ANALYSIS OF EFFECTS OF NON-MOTORIZED VEHICLES ON URBAN ROAD TRAFFIC CHARACTERISTICS*

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1. Introduction

Non-motorized vehicles have played a major role in meeting the demand for door-to-door transport services in some south Asian developing countries. Popular non-motorized vehicles include Bangladesh's rickshaws and rickshaw-van, India's rickshaw-puller. These modes performed an important role in moving people and goods safely, efficiently and cheaply in the absence of so-called mass transport systems. Non-motorized vehicles account for 70 percent of vehicle trips in Dhaka metropolitan, more than anywhere else in the world. Moreover the rickshaws contributed around 30 percent of the total value-added by the transport sector. This is more than double the contribution of all motorized road transport.

In Highway Capacity Manual the impacts of bicycle presence on intersection capacity, roadway segments between intersections and the capacity of designated bicycle facilities are discussed[1]. However the proportion of bicycle is very small in most of the Asian countries except China. Further more in Highway Capacity Manual there is no provision to analyze the effects of non-motorized vehicles in heterogeneous (non-motorized vehicles and motorized vehicles on the same roadway) traffic flow on fundament traffic parameters. The flow of heterogeneous traffic on urban roads is highly complex and the existing analytical procedures cannot be used directly to predict the flow behaviors on urban road.

Due to the reasons as mentioned above and the lack of study on effects of non-motorized vehicles on traffic characteristics, the objectives of this study are to present analytical procedure of heterogeneous traffic flow and to develop models of passing/overtaking and lane-utilization for heterogeneous traffic flow. This paper examines macroscopic flow relationships of fundamental traffic parameters (speed-flow-density) for heterogeneous traffic flow based on cross-section basis. Furthermore passing/overtaking model for heterogeneous traffic flow will be developed.

2. Background

(1) Non-motorized vehicles

Studies related to traffic characteristics, non-motorized vehicles in particular, are few in number and are of very limited scope. Gupta[2] conducted a study in metropolitan Dhaka concerning rickshaw, rickshaw owners and impact of rickshaw in passenger transport. Gallagher[3] made a study on rickshaws of Bangladesh. In this study the authors investigated the uses and characteristics of rickshaws and its growth trend. The authors also studied the characteristics of rickshaw users and investigated involvement of rickshaw in traffic accidents. Government of Bangladesh[4] investigated the uses and physical characteristics of non-motorized transport as a component of the integrated transport study.

Most of the previous studies focused on the physical, economical and social aspects of the non-motorized transport. Very few of them, however, in a limited scope investigated the traffic performance of non-motorized vehicles. No study includes the effects of non-motorized vehicles on fundamental traffic flow characteristics.

(2) Fundamental traffic parameters

In the study of traffic flow, two approaches immediately come to mind, i.e. macroscopic and microscopic. The macroscopic approach considers the traffic stream as a whole and this is evident in the use of fluid flow and heat flow analogies to describe the behavior and conditions of the stream. The three fundamental parameters employed to describe macroscopic conditions are flow rate of volume (q), speed (u) and concentration or density (k). Greenshield[5] suggested a linear relationship between speed and density.

The microscopic approach considers the behavior of individual vehicles in the traffic stream. This approach is very popular especially in the development of models to explain the prevailing condition of traffic flow, when fundamental traffic parameters cannot clearly explained the conditions. In this study both macroscopic and microscopic approaches used to analyze the observed data.

3. Collection and Processing of Data

All data were collected from the midblock section located in Dhaka metropolitan of Bangladesh. Four sites are selected for this study, two sites for passing overtaking analysis (traffic is not separated by median) and two sites for lane utilization analysis (traffic is separated by median). The following criteria were used in the selection of study sites: high traffic volume,

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level terrain, higher proportion of non-motorized vehicles, no parking allowed and insignificant disturbance from bus stops, pavement of good condition.

Vehicle movements were recorded by using a portable digital video camera system for all the selected sites. All fields videotaping of traffic movements were conducted in December of 2002. Data were collected for a 20 meters segment. Upstream and downstream intersections were located 200 meters, 320 meters and 200meters, 210 meters for site 1 and site 2 respectively. Road width of site 1 and site 2 is 15 meters and 14 meters respectively excluding shoulders. There is no median or road marks to separate the traffic flow of two directions. Configurations of site 1 and site 2 shows in figure 1. Fields videotaping of traffic movements were conducted on only weekdays during morning peak periods. In all more than ten hours data were collected for this study.

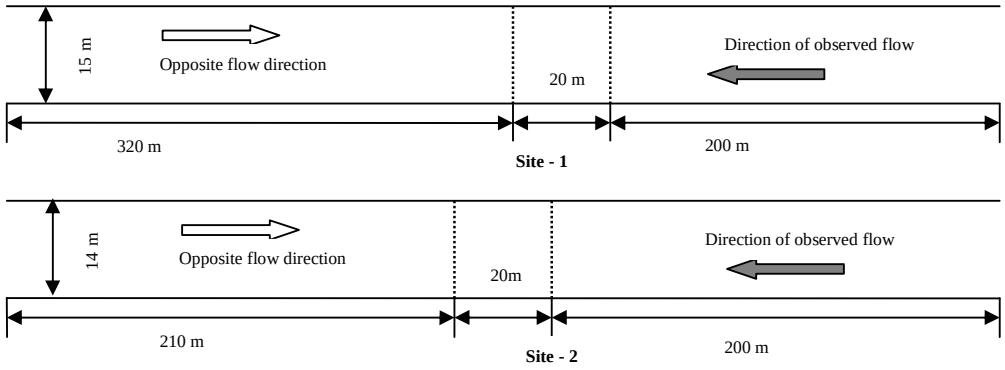

Figure 1: Configurations of Site 1 and Site 2

Data encoding was undertaken in the laboratory. Time code (TC) reader software was used to extract the raw data from video footage. Data were recorded in five minutes interval. Five minutes intervals for the data were decided according to the Highway capacity Manual (1994)[1].

4. General Traffic Characteristics

In order to have an overall view of the conditions along the two segments, it is necessary to present some general characteristics based on the three fundamental traffic parameters: flow (q), speed (u) and density (k). Assuming a linear speed-density relationship, the figure 2 and 3 shows the plots for flow-speed-density for the site 1 and site 2 respectively.

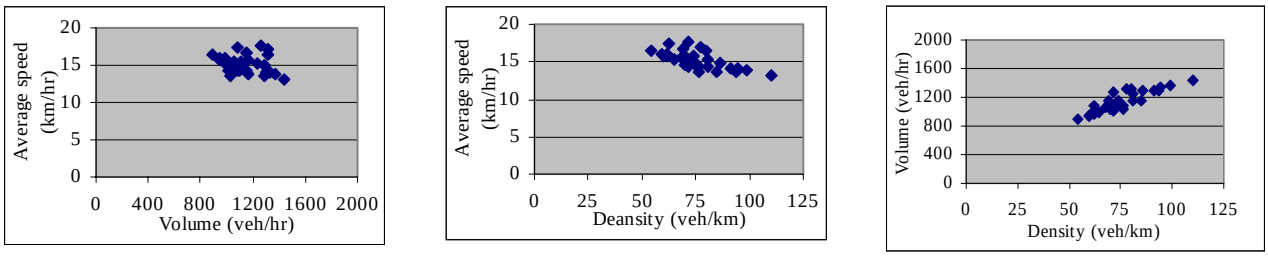

Figure 2: U-Q, U-K and Q-K scatter plots for site1 (81% non-motorized vehicles)

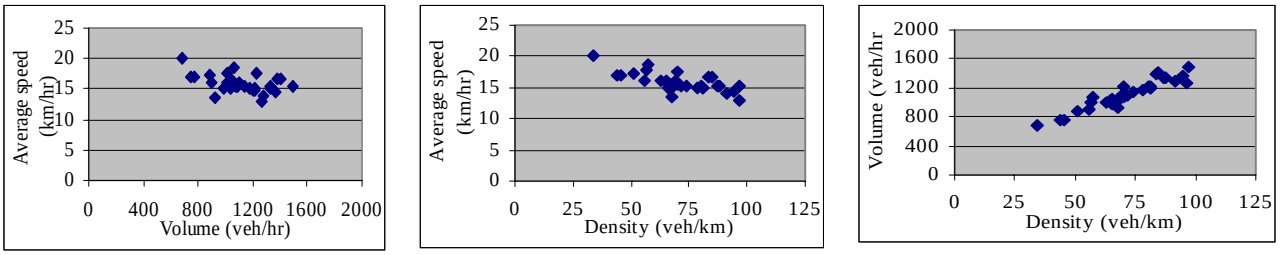

Figure 3: U-Q, U-K and Q-K scatter plots for site2 (75% non-motorized vehicles)

Figure 2, 3 demonstrate that traffic conditions are in the uncongested region along both site 1 and site 2. The significance of this is that uncongested conditions allow us to make the assumption that other elements affecting traffic flow during congested periods would have minimal impact. While upstream and downstream conditions (presence of intersections) as well as the factors within the segments (adjacent land use), opposite directional flow may affect flow along mid block section. Upstream and downstream intersections operated manually and cycle time varied depending on the demand of queued vehicles, which might be affects the flow of observed mid block sections.

The traffic composition may be easily determined from the classified volume counts along the two sites. For the purposes of this study, the counts were classified into six vehicle types: rickshaws, other non-motorized vehicles (NMV), small size

motorized vehicles (SSMV), passenger cars (PC), bus/truck and other motorized vehicles (MV). In other NMV group bicycle and rickshaw-van included while in other MV group motor-cycle, jeep, utility vehicles included. Figure 4 and 5 shows the average traffic composition along the two selected sites. As shown in figure 4 and 5 two sites have a similar traffic composition. Non-motorized vehicles comprise more than 80% of the total traffic and small size motorized vehicles and passenger car count the second highest proportion. So it is clear that these two sites are predominant by non-motorized vehicles and analytical approach should be different from that of homogeneous traffic flow.

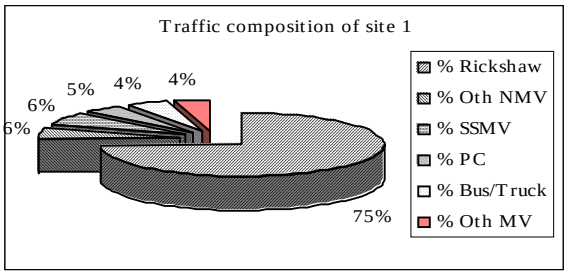

Figure 4: Average traffic composition of site 1

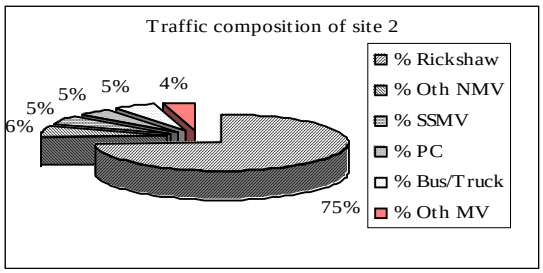

Figure 5: Average traffic composition of site 2

5. Macroscopic Flow Relationships

Effect of non-motorized vehicles on the basic traffic flow relationships is an important factor in capacity analysis procedures of heterogeneous traffic flow. Several empirical studies on speed-flow-density relationships had been completed by many researches directed toward only motorized vehicles. But almost none of the literature considered the effect of non-motorized vehicles (rickshaws and rickshaw-van) on these basic flow relationships. To analyze the effects of non-motorized vehicles on fundamental traffic parameters data are separated into various group based on proportion of non-motorized vehicles. Each group included ± 5% non-motorized vehicle class. Figure 6 shows the flow-speed-density relationships for various proportions of non-motorized vehicles for site 1 and site 2.

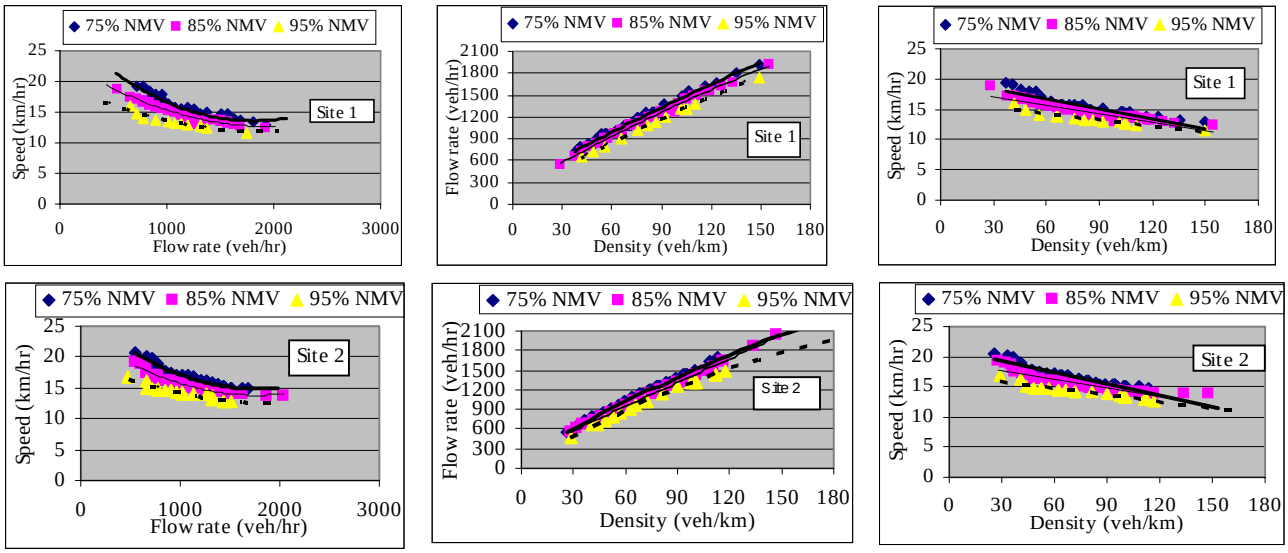

Figure 6: Effects of non-motorized vehicles on fundamental traffic parameters

The speed-flow relationship shows decreases in flow rate at particular speed with increase in the proportion of non-motorized vehicles. The speed-density relationship is also similar to the speed-flow relationship. The flow-density relationship shows decreases in density at particular flow rate with increase in the percentage of non-motorized vehicles. Combining all the flow relationships it can be concluded that the non-motorized vehicles have adverse effects in the flow relationships and this effects increase with increase in proportion of non-motorized vehicles. Non-motorized vehicles are driven by human power and have operating capabilities that are inferior to those of motorized vehicles. The effects is similar incase of site 1 and site 2. This seems to us occur due to similar traffic composition and geometric characteristics of site 1 and site 2. The effect of non-motorized vehicles might be different for different geometric conditions, so further study will required.

6. Identifying Patterns of Passing / Overtaking

In this study Passing / Overtaking is defined as the number of passing and overtaking of any vehicle by other vehicle within the observed roadway sections (20 meter) and expressed in no/hr/20m. Three type of passing or overtaking observed in the mixed traffic flow as follows:

MV – NMV: a motorized vehicle passed or overtakes a non-motorized vehicles
NMV – NMV: a non-motorized vehicle passed another non-motorized vehicle
MV – MV: a motorized vehicle passed or overtakes another motorized vehicle

Passing/overtaking phenomenon influenced by upstream and downstream intersection operation. Upstream intersection has a positive effect on the other hand downstream intersections have a negative impact on the passing/overtaking performance. Figure 7 and 8 show the distribution of passing / overtaking for site1 and site 2 respectively. As shown in figure 7 and 8 similar patterns of passing/overtaking observed for both site 1 and site 2. This is easily understandable as traffic compositions of both sites are quite similar. Maximum passing/overtaking resulted for MV-NMV group. This seems to us occur due to big speed difference between motorized vehicles and non-motorized vehicles. Lower passing/overtaking resulted for MV-MV group as speed difference within the motorized vehicles is small.

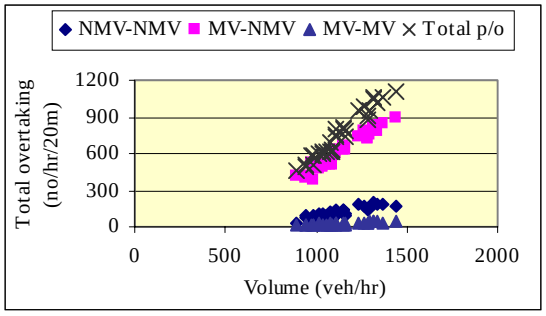

Figure 7:Distribution of passing/overtaking for site 1

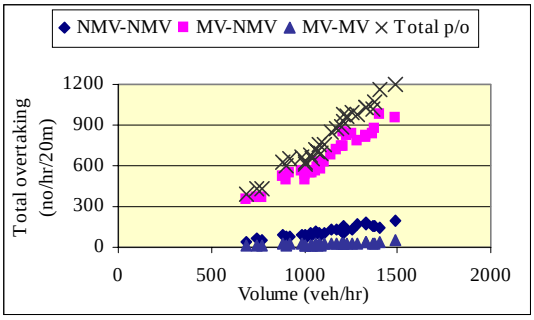

Figure 8:Distribution of passing/overtaking for site 2

To visualize the influence of various traffic parameters on passing/overtaking, it is necessary to identify the inherent patterns in passing/overtaking as functions of the several state variables. The relationships between passing/overtaking and others variables are shown in figure 9 and 10. Passing/overtaking phenomenon should be used as LOS measure for heterogeneous traffic flow as it shows a good correlation with flow rate.

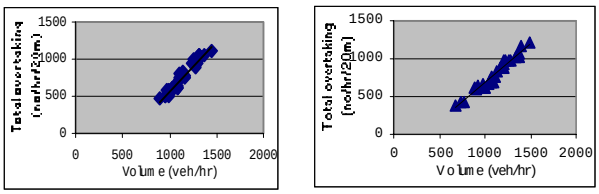

Figure 9: Passing/overtaking and total volume for site 1 and site 2

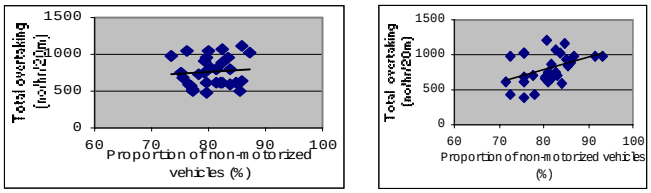

Figure 10: Passing/overtaking and proportion of non-motorized vehicles for site 1 and site 2

7. Conclusions

This paper examines the effects of non-motorized vehicles on the fundamental traffic parameters. The results of macroscopic flow relationships show that non-motorized vehicles have adverse effect on fundamental traffic parameter relationships. The general tendency is for passing/overtaking values to increases as the total traffic flow increases. At higher traffic volume more vehicles are involved which resulted more passing and overtaking. Opposite flow rate influences the passing/overtaking, when flow rate of opposite direction increases number of passing/overtaking decreases. The straight line relationship observed between passing/overtaking and total volume due to data range covered the uncongested flow region. There is no clear pattern for passing/overtaking and proportion of non-motorized vehicles.

8. Further Research

Passing /overtaking models will be developed using traffic parameters such as total traffic volume, total traffic density, the proportion of non-motorized vehicles and the average speed. Lane utilization patterns in mixed traffic flow will be observed to develop lane utilization models for site 3 and site 4.

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