted to develop a standard model in Rajshahi metropolitan city. Various studies on walking speeds were conducted by many researchers at different areas on walkways. It was found that walking speeds of pedestrians vary over a wide range depending on the personal physical condition, gender, age and other factors. Hoel (l968) conducted a study in Pittsburgh Central Business District during peak and off -peak periods of the day and obtained a mean walking speed of 4.80 ft/sec (88 m/min). Older (1968) conducted the same study in Oxford Street, London on footways and obtained a mean walking speed of 78.6 m/min. Navin and Wheeler (1969) who investigated a study among students in University of Missouri, Columbia was found a walking speed of 79 m/min. Fruin (1971) conducted a study among commuters in United States and obtained a mean walking speed of 81 m/min. Polus *et al.* (1983) examined the movements of individual pedestrians on sidewalks in the central business district of Haifa, Israel, using a modern technique. Instead of a cine camera, a video tape recorder and a digital clock were used and obtained an average walking speed of 78.8 m/min. Tanaboriboon *et al.* (1986) conducted the first study in Southeast Asia and obtained a mean walking speed of 74 m/min. Murata (1978) presented about utilizing the traffic cell principle which introduced pedestrianisation on most of the streets in Nagano City, Japan.

In order to develop pedestrian planning standards for Rajshahi metropolitan 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, density and space for the pedestrians at walkways of urban areas in Rajshahi metropolitan city. This result may be useful in the planning and design of pedestrian networks in Rajshahi and can be applied to other cities in Bangladesh.

Table 1. Comparison of the Observed Walking Speeds in Different Studies

City, Country	Mean Speed (m/min)	Author(s)
(a) America and Europe		
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) Asia		
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)
Singapore	74.0	Tanaboriboon et al. (1986)
Riyadh, Saudi Arabia	65.0	Koushki (1988)
Madras, India	72.0	Victor (1989)
Bangkok, Thailand	73.0	Tanaboriboon and Guyano (1991)
Kuwait	71.0	Koushki and Ali (1993)
China	72.0	Yu (1993)
Tiruchirapalli, India	74.0	Arasan et al. (1994)
Metro Manila, Philippines	70.6	Gerilla (1995)

2. DATA COLLECTION AND METHODOLOGY

This study was conducted in the Rajshahi Metropolitan City (RMC), Bangladesh. To conduct the speed studies in the concentrated areas, three walkways were selected. Pedestrians were manually timed over a measured test length and speeds were then measured.

Table 2. Details of Study Site Locations

Walkways			
Site ID	Location of Observation Sites	Dimensions	
		Length (m)	Effective Width (m)
Ia	Rajshahi City Corporation (Walkway beside Rajshahi City Corporation)	4.00	1.10
IIa	Rajshahi University (Walkway inside Rajshahi University)	6.00	0.90
IIIa	Shaheb Bazar (Walkway at the side of Shaheb Bazar)	4.50	1.05

Thompson and Heydon (1991) introduced the concept in the United Kingdom of using slow motion video surveys to collect pedestrian data to develop speed–flow–density-space relationships. Since then, the method has been widely used, and is perceived as the preferred method for collecting pedestrian data (Zegeer *et al.* 1994). This study is based upon this methodology. The concept involves marking out an area of known dimensions (length and breadth) and recording pedestrian movements through the study area. The video tapes are then played back, and data extracted manually by an enumerator. This can take a significant amount of time, especially with large numbers of pedestrians, but the advantages are that long time periods can be analyzed; more precise measurements of data can be obtained; and there is a permanent record of events.

3. RESULTS AND DISCUSSIONS

3.1 Pedestrian Flow Characteristics in Walkways

As mentioned before, there were total three observation sites in Rajshahi metropolitan city. The observation sites are Rajshahi City Corporation, Rajshahi University, and Shaheb Bazar. The details of each location are shown in Table 2. The observed walking speed for the various types of pedestrian facilities in walkways were obtained from the video recording surveys and tabulated in Table 3.

Table 3. Pedestrians Walking Speeds on Walkways

Pedestrian Types		Characteristics				
		Sample Size	Mean Speed (m/min)	Standard Deviation (m/min)	Range	
					Low	High
Overall	Male	2048	67.24	10.44	40.35	92.74
	Female	402	65.54	10.55	40.35	91.46
	Combined	2450	66.96	10.48	40.35	92.74
Children	Male	72	62.58	9.67	42.95	86.08
	Female	27	59.20	10.82	40.87	80.65
	Combined	99	61.66	10.06	40.87	86.08
Younger	Male	1002	67.72	10.50	40.35	91.88
	Female	214	66.34	10.38	40.87	91.46
	Combined	1216	67.48	10.49	40.35	91.88
Middle Aged	Male	892	67.46	10.35	40.35	92.74
	Female	154	65.51	10.29	40.35	89.29
	Combined	1046	67.17	10.36	40.35	92.74
Older	Male	82	63.01	9.54	41.21	80.65
	Female	7	66.00	14.05	45.84	84.87
	Combined	89	63.25	9.90	41.21	84.87

It is seen in Table 3 that the mean free-flow walking speed of pedestrians was found to be 67 m/min in Rajshahi metropolitan city. The observed mean free-flow walking speed of RMC's pedestrians is comparatively slower than the Asian and American counterpart (See Table 4). It was found that the RMC's males generally walked faster than the females as their mean free-flow walking speeds are 67.24 m/min and 65.54 m/min for males and females, respectively. The mean walking speeds for children,young, middle aged and elderly pedestrians were found to be 61.66 m/min, 67.48 m/min, 67.17 m/min and 63.25 m/min respectively. Any pedestrian who appeared to be over 60 years old was termed elderly.

Table 4: Comparison of Pedestrian Walking Speeds

	ASIA		EUROPE		U.S.A.		
	Japan	Singapore	Israel	Britain	Columbia	New York	Pittsburgh
Authors	Murata (1978)	Tanaboriboon, Sim & Chin (1986)	Polus *et al.* (1983)	Older (1968)	Navin & Wheeler (1969)	Fruin (1971)	Hoel (1968)
Mean Walking Speed (m/min)	73.0	74.0	78.8	78.6	79.0	81.0	88.0

The values of pedestrian flows, pedestrian speeds, pedestrian density and pedestrian area module were computed at each study location and were analyzed by using the statistical software SPSSv16. Graphical relationship 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 both directions. 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

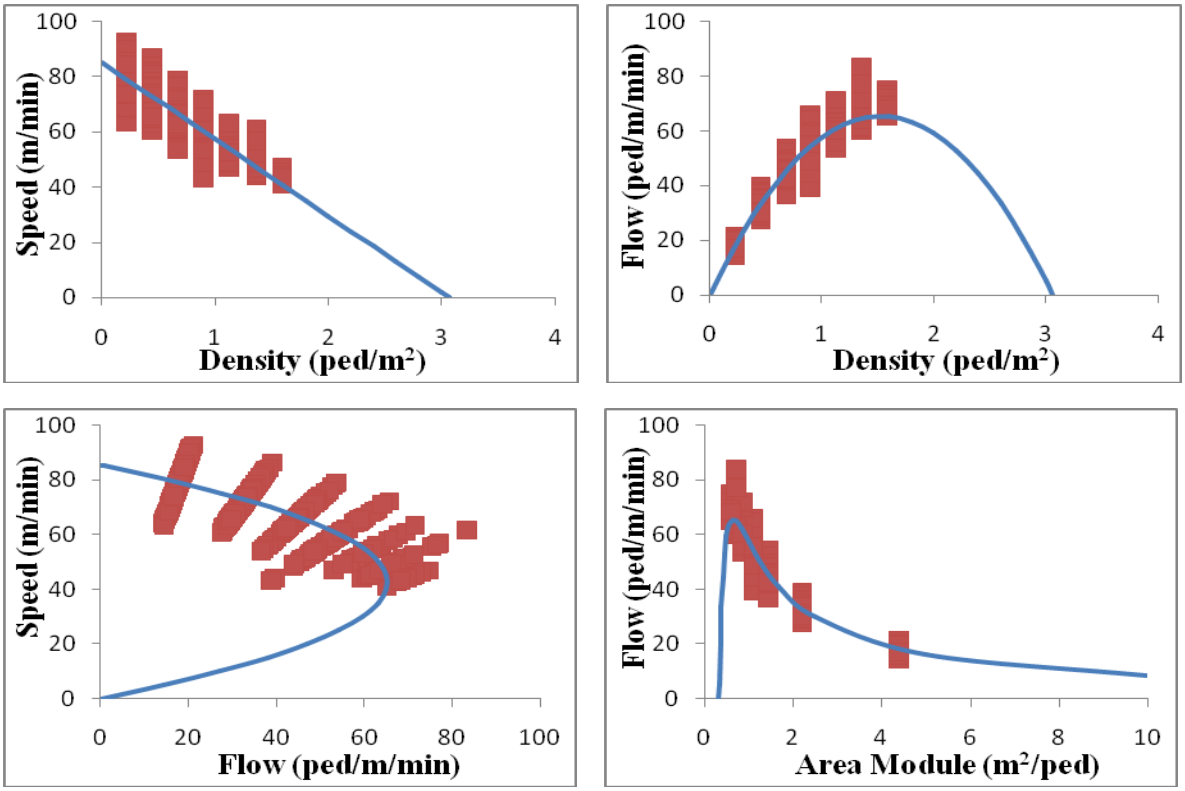

Figure 1: Pedestrian flow characteristics at Rajshahi City Corporation

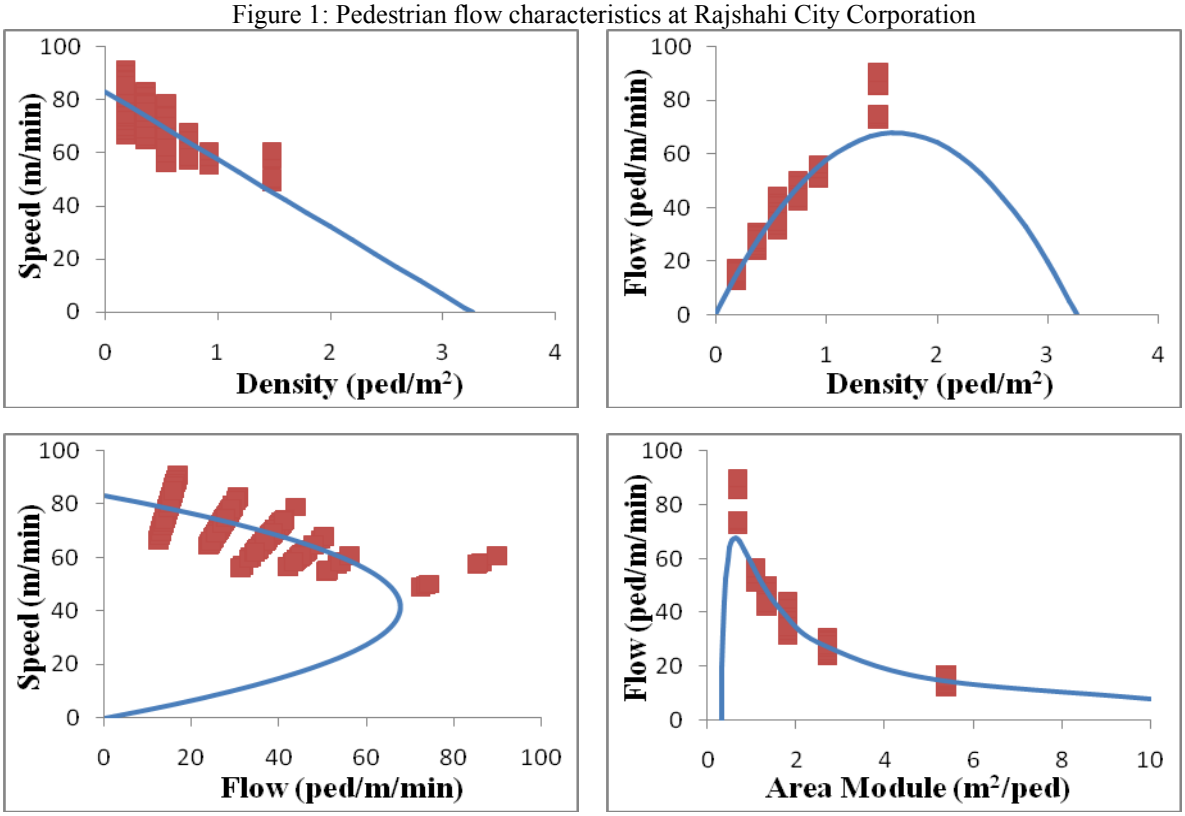

Figure 2: Pedestrian flow characteristics at Rajshahi University

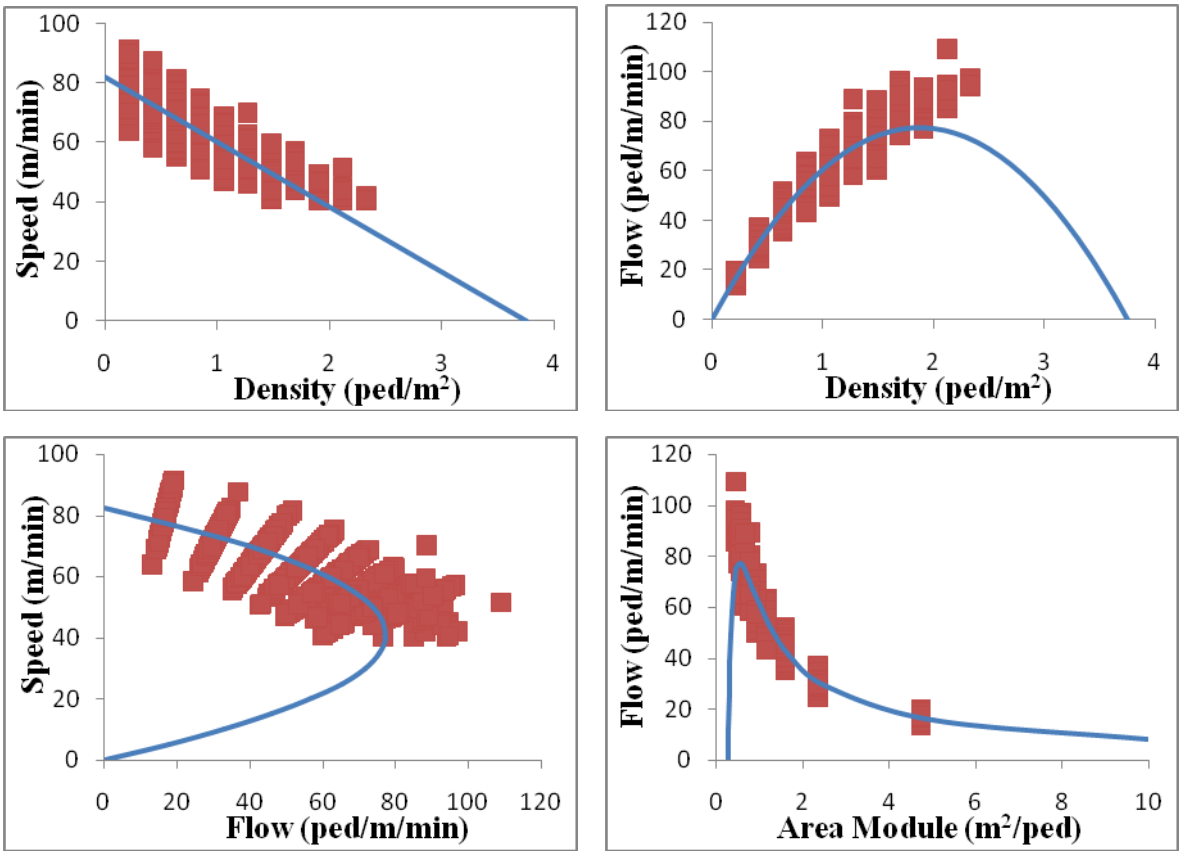

Figure 3: Pedestrian flow characteristics at Shaheb Bazar

The important flow characteristics and relationships obtained from the analysis of data are presented in Table 5. It is seen in Table 5 that the correlation coefficient R^2 varies between 0.54 and 0.97.

Table 5. Relationships Developed between Different Pedestrian Flow Characteristics for Walkways

Site ID	Location	Direction	Relationship	Model Equation	R^2 value
Ia	Rajshahi City Corporation (Walkway beside Rajshahi CityCorporation)	Mixed	Speed-density	$\mu = 85.26 - 27.81k$	0.76
			Flow-density	$q = 85.26k - 27.81k^2$	0.91
			Flow-speed	$q = \mu(85.26 - \mu)/27.81$	0.58
			Flow-space	$q = 85.26/M - 27.81/M^2$	0.85
IIa	Rajshahi University (Walkway inside Rajshahi University)	Mixed	Speed-density	$\mu = 83.17 - 25.48k$	0.63
			Flow-density	$q = 83.17k - 25.48k^2$	0.97
			Flow-speed	$q = \mu(83.17 - \mu)/25.48$	0.54
			Flow-space	$q = 83.17/M - 25.48/M^2$	0.76
IIIa	Shaheb Bazar (Walkway at the side of Shaheb Bazar)	Mixed	Speed-density	$\mu = 82.31 - 21.93k$	0.77
			Flow-density	$q = 82.31k - 21.93k^2$	0.92
			Flow-speed	$q = \mu(82.31 - \mu)/21.93$	0.62
			Flow-space	$q = 82.31/M - 21.93/M^2$	0.75

The free-flow pedestrian speeds are found to be more than 80 m/min at all of the three locations. These speeds are highest at Location Ia (85.26 m/min). This location has highest width of the carriageway (1.10 m) and the pedestrian face little frictions at this location. In case of Location IIa and IIIa, 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 IIIa as compared to the Location Ia and IIa. This has resulted in a reduction in speed at the location IIa (83.17 m/min) and IIIa (82.31 m/min) compared to Location Ia.

Table 6: Pedestrian Flow Characteristics at Different Study Locations of Walkways

Site 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
Ia	85.26	3.07	65	0.65	0.33
IIa	83.17	3.26	68	0.61	0.31
IIIa	82.31	3.75	77	0.56	0.27

It is seen in Table 6 that the maximum density was observed at Location **IIIa**, 3.75 ped/m^2 or 30 pedestrian in an area of 8 m^2. The minimum density was observed as 3.07 ped/m^2 at location **Ia** because of less frictions on roads and the high 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 77 ped./m/min or 4630 ped./h and 65 ped./m/min or 3900 ped./h. It is highest at location **IIIa** and lowest at location Ia. Flow rate is lowest at location **Ia** due to open area and pedestrian freedom to use the space. The minimum area module was observed between 0.27 to 0.33 m^2/ped. and the area module at maximum flow rate is found between 0.56 and 0.65 m^2/ped. The comparison of different flow characteristics is shown in Table 7.

Table 7: 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
Present Study	Rajshahi,Bangladesh	85.26	3.75	77

It is seen in Table 7 that the free-flow speed computed in this study are higher than those observed in Britain, United States and Singapore. The maximum density (3.75 ped./m^2) observed in this study is lower than the observed density in Britain, United States and Singapore. The maximum flow rate observed in this study (77 ped./m/min) is lower 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 Rajshahi metropolitan city. Significant variations of pedestrians mean walking speed with respect to age and gender were found. The results of the pedestrian of Rajshahi metropolitan city has a slower walking speed than the American and other Asian cities in walkways. 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 for walkways. 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 results of this paper will constitute an important contribution to an active field of research and 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 in Rajshahi and can be applied to other cities with similar pedestrian characteristics.

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