Evaluating Effect of on-Street Parking for Urban Arterials by Stream Equivalency Factor

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Abstract

In general, whenever it was needed to convert a heterogeneous traffic stream into a homogeneous traffic stream passenger car unit’s (PCU) plays an important role. In this paper the concept of stream equivalency factor was used to undermine the homogeneity of traffic stream when the section is completely affected by on street parked vehicle and when the section is without parked vehicle by using the composition of vehicle categories that was observed on the field in each data set and its volume to generate these models. The 6-lane divided urban arterial roads are considered and the models generated were compared to estimate the losses due to the parked vehicles which were affecting the flow as well as the speed of the vehicle in the traffic stream. The stream equivalency factor is denoted by K in this paper. The model developed for the section with no parking contains the entire vehicle categories whose composition is atleast 2% of the total vehicle composition. Similar concept is applied for the the section without on-street parked vehicles. The MAPE value obtained for both the model was less than 5% which mean these model were representing the actual field condition and can be suitable for any such 6-lane divided urban arterial road section.

Keywords: Traffic, Stream Equivalency Factor, On Street Parking, Heterogeneous Traffic Stream, 6-Lane Divided, Urban Arterial

I. INTRODUCTION

Speed, flow and density are basic traffic flow characteristics based on the condition of the facility that is being used by the user. But in countries like India along road side various kind of activities takes place which cause serious deterioration in the level of the service of the facility as well as capacity of the facility keeping density as governing factor. Density is treated as the fundamental macroscopic spatial parameter of traffic flow, as it directly indicates the quality of traffic and ease with which one can drive. Road side activities which takes place around road side are parked vehicle along the road, pedestrian movement along the road on the carriageways, non-motorized vehicles which are moving on the roads with the motorized vehicle and stopping of vehicle on the carriageways for pick-up and drop-down of public transport users. In the other hand in developed countries the categories of vehicles is heterogeneous in nature but in developing countries like India the traffic on the highway are completely different. As the vehicle which constitutes the traffic in India are of varying shape and size hence and this disparity in the shape and size of vehicle to create various kind of serious problem. According to various studies these varying shapes creates problem of congestion, speed as well as maneuverability of respected vehicle in traffic stream and it affects the level of service of the traffic stream as well as operation characteristics of the stream. In case of negligence of these conditions it creates very serious problem when model are developed of such situation.

In Highway capacity manual (HCM) by Highway Research board 1965 gave a term to create homogeneity in traffic by converting all the categories of vehicle in terms of standard passing car and it was defined as passenger car unit (PCU) or passenger car equivalent (PCE). Since then lots of efforts have been made to discuss about PCU for different categories of vehicle for different type of traffic scenarios.

II. LITERATURE REVIEWS

The various studies have been conducted to define the concept of passenger car unit in various forms from the time it was introduced. Lots of effort have been made to analyse the impact and effect of the the vehicle size as well as shape of the vehicles on passenger car unit (PCU).

In 1978, Branston and Zuylen presented the new concept of estimating passenger car units by comparing the ratio of headways of different categories of vehicles. Tanaboriboon and Aryal 1990 used simulation technique for the estimation of PCU.
and Sikdar (2000) studied the effect of lane width on the heterogeneity of traffic stream and its result on the PCU value. Chandra and Kumar (2003) represented the ratio of speed and area of standard car to different category of vehicle as the PCU value of vehicle of that category hence it can be stated that speed is considered as the prime variable in determining the PCU value. The study conducted by Golias (2003) developed the new term known as taxi equivalent factor in place of the PCE. The author argued that the flow characteristics of taxi in traffic stream is completely different from passenger car and two types of TEF were developed, based on capacity and other one based on delay. Terdsak et al. (2005) studied the effect of motorcycles on the operation characteristics of traffic in Arterial Street of Bangkok. Zhang et al. (2006) used the concept of vehicle moving space as the measure to derive PCU factor for different categories of vehicles for Chinese roadways and traffic conditions. In 2013 Dhamaniya and Chandra represented the new concept of Stream Equivalency Factor (SEF) in which they considered the ratio of volume in PCU/hr to volume in Vehicle/hr and developed the model by relating it with the traffic composition and volume on a road through the regression model.

III. Research Objective

The flow characteristics of the stream depend on various factors such as vehicle composition, speed and road geometric condition. There are numerous studies which showed the effects of these factors on the capacity of the road. Similarly, the environmental condition surrounding the road also influence the traffic flow characteristics of the road which is considered as side friction. Aronsson et al. (2006) the response of driver behaviour to studied side friction event for programming of model was done and it was then applied for the prediction of speed pattern. In 2014, the study conducted by Chand, Chandra and Dhamaniya examined the influence of curb side bus stop on the capacity drop of urban arterials by carrying out a mathematical relationship between bus frequency and capacity drop; dwell time and capacity drop was being proposed.

In the present study an attempt was made for analyzing the influence on the capacity as well as flow characteristics of stream due to the vehicle parked on the arterial roads by preparing stream equivalency model. Stream equivalency model for different condition roads are to be prepared with same geometric specification and to identify the change in the SEF values for different flow condition is to be observed. Further in this study the variation in SEF values was observed for different categories of vehicle when their composition was changed with the composition of Small car. For the preparation of model 6-lane divided urban arterials for different condition of road i.e. road with parked vehicle and road without parked vehicle is considered.

IV. Methodology

Stream equivalency factor is a function of vehicular composition of various categories of vehicle and flow in vehicle per hour. However, the geometric condition of the facility as well as surrounding environment may not change during the field observation for the given facility. It can also be understood that the K value depends on the relative interaction of vehicles which are govern by the flow and vehicle composition. It was also found that the size of the vehicle to effect the stream equivalency factor which can be used to identify the maneuvering of different categories of vehicle when its size is greater or smaller. Hence change in any of the above said factor may change the stream equivalency factor. The equation given below is a basic equation of stream equivalency factor given by Dhamaniya and Chandra (2013).

\[
k = \frac{\text{flow in PCU/Hour}}{\text{vehicles/hour}}
\]  

(1)

Where, k is the stream equivalency function or the ratio of flow in PCU per hour and vehicle per hour for the same data set.

In the same way the mathematical form of k equation was developed considering the traffic composition of various data sets as well as the flow value the mathematical form of the stream equivalency factor is given in equation no (2) given by Dhamaniya and Chandra (2013).

\[
K=1+a_1 P_{2w}+ a_2 P_{LCV}+ a_3 P_{BC}+ a_4 P_{HCV}+ a_5/N ...
\]

(2)

Where \(a_1 - a_5\) are the regression co-efficients and \(P_{2w}\) is the proportion of two-wheeler for the given data sets \(P_{LCV}\) is the proportion of light commercial vehicle of the given data sets similarly \(P_{BC}\) is the proportion of big car \(P_{HCV}\) is the proportion of heavy commercial vehicle \(N\) is the no of flow for the given data sets.

In this research work two such stream equivalency models were prepared to get an idea about the change in stream equivalency factor when the flow (veh/hr) condition for different types of section i.e. section with no on-street parking and section with street parking are same. The field data was collected for 5 minute data set and the classified volume count and the flow for each data set was estimated. The PCU value for each vehicle category for each data set was obtained from the formula suggested by the Chandra et al. (2003). The equation for the estimation of the PCU value is given below.

\[
\text{PCU} = \frac{V_C}{V_I} / \frac{A_C}{A_I}
\]

(3)

Where \(V_C\) is the velocity of the standard car for the considered data sets \(V_I\) is the velocity of the \(i^{th}\) category of vehicle from the same data set \(A_C\) is the area of the standard car \(A_I\) is the area of the \(i^{th}\) category of vehicle.

V. Field Data Collection

Field data for the study were collected at 3 six lane divided urban arterial roads in India. Out of these three sections two were from Surat in state of Gujarat and one was Noida in state of Uttar Pradesh. The sections which are selected in Gujarat is 6-lane
divided urban arterial out of which one section is without on street parking and the other one is with street parking and the section selected in Noida is without street parking. The basic considerations made for the selection of section for without parked vehicle are that it should be free from pedestrian movement, pickup and drop down activities of passenger, gradient, road side vendors, curvature and other kind of road side friction. Similarly in case of section with road side parking the section should not have any kind of pedestrian movement in lateral direction during the flow and presence of any other side friction except parked vehicles. The data for the study was collected in the weekdays from 9 a.m. in morning to 12 p.m. and then from 2 p.m. in afternoon to 5 p.m. in evening. The trap length of about 50 meter is made on each section for calculating the speed of the vehicle of various categories. The camera of high resolution is place in the high point in the locality of the section from where the trap length is clearly available and no kind of interference is created from the surrounding through-out the video graphic survey. Flow movement of vehicle was not affected during the survey. In all the three section the traffic stream was divided into five categories but in case of Noida instead of three-Wheeler Light commercial vehicle is considered as our fifth category rest other categories of the vehicle remained same. The car was divided into two categories one as small car which is also considered as the standard vehicle or standard car in the estimation of the PCU value for all categories of vehicles and other one is big car. Big car are generally defined as the car with power of more than 2500 cc. The projected area of each category of vehicle was taken on standard vehicle or standard car in the estimation of the PCU value for all categories of vehicles and other one is big car.

The data obtained for the speed of each category of vehicle and it was used for the estimation of PCU value for each data set. The flow value in PCU/hr to 3612 veh/hr for the Noida section selected in Noida is without on street parking. The bus and trucks are combined in the categories of heavy commercial vehicles and the light commercial vehicles and the 3w are combined with light commercial vehicles. From the obtained data the model for Stream equivalency factor for both the road condition i.e. with parked vehicles and without parked vehicles were generated. For the generation of model for 6-lane divided urban arterial roads without parked vehicle the vehicle composition and flow data of Noida- Greater Noida Road, Noida was considered in the same way for model of 6-lane divided road with parked vehicle section of Athwa – Dumas Road, Surat -session court, Surat was considered.

### VI. DATA ANALYSIS

The data collected in the form of video from video graphic survey was replayed in the large screen for the clear visibility of all categories of vehicle for all section considered in the study. Vehicle counts of each category of vehicle were taken through the recorded video by relaying the video to count one category of vehicle at one time and similar step was followed for all the sections. In the same way the data for the speed of each category of vehicle were taken by considering the entry time and exit time of vehicle passing the trap length marked for each section. The trap length of each section was 50 meters. The data was extracted for each vehicle in form of 5 minute data set. 5 minute count was taken because less than this may produce heavy variation in the data sets.

The data obtained for the speed of each category of vehicle and it was used for the estimation of PCU value for each data set to get an idea about the flow of the stream for respective data set in PCU per hour for calculating the stream equivalency factor (SEF). The table (3) shown below represents the composition of each section considered in this study.

### Table - 3

Vehicle compositions of various sections considered in this study

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Section Name</th>
<th>Veh. Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Udhna-Magdalla Road, Sansakar Society, Surat</td>
<td>2W: 51% 3W/LCV: 14% SC: 26% BC: 6% HCV/BUS: 3%</td>
</tr>
<tr>
<td>2.</td>
<td>Athwa-Dumas road, Surat session court, Surat</td>
<td>2W: 61% 3W/LCV: 15% SC: 19% BC: 4% HCV/BUS: 1%</td>
</tr>
<tr>
<td>3.</td>
<td>Noida - Greater Noida Road, Noida</td>
<td>2W: 19% 3W/LCV: 4% SC: 54% BC: 14% HCV/BUS: 9%</td>
</tr>
</tbody>
</table>

For the betterment of the study the bus and trucks are combined in the categories of heavy commercial vehicles and the light commercial vehicles and the 3w are combined with light commercial vehicles. From the obtained data the model for Stream equivalency factor for both the road condition i.e. with parked vehicles and without parked vehicles were generated. For the generation of model for 6-lane divided urban arterial roads without parked vehicle the vehicle composition and flow data of Noida- Greater Noida Road, Noida was considered in the same way for model of 6-lane divided road with parked vehicle section of Athwa – Dumas Road, Surat -session court, Surat was considered.

### A. Model for 6-Lane Divided section with Out On-Street Parking

The flow value in PCU per hour is ranging from 2700 PCU/hr to 5250 PCU/hr and flow value in vehicle per hour ranging from 1400veh/hr to 3612 veh/hr for the Noida – Greater Noida section.
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The data then was represented in graph which was generated by using the data of both the flow value. The intercept value for the graph was kept zero to get the equation of stream equivalency factor. The above figure (4) represents the average stream equivalency factor for Noida –Greater Noida section which was found to be 0.817 from the graph. The value of k varies from 0.89 to 1.44. The variation in stream equivalency factor is a result of variation in composition as well as variation in flow for veh/hr. In the above mentioned section the composition of LCV was higher hence the area of LCV was considered in the determination of PCU value.

The data sets of Noida–Greater Noida road section was then utilized for the generation of stream equivalency model for 6-lane divided urban arterial road for section with no street parking. The model prepared from this data set is given below in equation (4) the values given below the model are the t-stat values of the coefficient of all variables considered in the preparation of model.

\[ K = 1 - 0.7455P_{2W} + 1.026P_{LCV} + 0.390P_{BC} + 3.40P_{HCV} + 192.472/N \cdots (R^2=0.943) \cdots (4) \]

Where;

- \( k \) = stream Equivalency Factor (SEF), \( P_{2W} \) = percentage composition of two wheeler, \( P_{BC} \) = percentage composition of big car, \( P_{LCV} \) = percentage composition of LCV, \( P_{HCV} \) = percentage composition of heavy commercial vehicle in the traffic stream, \( N \) = total volume at vehicles/hour.

T-stat value of all the coefficient are showing that the all the variable considered are significant for 95% confidence limit because t value of all the coefficient is above 1.96. The sign of each coefficient also represent the good relation with the field condition such as the coefficient sign of 2W was negative which shows that the SEF value get least affected by the composition of 2W as its size compared to Standard Car is less in the same way the size of other categories of vehicle which is greater than sytandard car is more their sign will be positive and they will affect the SEF value tremendously. The \( R^2 \) value of the model was 0.943 which represent a good relationship with field condition.

**B. Model for 6-lane divided section with on-street parking**

The flow value of the section considered in Athwa-Dumas road, Session court area, Surat was found to be in the range of 3100 Veh/hr to 5175 veh/hr and the flow value in PCU/Hr was found to be around 1800 PCU/Hr to 2650 PCU/Hr.

Both the above flow values were plotted in graph and the average stream equivalency factor for this section was obtained by keeping the intercept. The graph shown below in figure (2) gives the idea about the stream equivalency factor for 6-lane divided urban arterial when affected by the on-street parking which was found to 0.55 which is due to the presence of heavy proportion of 2W which is responsible for the lower stream equivalency factor. The variation for K value for this model was obtained in the range of 0.43 to 0.70.
The same procedure was repeated for the model generation of 6-lane divided urban arterials for section with on-street parking from the data of Athwa-Dumas road, Session court area, Surat. The model prepared from this data set is given below in equation (5) and the values in brackets represent t-stat value of the coefficient.

\[ K = 1 - 0.827P_{2W} - 0.175P_{3W} + 0.699P_{BC} + 204.250/N \] ...

\[ (r^2 = 0.98) \text{ ... equation no. (5)} \]

(48.612) (3.058) (5.099) (4.243)

Where:
- \( K \) = stream Equivalency Factor (SEF)
- \( P_{2W} \) = percentage composition of two wheeler;
- \( P_{3W} \) = percentage composition of three wheeler
- \( P_{BC} \) = percentage composition of big car
- \( N \) = total volume at vehicles/hour.

The value of t-stat values of the coefficients of the model developed for 6-lane divided road section with on-street parking shows that the model is significant for 95% confidence interval and the \( R^2 \) value obtained for this model gives an idea that the model is able to replicate the field condition correctly. The variation in the sign also gives idea about the maneuverability of various categories of vehicles. The size of vehicle which are comparatively less than the standard car are will give negative and the vehicle size which was greater than the standard car will give positive sign as there flow will affect more to SEF as compared to the vehicle with less size.

**VII. VALIDATION OF MODEL**

**A. Validation of model for 6-lane divided section with out on-street parking**

In order to estimate the accuracy of the model developed for 6-lane divided urban arterial road without on-street parking this model was validated from the data of another section. The section selected for the validation of model was Udhna-Magdalla Road, Sanaskar society, Surat. In this section the data was collected in the similar manner as collected for Noida section. Data set of flow and composition was prepared for 5 minute interval. Total 344 data sets were created for the validation purpose. The model was then evaluated based on the MAPE value for the observed flow in PCU/Hr to the predicted flow in PCU/hr. The various categories of vehicle considered in this section were similar to that of the vehicle categories considered in Noida section. The area considered for PCU estimation was the highest for the observed category of vehicle was considered as the area of the vehicle category.

Linear plot of observed and predicted flow was drawn and the relation obtained was given below in the equation (6). The figure (3) shows the Q-Q plot between the observed flow and predicted flow. The MAPE value observed for the validation of observed and predicted flow is 2.35%.
**B. Validation of model for 6-lane divided section with on-street parking**

Similar model for the 6-lane divided section with on-street parking was developed from the data of Athwa-Dumas road, Surat session court area, Surat. The data set for the generation of model was prepared in the similar manner as the data set was prepared for above models. In this model the hcv flow was not considered in the generation of model due to composition of HCV was less than the 2% (HCM 2010). The model was generated from the 80% data set and the rest data were used for the validation of the model. The MAPE value observed for the data set was 4.06%. It can be stated from MAPE value that the model is fit for any kind of such midblock section. Q-Q plot was plotted between observed flow (PCU/hr) and predicted flow (PCU/hr) as shown in figure (4) and the equation (7) obtained is given below.

\[
Y = 1.01X \quad R^2 = 0.72 \quad (7)
\]

Where:
- \(X\) = Observed flow (PCU/hr), \(Y\) = Predicted flow (PCU/hr)
VIII. VARIATION IN FLOW VALUE

The flow values of observed field condition were used to estimate the variation in flow value in PCU/hr for the same volume of traffic in Veh/hr. Both these above condition were further utilized for preparing the table based on vehicular flow and with respect to which its flow in PCU values for base condition and when vehicles are parked on-street was obtained. The table was helpful to determine how the variation in flow (PCU/hr) will vary with respect to the same flow (veh/hr) for both base section and friction section i.e. section with on-street parking.

![Fig. 5: Comparison of base section with section with on street parking](image)

From the above figure it can be concluded that the major composition of vehicle in base section was of heavy vehicle such as big car, bus and HCV were as in case of friction section the major composition of vehicle was for vehicle of smaller dimension and shapes i.e. two-wheeler and three-wheeler. Similar variation was observed in the form of table to get an idea about the loss in flow in (PCU/hr) due to on-street parking when both the sections were compared for the same flow in (veh/hr). The maximum flow value to get this table is considered based on the flow value (veh/hr) observed on the field condition for both the section.

<table>
<thead>
<tr>
<th>Flow (Veh/hr)</th>
<th>Flow (Pcu/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Base</td>
</tr>
<tr>
<td>500</td>
<td>408.00</td>
</tr>
<tr>
<td>1000</td>
<td>817.00</td>
</tr>
<tr>
<td>1500</td>
<td>1226.00</td>
</tr>
<tr>
<td>2000</td>
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<td>2500</td>
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<td>4000</td>
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<td>4500</td>
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<tr>
<td>5000</td>
<td>4088.00</td>
</tr>
<tr>
<td>5500</td>
<td>4497.00</td>
</tr>
<tr>
<td>6000</td>
<td>4906.00</td>
</tr>
</tbody>
</table>

IX. STREAM EQUIVALENCY FACTOR WITH VARIATION IN TRAFFIC FLOW

The models were used to determine the variation in stream equivalency factor for change in the traffic volume (veh/hr) for both base section and section with on-street parking for the observed composition of vehicles category in the field. The value of SEF obtained from the model was used to plot the graph shown below in figure no. (6). The variation in the SEF clearly indicate the effect of varying proportion of vehicles as the section which is considered as base section was having higher composition of heavy vehicle categories whereas the section considered as friction section was having lower proportion of higher vehicle categories due to which the difference in the SEF values for same vehicle flow (veh/hr) can be seen in this graph.
X. Conclusion

The field data was collected from two cities of India and the SEF models were generated, one for representing the base condition whereas another one for representing the condition when the section is highly affected by the on-street parking. The model prepared for representing the base condition was formed from the data of Noida city and the model prepared for representing the condition when section is affected by on-street parking was formed from the data of Surat city. It was observed from this study that the model which are prepared to determine the SEF of the sections considered in this study are replicating the actual field condition as their $R^2$ value was found to be 0.94 for base section and 0.98 for section with on-street parking. The models which were prepared were further validated from the field data. The model for base section was validated from the base section considered in Surat city and it was obtained that the model is representing the generalized condition of 6-lane divided urban arterial road ehen there is no on-street parking. The MAPE value obtained for this model was 2.35. Similarly, the model for section with on-street parking was validated from the 20% data set of the same location and it was observed that it also represent the general condition of such type of section as MAPE value obtained for this model was 4.06%. It was also found from the above study showns how the value of flow in PCU/hr is changing as the as the flow value of veh/hr is changing. Similarly from the models the SEF variation of varying flow value (veh/hr) was obtained to understand the nature of stream equivalency factor for both base section and section with on-street parking. It can be concluded from the above research that SEF is an effective tool to determine the homogeneity of the traffic flow as well as it also helped to determine the effect of on-street parking on the 6-lane divided urban arterial.

References