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A STUDY ON PASSING - OVERTAKING CHARACTERISTICS AND LEVEL OF SERVICE OF HETEROGENEOUS TRAFFIC FLOW

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Abstract: Abstract: A model of passing-overtaking maneuvers in terms of total traffic volume and percent of rickshaws is presented in this paper; the model is applicable to undivided urban streets with relatively high proportion of rickshaws. Effects of non-motorized rickshaws on passing-overtaking are also presented. The results suggest that rickshaws have an adverse effect on the passing-overtaking maneuvers. This paper has also attempted to provide a classification of Level of Service (LOS) for heterogeneous traffic composition in urban areas. In this study LOS are firstly defined in six standard groups, such as levels A, B, C, D, E, and F. The operating characteristics considered to define the level of service are: total number of passings -over takings (no/hr/20m) and average speed of passenger cars (km/hr). Based on the observed data the levels of service are classified into four groups from the road users point of view, namely LOS I (Free-flow condition), LOS II (Partial-constraint flow condition), LOS III (Constraint flow condition), and LOS IV (Congested-flow condition). Level of service classification evolved in this study will help to identify deficiencies of an urban streets system and to plan for alternative improvement measures to attain a desired level of service.

Key Words: Level of service, passings-over takings, heterogeneous traffic flow, highway capacity, non-motorized vehicles (Rickshaws)

1. INTRODUCTION

The term Level of Service (LOS) denotes any one of a numerous number of differing combinations of vehicular and roadway operating conditions that may occur on a given lane or road while it is accommodating various traffic volume. It is an important parameter for traffic engineers, transport planners and road users. Therefore, levels of service should be consistently defined and understandable to all of them.

The Highway Capacity Manual (HCM, 1994) has defined level of service mostly for countries having predominantly homogeneous traffic streams of motorized vehicles. Very little studies have been conducted on level of service criteria on urban heterogeneous traffic flow having significant proportion of Non-Motorized Vehicles (NMV). These types of flows occur mostly in countries of South and South- East Asian regions. The flow of heterogeneous traffic on urban streets is highly complex in nature. At present, the levels of service criteria are based on macroscopic parameters, that is traffic density, speed and volume. However, inconsistencies exist in these parameters in varying traffic conditions. Moreover, in the HCM there is no provision for levels of service classification criteria for mixed traffic stream flow (motorized vehicles and non-motorized vehicles using the same road/street). Therefore,

alternative parameters, which can explain the mixed traffic flow situation, should be proposed and the validity of such parameters should be investigated. Passing and overtaking maneuvers, which represent freedom of maneuver ability of road users, were studied and new levels of service criteria are proposed in this paper for mixed traffic flow composition on urban streets. The study has been conducted in streets of Dhaka, the capita of Bangladesh.

Various points of view on passing and overtaking behaviors were investigated in this study. The characteristics of passings and over-takings at varying proportions of non-motorized vehicles were studied and an attempt was made to explain by traffic volumes and average speed differences of motorized and non-motorized vehicles. In the later part of the paper, a new set of criteria to classify levels of service in pragmatic understandable terms were recommended for mixed traffic flow situations.

2. PASSING – OVERTAKING AND LEVEL OF SERVICE

Passing and overtaking is defined as the total number of passings and over-takings of any vehicle by other vehicles in a defined roadway/street section (for this study 20 meter) and expressed as the number of vehicles/hour/20meter in an undivided urban street. Three types of passings and over-takings are observed in the mixed traffic stream flow as follows:

MV – NMV : a motorized vehicle passing or overtaking a non-motorized vehicle
NMV – NMV : a non-motorized vehicle passing or overtaking another non-motorized vehicle
MV – MV : a motorized vehicle passing or overtaking another motorized vehicle

Passing and overtaking phenomena are influenced by upstream and downstream intersection operations. Incase of a mixed traffic flow, the maximum number of passings-over takings will consist of MV-NMV groups as a big speed differential exists between the two types of vehicles. A low number of passings-over takings will occur for the MV-MV groups as speed differences among theses vehicles even in mixed traffic flow condition is relatively low. In this study Rickshaws are defined as manually derive three wheeled non-motorized vehicles.

The concept of levels of service is utilized as measures of effectiveness (MOE) to characterize conditions within the traffic stream. LOS is often expressed as a letter from ‘A’ to ‘F’. Each level is defined both qualitatively and quantitatively. That indicated level corresponds to the appropriate MOE with LOS. Level ‘A’ is termed as ideal flow while Level ‘F’ represents unstable or congested flow. Meanwhile, the quality of flow is also defined as perceived by motorists and passengers.

According to the HCM, MOE is employed to distinguish among various traffic conditions. For intersections, the MOE is the stopped delay per vehicle, for an urban arterial section it is average travel speed, for freeways it is the density and for multilane highways it is the maximum densities. So MOE is different for different roads/streets and traffic conditions. For an undivided urban street with heterogeneous traffic flow, the MOE should be so describe as to reflect the LOS in the actual situations of flow of the traffic stream. Drivers can easily know their spot speeds from their speed meters but they hardly know the average travel speed or space mean speed. Hence, it becomes more difficult to describe the service quality on road/street with the average speed criterion only. Freedom of maneuvers, traffic safety and driving comfort, which are important factors for highway service quality, should be more considered. The average travel speed is not enough for evaluating these factors but they could

be evaluated by using passings-over takings phenomena.

The number of passings and over takings could simply act as a parameter to describe driving conditions according to driver perceptions because it reflects the freedom of maneuver ability and the driving comfort directly. Passing-overtaking is the parameter that is easy to communicate with the road users.

3. EVOLUTION OF LEVEL OF SERVICE CONCEPT

Although many Level of Service (LOS) measures for two-lane roads/streets have been developed, international agreement on a specific measure has not been reached. Further, problems of two-lane roads/streets have not been clearly formulated, even in the 1987 World Road Congress (WRC). However, the lack of consensus is not surprising, given the complex nature of traffic flow on two-lane undivided roads and streets.

The evolution of the concept of level of service measures in Canada and USA can be traced through the three Highway Capacity Manuals (HCM). In the HCM passing opportunities index is defined as 'The availability of opportunities for vehicles to overtake and pass slower vehicles in the same direction of travel. The ratio of the number of passings required per kilometer of highways for drivers to maintain their desired speeds to the number of passings that they can eventually perform, is a measure of traffic congestion. Although the concept of over-takings as a measure of level of services has not been exploited to date, it is not new and in fact predates the 1950 Highway Capacity Manual. Overtaking is being reintroduced here as one of the measures of level of service for two-lane highways. Level of service on two-lane highways in the 1985 HCM is described by three parameters: (a) average travel speed, (b) percentage of time delayed, and (c) capacity use. The percentage of time delayed, the primary measure of service, is defined as the average percentage of time that all vehicles are delayed while traveling in platoons because of their inability to pass.

Morrall and Werner (1990), presented a level of service concept for two-lane highways that is based on the supply of passing opportunities and demand for over-takings. The relationship between supply and demand for over-takings forms the basis of a level of service measure as defined by the overtaking ratio. Marwah and Singh (2000), attempted to provide a classification of level of service for urban heterogeneous traffic condition. Based on the simulation results, the authors classified the level of service into four groups. The operating characteristics considered to define the level of service are: journey speed of cars and motorized two-wheelers; concentration; and road occupancy.

Kita (2000), tried to develop a level of service measure of road traffic based on the drivers' perception, since currently used measures of level of service to evaluate the traffic condition of a specific road sections are not necessarily linked to the perceived level of service by the drivers. This study aims to propose a universal level of service measure of road traffic based on the drivers' perception in relation to prevailing driving environment. The idea of the proposed measure is that the degree of satisfaction at an instance will be formed of the drivers' perception of speed, the degree of freedom to maneuver, and the degree of safety. The measure is composed of aggregated driving utility, and the utility is estimated by drivers' utility function with surrounding driving conditions.

Surasak *et al*. (2002) developed a new method to measure level of service by using platoon

mechanism. From the study of platoon characteristics, four levels of service criteria for road users based on platoon parameters were proposed. The specified four levels are composed of free-flow condition, partial-constraint condition, constraint condition, and congested condition. Each level can be determined from either average platoon size or percent of followers. Regidor (1999) examined the road level of service using established criteria from the US Highway Capacity Manual. It was proposed that alternative criteria be developed especially for cases wherein the established measures of effectiveness are insufficient to describe the state of flow. The authors introduced lane changing frequencies as alternative criteria of level of service classification on urban arterials.

An overall review of the previous studies indicated that most of the studies deal with homogeneous traffic that is the traffic stream consisting of a mixture of motorized vehicles. Only Marwah and Singh (2000), considered the heterogeneous traffic stream flow but the authors considered a particular traffic composition which is not always compatible with the traffic situation in the real field. This paper has attempted to provide a classification of level of service for urban heterogeneous traffic condition based on the passing/overtaking phenomenon, which can directly explain the constraints of vehicles in mixed traffic flow.

4. DATA COLLECTION AND PROCESSING

All data were collected from the two mid-block sections located in Dhaka metropolis, the capital of Bangladesh. Several criteria were used in the selection of the study locations. The selection criteria were as follows: high traffic volume, higher proportion of non-motorized vehicles, pavements with good conditions, level terrain, non- allowable of parking and insignificant disturbances from bus stops. In Dhaka metropolis it was very difficult to identify the locations which satisfy all of the above 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 long road segments. Upstream and downstream intersections were located 200 meters, 320 meters and 200meters, 210 meters for site 1 and site 2 respectively. Road widths of site 1 and site 2 are 15 meters and 14 meters respectively excluding shoulders. There is no median or road marks to separate the traffic flows of two directions. Configuration of site 1 and site 2 are shown in figure 1. They are located in Azimpur and Palashi areas of Dhaka city.

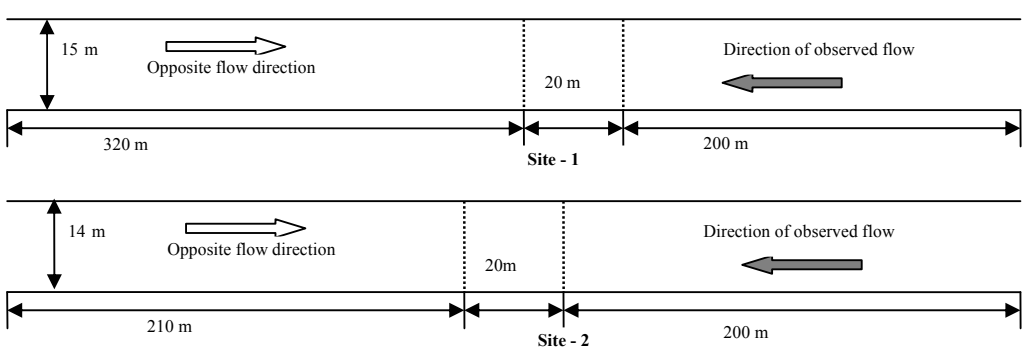

Figure 1: Configurations of Site 1 and Site 2

Field data were collected during the 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 gleaned data was used in analyses of speed, volume, and density and traffic compositions. Other types of vehicle (Bus, Truck) in the downstream have significant effect on data collection and the study objectives. But the proportion of buses and trucks in the selected sites are very low (4 to 5%), so in this study effects of these types of vehicles on the flow conditions were not taken into consideration.

The traffic composition may be easily determined from the classified volume counts in the two sites. For the purposes of this study, the counts were classified into six vehicle types: rickshaws, other non-motorized vehicles, small size motorized vehicles, passenger cars, buses, and truck, and other motorized vehicles. Non-motorized vehicles comprised more than 80 percent of the total traffic and small size motorized vehicles and passenger cars were the second highest in proportion. It is clear that two selected sites are predominantly by non-motorized vehicles, and analytical approach should be different from that of the homogeneous traffic stream flow conditions.

Unfortunately, data during the forced flow condition would rarely be gleaned from these sets of data. Data at high volume traffic were found for only short period of time. Therefore, this study focuses on passing-overtaking characteristics and service quality at free-flow condition and near capacity flow condition only.

5. CHARACTERISTICS OF PASSINGS - OVERTAKINGS

It is necessary to identify the inherent patterns in passings-over takings in order to visualize the influence of various traffic parameters on them. The basic approach for this is to plot passings-over takings as a function of the several stated variables. Among these are total traffic volume, proportion of non-motorized vehicles (rickshaws) and speed differences of non-motorized and motorized vehicle.

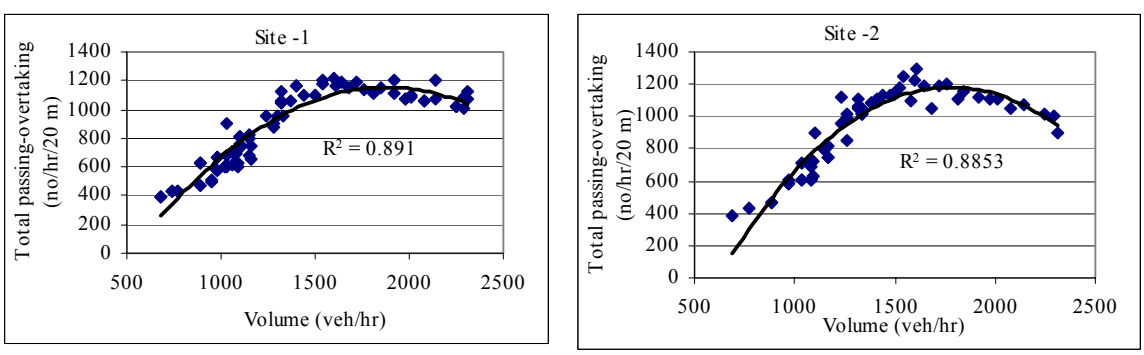

Figure 2: Relationships between passings-over takings and total traffic volume (1min data)

The relationships between passing-overtaking and total traffic volume of site-1 and site-2 are presented in figure 2 and relationships between passings-over takings and proportion of non-motorized vehicles (rickshaws) are presented in figure 3 respectively. As shown in figure 2; the general tendency of passings-over takings is that the total number of passings-over takings increases with the increase of traffic volume but at higher volumes number of passings-over takings decreases. A possible reason for these findings was that at lower volume the high speed of motorized vehicles resulted in higher number of passings-over takings, on the other hand at higher volume the speed of motorized vehicles reduced which resulted in less number of passings-over takings. Furthermore, at higher volume, opportunities and frequencies of passings-over takings decrease due to restricted maneuverability.

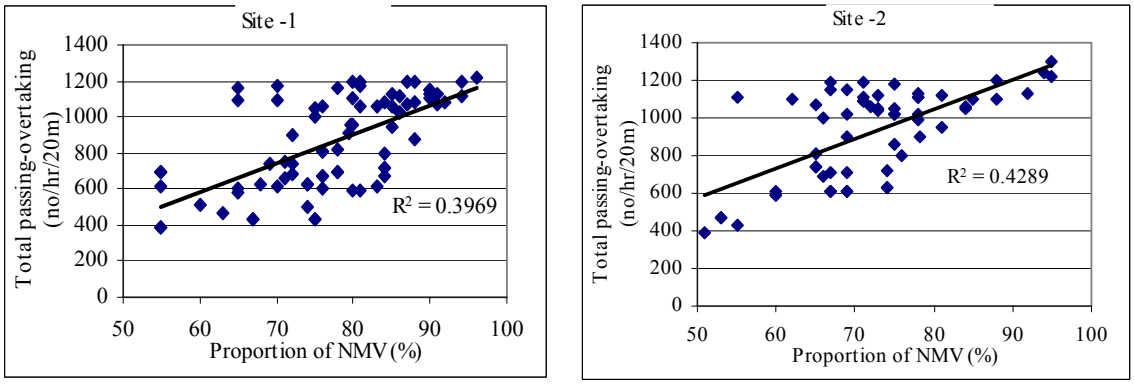

Figure 3: Relationships between passings-over takings and proportion of non-motorized vehicles (Rickshaws)

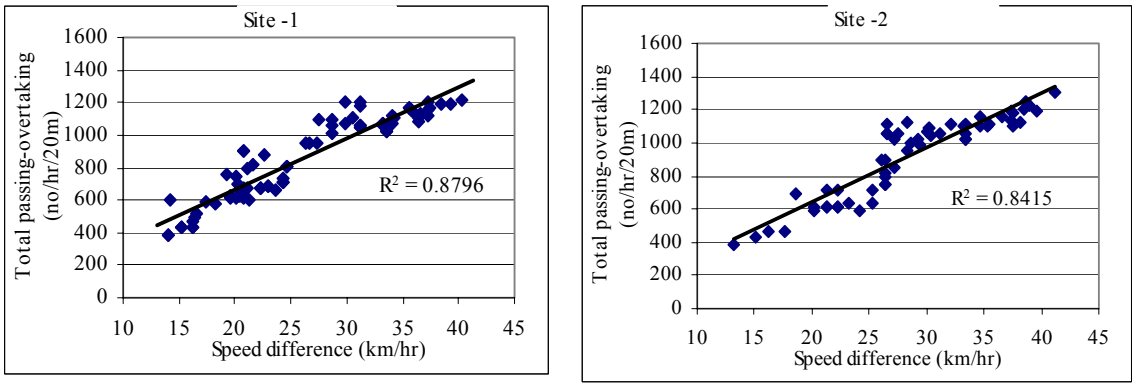

Figure 4: Relationships between passings-over takings and speed differences

As shown in figure 3; there is somewhat a linear relationship between total number of passings-over takings and the proportion of non-motorized vehicles (rickshaws). The total number of passings-over takings increases as the proportion of rickshaws in the traffic stream increases. This is obvious as the speed of rickshaws are low and the number of passings and over takings by motorized vehicles increases with the increase of number of rickshaws.

The relationships between passings-over takings and the speed differences of motorized and non-motorized vehicles (rickshaws) are presented in Figure 4. These relationships can explain the mechanism of passings-over takings phenomenon in mixed traffic flow. As motorized vehicles pass or overtake the rickshaws, the maximum number of passings-over takings will result when the average speeds of motorized vehicles are high and the average speeds of

rickshaws are low. On the other hand, the minimum number of passings-over takings will result when the average speed differential of these two types of vehicles are lower.

6. EFFECTS OF RICKSHAWS

In order to study the effects of rickshaws (non-motorized vehicles) on passings-over takings, passing-overtaking characteristics at different percentage of rickshaws are investigated. Due to the lack of a wide range of variation in the percentages of rickshaws data were classified into three groups. Each group included ±5% rickshaws class. Passings-over takings from every 1-minute and trend of each group were plotted against the total flow rate of traffic in veh/hr. The results are shown in figure 5 for the combined data from site 1 and site 2.

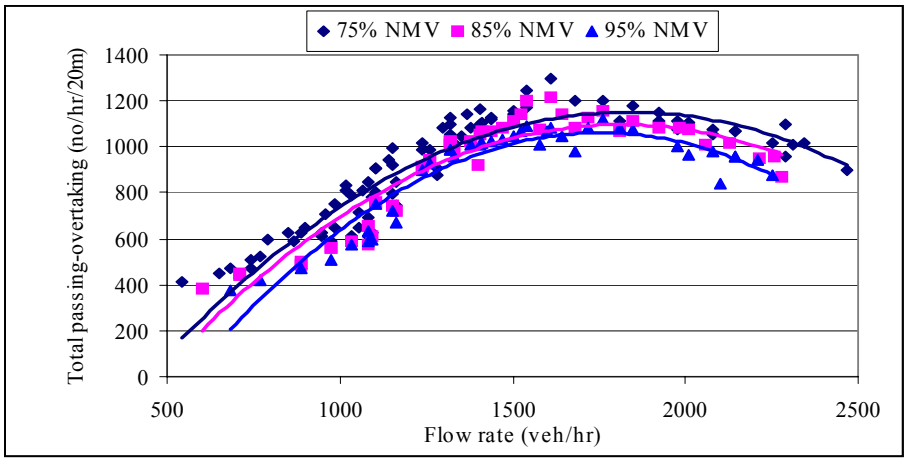

Figure 5: Effects of rickshaws on passings-over takings

Figure 5 illustrates that the total number of passings-over takings at the same volume of traffic with low percentages of rickshaws is higher than with high percentages of rickshaws. At higher proportions of NMV the number of motorized vehicles, which are the major overtakers/passers are less. So the number of passings-over takings may decrease. It can therefore be concluded that non-motorized vehicles (rickshaws) have adverse effects on the passings-over takings phenomenon and this effects increase with the increase in the proportions of rickshaws. The effects of rickshaws might differ for different geometric conditions of the road sections and as such a comprehensive study will be required for this purpose.

As shown in figure 6, the effects of non-motorized vehicles (rickshaws) on passings-over takings phenomenon are different in different flow conditions. At lower traffic flow (< 1000 veh/hr) there is a linear relationship between passings-over takings and the proportions of rickshaws. At medium rate traffic flow (1000 veh/hr to 2000 veh/hr) passings-over takings rates increase with the increases in the proportions of rickshaws but the rate of increases is lower than that of at lower traffic flow as passings-over takings frequencies decreases with the increase in volume. At higher traffic flow (> 2000 veh/hr) relationship of passings-over takings and proportion of rickshaws is non-linear.

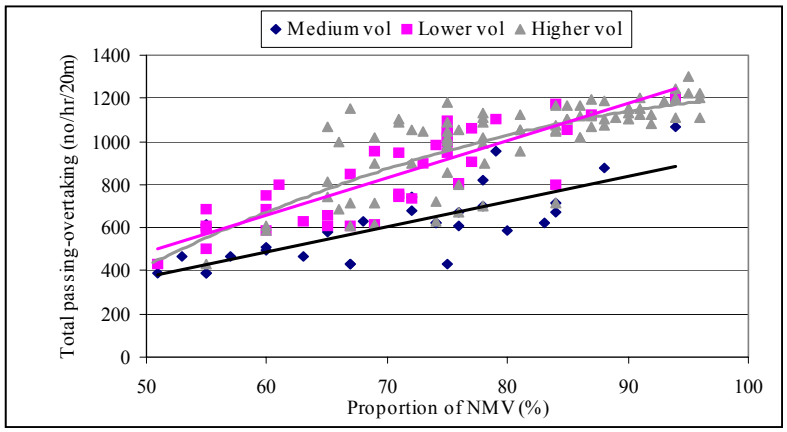

Figure 6: Effects of rickshaws at various traffic flow conditions

7. PASSING – OVERTAKING MODEL FOR HETEROGENEOUS TRAFFIC FLOW

As discussed in the previous sections, it can obviously be understood that passing-overtaking varies depending on traffic volume, proportion of rickshaws and speed differences of motorized and non-motorized vehicles. Traffic volume is still the most important factor that affects traffic conditions and passing-overtaking behavior. Since, driving behaviors and traffic characteristics are different in different countries; empirical formula for specific type of roadway in each country must be developed. Multiple linear regression analysis was applied to find the mathematical model of relationships between passing-overtaking and traffic data for two-lane urban streets in Bangladesh.

Table 1: Correlation matrix for dependent and independent variables

	Passing-Overtaking	**Volume**	**% Rickshaws**	**Speed difference**
Passing-overtaking	1	0.7708405	0.583801	0.92995
Volume	0.7708405	1	0.21356	0.72852
% Rickshaws	0.583801	0.21356	1	0.569340
Speed difference	0.92995	0.72852	0.569340	1

Multiple regressions were chosen since it provides us with the simplest tool for building models. This is especially useful for developing a model that will be used to evaluate a certain parameter as a function of various state variables. Before developing the models it is of utmost important to examine to correlations between the dependent and the independent variables. Table 1 shows the correlations of dependent variable and all independent variables.

As shown in table 1 there is a significant correlation between the dependent variable and all the independent variables. The significant correlation between volume - speed difference, and speed difference-percentage of rickshaws indicates that these variables may not be combined in one equation. Traffic volume (Q, Q^2 and Q^3) and percent of rickshaws (%NMV) were selected as the independent variables for passing-overtaking prediction. Considering the boundary condition of regression equation that when there is no traffic volume or at volume equal to zero, the number of passings-over takings must also be zero. Hence the intercept point of regression equation was set at zero. A multiple linear regression model for passings-

over takings (PO) for volume (Q) and percent of rickshaws (%NMV) is given in equation (1). Statistical parameters for evaluating the passings-over takings model for combined data are shown in table 2.

$$PO = a\,Q + b\,Q^2 + c\,Q^3 + d\,\%NMV \qquad (1)$$

Table 2: Statistical results of regression model

Coefficients				**t-value**				**R^2**	**F**
a	b	c	d	t_a	t_b	t_c	t_d		
-0.322	0.0013	-4.4×10^{-7}	1.597	-2.77	13.05	-15.49	1.94	0.89	283

Considering R^2 and t-values from table 2, regression model is seen to provide fairly good predictions. The critical t-value for 95% level of confidence that is five percent level of significance, for this data set is about 1.65. All independent variables appear is significant at this level of significance. Signs of the variables seem to be correct. The comparisons of observed data and predicted data from regression model are depicted in figure 7. Passing-overtaking model shows the acceptable results. Therefore, the model could reasonably be used to estimate the total number of passings-over takings at selected sites. The two independent variables namely, the total volume and the percent of rickshaws can easily be measured in the field. One drawback of the model is that it is applicable for only free flow and near capacity flow regions and with higher proportions of rickshaws.

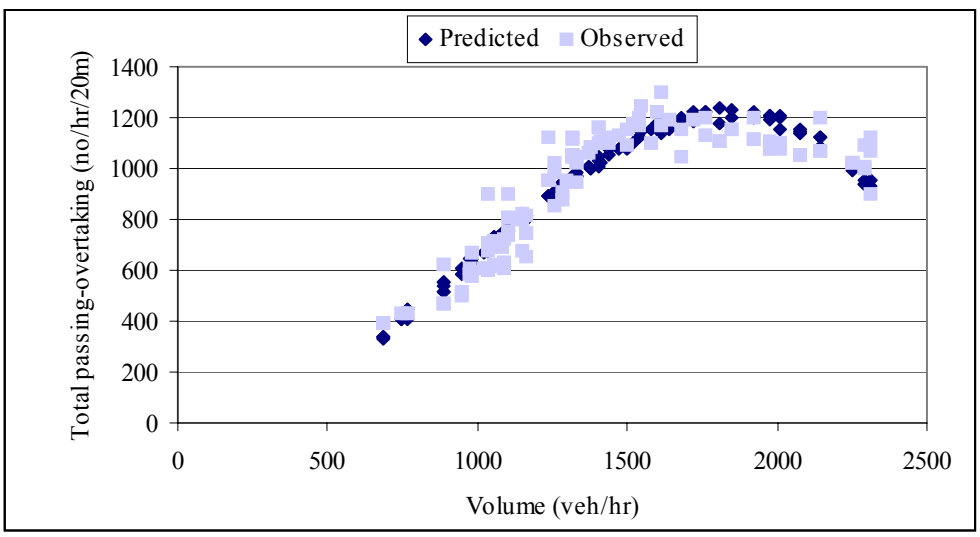

Figure 7: Prediction of passings-over takings at selected sites

8. LEVEL OF SERVICE CLASSIFICATION FOR HETEROGENEOUS TRAFFIC FLOW

Presently used levels of service criteria which mainly are based on traffic density have some drawbacks. Levels of service criteria were designed based on the road engineering point of view instead of the road users' point of view. They consider number of vehicles per unit distance but they do not consider the driving conditions and the pattern of traffic stream. Therefore, the presently used levels of service criteria cannot represent the exact service quality as perceived by road users. These criteria might be good enough for highway design

engineers but they might not be meaningful in the sense of road users.

Passing-overtaking characteristics that directly explain constraint conditions of vehicles in traffic stream on urban streets with mixed traffic flow conditions should be good parameters for levels of service criteria. Passings-over takings can show general traffic conditions and driving patterns of the traffic stream and it can also explain the freedom of lane changing maneuver. Therefore, with this passing-overtaking phenomenon, engineers can estimate the levels of service on urban streets as the same quality of service which the drivers and the road users perceive.

At the first step, traffic flows were classified into each level of service based on traffic conditions by using passing-overtaking characteristics. Characteristics of passing-overtaking are very useful to divide each level start from the increasing phase to a constant phase until the decreasing phase. The LOS from A to F on an urban undivided street can approximately be divided according to driving conditions as shown in figure 8.

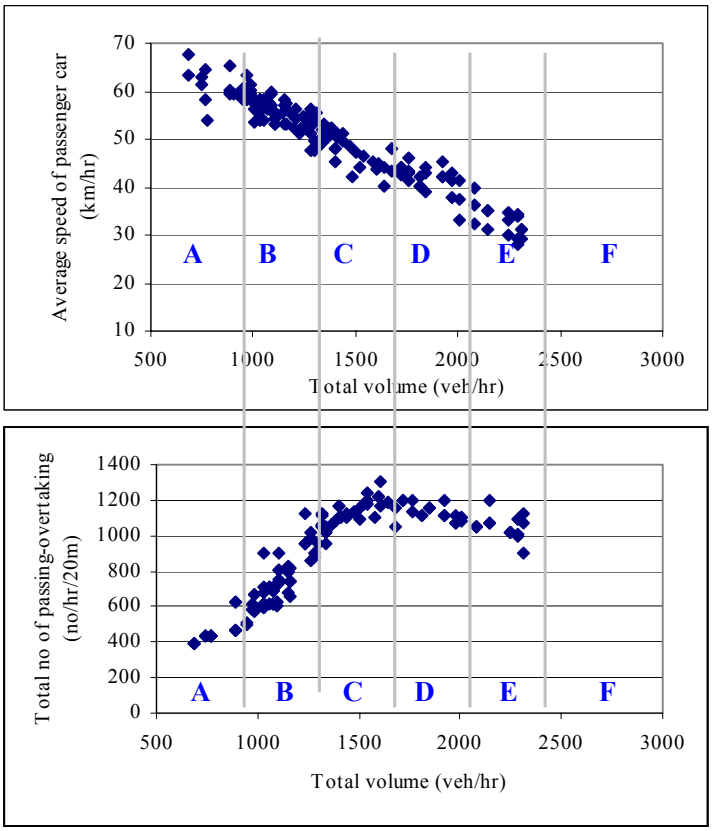

Figure 8: Level of service classification based on passings-over takings

LOS A was represented by ranges that the relationship between passing-overtaking and traffic flow rate is linear. In this situation, drivers had no restriction to pass or overtake another vehicle. This condition of flow occurred at low traffic volume. LOS B is the range that passing-overtaking still increases as volume increase and the relationship is still linear. In this condition driver faces slight to no restriction for passing or overtaking.

Table 3: Level of service classification criteria for mixed traffic flow

Level of service	Road user's understanding	Opportunity of passing-overtaking	Average speed of passenger cars (km/hr)
LOS A	Smooth flow LOS I	No restriction to P/O	> 60
LOS B		Slight restriction to P/O	55 - 60
LOS C	Partial-constraint flow LOS II	More marked restriction to P/O	45 - 55
LOS D		Little freedom to P/O	35 - 45
LOS E	Constraint flow LOS III	Very little freedom to P/O	25 – 35
LOS F	Congested flow LOS IV	No opportunity to P/O	< 25

LOS C is the range that passing-overtaking still increases as volume increase but not as linear relation. At this stage passing-overtaking curve is similar to a parabolic curve. Driver faces more marked restriction to pass or overtake other vehicles. LOS D was divided as the section that passing-overtaking start to decrease when traffic volume increases. At this level freedom of maneuver becomes more limited and little opportunity to pass or overtake exists.

The conditions that passing-overtaking decrease more rapidly even if a small change in volume increase occurs, most of vehicles lose their freedom of maneuver and have very little freedom to pass or overtake. This condition commonly defines as LOS E or capacity level. At LOS F, traffic stage change from stable flow to unstable flow. In this condition there is no opportunity for the drivers to pass or overtake.

Service levels were not only divided into six levels following the HCM but also proposed are four levels of service for road users. Because in actual conditions, drivers or road users are hardly identify levels of service in too detail. From several researches related to level of service, most of the authors presented that the road users hardly perceive all six level of services as mentioned in the Highway Capacity Manual. Furthermore, most of the drivers cannot identify the differences between each level of service especially between good service and very good service. Therefore level of services for road users should be reduced. Four level of services name as LOS I, LOS II, LOS III and LOS IV based on passings-over takings and average speed of passenger cars in mixed flow conditions are proposed. These four levels of service criteria are shown in table 3.

The result can be concluded that the first level is the traffic condition at number of passing-overtaking increases. The second level is the traffic condition during the transition of passing-overtaking from increasing to decreasing. The third level is the traffic condition at passing-overtaking decreases until reach the capacity and the fourth level is the traffic condition after capacity level or after traffic stream break down. Theses four levels can be simply named as Free-flow condition, Partial-constraint flow condition, Constraint flow condition, and Congested-flow condition from the view point of road user understands.

9. CONCLUSIONS

Levels of service criteria are important factors in highway design. Highway design engineers have to follow the levels of service criteria to determine the number of lanes and other geometry to suit with predicted traffic volume. Since new levels of service criteria are proposed that use different parameters, some steps in highway design procedures should be modified. Engineers have to calculate passing-overtaking from the projected traffic volume, and then use these values in the highway design process. A model of passings-over takings in terms of total traffic volume and percentage of rickshaws is presented which is applicable to urban undivided streets with high proportions of rickshaws. Effects of non-motorized vehicles (rickshaws) on passings-over takings also presented. The results suggest that rickshaws have an adverse effect on the passings-over takings phenomenon.

This paper has attempted to provide a classification of levels of service for urban heterogeneous traffic condition. The Level of Service (LOS) is a composite of several operating characteristics that are supposed to measure the quality of service as perceived by the road users at different flow levels. The operating characteristics considered to define the level of service are: the total number of passings-over takings (no/hr/20m) and the average speed of passenger cars (km/hr). Based on the observed data the levels of service are classified into four groups; LOS I (Free-flow condition), LOS II (Partial-constraint flow condition), LOS III (Constraint flow condition), and LOS IV (Congested-flow condition).

Level of service classification evolved in this study will be helpful in identifying deficiencies of an urban street system and to plan for alternative improvement measures to attain a desired level of service. The passing-overtaking model that is developed in this study is applicable only for undivided urban streets with high percentage of rickshaws. Further comprehensive studies required for developing a passing-overtaking model suitable for all proportions of non-motorized vehicles.

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