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Developing Passenger Car Unit (PCU) at Signalized Intersection in Context of Bangladesh

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ABSTRACT: *Passenger Car Unit (PCU) is an important metric to measure traffic load in transportation system. PCU measures the impact of different transport modes on traffic variables compared to passenger car. It converts the heterogeneous traffic into homogeneous traffic condition. PCU, itself is dynamic in nature, so, it changes in regular basis depending on road environment and traffic condition. PCU varies country to country and even within the country. Developed countries have sufficient research on determining PCU for their own highways, but developing countries like Bangladesh has extreme laggings in determining PCU for its built roadways. So, this research contributes to estimate PCU at signalized intersections based on traffic speed and volume using multiple linear regression model. Our results suggested PCU values of motorbike, autos, buses and trucks, which give different results compared to Highway Capacity Manual (HCM). In some cases, motorbikes possess PCU more than 2.0 which indicates its ample influence of creating traffic anomaly at intersections. Also, bus possesses PCU more than 6.0 which indicates large queue and illegal maneuver of heavy vehicles while entering or exiting into an intersection.*

KEYWORDS: Passenger Car Unit, Passenger Car Unit, Multiple linear regression method, Signalized intersections, Speed, Volume

1. Background

Passenger Car Unit (PCU) is a metric that is used to assess traffic-flow rate on highway or expressway or freeway. PCU is a measurement that evaluates the impact of different modes of transport i.e., heterogeneous traffic on different traffic variables e.g., headway, speed, density or occupancy compared to single passenger car. The logic of PCU actually lies in to convert mixed traffic into a homogeneous traffic stream assuming that only cars are travelling on a road (Cao et al., 2010). Various confounding factors; environment, weather condition, time of the day etc, significantly effect on traffic flow parameters and therefore, PCU depends closely on these parameters (Ahmed, 2009). The main importance of PCU is its ability to convert a mixed traffic flow into homogeneous and to derive different traffic characteristics, for example, capacity analysis, saturation flow rate, traffic stream model, etc. (Prasetijo, 2007). Moreover, road environments vary among different countries. So, a country-wise PCU estimation is of necessity for transportation planning purpose. Consequently, PCU determination would help the policymakers and transport authorities to develop road safety standards for developing countries like Bangladesh.

PCU is of utmost important in context of transportation science. It extracts the traffic characteristics of an urban and or rural highway. Several research attempts have been carried out to extract information about PCU in highways, expressways and intersections for both developed and developing countries. PCU was first introduced and defined in 1965 US Highway Capacity Manual (HCM) as the number of passenger cars displaced in the traffic flow by a truck or a bus, under the prevailing roadway and traffic conditions. In 2010, it was redefined by Transportation Research Board: National Research Council as the number of passenger cars which will result in the same operational condition as a single heavy vehicle of a particular type under specified roadway, traffic and control conditions. There is a unique nature between homogeneous and heterogeneous traffic flow and therefore, there are complexities involve in determingin PCU (Raj et al., 2019). Different models have been developed to estimate PCU considering different attributes. The attributes that directly affect on PCU are e.g., flow, speed, headway, density, delay, travel time in homogeneous traffic condition (Raj et al., 2019), on the contrary in heterogeneous traffic condition, influence area, effective area, travel time, volume-to-capacity ratio, directional split, queue discharge, etc are extracted for PCU estimation (Homburger, 2019). To develop the methodology for PCU estimation, several attempts have been made e.g., Tiwari et al. (2000) developed PCU based on modified density method using car following and lane discipline behavior. Minh and Sano (2003) used Multiple Linear Regression (MLR) to derive PCU where average traffic speed is used as dependent variable, and number of passenger cars, buses, motorcycles, and heavy vehicles are taken as independent variables. The estimated regression coefficients are regarded as the marginal effect of respective transport mode and the ratio of each of the coefficient of other modes to the coefficient of passenger car is taken as PCU. Patil and Adavi (2015) estimated PCU for urban mid-blocks using headway method by extracting time headway of cars and other vehicles. Another method namely, Chandra's method (Chandra and Kumer, 2003) had been developed using mean speed of car and other vehicles along with the projected rectangular area of vehicles and road width. It was suggested that Chandra's method is more applicable in developing countries like India compared to other methods include speed modeling (Aerde and Yagar, 1984), flow rates and density (Huber, 1984), relative delay method (Craus et al., 1980), space occupancy method (Kumar et al., 2017), etc. In recent years, simulation methods become popular though that was introduced in late 90's by Elefteriadou (1997) while Al-kaisy et al.

(2005) utilized microscopic traffic simulation to develop PCUs, Bains et al. (2012) modeled traffic flow by determining PCU of vehicles at different volume levels using VISSIM for multilane expressways, and Mehar et al. (2014) used simulation to extract the impact of

capacity on PCU determination. Besides, having studies on methodology development and traffic flow parameters, several studies attempted to extract dynamic PCU based on static and dynamic traffic condition (Arasan and Akatkar, 2010), and geometric features (Mardani et al., 2016), etc.

Hence, the problem is, most of the aforementioned studies have been carried out in the highway segments rather than intersections in developed countries and very little research have also been conducted in context of developing countries like Bangladesh. So, there is a need to extract information about motorized and non-motorized mixed traffic flow in the different intersections of different cities of Bangladesh based on PCU. In this paper, the authors have tried to extract PCU of different vehicles at different intersections of Dhaka city to understand the jamology at the entrance and exit of an intersection.

2. Study Area

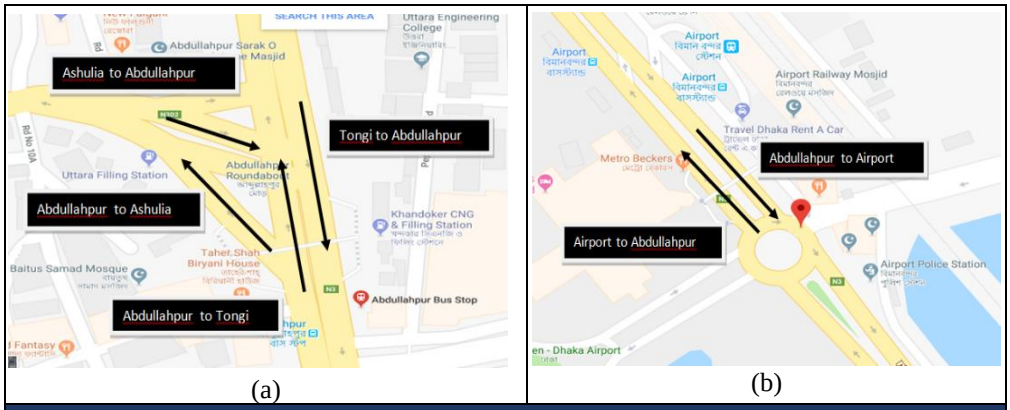
For collecting traffic flow data, Abdullahpur intersection and Airport intersection were selected as the study area based on the criteria of high traffic volumes and significant queuing. Both manual and video-based data were collected. Traffic volume and average speed of each of the vehicles have been extracted from the collected data. Selected study area and the direction of traffic flows for different intersections are shown in Fig. 1

3. Methodology

Multiple Linear Regression

To estimate PCU, this study adopts multiple linear regression model to represent speed of a traffic stream as a function of independent variables e.g., number of passenger cars, number of trucks, etc. To estimate PCU, the following equation can be derived:

$$S = FFS + a_1\, MC + a_2\, Auto + a_3\, PC + a_4\, Bus + a_5 Truck \quad (1)$$



(a) (b)

Figure 1: Study area of data collection (a) Abdullahpur intersection, (b) Airport intersection

where, S = avg. traffic stream speed, FFS= free flow speed, MC = number of Motorcycles, Auto = number of Auto-rickshaw, PC= number of Passenger Cars, Bus= number of Bus, Truck= number of Truck and a_1, a_2, a_3, a_4, and a_5 = regression coefficient based on the estimation of the above coefficient from equation 1, PCU factor is derived for different types of vehicles on un-signalized intersections by taking the ratio of coefficients obtained for each vehicle type (air) with the coefficient obtained for reference vehicle, i.e., passenger car (a1) using the following equation:

$$PCU = \frac{coefficient\ of\ different\ vehicles}{coefficient\ of\ passenger\ car} \qquad (2)$$

4. Results and Discussion

This section discusses the variation of PCU of different vehicles at these two intersections considering the inflows and outflows of traffic volume.

Highway Capacity Manual advises to take PCU for Bike as 1.0 or less than 1. In this study, we have derived PCU ranges from 1.5 to 2.7 for the flow from Ashulia to Abdullahpur, that indicates bikes coming from Ashulia have a significant impact on traffic congestion in that intersection, the PCU value reached in peak on Saturday and exhibit more than 2 for Saturday, Sunday and Monday (shown in Fig. 2). The result for Abdullahpur to Tongi and Abdullahpur to Ashulia flow where PCU values are more than 2.0 and it is reached in peak on Monday. It indicates that at Abdullahpur intersection, for both outflow and inflow, bike is likely to be responsible for traffic congestion and travel-time delay. Also, encroachment of motorbike might be another reason for this high PCU value.

For Autobike (three-legged vehicles), PCU gives high stochastic result in different days shown in Fig.3. From Ashulia to Abdullahpur, PCU gives an increasing pattern and lastly take more than 1.5 of PCU value. Little difference has been found among PCU values at Tongi to Abdullahpur, Abdullahpur to Ashulia, and Abdullahpur to Ashulia flow.

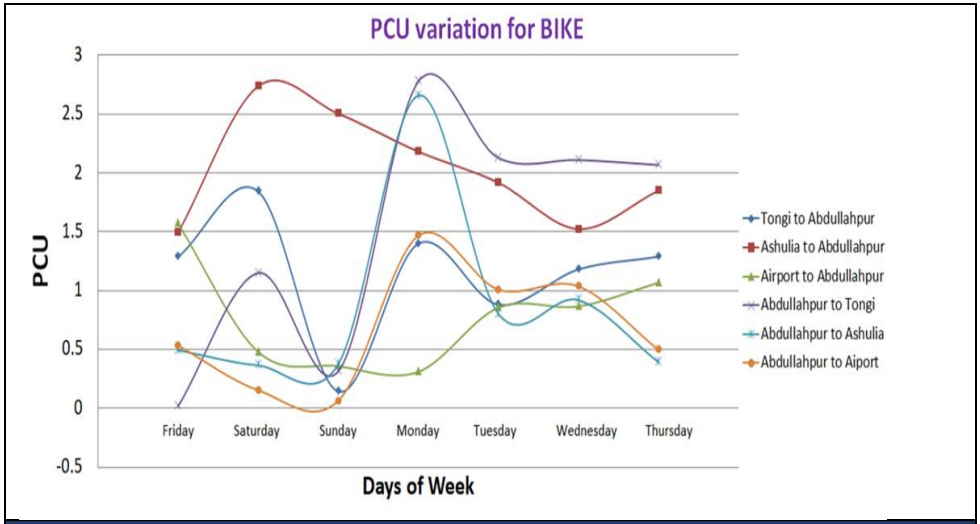


Figure 2: PCU variation in different days of week for Bike

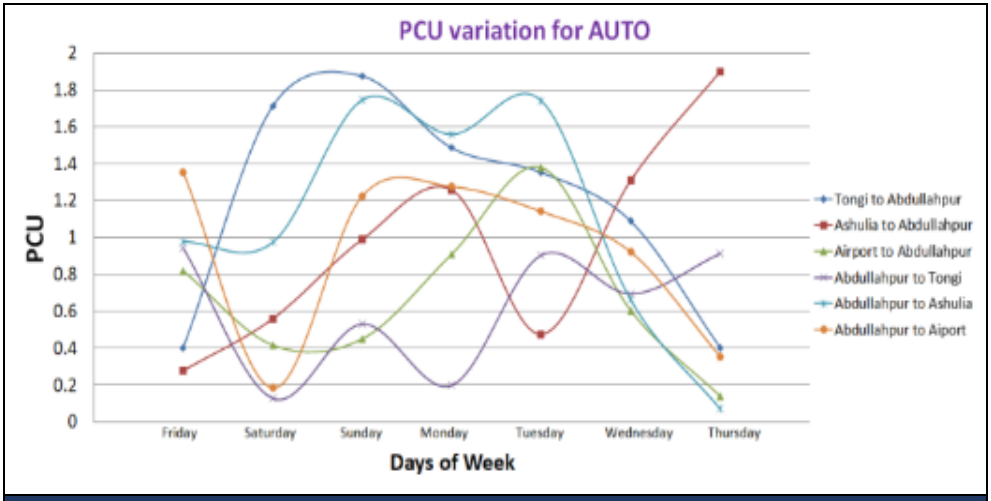


Figure 3: PCU variation in different days of week for Auto-bike (Three-legged vehicles)

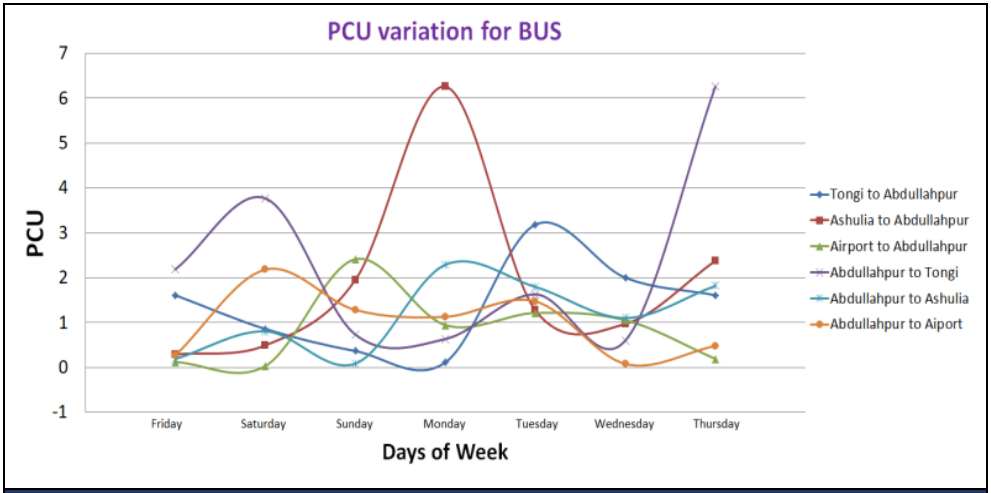


Figure 4: PCU variation in different days of week for Bus

Fig. 4 shows the variation in different days in a week for Bus. For every day in the week, we see almost identical PCU variations for the flow direction in Abdullahpur to Ashulia, Tongi to Abdullahpur, and Airport to Abdullapur. But, interestingly Ashulia to Abdullahpur and Abdullahpur to Tongi flow, both have shown PCU values more than 6, which might indicate to high queue of buses at Abdullahpur intersection. Also, unnecessary overtaking of

small buses decreases to capacity of the lane and thus creates both side queue.

Fig. 5 indicates to a PCU variation of truck – another heavy vehicle types. Except Abdullahpur to Tongi, in all other directions the PCU variations shows almost identical result which ranges from 0 to 3. However, in Thursday - the last weekday, the result shows an abrupt change in the variation which rises close to 8. This result indicates that before the weekend starts, Abdullahpur to Tongi direction experiences mixed traffic with a large proportion of trucks. Generally, at the end of the weekday the proportion of traffic generally increases which is also indicated at the result of preceding PCU of bike (Fig. 2), auto (Fig. 3) and bus (Fig. 4) at Abdullahpur to Tongi direction. Due to the heavy heterogeneous traffic flow, enlarged occupied space of the truck on the road, narrow width from Abdullahpur to Tongi might have changed the PCU variation abruptly.

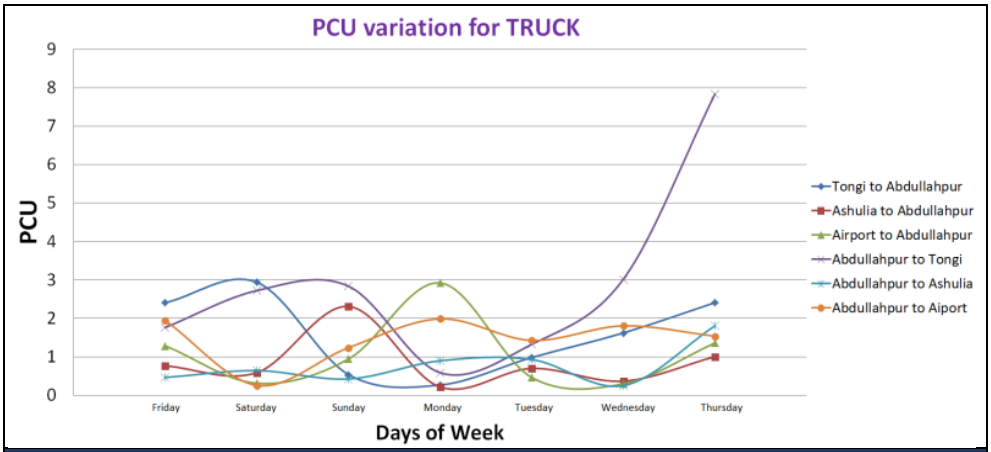


Figure 5: PCU variation in different days of week for Truck

5. Conclusion

This paper is dedicated to derive possible passenger car unit (PCU) of signalized intersections in Dhaka city. To derive this, multiple linear regression is implemented using average speed and total volume of different vehicles. Our analysis concludes that Abdullahpur intersection has sufficient burden of traffic congestion. As it is a three-legged intersection and one national highway and regional highway merges here, so the intensity of traffic jam here is a regular scenario. PCU of Bike and Auto indicates that due to high PCU at Abdullahpur, Airport intersection also suffers from acute traffic jam as most of the bikes and autos generate from Abdullahpur and creates a shockwave on Airport inflow. This paper has some limitation, for example, only multiple linear regression is not able to extract robust PCU, so other methods with the data of density (occupancy), vehicle dimensions, etc needs to be incorporated in developing PCU for Dhaka. There are some scopes for future research on this topic, i.e., developing dynamic PCU of an intersection in hourly basis, creating simulations to replicate the scenario of traffic flow and develop standard PCU.

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