International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 11, November-2014

Speed Flow Model on Undivided Rural National Highway

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***Abstract* - A two lane two-way undivided road is a common facility in both urban and rural settings in India. In spite of this fact, the research available on operation of these types of facilities is very limited. Many researchers have attempted to develop speed flow relationship in homogeneous traffic condition but studies on heterogeneous undivided two lane two-way traffic conditions are quite limited. Heterogeneous traffic condition is characterized by lack of lane discipline and wide variation in static and dynamic characteristics of vehicles sharing common road space. Hence it is very difficult to study the traffic flow behavior in heterogeneous traffic conditions. This work aims to study the traffic flow characteristics on two lane two way undivided roads under heterogeneous traffic environment. The speed of each category of vehicles is expressed in terms of total flow, class-wise flow and opposing flow for different road way width. The models were developed using empirical data collected over different stretches of NH 183. Multiclass linear regression models of speed flow relationships at mid-block sections are developed by using SYSTAT software. Three different stretches having different roadway width are considered. Class wise speed and flow were measured using radar speed meter and video recording. It has been observed from the study that heavy vehicles significantly influence the speed of every class of vehicle, due to their variation in operational characteristics. As the roads width increases speed of vehicles also increases. Both BPR and linear regression model perform well with total volume in PCU as the independent variable. It was observed that MAPE value of all classes is below 10%. The qualities of service for each class of vehicles are different for flow and roadway condition.**

Keywords—: Speed -flow relationship, undivided roads, SYSTAT, Quality of service

INTRODUCTION

Heterogeneous traffic prevails in India. Heterogeneous traffic comprises of different classes of vehicles with varying static and dynamic characteristics like car, truck, bus, scooter, auto etc. All these vehicles share the same road space without following lane discipline. Therefore to model the traffic flow behavior in heterogeneous traffic is very difficult. Several speed flow models are available for homogeneous and heterogeneous traffic conditions. Single class speed flow model is not sufficient for explaining the traffic performance in Indian condition. A multiclass speed flow model is desired for explaining the heterogeneous traffic condition. Class wise vehicle speed can be expressed in terms of volumes of individual vehicles. The speed of vehicle is influenced by the flow of vehicle in the same and opposite direction. In heterogeneous traffic condition the mean speed is influenced by the width of the roadway. A two lane two- way undivided road is a ubiquitous feature in any city roadway in India and

in-spite of this fact the research available on operation of these types of the facilities are very limited.. Hence the dissertation deals with the study of the traffic flow in two lanes two way undivided roads. Study also aims to develop a multiclass speed versus multiclass flow models in undivided road section in NH 183 as they account for the varying static and dynamic characteristics of different vehicles in a mixed traffic scenario. This study also includes the effect of the roadway width on speed flow model. The multiclass speed flow relationship developed would have larger application in traffic engineering as they can be used to calculate the speed for a given traffic volume and composition. Also it can predict the changes in speed of an individual vehicle due to the presence of other vehicles in the traffic stream and perform the quality of service analysis.

LITERATURE SURVEY

A lot of studies were conducted on speed flow relationship in homogeneous and heterogeneous traffic conditions. Lum et al (1998) studied arterial roads in Singapore in heterogeneous condition and expressed speed flow relationship in arterial roads using travel time and volume as the variables. Chandra et al (2003) explained capacity of a two lane road under heterogeneous traffic condition with the effect of lane width. Minh et al (2005) studied the motorcycle behavior in undivided roads and developed a speed flow relation in heterogeneous conditions by converting all vehicle classes in to a common unit called motor cycle common unit. Pratin et al (2006) studied the speed distribution in two lane divided roads in India and observed that proportion of slow moving vehicle does not influence the speed distribution curve. Dowling et al (2006) studied speed flow relationship in capacity and congested condition in divided roads and developed an improved field calibrated speed flow equation for predicting the speed of traffic. Basu et al (2006) used artificial network approach to model traffic stream speed in a heterogeneous traffic condition. Speed is expressed in terms of volume and composition of different vehicle. Scot and Eric (2010) considered both geometric design and traffic flow parameters in simultaneous equation framework to model the mean operating speed on a rural two lane divided highways in

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heterogeneous traffic condition and expressed class wise speed as a function of traffic volume, traffic composition, road width and road length. Gao and Zhou (2010) studied few Chinese highways an d expressed average speed as a function of overtaking ratio, acceleration noise and total flow rate. Sharma et al (2011) studied the behavior of heterogeneous mix of vehicles on undivided two lane road facility and expressed as a function of headway and flow. Dhanmaniya and Chandra (2013) studied different arterial roads in India and expressed class wise speed as function class wise densities. Thomas et al (2011) developed a multiclass speed flow model for vehicle in three lane two way undivided road in the city of Chennai. The speed of each category of vehicle is expressed in terms of total flow, class wise total flow and opposing flow.

Review of the literature shows that several speed models have been prepared for homogenous and heterogeneous traffic condition. In which single class speed flow model is abundant. Multiclass speed flow model is very limited. Most of the studies are for divided roads. The studies for undivided roads are very limited hence this paper aims to develop a multiclass speed flow model on undivided rural national highway and also study the effects of road width on speeds of different classes of vehicles on undivided roads.

DATA COLLECTION

Field data for the study were collected at three stretches in NH 183. All locations were two lane undivided roads without median and different roadway width with no gradient and curvature. The basic consideration in selection of a section is that it should be free from the effect of intersection, bus stops, parked vehicle, curvature, gradient and town. Traffic studies were planned to determine the traffic volume composition of traffic stream and the speed of different type of vehicle at selected locations. Alampally, Kothala and Kanijirapally are the stretches selected for the study. Each has different roadway width of 5.5 m, 6.5 m and 7.7 m respectively. Traffic flow was measured using video graphic technique. The data were collected through video camera at each section for 5 days during 7 am to 12 pm and 2 pm to 7 pm. The video camera was mounted on the stand and placed on the side of the road so as to cover the flow in both directions. The recorded video was replayed and the classified count was taken for two directions in 15 min interval. Radar speed meter was used for collecting the speed of individual vehicle. Speed measurement was taken for both the direction. Average speed of 20 observations of each category of vehicle in 15 min interval was taken as the speed value. This forms the basis of speed flow analysis.

MODEL FORMULATION

Linear regression and BPR model were used to develop the speed flow model. Class wise speed was taken as the dependent variable and total flow, class wise total flow and class wise and direction wise flows were taken as the independent variables.

MODEL ANALYSIS

In the Alampally stretch which had narrow width. It was observed that LMV and HMV influenced the speed of all categories of vehicle. This attributed to the fact that LMV and HMV tended to stay in their own lane given their bigger size and lesser maneuvering capacities; and affected the cars either way i.e., if they were in the same lane or in the opposite lane. Speed of vehicle was more influenced by the flow in the opposite direction. The speed of small size vehicle was more influenced by the volume of large size vehicle. Car and two wheeler had maximum free flow speed of 58.5 km/hr in the Alampally stretch. Two wheeler and car constituted the major component in the stretch hence stream speed was same as that of the speed of two wheeler and car. In Kothala stretch the speed of each category of vehicle was influenced by the volume of car in the same direction and opposite direction. This can be reasoned by the fact that cars have the ability to utilize the smaller gaps in the stream and due to this they tended to take opposite lane more frequently disturbing the speed of other vehicles. Large size of vehicle also influenced the speed of all category of vehicle. The flow of car in the same direction and opposite direction recurrently affected the speed of fast moving vehicles. The flow of HMV in the opposite direction was mostly influenced by the speed of heavy vehicles. In Kanijirapally stretch Volume of car in the opposite direction and volume of HMV in the same direction influenced the speed of all category of vehicle. This is because of the fact that cars have the ability to utilize the smaller gaps in the stream and tended to take opposite lane more frequently and this ability of car disturbed the speeds of other vehicles. Large size of HMV and LMV prevented the possibility of overtaking. Sample of model developed is shown in table1.

TABLE 1. MODEL FOR 5.5M WIDTH

class of vehicle	2W	3W	CAR	LMV	HMV	STRM SPEED
n	140	140	140	140	140	140
constant	58.2	47.8	58.5	47	53	57
q_1		-0.010				
q_2						-0.026
q_4	-0.062		-0.082		-0.040	-0.073
q_5	-0.040	-0.035	-0.062			-0.038
q_{11}				-0.005		
q_{31}						
q_{41}						
q_{51}				-0.05		
q_{12}	-		-0.02	-0.02	-0.018	-0.023

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	0.028					
q_{22}	-0.046	-0.06			-0.019	
q_{32}	-0.035	-0.024	-0.030	-0.026	-0.020	-0.028
q_{42}		-0.037		-0.034		
q_{52}				-0.032	-0.040	
R^2	0.717	0.647	0.680	0.627	0.5	0.767

Kanijirapally stretch had maximum free flow speed compared to other two stretches in the study. In the stretch, Car and HMV had the free flow speed of 72 km/hr.

To compare the MAPE value of the entire road stretch & each single stretch, separate BPR model was developed. The results are shown below in table 2.

TABLE 2. MAPE VALUE

Class of vehicle	mape (%)			
	Overall model	alampally	kothala	kanjirapally
2W	13.04	3.57	3.57	2.86
3W	12.27	5.48	4.03	3.10
CAR	17.187	3.57	4.90	2.23
LMV	13.388	4.76	3.85	3.93
HMV	18.657	2.26	4.61	2.58

It can be concluded that there is a significant difference in the MAPE value between overall model and model for individual stretch. The MAPE value of entire road stretch is greater than the MAPE value of individual road stretch model for all classes of vehicle. It is clear that the model developed for individual stretch perform well than the overall model for the entire stretch selected for the study.

EFFECT OF ROADWAY WIDTH ON THE SPEED OF DIFFERENT CLASSES OF VEHICLE

The speed of a vehicle will depend on the roadway width. When the volume of a traffic stream is high then roadway width will significantly influence the speed of the vehicle. The effect of roadway width on speed of different classes of vehicle was studied in this section. For the study the vehicles had been divided in to 2 classes, large vehicle and small vehicle. Large vehicles include HMV, LMV and small vehicles include 2w, 3w and car. Models were calibrated for the three stretches which have different roadway width, 5.5m, 6.5m and 7.7m. In the three stretches considered for the study two-wheeler speed was mainly influenced by the volume of large vehicle in the opposite direction. The coefficient decreased from -0.078 to -0.029 when the roadway width increased from 5.5 to 7.7 m. The percentage reduction was 55% in the case of Kothala stretch. The coefficient of large vehicle in the same direction also displayed the same trend. Coefficient reduced its value by 56% when the roadway width increased from 5.5m to 7.7m. Three wheeler speeds were mainly governed by the volume of heavy vehicles. The coefficient of the variables reduced its value when the roadway width increased. The effect of volume of large vehicle in the opposite direction decreased its value by 10% with an increase in the roadway width from 5.5m to 6.5m. Speed of car was mainly influenced by the volume of heavy vehicles. The coefficient of large vehicle in the opposite direction decreased from -0.054 to -0.031. A similar trend was seen in case of other variables also. The influence of large vehicle in the same direction decreased the speed of LMV very significantly. The coefficient was reduced to 81.5% in Alampally stretch. Speed of HMV was mainly influenced by the volume of large vehicles in the stream. The coefficient value was reduced when the roadway width increased. In the Alampally stretch coefficients of heavy vehicles with higher value of coefficients decreased its value to 50 – 30% compared to Kothala and Kanijirapally stretch. When the roadway width increased the coefficient of the variables reduced its value. It can be concluded that large roadway width help the vehicles to achieve more speed.

QUALITY OF SERVICE

The quality of a traffic stream was evaluated based on speed maintained by the traffic stream. In a heterogeneous traffic condition the quality of service experienced by each class of vehicle is different in the same stream. It can be evaluated by measuring the speed reduction from free flow speed with the speed at different volume condition for each category of vehicle. Reduction in speed is taken as the assessment of quality of service. Hence based on the reduction in the speed certain quality of service is assumed for the vehicle from A to F. as shown in Table 3.

TABLE 3. QUALITY OF SERVICE BASED ON SPEED

Speed reduction	**<10%**	**10% to 20%**	**20% to 30%**	**30% to 40%**	**40% to 50%**	**>40%**
Quality of service	A	B	C	D	E	F

Quality of service for different roadwidth is shown in table 4,5,6

TABLE 4. QUALITY OF SERVICE FOR 5.5M WIDTH

Class of vehicle	**2W**	**3W**	**CAR**	**LMV**	**HMV**
Median volume	B	B	B	B	C
Peak volume	D	C	D	C	D

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TABLE 5. QUALITY OF SERVICE FOR 6.5M WIDTH

Class of vehicle	2W	3W	CAR	LMV	HMV
Median volume	B	C	B	C	C
Peak volume	D	D	D	D	D

TABLE 6. QUALITY OF SERVICE FOR 7.7M WIDTH

Class of vehicle	2W	3W	CAR	LMV	HMV
Median volume	B	C	B	C	C
Peak volume	D	D	D	D	D

Qualities of service enjoyed by different vehicles in the same traffic stream are different. As volume increases from medium to high level, cars and two wheelers suffer the greatest loss of quality of service from B to D. This is due to their free speed being higher than other vehicle classes. There is a significant amount of speed reduction from 20 % to 40 % of buses also, as the traffic volume increases.

CONCLUSIONS

•For undivided roads, among the linear models a combination of class wise and class direction wise models performed the best fit for speed of all vehicle classes in the three stretches with MAPE value less than 10%.

•In the Alampally stretch where the width is the least, volume of large vehicles influences the speed of all categories of vehicles. This attributed to the fact that LMV and HMV tend to stay in their own lane given their bigger size and lesser maneuvering capacities and affect other vehicles irrespective of if they are in the same lane or in the opposite. On narrow road, (Alampally stretch) the flow in the opposite direction is more critical than volume in the same direction, influencing the speed of all categories of vehicles.

•On medium roadway width, (Kothala stretch) flow of car in the same direction and flow car in the opposite direction mostly influences the speed of fast moving vehicles. In Kanijirapally stretch which have more width than other two stretches Volume of car in the opposite direction and volume of HMV in the same direction influences the speed of all categories of vehicle.

•Road way width has a significant influence on the speed of vehicles. As the width increases the free flow speeds and coefficients of class volumes decrease in value; this implies that as the roadway increases speed of vehicle also increases.

•The models developed for individual stretch perform well than the overall model for the entire stretch. As volume increases from medium to high level, cars and two wheelers suffer the greatest loss of quality of service from B to D. This is due to their free speed being higher than other vehicle classes. There is a significant amount of speed reduction from 20 % to 40 % of buses also, as the traffic volume increases.

LIMITATIONS AND FUTURE SCOPE

The main limitation of the study is that the straight sections selected for the data collection were too short. Due to the limited length, the study of interaction between vehicles cannot be properly carried out. The research can be extended by conducting simulation studies using appropriate softwares like VISSIM. The model can be made more reliable by considering the influence of geometric features on speed flow relationships.

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