Gap Acceptance Behavior of Drivers at T-Intersections

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***Abstract*— Unsignalised intersections are one of the most hazardous locations on highways. Unsignalised intersections are usually controlled with stop or yield sign in developing countries, but in India, signs usually do not work and such intersections are treated as uncontrolled intersections. The main focus of this study is to develop a gap acceptance model for different classes of vehicle at three legged intersections in Kerala. Two T intersections were selected, one at Kottayam and another at Ernakulam. The vehicular interactions at Unsignalised intersections are complex and each driver has to make individual decisions about when, where and how to complete the merging and crossing manoeuvres. This study systematically analyses the right turning behaviour of vehicles at uncontrolled intersections. Data collection for the gap acceptance study is carried out using video recording. The parameters extracted through video recording are waiting time, approximate age of driver and gender of driver. Multiple linear regression models were developed using the collected data using SYSTAT for different classes of vehicles. For calibration of models, 70% of the collected data were utilized and the remaining 30% was used for model validation. Critical gap is an important parameter of gap acceptance behaviour. By plotting accepted gap and rejected gap, critical gap estimation was done. A hypothetical testing is used to compare the gap acceptance characteristics by different vehicle classes, different age groups and also based on gender.**

Keywords: Unsignalised intersections, gap acceptance, critical gap, SYSTAT

INTRODUCTION

Unsignalised intersections are one of the most hazardous locations on highways. The behavior of drivers at these locations is quite complex and risky. Gap is the time or space headway two successive vehicles in a particular traffic stream. When the distance between two vehicles is considered, gap can be expressed in terms of space. When time elapsed between arrivals of vehicles is considered, gap can be expressed in terms of time. Gap acceptance can be defined as the process through which the driver has to evaluate the gaps and judges whether the gaps are sufficient or not for merging or crossing. Critical gap is an important parameter in gap acceptance behaviour. For a consistent driver the value of critical gap lies between the largest rejected gap and one finally accepted. Estimation of critical gap under heterogeneous traffic conditions is more complex than that under homogenous conditions. The different types of vehicles have different operational characteristics like speed, dimensions, power weight ratio and response to presence of vehicles in traffic stream. All these vehicles share the same roadway which makes the gap acceptance more complex due to lack of lane discipline, complex queue formation, non adherence of priority rules of movements and also due to substantial speed variation among vehicle types. In this study a model is formulated considering the approximate age and gender of drivers and also incorporates the influence of waiting time on gap acceptance. Here a classified gap acceptance analysis is carried out. A comparison of gap acceptance by male and female drivers and based on age groups and also based on vehicle classification is carried out by hypothesis testing. The gap acceptance concept is very important because it is widely used in the determination of the capacity, delay and level of service at various transportation facilities. In dangerous situations such as unsignalised intersections, ramp merging points, U turns and two way two lane sections where passing is permitted, gap acceptance concept is used for safety evaluation. Recently, gap acceptance has been used to study simulation models and intelligent transportation systems. Due to vehicle interaction complexity, the mathematical approaches to model driver's gap acceptance are limited also.

LITERATRE REVIEW

Large number of literatures has been available regarding gap acceptance studies but majority of them are confined to homogenous traffic conditions. Rui-junGew *et al* (2011) studied the gap acceptance at priority controlled intersections. From the results it was observed that the exponential model of rejected proportion is more practical than linear model and the capacity functions were improved by using accepted proportion function. Ashalatha *et al* (2011) conducted a study on critical gap through clearing behaviour of drivers at unsignalised intersections under mixed traffic condition. The data collection was done at four three legged right angled intersection i.e., T intersection in urban areas of Hyderabad in Andhra Pradesh and Thiruvananthapuram in the state of Kerala. The intersection selected was similar in geometry and video recording technique was used for data collection. The method is simple and easy to implement and is applicable to traffic conditions and can be used for mixed traffic conditions also. Elayan *et al* (2013) studied the gap acceptance behaviour at U turn median openings in Jordan. Two models were developed, the first model developed estimated the time gap accepted by drivers and second model estimated the turning choice function. Accepting time gap estimation is done using regression model. A binary logistic model was developed to calculate the turning choice model. Tupper *et al* has (2011) has conducted studies on factors that influences the divers gap acceptance behaviour. The study shows that gap acceptance behaviour had clear impact on safety. From the study they observed that different age groups and gender groups have different gap acceptance behaviours. Sangole *et al* (2011) conducted a study on gap accepting modelling behaviour of two wheelers at uncontrolled T intersection using Neuro Fuzzy technique. Modelling of right turning vehicle is conducted. MATLAB is used to develop adaptive neuro fuzzy interface system which helps to find the parameters in fuzzy system that best fit data by an optimization scheme. Nabee *et al* (2011) conducted an evaluation of gap acceptance behaviour at unsignalised intersections. The variables used for study are driver's gender; driver's age, vehicle type, presence of queue behind the leading vehicle and presence of passengers in vehicles are collected. The data collection is done for different times of day i.e., the variables are collected as a function of time of day. The variation of accepted gap with waiting time is also studied. Sun Yon Hwang *et al* (2005) modelled the gap acceptance behaviour at merging section of urban freeways. In this paper discrete choice theory was used to develop gap acceptance behaviour. Even though various studies are available, the studies related to unsignalised intersections without priority which are more found in India are limited, so a comprehensive model to predict the gap acceptance behavior has yet to be developed.

DATA COLLECTION

Two intersections were considered for study, one at Kottayam and one at Ernakulum. At Kottayam, Manarcad junction was taken and at Ernakulum, hospital junction at Tripunithara near bus stand was taken. Both the intersections are three legged T intersections. Data collection was done during morning (8.30-11.30 a.m.) and evening (3.30-5p.m.) peak hours on 2014 in the month of May. Data collection was carried out for a period of two weeks.

DATA EXTRACTION

The collected data were extracted and analyzed. The recorded files were replayed on computer to extract the data of gap acceptance and rejection. The vehicles were classified into five categories, two wheelers, three wheelers, car, LMV and HMV. The gap acceptance and rejection data were extracted for these different classes of vehicle for lower priority movements i.e., right turn from minor stream to major stream. The proportion of heavy vehicles at these intersections for right turning is very less, so their gap acceptance characteristics as well as gap rejection process were not evaluated. Therefore the analysis is carried out only for car, two wheelers, three wheelers and LMV. Queuing situations were avoided during data extraction.

DATA ANALYSIS

The statistical analysis of the collected data was carried out and found that bike drivers were found to be more aggressive compared to other classes of vehicle and also younger drivers tend to accept shorter gaps. A hypothetical comparison of collected data was also carried out. From the class wise comparison it is observed that the significant difference in gap acceptance is observed only for car & bike and bike & LMV and rest of the vehicle classes does not show much difference in their time gap accepted. From the gender wise comparison it is observed that there is no significant difference between the gaps accepted by male and female drivers. From the age wise comparison it can be observed that younger drivers accept shorter gaps than middle aged and elder drivers. Hypothesis testing results are shown in table 1.

TABLE 1. HYPOTHESIS TESTING RESULTS

Type to be tested	H_o: Gaps are equal	H_o: Gaps are not equal
Bike vs. Car	Reject	Accept
Bike vs. Three wheeler	accept	Reject
Bike vs. LMV	Reject	Accept
Car vs. Three wheeler	accept	Reject
Car vs. LMV	accept	Reject
Three wheeler vs. LMV	Reject	Accept
Male vs. female	accept	Reject
Young vs. Middle	Reject	Accept
Middle vs. Elder	Accept	Reject

Critical gap is estimated by plotting accepted gap and rejected gap and is obtained as 5.1s for Tripunithura and 2.8s for Manarcad and is shown in figure 1 and figure 2.

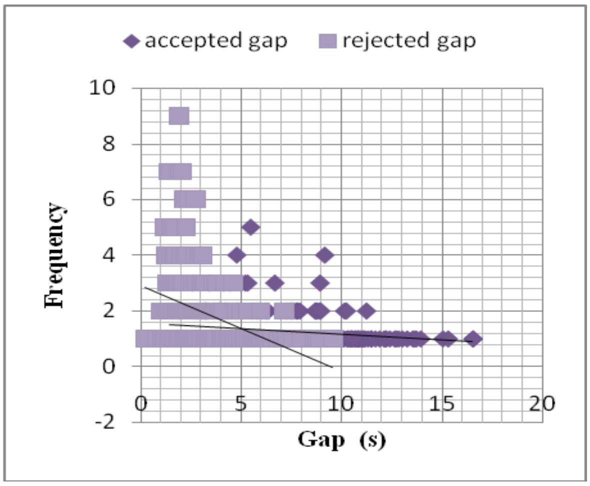

Figure1. Critical gap at Tripunithara

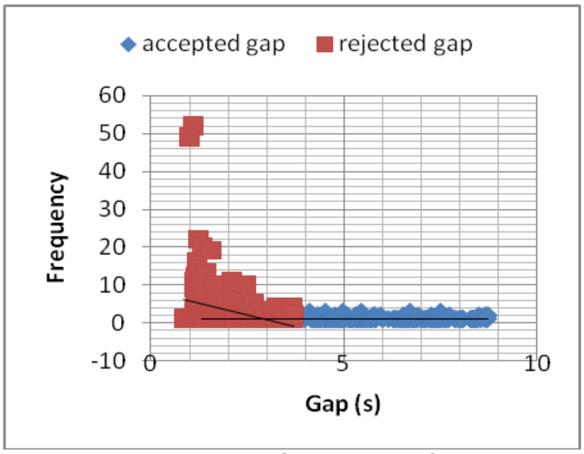

Figure2. Critical gap at Manarcad

MODEL FORMULATION

Multiple linear regression models were formulated considering accepted gap as dependent variable and waiting time before turning, age and gender as independent variables. Class wise models were developed for both intersections and also for combined model using data of two intersections. The summary of the models is shown in table 2.

TABLE 2. MODELS

Location	Class of vehicle	Model
Tripunithura	Bike	Accepted gap = 7.415-0.245 waiting time-0.952 gender+1.216 age
	Car	Accepted gap = 7.403-0.327 waiting time+1.765 gender+1.422 age
	Three wheeler	Accepted gap = 9.454-0.379 waiting time-1.732 gender+1.680 age
	LMV	Accepted gap = 11.823-0.630 waiting time-0.112 age
Manarcad	Bike	Accepted gap = 6.713-0.20 waiting time+ 0.529 age+0.321 gender
	Car	Accepted gap = 6.756-0.213 waiting time+0.218 gender+0.541 age
	Three wheeler	Accepted gap = 6.811-0.191 waiting time-0.721 gender+0.498 age
	LMV	Accepted gap = 7.679 -0.299 waiting time+0.440 age
Aggregate model	Bike	Accepted gap = 5.241-0.143waiting time+ 0.912 gender+1.708 age
	Car	Accepted gap = 6.114 -0.184 waiting time+1.328age+0.773
	Three wheeler	Accepted gap = 6.354-0.184waiting time+1.053 age+ 0.308 gender
	LMV	Accepted gap= 6.709-0.171 waiting time+1.116 age

The software used for modelling is SYSTAT. SYSTAT is statistical software used for analysis of sample data collected. SYSTAT can take data from almost any type of file and use them to generate tabulated reports, charts, and plots of distributions and trends, descriptive statistics, and conduct complex statistical analyses. In this study, the data sheets from excel is imported to SYSTAT and is used for conducting multiple linear regression analysis

MODEL VALIDATION

The collected data are classified into two sets as one set for calibration and other set for validation. 70% of the collected data is used for model calibration i.e., it is used for formulating the models of both junctions. The remaining 30% is used for model validation The expected values were calculated by substituting the values of variables in the obtained model and comparing it with observed value, mape error is obtained and was found to be within the limits.

CONCLUSION

Gap acceptance is the process that occurs when a traffic stream known as opposed flow has to cross another traffic stream known as opposing flow or merge with opposing flow. Two T-intersections were selected for study, one at Kottayam and one at Ernakulam. Detailed literature review and data collection and extraction were carried out on selected intersections. The different variables affecting the gap acceptance have been identified as waiting time before turning, approximate age of driver and gender of drivers. Multiple linear regression models were formulated for crossing gap acceptance behaviour of four different classes of vehicles at the selected intersections. SYSTAT software was used for model development. The model formulated was validated using mean absolute percentage error and was found to be within the limits. From the developed models it was observed that the waiting time shows a negative relationship with accepted gap i.e., as waiting time increases drivers tends to accept shorter gaps. The critical gap values were obtained by plotting the accepted and rejected gaps and were obtained as 5.1s for Tripunithara and 2.8s for Manarcad. From the analysis of descriptive statistics it was observed that bike drivers have a tendency to accept shorter gaps than other classes of vehicles and also younger drivers were observed to accept shorter gaps than middle and elder drivers. From hypothesis testing it was observed that the significant difference between gap acceptances was observed only for car & bike and bike & LMV among the different types of vehicle combinations and rest of vehicles does not show any significant difference in gap acceptance behaviour. From the hypothesis testing it was also observed that male and female drivers does not show any significant difference in gaps accepted and also the younger drivers have tendency to accept smaller gaps than elder drivers.

FUTURE SCOPE

In this study a multiple linear regression model considering different vehicle classes are developed. The model can be made more reliable by adding the intersection characteristics also as variables. Other models incorporating time of the day can also be developed. Other modelling techniques like binary logit model, fuzzy logit models etc can be used for model making. The study can be made more precise by adding the influence of oncoming vehicles on the main stream and their types on gap acceptance behaviour of minor stream vehicle.

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