

## MEASURING PASSENGER CAR EQUIVALENTS FOR NON-MOTORIZED VEHICLE (RICKSHAWS) AT MID-BLOCK SECTIONS

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**Abstract:** The effects of non-motorized vehicles (Rickshaws) are different at signalized intersections and mid-block sections. So, different approach should be used to estimate passenger car equivalents of rickshaws at mid-block sections. This study introduces a method for estimating passenger car equivalents (PCE) for non-motorized vehicle (Rickshaws) at mid-block sections of urban arterials based on speed reduction of passenger cars in the mixed flow due to the presence of non-motorized vehicles. In this study PCE value for rickshaws are estimated as a unit value plus the ratio of the speed difference of passenger cars in basic flow and mixed flow to the speed of passenger cars in the basic flow. Principal Component Analysis was performed to establish the relationships between PCE values and proportion of non-motorized vehicles and flow level. Average speed of passenger cars in basic flow and mixed flow are calculated from the observed data collected from two mid-block sections of Dhaka metropolis, Bangladesh. It was suggested by the study results that presence of rickshaws had a significant impact on the average speed of passenger cars in the mixed flow.

**Key Words:** Passenger car equivalents (PCE), principal component analysis, mid-block sections, capacity reduction factor, speed difference

### 1. INTRODUCTION

The term passenger car equivalent (PCE) was introduced in the 1965 Highway Capacity Manual. Since 1965, considerable research effort has been directed toward the estimation of PCE value for various roadway types. However, at present, there is neither a commonly accepted nor clearly defined theoretical basis for the concept of passenger car equivalent. There have been many researchers to estimate PCE at mid-block sections based on microscopic as well as macroscopic approach, giving different numerical results. Importance of these result lies on the purpose of application and the way PCE value is used. PCE values are employed as a device to convert a traffic stream composed of a mix vehicle types into an equivalent traffic stream composed exclusively of passenger cars or basic vehicles. The availability of such values permits the specification of capacity in terms of PCEs exclusively and provides the basis for development of procedures to express any traffic-stream composition in terms of PCEs. Two basic principles should be applied to estimate of PCE values for any of the roadway type identified in capacity analysis procedures. The first principle links the concept passenger car equivalency to the level of service (LOS) concept. The second principle emphasizes the consideration of all factors that contribute to the overall effect of concern vehicle (other than passenger cars) on traffic stream performance.

## 2. PCE MEASURING METHODS AT MID-BLOCK SECTIONS

The Highway Capacity Manual (1965) used Walker Method to estimate PCE values, which compares the relative number of passing of trucks by passenger cars in relation to number of passing of passenger car by passenger cars. On the other hand, Craus et.al (1980) in their equivalent delay method considered the difference between delay caused by heavy vehicle to standard passenger cars and delay caused by slower passenger car to standard passenger cars. Cunagin and Messer (1983) applied Walker method for lower volume level and equivalent delay method for higher volume level.

Huber (1982) proposed a model for estimating PCE-values for vehicles under free-flowing, multilane conditions. Some measure of impedance as a function of traffic flow is used to relate two traffic streams-one that has trucks mixes with passenger cars and the other that has passenger car only. PCE-values are related to the ratio between the volumes of two streams at some common level of impedance. A deterministic model of traffic flow (Greenshield) is used to estimate the impedance-flow relationship. Three measures of impedance were considered by the author, each of which will generate a separate PCE-value for a truck of given characteristics. The author also suggested that PCE-values are related to speed and length of subject vehicles and to vary with the proportion of trucks in the traffic stream.

The 1985 HCM, revised Chapter 7 (1992) on Multilane Rural and Suburban Highways, considered density to be the governing parameter for LOS, although it is defined both by density and speed. It explains, density is a measure that quantifies the proximity of vehicles to each other within the traffic stream and indicates the degree of maneuverability within the traffic stream. For these reasons Mcshane and Roess (1990) stated that equal density approach will be more appropriate since density is the primary parameter for LOS. Density could be an indication of degree of maneuverability if we consider a single flow relationship. In other words, various points in same flow relationship at different density will give different degree of maneuverability without any doubt. But, this may not necessarily be true that same density in two different flow relationships (basic and mixed) will still produce the same degree of maneuverability. If the degree of maneuverability in basic stream and in mixed stream (with heavy vehicle) is considered equal at equal density, it means that the maneuvering situation for a heavy vehicle and for a passenger car is the same.

Linzer et. al. (1979) estimated PCE based on Midwest Research Institute (MRI) simulation model. Truck equivalents were based on keeping effective value of volume/capacity constant for given LOS. PCE values in Circular 212 were also based on MRI studies. Roess and Messer (1984) revised Circular 212 values by using performance curves of speed on extended upgrades. However, the PCE values were based on simulation results on trucks with certain assumed weight-to-horsepower ratio. It had been of many debate on what should be the most representative weight-to-horsepower ratio, because, results of different studies varied considerably and produced different curves. An overall review of the previous studies suggested that most of the studies dealing with heavy vehicles i.e. motorized vehicles. No study considers the effect of non-motorized vehicles (rickshaws) to estimate PCE-values at mid-block sections, although non-motorized vehicles played an important role in transportation sector of south Asian countries and they are very popular and common mode in these countries. The objectives of this study to estimate the effect of rickshaws on average speed of passenger cars in mixed flow condition and develop PCE values of rickshaws based on speed difference of passenger cars in mixed flow and basic flow.

### 3. STUDY DATA

All data were collected from two mid-block sections located in Dhaka metropolis of Bangladesh, December 2000. Two locations were identically and there was no obvious deficiency of roadway or traffic condition that would affect the PCE value.

Several criteria were used in the selection of study locations. The selection criteria were as follows: high traffic volume, higher proportion of non-motorized vehicles, pavements of good conditions, level terrain, no parking allowed and insignificant disturbances from bus stops. In Dhaka metropolitan it is very difficult to identify the locations which satisfy all the mentioned criteria. However two locations were found which nearly satisfy the desired selection criteria.

Vehicle movements were recorded by using a portable video camera system. Data were collected for a 20 meter road segments. 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. Configuration of site 1 and site 2 shows in figure 1.

Field data were collected during morning peak period and in all more than twelve hours data were collected for the study. Data encoding was undertaken in the laboratory. Footage was played using available video equipment and data was extracted with the aid of computer programs that facilitates the process of encoding. Time code (TC) reader software was used to estimate speed of individual vehicles. Clocks from the video equipment and the computer were synchronized and data was recorded in one-minute intervals. One-minute intervals allowed a more detailed look into the arrival patterns of the vehicles as well as the possible fluctuations in the flow of traffic. The raw data used in analyses were speed, and traffic compositions. Other types of slow vehicle (Bus, Truck) in the downstream of traffic have significant effect on the data collection and study objectives. But the proportion of bus and truck in the selected sites are very low (4 to 5%), so in our analysis we assume that there are no effects of these types of vehicles.

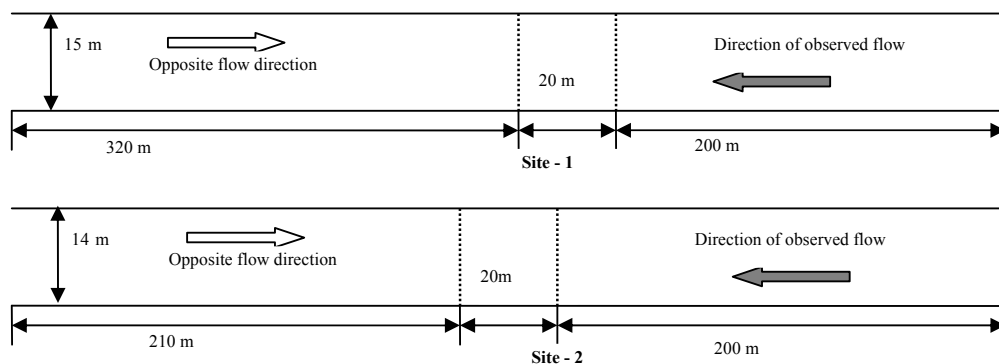


Figure 1: Configurations of Site 1 and Site 2

### 4. EFFECTS OF RICKSHAWS ON SPEED

Effects of non-motorized vehicles are different at signalized intersection and mid-block sections. So, different approach should be used to estimate PCE of non-motorized vehicles

at mid-block section. From the observed data it was evidenced that presence of rickshaws (non-motorized vehicles) affects the speed of passenger cars tremendously at mid-block section. Figure 2 presented the effect of rickshaws on speed of passenger cars. Average speeds of passenger cars in the basic flow were estimated as 51.35 km/hr. As shown in the figure 1 average speed of passenger car decreases as proportion of rickshaws increases.

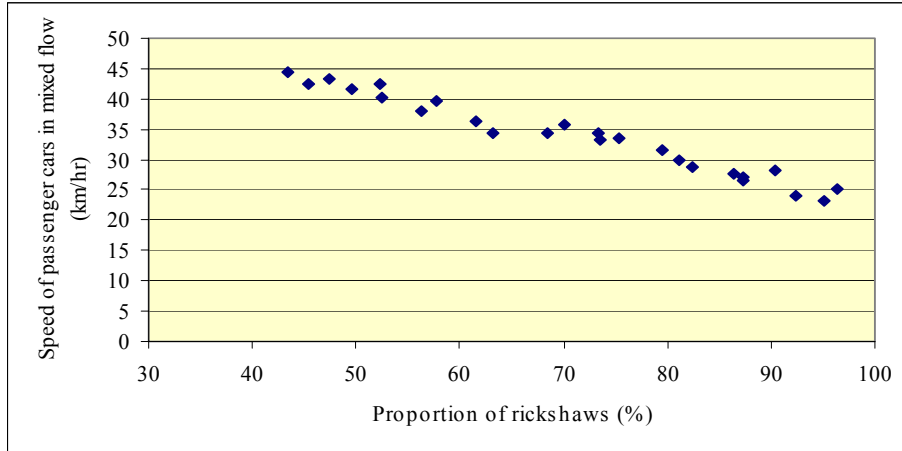


Figure 2. Effects of rickshaws on speed of passenger cars in mixed flow

### 5. PCE ESTIMATION METHOD BASED ON SPEED REDUCTION

Passenger car equivalent of non-motorized vehicles at mid-block section along urban arterial is estimated based on the speed difference of mixed flow and basic flow of passenger cars. PCE value for non-motorized vehicles are estimated as a unit value plus the ratio of the speed reduced due to the presence of non-motorized vehicles in the mixed flow to the speed of basic flow.

$$PCE_{nmv} = 1 + \frac{S_b - S_m}{S_b} \tag{1}$$

Where:

$PCE_{nmv}$  = Passenger car equivalents of non-motorized vehicles

$S_b$  = Average speed of passenger car in the basic flow (km/hr)

$S_m$  = Average speed of passenger car in the mixed flow (km/hr)

For basic flow average speed of passenger car is estimated from one minute interval data which contained only passenger cars. For mixed flow average speed of passenger car for various proportion of rickshaws were also estimated from one minute interval data which contained passenger cars and rickshaws. PCE values for various proportions of rickshaws at different flow rate are estimated using equation (1).

Figure 3 and Figure 4 represents the relationship between PCE value of rickshaws and flow rate and PCE value and proportion of rickshaws respectively. It was revealed from the relationship that PCE value of rickshaws increases with the increases of flow rate and proportion of rickshaws. This seems to occur due to at higher proportion of rickshaws and at higher volume rate the speed of passenger car reduced which increases the speed difference and also PCE values.

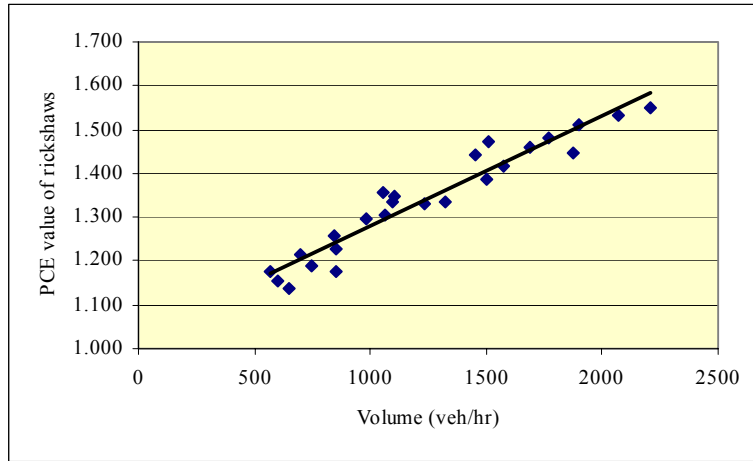


Figure 3. Relationship between PCE value of rickshaws and flow rate

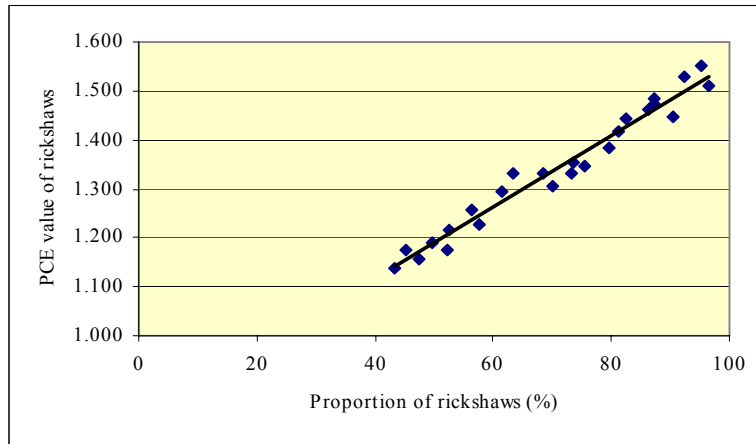


Figure 4. Relationship between PCE value and proportion of rickshaws

## 6. ESTIMATED PCE VALUE OF RICKSHAWS

As PCE value of rickshaws were estimated for various proportion of rickshaws at different flow rate, so it is necessary to establish the relationship between PCE value with flow rate and proportion of rickshaws. It was evidenced from Table 1; there is a strong relationship between independent variables volume and %NMV. If we want to express the dependent variable PCE in terms of independent variables volume and %NMV, Principal Component Analysis (PCA) has to be done.

Table 1. Co-relation matrix of variables

	PCE	Volume	%NMV
PCE	1		
Volume	0.9621	1	
%NMV	0.983625	<b>0.9608</b>	1

Table 2. Results of principal component analysis

Principal Component			Standardized Principal Component		
Component			Component		
Variables	1	2	Variables	1	2
Volume	0.7071068	- 0.7071068	Volume	0.5049732	- 3.5714173
% NMV	0.7071068	0.7071068	% NMV	0.5049732	3.5714173
Variance	1.9607997	0.0392003	Variance	1.9607997	0.0392003
% Variance	98.039986	1.9600123	% Variance	98.039986	1.9600123
Cum %	98.039986	100	Cum %	98.039986	100
p-values	0	1	p-values	0	1

$$\text{Principal component Z1} = 0.7071068 * \text{Vol} + 0.7071068 * \% \text{NMV} \quad (2)$$

Principal components are estimated using equation (2), and regression analysis was performed to establish the relationship between PCE value and principal components (Z1) as follows;

$$\text{PCE} = 1.020215 + 0.000243 * \text{Z1} \quad (3)$$

After transferring the principal component into original independent variables we obtained the following relationships;

$$\text{PCE}_{\text{nmv}} = 1.020215 + 0.00243 * \text{Vol} + 0.00243 * \% \text{NMV} \quad (\mathbf{R^2=0.93}) \quad (4)$$

Where:

Vol = Total volume of mixed flow (veh/hr)

% NMV = Proportion of rickshaws (%)

Table 3 Suggested PCE values for rickshaws

Percent NMV (%)	Traffic volume (veh/hr)							
	600	800	1000	1300	1500	1800	2000	2300
40	1.176	1.224	1.273	1.346	1.394	1.467	1.516	1.589
45	1.177	1.226	1.274	1.347	1.396	1.468	1.517	1.590
50	1.178	1.227	1.275	1.348	1.397	1.470	1.518	1.591
55	1.179	1.228	1.277	1.349	1.398	1.471	1.519	1.592
60	1.180	1.229	1.278	1.351	1.399	1.472	1.521	1.594
65	1.181	1.230	1.279	1.352	1.400	1.473	1.522	1.595
70	1.183	1.232	1.280	1.353	1.402	1.475	1.523	1.596
75	1.184	1.233	1.281	1.354	1.403	1.476	1.524	1.597
80	1.185	1.234	1.283	1.356	1.404	1.477	1.526	1.599
85	1.187	1.235	1.284	1.357	1.405	1.478	1.527	1.600
90	1.188	1.236	1.285	1.358	1.407	1.479	1.528	1.601
95	1.189	1.238	1.286	1.360	1.408	1.481	1.529	1.602

Considering the  $R^2$  and t-values, regression model provide very good predictions. Table 3 lists  $PCE_{nmv}$  values computed from the above model for selected traffic conditions. When traffic volume is in a range of 600 vph to 2300 vph and percentage of rickshaws is in a range of 40 to 95, the PCE values are 1.176 to 1.602 respectively.

In case of one lane the presence of rickshaws have more impact on the speed of passenger car as compared to many lanes. But in this paper we can not strongly concluded this as we are collected data only for two lanes (one direction). So a further comprehensive study is required to establish this conclusion.

### 7. CAPACITY REDUCTION FACTORS

Capacity reduction factor is an important parameter for the capacity analysis. Capacity reduction factor was estimated according to the Highway Capacity Manual as follows;

$$PCE = \left( \frac{100}{f_{nmv} * P_{nmv}} - \frac{100}{P_{nmv}} \right) + 1 \tag{5}$$

Using equation (5) and estimated PCE value of rickshaws of table 3, capacity reduction factor for various traffic conditions are developed and given in Figure 5. As shown in figure 5; capacity of mixed traffic flow reduced as volume of mixed traffic increases and also proportion of non-motorized vehicles increased. Maximum capacity reduction occurred at higher flow rate with higher proportion of rickshaws. The given value of capacity reduction factor could be used for two-way arterial in which traffic is separated without any median or road mark. The given value is applicable for a traffic flow rate ranges from 600 vph to 2300 vph with proportion of rickshaws about 40% to 95%.

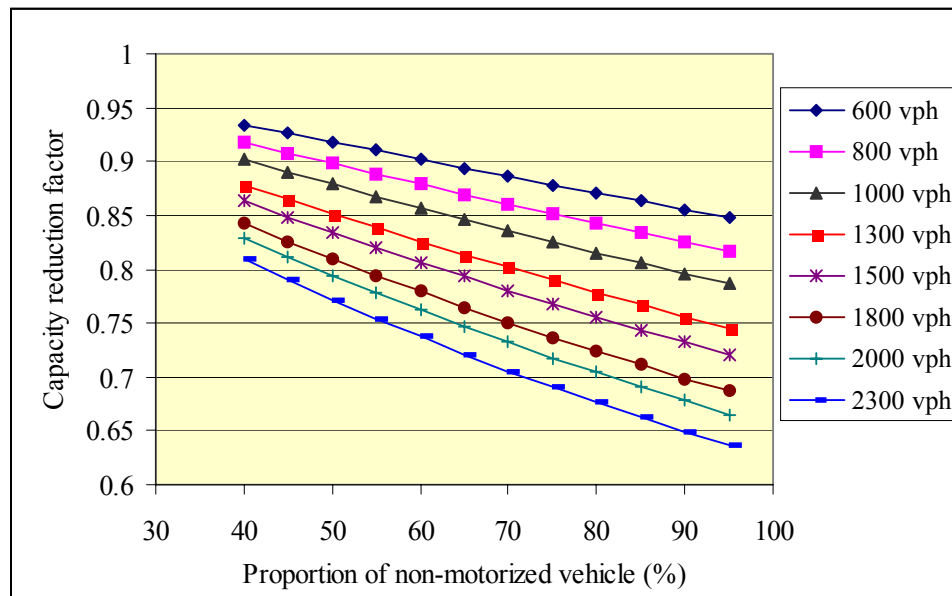


Figure 5. Capacity reduction factors of Rickshaws at different traffic conditions

## 8. CONCLUSIONS

This study introduces a method for estimating passenger car equivalents (PCE) for non-motorized vehicle (Rickshaws) at mid-block sections of urban arterials based on speed reduction of passenger cars in the mixed flow due to the presence of non-motorized vehicles. Based on the results of this study the following can be concluded;

Average speeds of passenger cars in the basic flow were estimated as 51.35 km/hr. The average speed of passenger car decreases as proportion of rickshaws increases in the mixed stream. PCE value of rickshaws increases with the increases of flow rate and proportion of rickshaws. There is a linear relationship between PCE value and proportion of rickshaws. Maximum capacity reduction occurred at higher flow rate with higher proportion of rickshaws.

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