

# Operational Effects of Critical Gaps and Turning Movements on NH-44 in Ranga Reddy District

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## Abstract

In this paper, a brief practical review is presented on U-turns have been considered among the most hazardous locations on highways. The maneuvering of the driver at these locations is quite complex and risky. The behavior of the driver when turning is governed by the gap acceptance concept. In this study, the driver's gap acceptance behavior at U-turn median openings was studied. U-turn median openings in City were investigated. Data was collected by video/manual recording. Two models were developed in this study. The first model estimated the time gap accepted by the driver. The second model calculated the turning function, which was used to estimate the probability of accepting gaps. Results showed that male drivers tended to accept shorter gaps than female drivers. Also, younger drivers were more likely to accept shorter gaps than older ones. The waiting time was also found to affect the gap acceptance behavior of the drivers. Drivers tended to accept shorter gaps after longer waiting times. Establishment of un-signalized median openings has expanded in numerous urban districts of cities in India. The thought process behind this establishment is to take out issues connected with illicit U-turns occurring at crossing points and other transportation facilities near these median openings on multi-lane urban streets. Gap Acceptance concept of U-turn drivers is an imperative angle at un-signalized median openings for deciding limit of accidents. Critical Gap structures the sole parameter in Gap acceptance models for assessing U-turns at median openings. Estimation of critical gaps for U-turn vehicles at median openings under mixed traffic conditions have not been addressed until today. U-turn at midblock median opening is frequently provided in developing countries to facilitate the local access. Movement capacity of such U-turn is of interest for deciding the necessary traffic management. HCM 2010 contains the methodology for U-turn capacity estimation, which is based on gap acceptance theory and assumption of major traffic headway distribution. This project evaluated the gap acceptance capacity model and proposed an adjustment method of the Data collection at a U-turn.

**Keywords:** CBR, Dynamic Cone Penetration, Correlation, Investigation

## I. INTRODUCTION

Gap is defined as the time or space headway between two successive vehicles in a particular traffic stream. Gaps are expressed in terms of space when the distance between the fronts of the two vehicles is considered. They are expressed in terms of time when the time elapsed between the arrivals of the vehicles is considered.

Gap acceptance is the process through which a driver has to evaluate the gaps and judge whether they are enough or not for merging. The gap acceptance concept is widely used in the determination of the capacity, delay and level of service at various transportation facilities. It is also used for safety

During the past two decades, more and more state departments of transportation and local transportation agencies have started installing non-traversable medians and directional median openings on multilane highways. By installing non-traversable medians and replacing full-median openings with directional median openings at various locations at NH-44 limiting median openings to left-turns from the major arterials. Hence, drivers desiring to make direct left-turn egress (DLT) maneuvers from a driveway or a side street onto major arterials would need to turn right onto the major-street and then make U-turns (RTUT) at a downstream median opening or a signalized intersection, as shown in Figure 1-1. The increasing installation of non-traversable medians and directional median openings reflects the increased attention given to access management. Access management is defined as the systematic control of the location, spacing, design, and operation of driveways, median openings, interchanges, and street connections to a roadway. It also involves roadway design applications, such as median treatments and auxiliary lanes, and the appropriate spacing of traffic signals (TRB, 2003). The purpose of access management is to provide vehicular access to land development in a manner that preserves the safety and efficiency of the transportation system (TRB, 2003). During the past few decades, more and more state departments of transportation came to realize the importance of access management to the modern traffic system and began to use various access management techniques to improve the traffic operations and safety along major arterials. Many states have developed or are considering developing their statewide comprehensive access management

programs one of the major principles of access management is to install non-traversable medians and directional median openings.

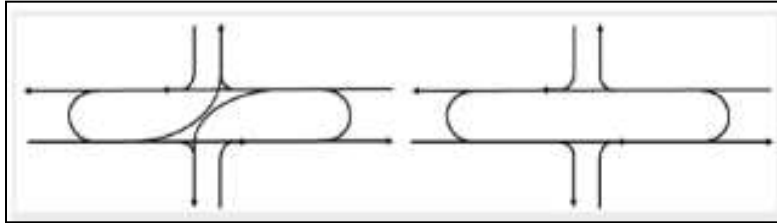


Fig. 1: Different Driveway Left-turn Alternatives

The purpose of using non-traversable and directional median openings is to eliminate problems associated with left-turns and crossing movements on multilane highways. As a result of this design decision, drivers desiring to make direct left-turns at a driveway will be relocated to a downstream U-turn bay to make U-turns. Replacing a full median opening with a directional median opening will reduce conflict points from 32 to 8, as shown in Figure 1-2. Thus, it will simplify driving tasks and could significantly reduce crash rate (Vargas and Gautam, 1989).

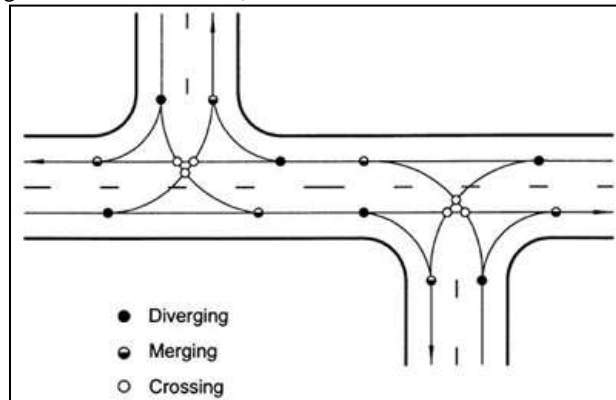


Fig. 2: Conflict Points at a Conventional Full Median Opening Versus a Directional Median Opening

## II. NEED FOR PRESENT STUDY

Drivers are encountering serious and hazardous situation during left turn on median openings coming from one or both directions if the opening is wide. Drivers are usually become indignant due to waiting long time stopping and enforced to reject short gaps (i.e. lags) between high speed vehicles opposing left turn vehicle movements.

Conflicts are the main events facing drivers in the scene mostly due to friction among vehicles tending to accumulate on this situation. To mitigate accidents and reduce conflicts, in depth study is required in this case. Sometimes traffic officers requiring convenient solutions to solve the problem. Type of control sign or signal required can be selected out of a deep observation of flow near the above locations.

Theoretical work may be needed to simulate the situation of traffic during dynamic flow of vehicles. To conduct such study, a practical data is usually needed to assist the theoretical solution.

## III. OBJECTIVE AND SCOPE OF THE STUDY

There have been considerable numbers of studies conducted concerning the safety effects of U-turns. However, relatively fewer studies are available concerning the operational effects of U-turn movement. Current concerns with regard to the operational effects of U-turn movement include the following:

- Drivers who lost the direct left-turn access could experience longer delay and travel time while making right-turns followed by U-turns;
- The increased numbers of U-turning vehicles could have some adverse impacts on the capacity of a signalized intersection;
- Unsignalized intersections may not be able to handle large numbers of U-turning vehicles due to the limited capacity of U-turn movement, and the increased numbers of U-turns may result in congestion at unsignalized intersections; and
- Some streets may have limited physical spaces such as narrow roadway widths and median widths to negotiate U-turns. Vehicles making U-turns at such locations may result in operational problems.
- Estimation and comparison of critical gap through existing methodologies and models present at a median opening for U-turns under mixed traffic
- Comparison of critical gap values b/w different motorized modes of transport prevalent under mixed traffic conditions at median openings

- To find the relationships between accepted gaps and merging times for U-turn 2 wheeler drivers based on Gender
- Modeling critical gap along with conflicting/ through traffic flow and speed under mixed traffic
- To study the effect of driver waiting time on critical gaps of U-turn vehicles

Besides, the separation distance between a driveway and the downstream U-turn bay is an important consideration for a driver deciding whether to make a right-turn followed by a U-turn or a direct left-turn. If the separation distance is too short, vehicles making right-turns followed by U-turns do not have enough spaces to make comfortable lane changes; this may result in safety problems at the weaving section. On the other hand, a separation distance that is too great may result in a longer travel time and, thus, discourage drivers from making right-turns followed by U-turns. Currently, there are no regulations or guidelines for determining the optimal location of a U-turn bay to facilitate driver use of right-turns followed by U-turns.

#### IV. LITERATURE REVIEW

Over the past few decades, many studies on gap acceptance concept have been conducted to analyze gaps and develop models correlating the previously mentioned factors with gap acceptance. However, a very small portion of those studies addressed U-turns.

Tupper et al. (2011) studied the factors that influenced the driver's gap acceptance behavior and had clear impact on safety. Different driver's age and gender groups were found to have different gap acceptance behaviors. Factors that had the greatest effect on gap acceptance behavior were found to be the presence of a queue behind the driver, the driver's waiting time and the number of the rejected gaps.

Nabae et al. (2011) developed and validated a procedure for observing the driver's gap acceptance behavior accurately at two-way left turn lanes (TWLTL) on the major road. Characteristics such as driver's gender, driver's age, vehicle type, presence of a queue behind the leading vehicle and presence of passengers in the vehicle were collected as a function of the time of day (TOD). This work provided updated measures for the accepted gap with the variation of TOD and showed how accepted gaps were related to the waiting time of the vehicle.

Zhou and Ivan (2009) studied the gap acceptance behavior of left turning drivers at six unsignalized intersections. Logit models were used for estimating the probability of accepting a given gap. Results showed that the number of lanes on the major road, the presence of left turn lanes and the gender of the driver explained the variation in the gap acceptance probability. It was also found that older drivers generally tended to accept longer gaps.

Yan et al. (2007) studied the effect of major traffic speed and driver's age and gender on the gap acceptance behavior of the driver at stop controlled intersections. Results showed that older drivers, especially older female ones, exhibited the most conservative driving behavior.

In this study, extensive work was conducted to search past studies and reports regarding the operational performance of U-turn movement were also searched and reviewed. Generally, the references can be categorized into different parts, including: the current indirect left-turn treatments, the delay and travel time for vehicles making direct left-turns and right-turns followed by U-turns, the weaving issues related to right-turn followed by U-turn movement, the capacity of U-turn movement at signalized intersections, the capacity of U-turn movement at unsignalized intersections and the median and roadway width to facilitate U-turns.

The previous study on u-turn movement shows that the longer time the driver waits at the stop line, the smaller gap the driver accepts. The waiting time of more than 30 seconds will frustrate the drivers to accept the significant smaller gap, which may lead to traffic safety problem (Jenjiwattanakul and Sano, 2011). Another study investigates the factors affecting the u-turn decision. The significant factors include gap size, conflicting speed, and waiting time. The queuing time does not significantly affect the u-turn decision (Jenjiwattanakul and Sano, 2012). Because the waiting time significantly affects the decision of u-turn's drivers, the current study developed the function to estimate the waiting time and set the warrant to control the u-turn movement for safety purpose.

Chandra et al. (2009) analyzed the waiting time at uncontrolled intersections in mixed traffic conditions by microscopic approach. The microscopic analysis considers each individual subject vehicle. The conflicting flow rate as seen by the particular subject vehicle is the number of observed conflicting vehicles divided by the observation time. Some advantages of this method are that the data is not lost by aggregation and the data points are increased. It also reflects the real conflicting flow rate the subject vehicle faces when waiting for an acceptable gap. The function of waiting time is in the exponential form.

Madanat et al. (1994) developed the waiting time function by probability theory. The expected waiting time at the stop line is the product of the average size of rejected gaps and the expected number of rejected gaps. The process of rejecting sequential gaps is expressed as a geometric distribution. The gap size is assumed to be negative exponential distributed in their study.

Al-Omari and Benekohal (1999) developed the linear waiting time models for unsaturated TWSC intersections by empirical approach. The separate models are also developed for different turning movements; right, left, and through. The statistical test unveils that there is no significant differences between the three models.

## V. EXPERIMENTAL INVESTIGATION

### A. Introduction

Traffic data was collected on the study section through manual survey and the location of vantage point was carefully selected by considering variables of interest to be observed through the survey. Total seven hours traffic data was collected for both upstream direction (Kompally to Bowenpally) and downstream direction (Bowenpally to Kompally). Manual data extraction was done. The study parameters namely rejected gap, accepted gap and waiting time of U-turn vehicles were recorded for modeling the gap acceptance behaviour at this study section. The sample size of U turning traffic on both directions of travel for the study period (total seven hours data) was presented in Table 1. Classified traffic Volume Counts (CVC) data was also extracted for both directions of travel for the study period and it was observed that the total traffic on upstream side and downstream directions are 12302 vehicles and 15992 vehicles respectively. Out of this, a total of 748 U- turning vehicles and 187 U-turning vehicles were observed on the upstream and downstream directions of travel and the same were considered for the gap acceptance analysis. The composition of the U-turning traffic at this median opening on the upstream and downstream directions of travel is presented in Figure 5. It can be inferred from Figure 3. composition of car (Small Car [up to 1400 cc] and big car [beyond 1400c including Vans / Jeeps]) is the dominant mode (68%).

Table – 1  
Sample size of U turning Traffic on both Directions of Travel

Time Period	Upstream Direction (Kompally to Bowenpally)		Downstream Direction (Bowenpally to Kompally)	
	U-turning traffic	Traffic Volume (Veh/hr)	U-turning traffic	Traffic Volume (Veh/hr)
	1 <sup>st</sup> hour	129	1496	42
2 <sup>nd</sup> hour	120	1747	19	2618
3 <sup>rd</sup> hour	141	1605	15	2436
4 <sup>th</sup> hour	147	1803	27	2211
5 <sup>th</sup> hour	97	2054	28	2350
6 <sup>th</sup> hour	56	1805	26	2028
7 <sup>th</sup> hour	58	1792	30	1788
Total	748	12302	187	15992



Fig. 3: Traffic Composition of U-turn traffic on Upstream direction



Fig. 4: Critical Gap of traffic on upstream direction



Fig. 5: U-Turn traffic on upstream and downstream directions

## VI. CONCLUSIONS

The behavior of gap acceptance at median opening for this study section on National Highway number 44 was identified and seven hours videography data was collected. Most widely used gap acceptance methods were considered in this study and critical gap acceptance for both upstream U-turn vehicles and downstream U-turn Vehicles were estimated and observed are

- Average critical gap period observed on U-turn median lane openings on arterials is 3.5 sec only.
- At highly congested U-turn locations, critical gaps observed are shorter than 3.5 sec but longer at other locations.
- Lower delays are observed at (50-55) km/hr, and higher delays resulted at (80-85) km/hr of major or street traffic speed.
- Lower approach width is passively affecting delays of traffic trying to make U-turn at median openings. Wider approaches are actively affecting time loss, for turning traffic.
- Delay is low at lower and higher conflict rates and high at moderate values of conflict rates of 9.5 conflicts/100 vehicles.
- Delay time is usually tending to increase with the increase in the flow of traffic from opposing direction with high correlation coefficient.

The Classified traffic volume counts data was also extracted for both directions for the study period and it was observed that the total traffic on upstream side and downstream directions of travel is 12,302 vehicles and 15992 vehicles respectively. Out of this a total of 748 U-turn vehicles data upstream direction and 187 U-turn vehicles downstream side direction were considered into gap acceptance analysis.

The average difference between critical gap for the upstream and downstream traffic were determined by using various deterministic methods to understand Critical gap values. These include Harder's methods which yields less variation in the estimated Critical Gap (CG) values. On the other hand, the stochastic models such as MLM and Ning Wu's methods yielded large variation. Based on the study results, Though the MLE method is developed based on robust mathematical concept, but the limitation of this model is that it is not considering the accepted gaps value smaller than the maximum rejected gap which generally occurs in mixed traffic condition due to forceful entry behavior resorted by the drivers under the conditions of traffic heterogeneity. Further study is required for quantification of the critical gap under varying sizes of median openings.

- The value of the accepted gap varies among drivers of different age groups. Younger drivers tend to accept shorter gaps than older drivers.
- Male drivers are more likely to accept shorter gaps than female drivers.
- The longer the drivers wait at the median opening, the more likely to accept shorter gaps they become.
- The probability of accepting a given gap is a function of driver's gender, driver's age and waiting time

## VII. RECOMMENDATIONS

The following points summarize the recommendations for further studies:

- 1) Covering the effect of the time of the day on the driver's behavior at U-turns in the study is recommended and is believed to produce better relationships.
- 2) This study addressed the effect of driver-related factors on the gap acceptance. It is recommended to study the effect of traffic conditions like traffic volume, speed limit, the existence of nearby traffic control devices and the presence of pedestrians in the area. Also, it is recommended to study the effect of the geometric conditions of the facility such as number of lanes, lane width, median width and the existence of a storage lane.

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