ESTIMATION OF PASSENGER CAR EQUIVALENTS FOR EASY BIKE AT MID BLOCK IN KHULNA METROPOLITAN CITY

Ankan Mohajan*[1] and Quazi Sazzad Hossain[2]

[1] *Student, Khulna University of Engineering & Technology, Bangladesh, ankan.mohajan2580@gmail.com*
[2] *Professor, Khulna University of Engineering & Technology, Bangladesh, sazzad1999@yahoo.com*

ABSTRACT

In developing countries like Bangladesh, the road traffic is heterogeneous in nature, consisting of vehicles of wide ranging physical dimensions, weight and power sharing the same lane. With the advancement of technology many alternative modes are now plying on the roads of urban areas in Bangladesh. Small size vehicles (i.e. easy bike) are popular para-transit modes that provided door-to-door service in congested parts of Khulna metropolitan area. The effects of small size vehicles (Easy Bike) are different at signalized intersections and mid-block sections. Therefore, an issue comes up to determine the passenger car equivalent (PCE) of easy bike at mid block for the Khulna Metropolitan City in Bangladesh. This study introduces a method for estimating passenger car equivalents (PCE) for Easy Bike at mid-block sections of urban areas based on speed reduction of passenger cars in the mixed flow due to the presence of easy bike. In this study PCE values for easy bike 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. Regression Analysis was performed to establish the relationships between PCE values and proportion of easy bike (%) and total volume of mixed flow (veh/hr). It is suggested by the study results that presence of easy bike had a significant impact on the average speed of passenger cars in the mixed flow.

Keywords: *Passenger Car Equivalents, basic flow, mixed flow, regression*

1. INTRODUCTION

A traffic stream generally composed of high presence of heavy and slow moving vehicles. In Bangladesh the road networks, local constraints and travel characteristics are very different than those of developed countries (Saha *et al*., 2009). Easy Bike is an informal transport mode in Khulna city. Public transport means that transport mode which is used for general public purpose. In developing countries, people generally consider bus, train, van, rickshaw, baby-taxi, easy Bike etc. as are our public transport mode. Among them easy Bike is a distinct identity of public transport in all divisional cities including Khulna. It is being extensively used for short distance travel, providing cheap alternative to rickshaw and other modes of public transport like bus, van and auto-rickshaw. In the year 2004, Mr. Khan the owner of Ma Enterprise is the introducer of electric vehicle in Bangladesh. Mr. Khan first imported four numbers of rechargeable battery operated auto-rickshaw along with other items from China. As commercial basis for the first time he launched this auto-rickshaw at his home town Comilla in the year 2005. Later, in the year of 2006 many importers imported this type of vehicles. In the year 2007 the battery operated auto-rickshaw started its main journey to many cities of Bangladesh (BPDB, 2012-13). Within a short time it has been well accepted as a cheap, comfortable and environment friendly transport mode. An estimated one million Battery Bikes are plying all over Bangladesh (Dhaka Tribune, 2014).

In Bangladesh, vehicle types are divided into several categories. Thus mixed traffic composition encountered in Bangladesh. Therefore, conversion of heterogeneous traffic into a stream of homogeneous one by using appropriate Passenger Car Equivalency (PCE) values is an elementary step for analyzing mixed traffic, and formulating traffic management measures for mitigation of congestion on urban roads (Basu *et al.,* 2006). Besides this, appropriate PCE values are also used for capacity analysis as well as traffic engineering research and applications (Parvathy *et al,* 2013). Passenger car equivalent is not only important for capacity reasons, but also as an input in highway cost allocation studies.

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. PCE is defined as "the number of passenger cars that are displaced by a single heavy vehicle of a particular type under prevailing roadway, traffic and control conditions" (TRB, 2000). For example, typical values of PCE (or PCU) are given below.

Table 1: Typical value of PCE (Ministry of Communications of Bangladesh, 2001)

Types of vehicle	PCE
Passenger cars	1.00
Pedal cycle	0.50
Buses	3.00
Motorcycle	0.75
Trucks	3.00
Rickshaw	2.00

But presently there is no widely acceptable guide line for traffic engineers of Bangladesh to estimate the PCE values of easy bike. The main theme of this study is to estimate the passenger car equivalents of easy bike and the effect of easy bike on the average speed of passenger car in mixed flow condition. Easy-bike is the most common public transport mode with high potential future growth opportunities for Khulna city. . The total number of Battery-bike or easy bike in Khulna city is not counted or registered by any authority but the approximate number 17000 is assumed by both BRTA and the Easy-bike union of Khulna. An estimated 17,000 Easy Bikes ply informally in Khulna city.

2. METHODOLOGY

In order to achieve the objective of this study, the overall methodology being used in this study are literature review, site survey, data collection, data analysis by using SPSS software and derivation of PCE value of easy bike. The purpose of site survey is to identify potential mid block section which is suitable for field data collection. The locations of the mid block section were in the central business district (CBD) areas. All data were collected from two mid-block sections located Khulna Metropolis of Bangladesh, June to July 2015.

2.1 Site survey and data collection

Two locations were identically selected 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 high traffic volume, higher proportion of easy bike, pavements of good condition, level terrain, no parking allowed and insignificant disturbance from bus stop. In this study, data were collected for easy bike at mid-block sections in Khulna Metropolitan city. Vehicle movements or data were recorded by using a portable videotape recording camera system. Before the start of data collection, the type of vehicles was divided into few categories that is cars, easy bike, CNG, baby taxi, buses, pickup, minibus, motorcycle etc. Before the collection of vehicle data, basic information such as date of observation, location, junction condition and other relevant information were recorded first with a portable video camera. Data were collected for 15.5 meter road segments for site 1 (mixed flow) and 13.2 meter for site 2 (basic flow). Road width of site 1 and site 2 is 7 meter and 10 meter, respectively excluding shoulders. There is no median and road mark to separate the traffic flow of two directions. Field data were collected during morning peak period and evening peak period for a period of twenty hours. After the completion of twenty hour video of the road, the numbers of vehicles passing were counted for the estimation of total volume per hour. The raw data used in the analysis were speed, and traffic compositions. Other types of slow moving 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 were very low. So in the analysis it was assumed that there are no effects of these types of vehicles. Then the speeds of the passenger cars were estimated. The observations were made over a period of fifteen days of June to July, 2015. The observations were made under dry weather conditions and during morning and evening peak hours.

2.2 Derivation of PCE values of easy bike

Passenger car equivalent of easy bike 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 easy bike are estimated as a unit value plus the ratio of the speed reduced due to the presence of easy bike in the mixed flow to the speed of basic flow (Rahman and Nakamura, 2005).

$$PCE = 1 + \frac{S_b - S_m}{S_b}$$

Where,
PCE = Passenger car equivalents of easy bike;

S_b= Average speed of passenger car in the basic flow (km/hr); and
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 easy bike were also estimated from one minute interval data which contained passenger cars and easy bike. PCE values for various proportions of easy bike at different flow rate are estimated by using the above equation.

Average speed of the passenger car in the basic flow and average speed of the passenger car in the mixed flow can be estimated from the following $S=Vt$ formula. Where, S= distance passed by passenger car, V= average speed of passenger car, t = time required to pass the distance S.

The time required to passing the distance S can be estimated by the stopwatch and the distance passed by passenger car can be measured by tape. By this process average speed of the passenger car in the mixed flow and average speed of the passenger car in the basic flow can be measured.

3. RESULTS AND DISCUSSIONS

In statistics, regression analysis is a statistical process for estimating the relationships among variables. It includes many techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables (or 'predictors'). More specifically, regression analysis helps one understand how the typical value of the dependent variable (or 'criterion variable') changes when any one of the independent variables is varied, while the other independent variables are held fixed. Most commonly, regression analysis estimates the conditional expectation of the dependent variable given the independent variables – that is, the average value of the dependent variable when the independent variables are fixed. Less commonly, the focus is on a quintile, or other location parameter of the conditional distribution of the dependent variable given the independent variables. In all cases, the estimation target is a function of the independent variables called the regression function. In regression analysis, it is also of interest to characterize the variation of the dependent variable around the regression function which can be described by a probability distribution (Armstrong, 2012).

Regression analysis is widely used for prediction and forecasting, where its use has substantial overlap with the field of machine learning. Regression analysis is also used to understand which among the independent variables are related to the dependent variable, and to explore the forms of these relationships. In restricted circumstances, regression analysis can be used to infer causal relationships between the independent and dependent variables. However this can lead to illusions or false relationships, so caution is advisable; for example, correlation does not imply causation (Lindley, 1987).

Linear regression was the first type of regression analysis to be studied rigorously, and to be used extensively in practical applications. This is because models which depend linearly on their unknown parameters are easier to fit than models which are non-linearly related to their parameters and because the statistical properties of the resulting estimators are easier to determine (Yan, 2009).

3.1 Derivation of PCE values by regression analysis

Linear regression analysis was used to determine the PCE values. The data used in this analysis to derive PCE values are presented in Appendix. The variables used in this study are PCE value per hour, volume of mixed flow and percentage of easy bike. The regression analysis is conducted by using the SPSS software.

The software name originally stood for Statistical Package for the Social Sciences (SPSS). SPSS is a widely used program for statistical analysis in social science. It is also used by market researchers, health researchers, survey companies, government, education researchers, marketing organizations, data miners, and others.

As PCE value of easy bike were estimated for various proportion of easy bike at different flow rate, so it is necessary to establish the relationship between PCE value with flow rate and proportion of easy bike. It was evidenced from Table 4.1 that there is a good relationship between independent variables volume and proportion of Easy Bike (% EB).

Table 3.1: Co-relation of variables

	PCE	Vol	%EB
PC	1	0.67812992	0.5272832
Vol		1	0.0299352
%EB			1

The values of R^2 and adjusted R^2 obtained from regression analysis are as shown in Table 3.2. The values of R^2 and adjusted R^2 of 0.717 and 0.684, respectively indicates that the model predicts well.

Table 3.2: Model Summary

Model	R	R Square	Adjusted R Square	Standard Error Of The Estimate
1	0.846831	0.717123	0.684	0.02596

Table 3.3: ANOVA

Model	Sum of squares	d.f.	Mean square	F	Sig.
Regression	0.029043701	2	0.014522	21.55	0.0000218
Residual	0.011456621	17	0.000674		
Total	0.040500321	19			

Based on Table 3.3, the value of observed significance level for the F-statistics is less than 0.05 indicating that the simultaneous of each coefficient of zero is rejected. The estimation results obtained from the linear regression analysis are as shown in Table 3.4. Based on Table 3.4, all of the t-values are well above 2. This shows that all of the independent variables meet the guidelines.

Table 3.4: Estimation of co-efficients by regression analysis

Model	Unstandardized co-efficients		standardized co-efficients	t	Sig.
	B	Std.Error	Beta		
Constant	0.5810062	0.08515005		6.823321	0.0000029
Vol.	0.0001031	0.00002007	0.662939674	5.136943	0.0000824
%EB	0.0065691	0.0016707	0.507437952	3.932001	0.0010744

Hence, upon obtaining the coefficients in Table 3.4, the following equation (3.1) can be obtained;

$$PCE = 0.581 + 0.0001031 * Vol + 0.00657 * \%EB \quad (3.1)$$

Where,
Vol =Total volume of mixed flow (Veh/hr)
$\%\ EB$ = Proportion of Easy bike (%)

For various proportion of easy bike (40-95%) and various proportion of total volume, the PCE value for easy bike are given in Table 3.5

In this study considering the R^2 and t values, regression model provide very good predictions. Table 3.5 lists PCE 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 easy bike is in a range of 40 to 95 percent, the PCE values are 0.6457 to 0.8248, respectively.

Table 3.5: Suggested PCE values for easy bike

Easy Bike	Traffic volume (veh/hr)								
(%)	600	800	1000	1200	1400	1600	1800	2000	2300
40	0.6457	0.6663	0.6869	0.7075	0.7282	0.7488	0.7694	0.7900	0.8210
45	0.6460	0.6666	0.6873	0.7079	0.7285	0.7491	0.7698	0.7904	0.8213
50	0.6464	0.6670	0.6876	0.7082	0.7289	0.7495	0.7701	0.7907	0.8217
55	0.6467	0.6673	0.6880	0.7086	0.7292	0.7498	0.7705	0.7911	0.8220
60	0.6471	0.6677	0.6883	0.7089	0.7296	0.7502	0.7708	0.7914	0.8224
65	0.6474	0.6680	0.6887	0.7093	0.7299	0.7505	0.7712	0.7918	0.8227
70	0.6478	0.6684	0.6890	0.7096	0.7303	0.7509	0.7715	0.7921	0.8231
75	0.6481	0.6687	0.6894	0.7100	0.7306	0.7512	0.7719	0.7925	0.8234
80	0.6485	0.6691	0.6897	0.7103	0.7310	0.7516	0.7722	0.7928	0.8238
85	0.6488	0.6694	0.6901	0.7107	0.7313	0.7519	0.7726	0.7932	0.8241
90	0.6492	0.6698	0.6904	0.7110	0.7317	0.7523	0.7729	0.7935	0.8245
95	0.6495	0.6701	0.6908	0.7114	0.7320	0.7526	0.7733	0.7939	0.8248

3.2 Effects of easy bike on the speed of passenger car

Effects of easy bike are different at signalized intersection and mid block sections. So different approach should be used to estimate the PCE of easy bike at mid block section. From the observed data it was evidenced that presence of easy bike affects the speed of passenger cars tremendously at mid block section.

Figure 1 represents the effect of easy bike on speed of passenger cars. Average speeds of passenger cars in the basic flow were estimated as 22.717 km/hr. Figure 1 represents the average speed of passenger car decreases as proportion of easy bikes increases.

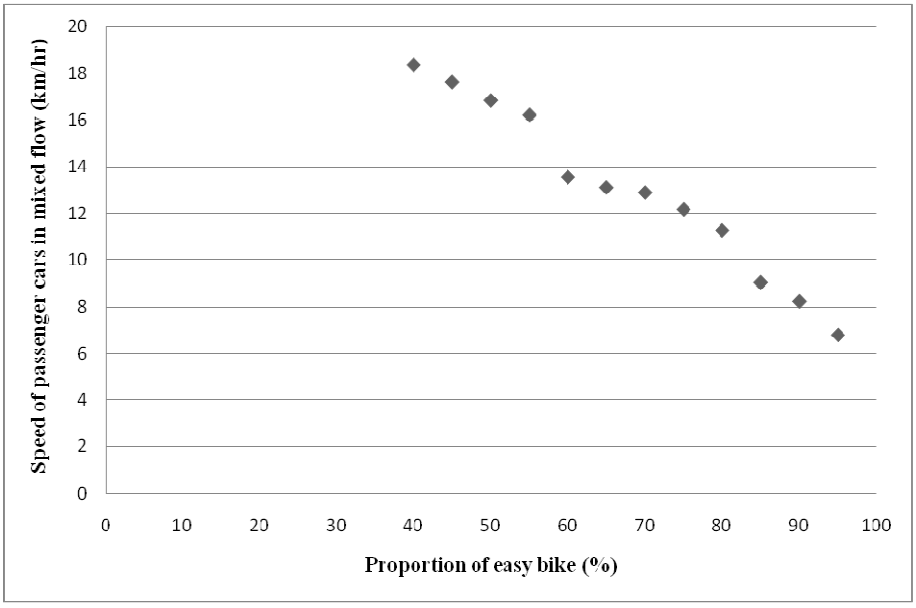

Figure 1: Effects of easy bike on speed of passenger cars in mixed flow

Figure 2 represents the relationship between PCE value of easy bike and flow rate. It was revealed from the relationship that the PCE value of easy bike increases with the increases of flow rate or volume. This seems to occur due to at higher volume rate the speed of passenger car reduced which increases the speed difference and also PCE values.

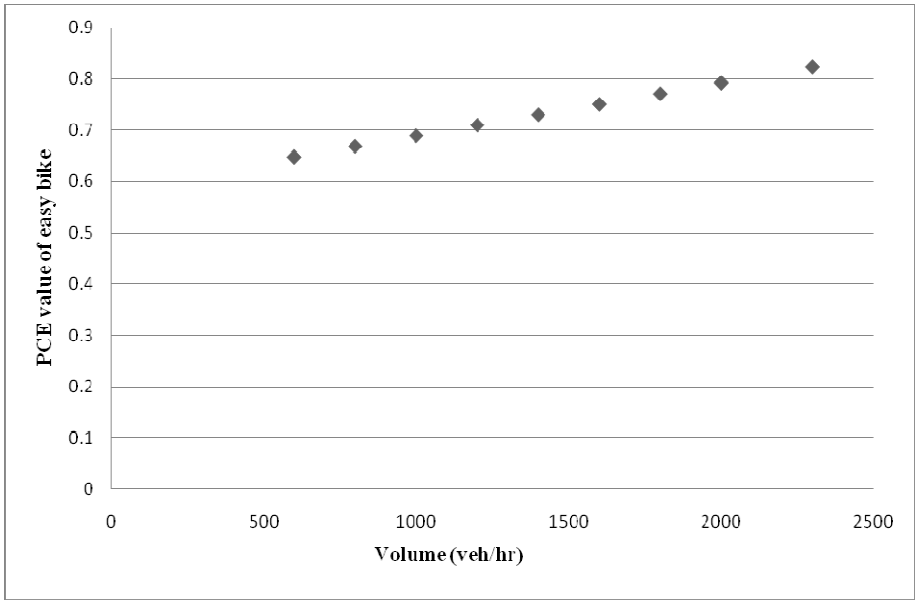

Figure 2: Relationship between PCE value of easy bike and volume

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

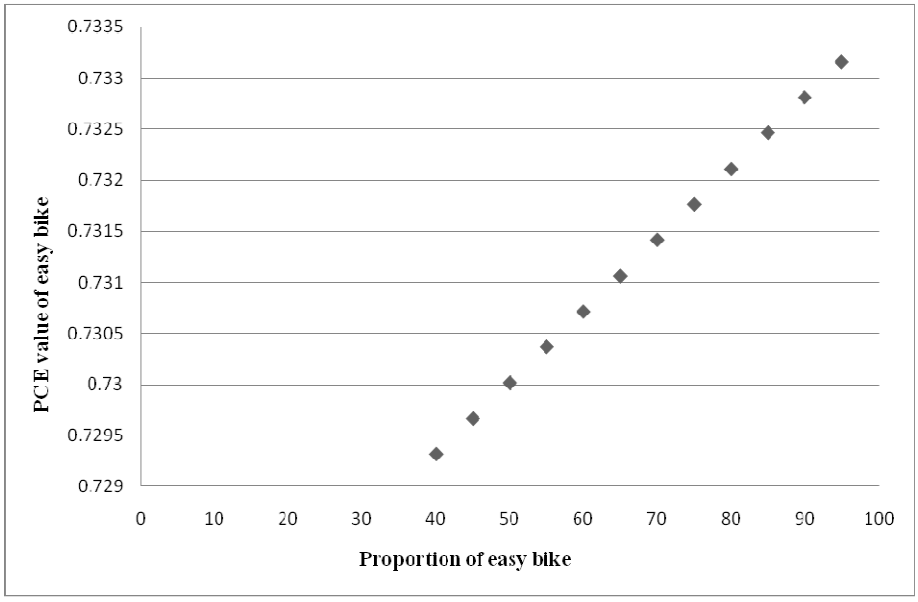

Figure 3: Relationship between PCE value and proportion of easy bike

4. CONCLUSIONS

The PCE values of easy bike which are successfully established using the method of derivation namely the regression analysis. It depends on traffic conditions that whether the traffic system is homogeneous or mixed or how much car's ratio in the mixed system is. It is found that, under heterogeneous traffic conditions, for a given

roadway condition and traffic composition, the PCE value of easy bike varies significantly with change in traffic volume and composition. Hence, it is desirable to treat PCE as dynamic quantity for the different vehicle categories. It is also found that by virtue of the complex nature of interaction between vehicles under the heterogeneous traffic condition, the PCU value of easy bike increases with increases in traffic volume and the PCE value of easy bike increases with the increases of proportion of easy bike. The results will be useful for many research applications in developing countries. Mathematical models and useful technologies that facilitate the efficient solution and improvement of traffic problems in developed countries where the car is the main transport mode can be applied in analogous ways.

REFERENCES

Armstrong, J. S. (2012). Illusions in Regression Analysis, International Journal of Forecasting (forthcoming) 28 (3): 689.

Basu, D., Maitra, S. R., Maitra, B. (2006). Modeling Passenger Car Equivalency at an urban midblock using stream speed as measure of equivalence. European Transport \ Trasporti Europei. 34, 75-87.

BPDB. (2012-13). Annual report of Bangladesh Power Development Board, Dhaka.

Dhaka Tribune. (2014). Solar-powered charging stations for easy-bikes, battery-run rickshaws on the cards. Available at (last accessed on 14 March, 2015): http://www.dhakatribune.com/sci-amp-tech/2014/mar/01/solar powered charging stations easy-bikes-battery-run-rickshaws-cards.

Lindley, D.V. (1987). Regression and correlation analysis, New Palgrave: A Dictionary of Economics, 4, 120–23.

Ministry of Communication (2001). Geometric Design Standards of Roads and Highways Department, Government of the People's Republic of Bangladesh.

Parvathy, R., Sreelatha, T. and Koshy, R. Z. (2013). Development of new pcu values and effect of length of passenger cars on PCU. *International Journal of Innovative Research in Science*, Engineering and Technology An ISO 3297: 2007 Certified Organization, 2 (1).

Rahman, M. M. and Nakamura, F. (2005). Measuring passenger car equivalents for non-motorized vehicle (RICKSHAWS) at mid-block sections. Journal of the Eastern Asia Society for Transportation Studies, 6, 119-126.

Saha, P., Hossain, Q. S., Mahmud, H. M. I. and Islam, M. Z. (2009). Passenger car equivalent (pce) of through vehicles at signalized intersections in Dhaka Metropolitan City, Bangladesh, IATSS Research 33(2), 99-104.

Transportation Research Board. (2000). Chapter 16: Signalized intersection. Highway Capacity Manual. National Research Council, Washington, D.C., U.S.A.

Yan, X. (2009). *Linear Regression Analysis: Theory and Computing*, World Scientific, 1–2, ISBN 9789812834119.