MODELLING CRITICAL GAPS FOR U-TURN VEHICLES AT MEDIAN OPENINGS UNDER INDIAN MIXED TRAFFIC CONDITIONS AT HYDERABAD CITY

1JAINAB NAZMA, M.Tech Scholar,
2Mr. G. Uday kiran, Asst.Prof
3Dr. ANAND SWAROOP GOYAL, Professor
DEPARTMENT OF CIVIL ENGINEERING
Ashoka Institute of Science & Technology, Hyderabad, Telangana, India

ABSTRACT

In the project of recent years there has been expanded establishment of non-navigable un-signalized middle openings in the greater part of the urban locales in India. The thought process behind this establishment is to wipe out issues related with illicit U-turns at crossing points and other activity offices near the middle openings on multi-path urban streets. Information gathered for this investigation is as video-pictures of six U-turn middle openings on 4-path and 6-path streets arranged in the urban areas of Hyderabad City (i.e. Uppal U-turn near Uppal metro station, Tarnaka U-Turn near Railway Nilayam, Kukatpally U-Turn near Y-junction, Dilsukhnagar U-turn near RS brothers shopping mall, Nagole U-turn near city bus stop) five locations situated in the highly traffic in the Hyderabad. This project presents another idea on blending conduct of U-turn vehicles for assessment of Gaps acknowledged by drivers at middle openings in light of the "INAFOGA" technique; which is additionally contrasted and the basic Gap esteems got by and Macroscopic Probability Equilibrium idea for heterogeneous movement stream in the urban district of the Indian states. IBM-SPSS 22.0 has been utilized to play out a combined specimen Hypothesis (t-test) between these two techniques which uncover that basic Gap esteems got by "INAFOGA" are 18-31% more than those got by Probability Equilibrium strategy. Radar plots, box-plots, t-measurement, two-followed importance esteem combined with higher basic Gap esteems for various methods of transport (aside from Sport Utility Vehicles) approves the way that "INAFOGA" technique is for sure suitable under blended movement conditions.

A portion of the delicate products utilized for bend fitting, information association and factual examination of basic Gaps incorporate Origin Lab 9.1, Graph Pad Prism 6.0 and MS-Excel 2013. Radar plots, group charts, box plots, measurement and two-followed hugeness values combined with higher scopes of basic Gap esteems for various modes(except Sport Utility Vehicles) approves the way that "INAFOGA" strategy is in fact suitable to address U-turn Gap acknowledgment conduct under Indian blended activity conditions. Different techniques discovered fitting close to "INAFOGA" are Ning Wu's Macroscopic Probability Equilibrium, Maximum probability and Harder’s strategies. ANOVA relapse displaying is done in IBM – SPSS which brought about anticipating power variety of combining time with acknowledged Gaps for both male and female 2 Wheeler drivers.

Keywords - Critical gap, Gap acceptance, Indian traffic, Median openings, SPSS, U-turns, Unsignalized, Traffic Analysis etc.

I. INTRODUCTION
1.1 Contextual

The present examination gives a system to recognizable proof of the contention zone between a turning vehicle and on-coming vehicles at uncontrolled middle openings on urban streets under blended movement conditions. Information for turning developments of various sorts of vehicles was gathered at 13 middle openings on 6-path streets and 8 middle openings on 4-path streets in various urban communities of India. This information are dissected factually and it was discovered that the basic position (way of the external wheel) of a vehicle is affected by the vehicle measure and the street width.

1.1.1. Gap Acceptance at Median Openings

Progressively, U-turns at middle are utilized as another option to guide left turns with a specific end goal to decrease clashes and enhance movement operations along blood vessel streets when the volumes on the two bearings are high. Contrasted and other turning developments at convergences (right/left turn), U-turn development at middle openings is exceedingly intricate and dangerous.
Ordinarily, the speed of clashing activity stream (primary road volume) is to some degree high and the U-turn vehicles must hold up and after that turn with extraordinary alert since this move is moderately troublesome. This investigation investigates the basic Gap of the U-turn at middle openings utilizing Raff's strategy and Log it demonstrate. The outcomes from both methodologies were thought about and exhibited in this examination. Ten locales situated in Tampa, Florida were chosen to do the field information gathering. The field information gathering was directed with the assistance of a PC program produced for the Gap acknowledgment contemplates. The outcomes from this investigation demonstrated that the basic Gap of a U-turn at middle openings extended from 5.8 seconds to 7.4 seconds concerning shifted geometric and movement conditions at these 5 areas. Additionally, the conveyances of the U-turn Gaps demonstrated that drivers' conduct incredibly influenced the estimation of U-turn Gaps. It was likewise discovered that the separation between a signalized crossing point and a U-turn site incredibly influenced the conduct of the drivers influencing the U-to turn. This is the primary examination of Gap acknowledgment qualities under multi-path conditions (two, three, and four paths toward every path). The aftereffects of this investigation may help assess the limit of U-turns at medians, which was not tended to in the Highway Capacity Manual (HCM 2000).

1.1.2 Importance of “Critical Gap” in traffic flow

Crossing point crashes, particularly those that happen in rustic territories speak, to a noteworthy extent of roadway fatalities. The Cooperative Intersection Collision Avoidance System – Stop Sign Assist (i.e., CICAS-SSA) was created with the point of diminishing the quantity of fatalities at rustic convergences. The CICAS-SSA was produced as a roadside-based framework, which helps drivers on a minor street to choose the proper Gap when crossing a rustic thruway. In this report we exhibit the examination which changes the Roadside-based CICAS-SSA to a framework in which the showcases introducing movement related data are situated inside a vehicle. To altogether look at the practicality of the in-vehicle CICAS-SSA, we directed three examinations, each of which investigated particular issues.

1.3 Objective and Organization of the Report
1.3.1 Research Objectives:
Despite the fact that the CICAS-SSA has been appeared to be exceedingly instinctive and simple to translate (Creaser et al., 2008), it doesn't really take after that the comprehension and use of the sign would be quick. Building certainty and trust in a framework may require more than a modest bunch of associations with a framework.

- A profoundly sure driver will probably utilize an emotionally supportive network than a respectably certain driver. Moreover, older grown-ups require longer introduction to new innovation before they achieve a specific level of certainty.

II. U-TURN MEDIAN OPENINGS, GAP ACCEPTANCE AND MIXED TRAFFIC CONCEPTS

2.1 Introduction

Progressing research from a lab setting into a certifiable circumstance could be seen as the culmination phase of an exploration procedure. The lab setting in transportation look into as often as possible includes a driving test system, just like the case for the arrangement of studies introduced in this report. Because of security concerns, test technique in which a driver is being diverted, similar to the case in Study One is most appropriate to be directed in a test system. Wellbeing of a driver is clearly a critical factor, yet similarly as imperative is the control the scientists need to control condition and visual mess as was done in Study Two. Besides, interface advancement and ease of use testing can fundamentally decrease cost when led in a test system.

The accompanying is the principle investigates issues inspected in the Field Study:

- Evaluation of the adequacy of the in-vehicle CICAS-SSA on rustic convergence crossing execution at a genuine crossing point
- Driving execution in the Control condition (i.e., no in-vehicle CICAS-SSA sign) was contrasted with the Treatment condition in which drivers were presented to the in vehicle CICAS-SSA.
- Examination of the Age-related impacts on the drivers’ utilization of the framework and their driving execution.
- Driving execution of older drivers was contrasted with driving execution of their Younger partners.
2.2 U-turn Median Openings

Many state and neighborhood transportation organizations introduce no navigable medians on multilane parkways to enhance security and travel times and to oversee nearby access better. While no navigable medians limit guide left-swing access to and from neighboring improvements, activity bound for these areas must utilize backup courses of action, some of which may include making U-turns at close-by middle openings—a development frequently alluded to as an aberrant left turn.

2.3 Gap Acceptance and Critical Gap
2.3.1 The concept of Gap acceptance
Gap acceptance is one of the most important components in microscopic traffic characteristic. The gap acceptance theory commonly used in the analysis of uncontrolled intersections based on the concept of defining the extent drivers will be able to utilize a gap of particular size or duration.

Basic Terminologies
Gap means the time and space that a subject vehicle needs to merge adequately safely between two vehicles. Gap acceptance is the minimum gap required to finish lane changing safely. Therefore, a gap acceptance model can help describe how a driver judges whether to accept or not.  

Gap acceptance: The process by which a minor stream vehicle accepts an available gap to maneuver.  
Critical gap: The minimum major-stream headway during which a minor-street vehicle can make a maneuver.  
Lag: Time interval between the arrival of a yielding vehicle and the passage of the next priority stream vehicle (Forward waiting time).  
Headway: The time interval between the arrivals of two successive vehicles. Headway differs from gap because it is measured from the front bumper of the front vehicle to the front bumper of the next vehicle.  
Minimum Headway: The minimum gap maintained by a vehicle in the major traffic stream.

III. REVIEW OF LITERATURES
3.1 Introduction
Substantial measure of research has been done on "Gap acknowledgment" all through the previous couple of decades, yet lion's offer of them are engaged around homogeneous activity stream conditions. A few methods or models have been set up since the time of 1947 in written works to assess "basic Gap" as nearly as could be expected under the circumstances. In this way, unmistakably written works with respect to movement Gap acknowledgment wonder is rich.  

Gaps are GAMMA DISTRIBUTED.
Hewitt (1983) construed a technique which gages the likelihood dissemination of the basic Gaps of those drivers entering a principle street at a need intersection who have expelled the underlying slack offered to them, using impression of the sizes of the Gaps declined and that over the long haul acknowledged by the driver. Later a surmised system was proposed whereby unique likelihood appropriation of basic Gap of all drivers, including the people who acknowledge the underlying slack, could be assessed from the example frame for any differentiation between the conveyances of basic slacks and Gaps. Hewitt again in 1985 depicted his strategy in detail. Beforehand, a comparable strategy as the Hewitt's technique was proposed by Harder which turned out to be fairly well known in Germany in the time of 1968.

IV. METHODOLOGY AND TOOLS
4.1 Estimation of Critical Gaps
The critical gap $t_c$ can be defined as the minimum time interval between the through traffic stream vehicles that is necessary for U-turning vehicle to make a merging maneuver. Values of critical gaps are different for different drivers (some of them are too fast or risky, some of them are slow or careful) and there are dependent on types of
movements, geometry parameters of median openings, traffic situation. Due to this variability gap acceptance process is consider as a stochastic process and the critical gaps are random variables. The estimation of critical gaps tries to figure out qualities for the variables and also for the parameters of their distributions, which speak to normal driver conduct at the investigated openings. The problem is that the critical gaps cannot be measured directly. Only rejected gaps and accepted gaps of each U-turning vehicle can be measured at the Median Opening. The critical gaps can be estimated from these input data using some statistical method or procedures. For the estimation of critical gaps from the field data extracted, Seven different methods which will be used for analysis and comparison are described in this Chapter of the Report – Modified raff method (1950), Ashworth’s method (1968, 1970, 1979), Harder’s method (1968), Cumulative gap acceptance method (1970) Maximum likelihood method (MLM) of Trout beck (1992) and Macroscopic probability equilibrium method of Ning Wu (2006) and “INAFOGA” method.

4.1.1 Models/Methods Utilized For Estimation of Critical Gaps

4.1.1 (A) Modified Raff Method

The method of Raff (1950) is based on macroscopic model and it is the earliest method for estimating the critical gap which is used in many countries because of its simplicity. This method involves the empirical distribution functions of accepted gaps \( F_a(t) \) and rejected gaps \( F_r(t) \). As per Raff method critical gap at un-signalized intersections is defined as “as gap/lag for which no. of accepted gaps shorter than it is equal to the no. of rejected gaps longer than it”. (1950, RAFF & HART)

Two cumulative distribution curves are drawn with no. of gaps as the ordinate \& length of gaps in secs in the abscissa. One relates gap lengths \( t \) with the number of accepted gaps less than \( t \), while the other one relates \( t \) with the number of rejected gaps greater than \( t \). Critical Gap, \( T_c \) is obtained by projecting the intersection of these curves on the X-axis corresponding to the no. of gaps.

From the above cumulative distribution curves of accepted and rejected gaps, with an assumption of the curves being linear between two time instants \( t_1 & t_2 \), the point of intersection of these two lines represents the critical gap. Critical gap lies between \( t_1 & t_2 = t_1 + \Delta t \), where \( \Delta t \) = time increment used for Gap analysis.

Considering similar triangles, \( r-m \)

\[ \frac{\Delta t_1}{\Delta t} = \frac{\Delta t_1}{n-p} \]

Now,

\[ \Delta t_1 = \frac{\Delta t (r-m)}{(n-p)+(r-m)} \]

Again critical gap,

\[ T_c = t_1 + \Delta t_1 \]

Thus the expression of critical gap by Modified Raff method is:

\[ T_c = t_1 + \frac{\Delta t (r-m)}{(n-p)+(r-m)} \]

(3.4)

Modified Raff method for U-turns

\[ \text{Figure 3 Example of Modified Raff Method for U-turns} \]

CUMULATIVE GAP ACCEPTANCE METHOD - U

\[ \text{Figure 4. Example of Critical Gap Distribution by Cumulative Gap Acceptance Method} \]
Both accepted lags and gaps are used in this method to determine critical gaps. Cumulative frequency percentages of lags and gaps are plotted against merging time expressed as frequency distribution. Fig. 5 predicts the critical gap of U-turning 4 wheelers and SUVs using “INAFOGA” method.

V. STUDY AREA AND DATA COLLECTION

5.1 Description of the Study Area

The study area from two cities (i.e. Hyderabad and Secunderabad) are considered in such a fashion that the road networks give the required input data for analyzing “Critical Gap” and comparing the same between different modes of transport. Median openings at four-lane and six-lane divided urban roads are considered in the present study. In Indian context, median openings are generally provided in urban areas on major streets for minimum flow of 500 vehicles/day with maximum speed limit of 70-80 kmph.

Data collection primarily comprised of video recording of the selected median openings by a Sony Handy cam capable of playing videos at a rate of 30 frames/second. Data sets were collected during peak hours for the morning (8:30-10:30 AM), noon (12:30-2:00 PM) and afternoon (5:00-6:00 PM) between October 2017 and November 2017. Shooting was done only during weekdays. Weekends and public holidays were generally neglected due to large discrepancy among data sets which leads to erroneous estimation of critical gaps of U-turning traffic at median openings.

Figure 5. Layout of Median Opening on a 4-lane road
Table 5.1. PCUs for Flow Calculation as per Indian Roads Congress (1983), Code Number - 86

<table>
<thead>
<tr>
<th>S.no</th>
<th>Vehicle Type</th>
<th>PCU Equivalents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Car, LCV, 3W, SUV</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>HV (i.e. truck, bus, lorry)</td>
<td>3.0</td>
</tr>
<tr>
<td>3</td>
<td>2W (i.e. bikes, scooters, Bicycles)</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Table 5.2. Traffic Characteristics and Geometry of the Five Median Opening sections Observed

<table>
<thead>
<tr>
<th>Median Opening Section No.</th>
<th>Location</th>
<th>Median Opening Width(m)</th>
<th>Volume of through traffic (PCU/hr)</th>
<th>Proportion of U-turn drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Uppal U-turn, near Uppal metro station</td>
<td>14</td>
<td>4100</td>
<td>1184(24%)</td>
</tr>
<tr>
<td>2</td>
<td>Tarnaka U-turn, near Railway Nilayam, Secunderabad</td>
<td>20</td>
<td>4700</td>
<td>715(25%)</td>
</tr>
<tr>
<td>3</td>
<td>Kukatpally U-turn, near Bus stand</td>
<td>10</td>
<td>4000</td>
<td>670(27%)</td>
</tr>
<tr>
<td>4</td>
<td>Dilsukhnagar U-turn, near RS brother’s shopping mall</td>
<td>23</td>
<td>3900</td>
<td>838(25%)</td>
</tr>
<tr>
<td>5</td>
<td>Nagole U-turn, near city bus stop</td>
<td>20</td>
<td>2490</td>
<td>994(20%)</td>
</tr>
</tbody>
</table>

\[ \text{d} = \text{horizontal width of median opening}; \quad c^{**} = \text{distance between outer edge of inner lanes} \]

The variation of U-turning flow with respect to through or conflicting traffic flow can be graphically represented as a cumulative distribution in Passenger Car Unit (PCU)/hr. The conversion factor, PCU for different vehicle types are followed from Table 2 of Indian Roads Congress (1983), Code number -86 (Geometric Design Standards for Urban Roads on Plains). Fig. 1 shows the frequency distribution curve of U-turn flow vs through traffic flow, both expressed in PCU/hr, for six different sections. It has been observed from this figure that with increase in percentage of through traffic flow, there is an exponential decay of U-turn traffic gap acceptance.
5.2.1 Extraction of necessary decision variables as per “The Merging Behavior” Concept

After video shooting of the median openings, extraction of necessary decision variables for the estimation of critical gap was done. The video data collected from the field was converted to .AVI format from MPG file type. All decision variables were extracted by playing the .AVI videos in demurer software named as AVIDEMUX Version 2.6 capable of running videos at a frame rate of 25 frames/second. The time frames chosen for data extraction was based on the new concept on merging time are explained below.

Table 5.3. Statistical and Parametric Details of the Regression Model for SUVs

<table>
<thead>
<tr>
<th>Number of Points</th>
<th>Waiting Times for SUVs</th>
<th>Conflicting Traffic flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degrees of Freedom</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>Reduced Chi-Square</td>
<td>1.86415</td>
<td>0.00617</td>
</tr>
<tr>
<td>Residual Sum of Squares</td>
<td>61.51691</td>
<td>0.20367</td>
</tr>
<tr>
<td>Adj. R-Square</td>
<td>0.89749</td>
<td>0.94613</td>
</tr>
<tr>
<td>Fit Status</td>
<td>Succeeded(100)</td>
<td>Succeeded(100)</td>
</tr>
</tbody>
</table>

Equation for Non-linear Curve fit: y = a. x^b

VI. CONCLUSIONS AND DISCUSSIONS

Conclusions regarding the Comparison between Harder’s and “INAFOGA” Methods

Two existing methods available in previous literatures were used to estimate the critical gap values. Using the “INAFOGA” concept for data extraction, estimation of critical gaps for U-turns at median openings under mixed traffic conditions have been done in this study. The only limitation found while studying gap acceptance is the inefficiency of Harder’s method in predicting appropriate critical gap values under mixed traffic conditions. The reason being the use of this method by previous researchers under uniform traffic conditions only. A paired sample t-test between critical gap values for Harder’s and “INAFOGA” method was performed to find out the difference in means of the values. The values were found to be 28-41% lesser as compared to the values obtained using form Satish et al “INAFOGA” method. Cluster diagrams plotted gives the comparison of critical gap values for the four different modes considered in this study for all the four sections.

Conclusions in General on Estimation of Critical gaps

- For every sections selected for analysis, the critical gap values for a 4wheeler was found to be more than that for a 2 wheeler driver
The above step contradicted for the road leading to C.S. Poor for critical gap values obtained by Modified Raff method.

Values of critical gaps obtained by “INAFOGA” method are about 18-41% higher than other values of critical gaps obtained by existing methods.

This research initiative introduces the new concept of merging behavior for estimating critical gaps of U-turn drivers at median openings on multilane roads under mixed traffic flow in Indian context.

Merging time indicates the complete merging maneuver of U-turn vehicles at median openings. The present study also modeled drivers waiting time with his critical accepted gap. The study certified that with increase in the driver waiting time there is a power or exponential decay in critical gaps accepted by the driver. Thus, stating critical gap also as a behavioral aspect. Another important factor in behavioral analysis is the effect of driver gender on accepted gaps and merging times. Analyzing the selected median opening sections it was ascertained that female drivers accept gaps more lately than male ones. Also, the female drivers take longer time in completing the U-turn man oeuvres at median openings than male drivers. Regarding the same analysis, power regression decay was obtained for the increase in accepted gaps with increase in merging times for both the sexes. Other traffic characteristics like conflicting traffic flow and speed have direct effect on gap acceptance and critical gaps of U-turn drivers at median openings. Empirical regression models between these conflicting traffic stream characteristics with the gap acceptance phenomenon (i.e. critical gaps) are developed. Models show that there is linearity between speed and critical gaps while power variation between flow and critical gaps which in turn indicates that both behavioral and traffic properties of vehicles and drivers affect driver gap acceptance grossly.

**Future Scope:**

This new concept thus used for estimating U-turn critical gaps and evaluating driver gap acceptance have never been used previously and can be unpretentiously used by any traffic engineer/policy makers to address gap acceptance under mixed traffic conditions. Thus, all the aspects introduced through this study will definitely serve as a handy tool to improve traffic operations on unsignalized transportation facilities. However, there is still doubt about the utilization of the new concept of merging behavior to other transportation facilities like roundabouts, interchanges, etc. and thus further research in this field is strongly recommended.

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