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STUDYING AGGRESSIVE CLEARING BEHAVIOR OF DRIVERS AT UNCONTROLLED INTERSECTIONS UNDER MIXED TRAFFIC CONDITIONS

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Abstract - In this paper gap acceptance model and aggressive clearing model are developed for two uncontrolled 4-legged intersections in the state of Andhra Pradesh, India. Gap duration, type of major and minor road vehicles, speed of major road vehicle and clearing time are the parameters considered in this study which particularly reflects the driver's clearing behaviour. This analysis showed that the probability of accepting a gap increases with increase in gap/lag value and decreases with increase in clearing time. It also decreases with increase in size of major road vehicle but increases with increase in size of minor road vehicle The level of aggressiveness of right turning vehicles increases with decrease in gap/lag and speed of major road vehicles, and it decreases with decrease in clearing time and size of minor road vehicles. Thus, in order to improve safety at uncontrolled intersections, measures such as minimization of side friction, installation of speed breakers on minor roads etc., should be followed which leads to faster movement of major road vehicles and thus lower the aggressiveness of drivers and increases safety.

Keywords- aggressive clearing; uncontrolled; safety; binary logit model; ordinal logit model.

INTRODUCTION

For a driver, gap refers to the region of maximum uncertainty in decision making. While a cautious driver tends to reject all gaps which are less than critical gap for a movement, an aggressive driver may even accept these smaller gaps. Researchers discovered that drivers' willingness to take risks and consider narrower gaps improves with increasing delay and eventually results in drivers embracing shorter gaps. However, others found driver's aggressiveness to arise mainly from personal attitude and not due to waiting. Although presence of aggressive drivers tends to increase the capacity of movements, they present a serious threat to the safe operation of unsignalized intersections as the acceptance of a shorter gap always occurs at the expense of safety.

Amin and Maurya demonstrate that the clearing behavior methodology accurately represents the real circumstances surrounding the essential gap under a variety of traffic conditions [1]. Chandra and Mithun identifies lesser critical gap of Indian drivers in comparison to their western counterparts indicates their aggressive and risk taking behavior, which often leads to road accidents [2]. Dutta and Ahmed concealed that when aggressive driving behavior and clearing time of drivers are weighed, the Critical gap calculation becomes more realistic [3]. Dutta and Ahmed explored the feasibility of using micro simulation to determine critical gaps at unsignalized intersections and found out the time taken to generate simulation data was only 3.6 percent of the time necessary to collect field data [4]. Patil and Sangole investigated and modeled two-wheeler gap acceptance activity at unsignalized T-intersections using Raff's system, lag method, maximum likelihood method, and logit method. They discovered that the maximum likelihood approach produces the most accurate values [5].

Most of the studies have been modeled the gap acceptance behavior in order to determine the critical gap values. None of the studies have investigated the reasons for which drivers behave aggressively at uncontrolled intersections.

The goal of this study is to evaluate gap acceptance behavior of various drivers at uncontrolled intersections under heterogeneous traffic situations, and also to find out the factors prompting drivers to clear the intersections aggressively.

METHODOLOGY

The approach involved in investigating aggressive clearing behavior of drivers was separated into many distinct phases. After the identification of appropriate unsignalized intersection, the first job was to perform video graphic survey to gather footage data from the research intersections. The data was extracted from this footage to determine the gap acceptance parameters which are useful in developing gap acceptance model and aggressive clearing model. Binary logistic regression and ordinal logistic regression are the two approaches used to develop gap acceptance model and aggressive clearing model respectively. By examining the output of these models, it quantifies the parameters

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by how much they are influencing aggressiveness of drivers.

A. Extraction of gap acceptance data from video graphic survey

In order to collect the data, on average weekdays, videos were recorded during the peak period at mornings (09:00-11:00 hrs) and the input parameters like clearing time, Gap/lag, Speed of major road vehicle and whether the Gap is accepted or rejected are selected. These variables are listed in Table I as follows.

TABLE I
(EXTRACTED VARIABLES FROM THE VIDEO GRAPHIC SURVEY)

Variable	Symbol Used	Description
Gap/Lag (s)	G	Lag or gap duration in seconds.
Clearing Time(s)	CT	Time taken by the minor street vehicle to cross the intersection area in seconds.
Major Road vehicle type	MJV	For 2- wheeler – 0 Auto - 1 Car - 2 Truck - 3 Tractor - 4
Minor Road Vehicle type	MNV	For 2- wheeler – 0 Auto - 1 Car - 2 Truck - 3 Tractor - 4
Speed of Major Road vehicle	V	Ratio of distance travelled between points PQ and its time taken.
Accept or Reject	AR	When Driver accepted =1 and rejected the gap/lag = 0

B. Gap acceptance model:

A driver can experience lag and a number of gaps in the main approach when entering an unregulated intersection while driving through a minor lane. The driver analyses the available gap and lag on a main road and decides whether to consider or deny the gap. Drivers' ability to make decisions differs from one individual to the next. To reflect the driver characteristics, a binary explanatory variable such as whether the distance is denied or approved is now used. A model is developed here to describe the discrete option behavior of Gap acceptance using the Logistic Regression methodology.

1) Binary logit model and its structure:

To determine a suitable gap in the main road stream, drivers on minor streets have a choice of selecting ‘i’ and 'j' only, where i indicates acceptance of the gap for merging or crossing movement and j indicates rejection. When drivers acknowledge a gap, they will proceed across the intersection immediately, while refusing the gap increases protection, since approving shorter gaps can be dangerous.

The total utility (U) is described as the sum of a deterministic (observed utility (V)) and a random (unobserved utility (e)) concept. Equations (1) and (2) define a basic utility function for accepting and refusing a gap, respectively:

$$U_i = V_i + \epsilon_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

$$U_j = V_j + \epsilon_j \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Where U_i - The total utility to accept a gap and

U_j - The total utility to reject a gap

The deterministic component (V_i) is the observed utility, which is a feature of the various variables (X_{ik}/X_{jk}) affecting gap/lag acceptance. Equations (3) and (4) can be used to express this utility function:

$$V_i = \alpha+\beta_1 X_{i1}+ \beta_2 X_{i2}+ \beta_3 X_{i3}+\ldots\ldots\ldots\ldots+ \beta_k X_{ik} \quad \ldots\ldots\ldots \text{(3)}$$

$$V_j = \alpha+\beta_1 X_{i1}+ \beta_2 X_{i2}+ \beta_3 X_{i3}+\ldots\ldots\ldots\ldots+ \beta_k X_{ik} \ldots\ldots\ldots\ldots \text{(4)}$$

Where α, β_1, β_2, β_3………β_k are values to be determined;

X_{ik}- k^{th} attribute when rejection;

k - Total no. of attributes;

The logit model implies that the error terms (ϵ_i,ϵ_j) in Equations (1) and (2) are Gumbel distributed. Within this supposition, the logit function provides the likelihood that a randomly chosen driver would consider a distance as Equation (5).

$$P_i(t) = 1/ [1+\exp(-V_i)] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5)}$$

Eq. (6) illustrates the efficiency equation for distance acceptance derived from Eq. (5)

$$\ln [P_i(t)/\{1-P_i(t)\}] = V_i$$
$$=\alpha+\beta_1 X_{i1}+\beta_2 X_{i2}+\beta_3 X_{i3}+\ldots\ldots\ldots\ldots\ldots+\beta_k X_{ik}\ldots. \text{(6)}$$

C. Aggressive clearing model:

When there is no lane discipline or explicit priority at uncontrolled intersections, aggressive driving is an obvious phenomenon. But field observation shows that the level of aggressiveness varies from driver to driver and also varies with the traffic condition. An ordinal logit model has been developed to study the aggressive clearing behavior of drivers.

1) Ordinal logit model and its structure:

Numerous regression models have been developed over the years for the purpose of analyzing ordinal response variables. The ordinal regression model is rooted in the generalized linear model system. To build unique models in ordinal regression, two main relation functions, logit and cloglog, are used.

There is no precise method for distinguishing the use of various relation functions. Of the available connections, the logit connection is better suited for examining organized categorical data values that are uniformly dispersed, while the clglog link is better suited for analyzing when higher categories are more likely. The following is the ordinal regression model using the logit link:

$$F\left(\gamma_J(X)\right) = \log\left(\frac{\gamma_J(X)}{1-\gamma_J(X)}\right) =$$

$$\log\left(\frac{P\{Y \le y_j/X\}}{P\{Y > y_j/X\}}\right) = \alpha_{j} + \beta X, \text{ j = 1,2,..,k-1} \qquad (7)$$

$$\gamma_J(X) = \frac{e^{\alpha_j + \beta x}}{1 + e^{\alpha_j + \beta x}} \qquad (8)$$

Where j = the cut-off points for all categories (k) of the outcome variable

For each cut-off point j, it is presumed that the regression coefficients for the specified relation function f are equivalent. The linear combination of ($\beta_1X_1 + \beta_2X_2 + \ldots + \beta_pX_p$) can substitute β_x in the ordinal regression model if several explanatory variables are included.

Where α_j - Threshold for each cumulative probability;

β- Regression coefficient;

STUDY AREA

The data for this research was obtained at two four-legged right-angled intersections in the semi-urban district of Tirupati, Andhra Pradesh. The layout of the two intersections was comparable, with two lanes undivided on the minor street approach and two lanes undivided on the major street approach. Both sites were on flat terrain with sufficient sight distances for each movement. The two intersections are shown below in Fig 3(a), 3(b).

Fig.3 (a), 3(b) Camera view at Intersections 1&2

A. Development of models and validation

1) Using Binary logistic Regression:

Results obtained from Logistic regression technique were done by using software named Statistical Package for the Social Sciences (SPSS). An aggregate gap acceptance model for both the Intersections was developed using Binary logistic regression. This model calculates the likelihood that a driver would consider or refuse a gap/lag posed to him or her for various scenarios involving the variable classes described below. Table II contains descriptive figures.

The mathematical findings indicate that the gap has a positive value. This means that the probability of accepting a gap increases with increase in gap/lag value and decreases with increase in clearing time. The negative coefficient of major road vehicle type indicates probability of gap acceptance decreases with increase in size of major road vehicle.

The positive coefficient of minor road vehicle type indicates the gap acceptance probability increases with increase in size of minor road vehicle.

From the correlation matrix table obtained, it was found that clearing time has a significant influence on gap and clearing time is influenced by type of major road vehicle. Additionally, it was discovered that speed of major road vehicle has no significant effect on the probability of gap acceptance.

TABLE II
(DESCRIPTIVE STATISTICS RESULTS FOR THE GAP/LAG ACCEPTANCE MODEL)

	coefficient (β_k)	standard error	wald	p-value	exp(b)	lower	upper
Intercept	-2.79	0.83	11.42	0.00	0.06		
Minor road vehicle type (MNV)	1.20	0.55	4.67	0.03	3.31	1.12	9.83
Major road vehicle type (MJV)	-1.67	0.36	21.05	0.00	0.19	0.09	0.38
Gap/lag (G)	2.41	0.26	83.32	0.00	11.1	6.62	18.62
Clearing time(CT)	-1.41	0.38	13.46	0.00	0.24	0.12	0.52
Log Likelihood Function = -74.68 ; McFadden R^2 = 0.74 ; Nagelkerke R^2 = 0.85 Chi-Squared Statistic = 431.58 ; Cox and Snell R^2 = 0.60 ; % of rightprediction = 93							
ln (p/1-p) = -2.79 + 2.41 *G - 1.41 * CT - 1.67*MJV + 1.20*MNV							

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2) Model validation

The results obtained from binary logit model are validated using some of the unconsidered observations. It showed an accuracy of 94% in achieving the results. TableIII shows the success prediction table.

TABLE III
(PREDICTION SUCCESS TABLE OF GAP ACCEPTANCE MODEL)

	Suc-Obs	Fail-Obs	Total
Suc-Pred	35	0	35
Fail-Pred	7	75	82
Total	42	75	117
Accuracy	0.83	1	0.94
Sensitivity = 0.83 Type II error = 0.17		Specificity = 1 Type I error = 0	

suc-pred: success prediction, fail-pred: failure prediction, fail-obs: failure observation , suc-obs: success observation .

3) Using Ordinal Logistic Regression

In order to determine aggressive clearing behavior, ordinal logit model was developed using SPSS. The following Table IV shows the statistical results obtained.

TABLE IV
(DESCRIPTIVE STATISTICS RESULTS FOR THE AGGRESSIVE CLEARING MODEL)

parameters	estimate	standard error	wald-statistic	p-value	95% confidence interval	
					lower bound	upper bound
Threshold Parameters						
LOA =0	-2.04	.457	19.934	< 0.001	-2.936	-1.144
LOA=1	-.531	.449	1.400	.037	-1.411	.349
LOA=2	1.189	.478	6.190	.013	.252	2.126
Location parameters						
Gap/lag (G)	-.228	.043	27.973	< 0.001	-.313	-.144
Speed (V)	-.767	.123	39.064	< 0.001	-1.007	-.526
Clearing time (CT)	.298	.104	8.156	.004	.094	.503
Minor road vehicle (MNV)	1.004	.176	32.529	< 0.001	.659	1.349
Model fitting Information						
Model	Log Likelihood		Chi-Square	df	Significance (p)	
Intercept Only	-498.8315		98.985	4	< 0.001	
Final	-449.339					
Pseudo R^2						
Cox and Snell R^2 =0.202; NagelkerkeR^2=0.225;						

From this ordinal regression analysis, it was found that aggressiveness of vehicles increases with decrease in Gap and Speed of major road vehicle. It was also examined that the aggressive behavior decreases with reduction in clearing time.

The positive coefficient of minor road vehicle type indicates that the aggressiveness of drivers also depends on type of minor road vehicle as its level will be more for higher size vehicles.

CONCLUSION

Binary logit model was used to develop the gap acceptance model and Ordinal logit model was used to develop the aggressive clearing model. The results obtained from binary logit model showed that the probability of accepting a gap increases with increase in gap/lag value and decreases with increase in clearing time. The gap acceptance probability also decreases with increase in size of major road vehicle but increases with increase in size of minor road vehicle. This phenomenon at these intersections states that drivers of larger vehicular sizes from minor roads don’t bother much about their safety while accepting narrow gaps. This regression analysis was validated using success prediction table and it showed an accuracy of 94%.

The results obtained from ordinal logit model was showed that the level of aggressiveness increases with decrease in gap/lag and speed of major road vehicles, and it decreases with decrease in clearing time and size of minor road vehicles. This shows that the vehicles accepting narrow gaps or having larger clearing time are more aggressive in nature. This supports the results obtained from gap acceptance model as the larger sized vehicles from minor road are having more gap acceptance probability. This clearly indicates that a tractor behaves more aggressively as compared to truck and this phenomenon goes on decreasing with decrease in size of vehicles: car, auto, and bike.

RECOMMENDATIONS

As aggressiveness of divers explains matter of safety, it is necessary to lower the level of aggression of the drivers at uncontrolled intersections. From aggressive clearing model, it was observed that aggressiveness increases with decrease in speed of major road vehicles. The following are the recommendations to improve the safety at uncontrolled intersections.

Side friction should be minimized as much as possible to increase the speed of the major road vehicles. This would reduce the level of aggressiveness of the minor road drivers. Speed breakers are more effective in reducing speeds of large sized vehicles. So, installing speed breakers on the minor approaches would make sure that the large sized vehicles slow down, and hence reduce their propensity to behave aggressively.

Additional research can be undertaken to determine the effect of different criteria (such as the driver's age, occupancy, sex and the amount of rejections) on the gap acceptance and aggressive behavior of drivers, especially under diverse traffic conditions.

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