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Driver Behavioral Analysis in Heterogeneous Traffic Conditions

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Abstract: Heterogeneous traffic conditions in the developing world is characterized by the presence of different vehicle types and weak lane discipline. Different vehicle types have varying manoeuvring capabilities which lead to vehicle-type dependent longitudinal and lateral movement driving behaviors. Poor or no lane discipline leads to frequent movement of drivers within and across lanes or all along the road width. However, existing driver behavioural studies seem to place less consideration in understanding these typical driving behaviors. Thus, a comprehensive driver behavioural analysis is conducted and presented in this paper using a trajectory data of four vehicle types obtained from a purely heterogeneous traffic stream in India. Wide variations in driver behavior characteristics were observed for different vehicle type drivers, especially that of motorbikes. The results indicate better prediction of the driver behavior and thus more realistic representation in the mixed traffic systems. The practical applicability of this analysis comes in developing vehicle-type dependent driver behavioural models which form the core of any heterogeneous traffic simulator.

Keywords: driver behaviour, heterogeneous traffic, lateral movement,

1. INTRODUCTION

In homogenous traffic conditions the conventional car following and lane changing models assume uniformity with vehicle type and drivers strictly follow lane discipline. Unlike homogenous traffic conditions, several kinds of motorised and non-motorised vehicles form a part of heterogeneous traffic stream with the drivers negligent towards lane discipline. In absence of lane discipline the behavior of the driver plays a very crucial role in the traffic flow modelling either at microscopic level or macroscopic level. As a matter of fact, driver behavior is too stochastic in nature which varies with factors like age, gender, emotional aspect and medical conditions of the driver (Summala, 2000). Recent studies propose that vehicle type can be used as a classifier for studying nature of driver behavior. In a mixed traffic scenario modeling, calibration and validation of driving behavior have mostly been based on macroscopic flow characteristics, such as flows, speeds and densities (Arasan and Koshy 2005, Arasan and

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Vedagiri 2010, Asaithambi et al. 2012, Mathew and Radhakrishnan 2010). Few studies utilized trajectory data, but these are often small samples collected for a specific study. Kanagaraj et al. (2010) collected the trajectories of the subject and lead and lag vehicles in a merging situation. Sangole and Patil (2014) selectively collected trajectories for the involved vehicles in group gap acceptance behavior at uncontrolled intersection. Usually, vehicle trajectory data are not publicly available in the context of mixed traffic. This may, to a large extent, be due to the difficulty and high cost involved in data collection and extraction, and the technical complexities associated with having a wide mix of vehicles types with varying physical dimensions and dynamics characteristics (speed and acceleration capabilities) and non-lanes based movements (Munigety et al. 2014). Thus, a comprehensive driver behavioral analysis is conducted and presented in this paper using the half-an-hour trajectory data of four vehicle types including motorbikes, auto-rickshaws, passenger cars and, heavy vehicles obtained from a purely heterogeneous traffic stream in India.

This paper aims to obtain the trajectory data of vehicles from a non-lane disciplined traffic stream in order to understand longitudinal as well as lateral movement behaviours of drivers with a major focus over lateral movements, their frequency and durations for different vehicle types.

2. DATA COLLECTION

No data collection was done instead the data collected for Kanagaraj et al. (2015) study, which is publically available for further studies, has been utilized for this study. The video data captures a 245m long uninterrupted stretch in Chennai, India for a duration of 30 minutes (2:45 PM to 3:15 PM). The stretch being recorded is a six lane separated arterial having purely heterogeneous traffic conditions. Data smoothening had been done over trajectories extracted, which is an important step to obtain internal consistency among the trajectories (Ossen et al., 2008; Thiemann et al., 2008; Punzo et al., 2011). Several entities such as vehicle type, time (sec), vehicle length (m) and width (m), longitudinal distance (m), longitudinal speed (m/sec), longitudinal acceleration (m/sec^2), lateral distance (m), lateral speed (m/sec) and lateral acceleration (m/sec^2) are listed in the data at resolution of half second.

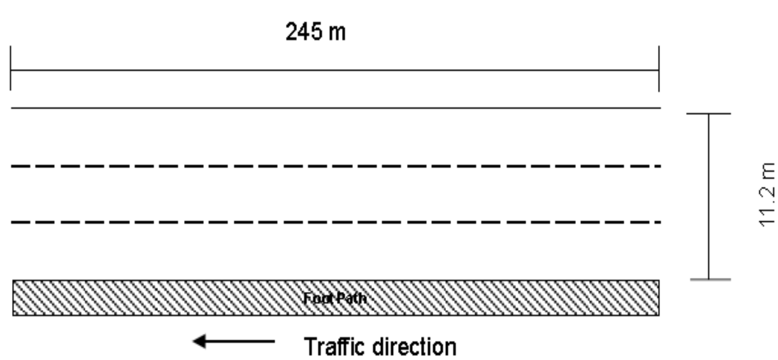

Figure 1 Data collection site Kanagaraj et al. (2015)

3. DATA PROCESSING

The vehicle trajectories were processed to obtain various driver behavioral characteristics like speed and acceleration in the longitudinal as well as in lateral directions, number of movements carried out in lateral direction, and duration of such lateral movements. A generalised computer program in C++ language was developed in order to segregate and analyse the huge raw trajectory data based on different vehicle types. The code was also used to determine the number of lateral movements made by a vehicle along with the direction (left/right) and durations for such lateral movements. As a part of logic behind the code, a vehicle is said to have undergone a lateral movement if cumulative difference of lateral coordinates exceeds a lateral shift threshold value. In this study lateral movement has been defined as threshold lateral shift of 3.5 metres i.e. a lane width. The developed code has the flexibility of user defined/entered value of lateral shift threshold. Following is the algorithm for C++ code developed to process the raw data file:

start
    read the trajectory data file
    for all entries
        get the vehicle number and vehicle type
        get the time
            sort according to the vehicle number, vehicle type and time
    end for
    for all vehicle types
        read the lateral shift threshold values
    for all vehicle types
        get cumulative differences of lateral coordinates
            if cumulative difference > threshold value and >0; count as right movement
            if cumulative difference > threshold value and <0; count as left movement
            get the corresponding lateral movement durations
    end for
end

4. ANALYSIS AND RESULT

4.1 Descriptive Statistics

Trajectories of 3005 vehicles were extracted at a resolution of 0.5s generating a total of 111,629 observations. The dataset comprised of 56.4% motorbikes (two wheel motorized vehicle, MB), 12.2% auto rickshaws (three wheel motorized passenger vehicles, AUTO), 26.4% passenger cars (PC) and rest 4.8% included heavy vehicles (HV) like buses, light and heavy trucks. It can be clearly seen in fig. 2 that sample size of heavy vehicle is less as compared to other types of vehicles. The traffic flow during the observed period was found to be 6010 veh/hr.

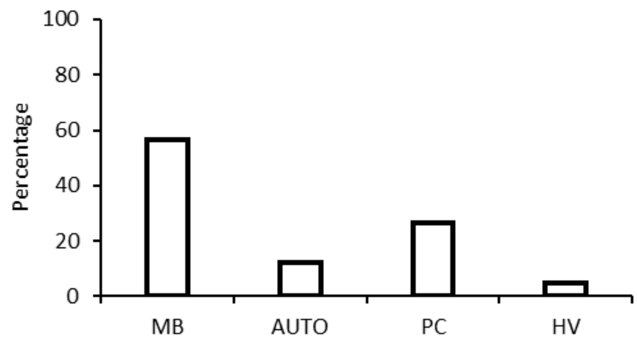

Figure 2. Traffic composition

4.2 Flow Behaviour

Following vehicular parameters were observed and studied in order to have a better understanding of driver behavioural characteristics.

4.2.1 Longitudinal speed

Since the data collection site was an uninterrupted section, therefore traffic stream can be assumed to be in free flow regime. Under such regime the median longitudinal speed of all vehicles must be close to each other. This can be noted from the box plot shown in fig 3. Clearly longitudinal speed of motorbikes has maximum variation (max- 15.22 m/s, min- 0.02 m/s) due to higher manoeuvrability and small size as compared to other vehicle types (Munigety 2018). ANOVA tests were conducted over median longitudinal speed values of different vehicle types. Test result show that differences in vehicle types is statistically significant (p- value: 0.0)

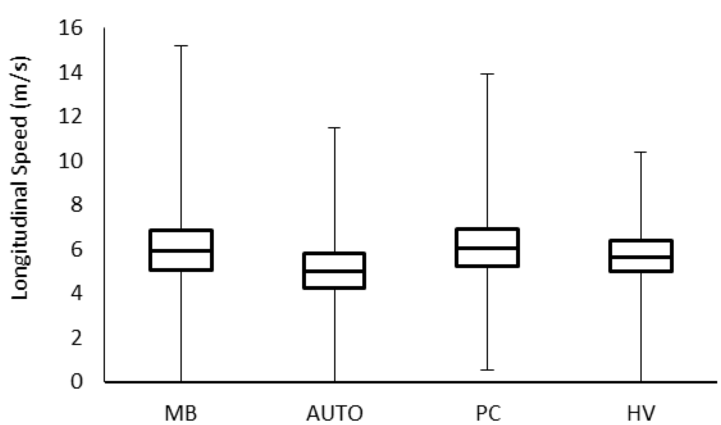

Figure 3 Longitudinal Speed

4.2.2 Longitudinal acceleration and deceleration

Acceleration and deceleration characteristics change with vehicle type. Motorbikes, being light weighted and small sized can attain higher acceleration values quickly in order to accept every gap available. The variation in longitudinal acceleration and deceleration with different vehicle types reflects the aggressiveness in the driver behaviour which can be clearly observed in fig 4 and fig 5. Variation (max- 14.63 m/s^2, min- 0.0 m/s^2) as well as median longitudinal acceleration values (3.59 m/s^2) of motorbikes is much higher as compared to other vehicle types. This is in support of the argument that motorbike driver behaviour is aggressive in case of longitudinal acceleration. Unlike acceleration, longitudinal deceleration values of different vehicle type assume close values (0.5 m/s^2, 0.43 m/s^2, 0.41 m/s^2 and 0.43 m/s^2). Therefore drivers of different vehicle behave in same manner if it is the case of longitudinal deceleration. ANOVA tests were conducted over median values of longitudinal acceleration and deceleration for different vehicle types. Test result show that differences in vehicle types is statistically significant (p- value: 1.62E-12 and 5.0E-59)

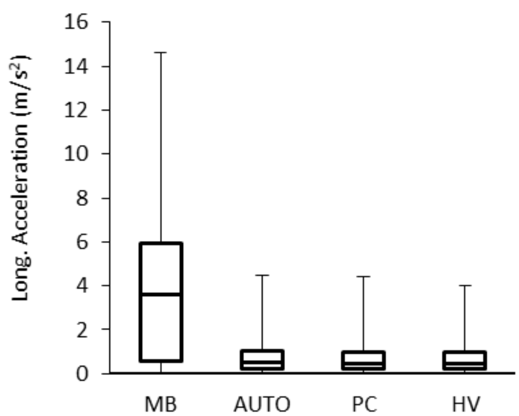

Figure 4. Longitudinal Acceleration

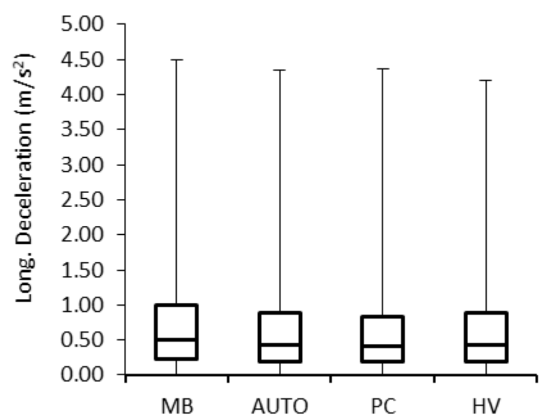

Figure 5. Longitudinal Deceleration

4.2.3 Lateral speed

In absence of strict lane discipline, lateral movement of vehicles in available gaps is unavoidable. Lateral speeds for different vehicle types has been plotted in fig 6. The total variation in lateral speeds of motorbikes is highest and is lowest in case of heavy vehicles. Heavy vehicle drivers tend to restrict their lateral speeds due to poor manoeuvrability and large size of trucks and buses whereas motorbike drivers move laterally at higher speeds. ANOVA tests were conducted over median lateral speed values of different vehicle types. Test result show that differences in vehicle types is statistically significant (p- value: 0.0) hence neglecting the null hypothesis.

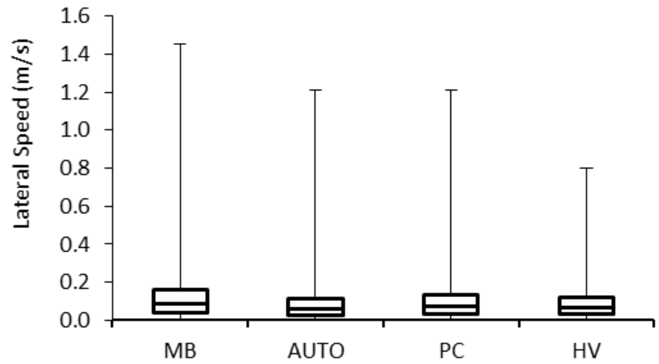

Figure 6. Lateral Speed

4.2.4 Lateral acceleration and deceleration

The lateral acceleration and deceleration for different vehicle types is similar as shown in fig 7 and fig 8. Though the lateral speeds are higher for motorbikes and lower for heavy vehicles but rate of change of this speed is similar for all vehicle types.

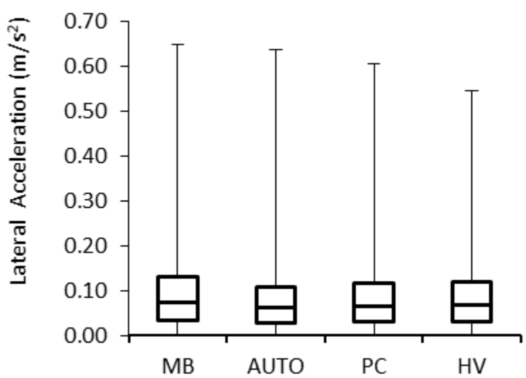

Figure 7 Lateral Acceleration

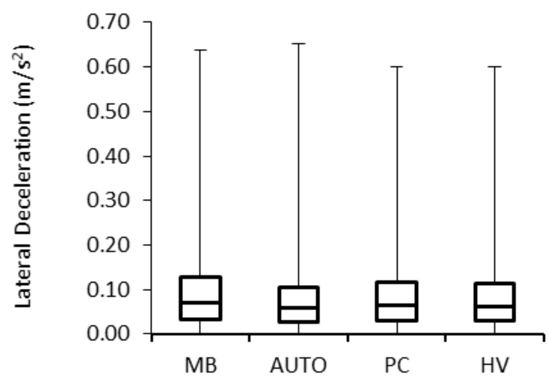

Figure 8 Lateral Deceleration

4.2.5 Lateral position

The data collected had the trajectories for each vehicle entering the study section. These trajectories included longitudinal and lateral position of the vehicle. Lateral position of a vehicle was measured from the left most side of roadway to the centre of vehicle. Though the complete width of road is used by each different vehicle type, but the median lateral position of passenger cars is farthest (7.34 m) from the left shoulder. Passenger cars mostly occupy farthest lane in order to easily perform overtaking manoeuvres while motorbikes and auto-rickshaws occupy nearest lane.

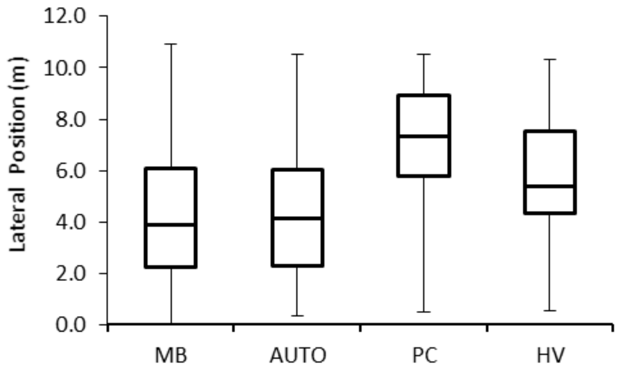

Figure 9 Lateral Position

4.2.6 Frequency of lateral movement

In order to determine number of lateral movements made by a vehicle, a threshold value of lateral shift was assumed to be 3.5 metres (standard single lane width). If cumulative lateral shift made by a vehicle exceeds this threshold value, then the vehicle is said to have a lateral movement. This logic was implemented using the C++ program developed and results can be seen in fig 10. Motorbikes have undergone maximum lateral movements due to obvious reasons of high manoeuvrability. Therefore motorbike drivers can be said to be most indiscipline regarding lane following in heterogeneous traffic conditions.

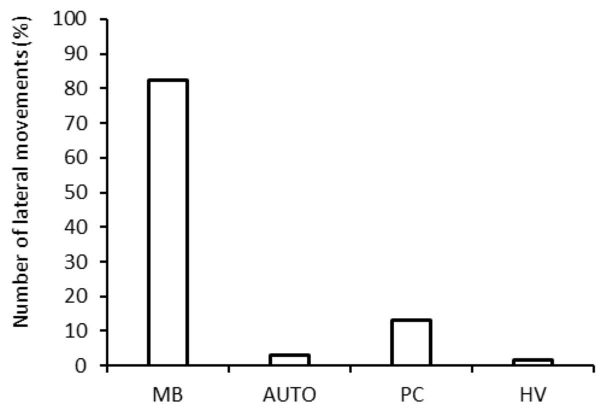

Figure 10 Frequency of lateral movements

4.2.7 Lateral movement duration

The duration for lateral movement is the time difference between start and end of a lateral movement in a particular direction (left or right) such that cumulative lateral displacement is more than threshold lateral shift value as specified. Variation in these durations is maximum for passenger cars (max- 11.5 sec, min- 0.5 sec) as this is subjected to the availability of sufficient gaps for a car to move laterally. Unlike cars, motorbikes do not require larger gaps for manoeuvring therefore their median lateral movement duration is least among all vehicle types.

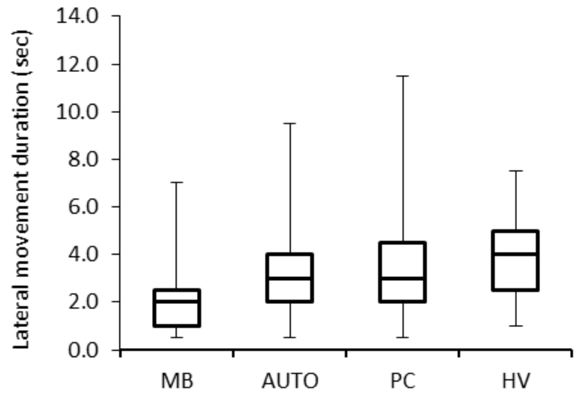

Figure 11 Lateral movement durations

5. CONCLUSIONS

The main objective of this paper was to study behavioral characteristics of drivers for different vehicle type while focusing over lateral movement behaviors. Wide variations in these characteristics were observed for different vehicle type drivers, especially that of motorbikes. The average speed and acceleration values of motorbikes were found to be quite different from other vehicle types. Moreover, the frequency of their lateral movements was quite higher when compared to other vehicle types. On the other hand, their lateral movement durations were significantly lesser than the other vehicle types. These typical behaviors can be attributed to the small size of motorbikes when compared to the other vehicle types allowing its drivers to maneuver quickly in both the longitudinal and lateral directions. To summarize, analysis of various vehicular maneuvering characteristics revealed the influence of ‘vehicle-type’ and ‘weak lane discipline’ on the longitudinal and lateral movement driving behaviors in heterogeneous traffic conditions. The practical applicability of this analysis comes in developing vehicle-type dependent driver behavioral models which form the core of any heterogeneous traffic simulator. Most of the simulators only consider car following behaviour in driving behaviour parameter. But the longitudinal movement models should focus not only on car following, but also consider other situations in which a vehicle does not strictly follow another one. More attention should be given to lateral movement especially for motorized two wheeler.

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7. APPENDIX

Table: Sample of the trajectory dataset sorted from the raw data

Vehicle Number	Vehicle Type	Time (sec)	Length (m)	Width (m)	Long. Distance (m)	Long. Speed (m/sec)	Long. Acc. (m/sec2)	Lat. Distance (m)	Lat. Speed (m/sec)	Lat. Acc. (m/sec2)
1	1	12.00	1.80	0.60	116.97	6.87	-0.09	2.81	-0.15	-0.16
2	1	12.00	1.80	0.60	23.46	5.50	0.38	2.49	0.22	-0.35
1	1	12.50	1.80	0.60	123.43	6.79	-0.18	2.59	-0.14	0.16
2	1	12.50	1.80	0.60	28.62	5.47	0.83	2.50	-0.04	-0.12
1	1	13.00	1.80	0.60	129.82	6.01	-1.06	2.55	-0.01	0.11
2	1	13.00	1.80	0.60	34.72	5.45	-2.22	2.41	0.04	0.26
3	1	13.00	1.80	0.60	33.53	10.34	-0.91	4.97	0.04	0.10
1	1	13.50	1.80	0.60	135.17	5.45	-0.48	2.58	0.07	0.07
2	1	13.50	1.80	0.60	38.52	3.81	-0.16	2.59	0.26	0.17
3	1	13.50	1.80	0.60	43.14	8.84	-2.65	5.06	0.05	-0.07