An Experimental Analysis on Capacity Estimation for Undisciplined Intersections/Junctions

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ABSTRACT

This paper covers an experimental analysis on capacity estimation for undisciplined intersections/junctions. Rotary intersections are special form of at-grade intersections laid out for the movement of traffic in one direction around a central traffic island. Essentially all the major conflicts at an intersection namely the collision between through and right-turn movements are converted into milder conflicts namely merging and diverging. The vehicles entering the rotary are gently forced to move in a clockwise direction in orderly fashion. Rotary intersections are an effective intersection type which is also called as Roundabout which is provided for easier decision making than conventional intersections. These rotary intersections have a traffic calming effect by reducing vehicle speeds using geometric design. Rotaries require less maintenance than traffic signals. A well designed roundabout achieves a balance of safety and efficiency. Traffic rotaries reduce the complexity of crossing traffic by forcing them into weaving operations. The shape and size of the rotary are determined by the traffic volume and share of turning movements. Capacity assessment of a rotary is done by analyzing the section having the greatest proportion of weaving traffic. In the past years various models have been developed for analyzing the traffic flow on this intersection. These methods are classified in two groups. The first group consists of methods which are purely empirical and based on geometry of intersection. The second group consists of methods which are based on Gap acceptance process.

Keywords: Capacity, Conflict technique, Surveys, Tanner Model, Traffic Parameters, Unsignalized Intersections.

1. INTRODUCTION

Traffic intersections are complex locations on any road. This is because vehicles moving in different directions want to occupy same space at the same time. In addition, the pedestrians also seek same space for crossing. Drivers have to make split second decision at an intersection by considering his route, intersection geometry, speed and direction of other vehicles etc. A small error in judgment can cause severe accidents. It also causes delay and it depends on type, geometry, and type of control. Overall traffic flow depends on the performance of the intersections. It also affects the capacity of the road.

Merits and Demerits of Roundabouts

The key advantages of a rotary intersection are listed below:

a) Traffic flow is regulated to only one direction of movement, thus eliminating severe conflicts between crossing movements.
b) All the vehicles entering the rotary are gently forced to reduce the speed and continue to move at slower speed. Thus, none of the vehicles need to be stopped, unlike in a signalized intersection.
c) Because of lower speed of negotiation and elimination of severe conflicts, accidents and their severity are much less in rotaries.
d) Rotaries are self-governing and do not need practically any control by police or traffic signals.
e) They are ideally suited for moderate traffic, especially with irregular geometry, or intersections with more than three or four approaches.
f) Although rotaries offer some distinct advantages, there are few specific limitations for rotaries which are listed below.
g) All the vehicles are forced to slow down and negotiate the intersection. Therefore, the cumulative delay will be much higher than channelized intersection.
h) Even when there is relatively low traffic, the vehicles are forced to reduce their speed.
i) Rotaries require large area of relatively at land making them costly at urban areas.
j) The vehicles do no usually stop at a rotary. They accelerate and exit the rotary at relatively high speed. Therefore, they are not suitable when there is a high pedestrian movement.

Traffic Performance Analysis at Roundabouts: The author has focused on the problem of estimating traffic performance characteristics like, capacity, queue length, and delay at one and two lane traffic roundabouts. Where drivers have a choice of lane for maneuver, a user optimal model is used to allocate flow to alternative lanes. The analysis is suitable for inclusion in traffic assignment models which explicitly represent traffic conflicts at intersections, or in stand-alone analytically based computer programs which analyze a single roundabout.

Traffic Operation Performances at Roundabout Weaving Sections: There are frequent confluence and influence operations at roundabout weaving sections. The operation performances are complicated because the entry vehicles of turn-left and run-straight travel around the circle center. On the basis of the Shuma square in Dalian city roundabout survey using video cameras, some parameter performances were analyzed, which included the velocity distribution, the distance distribution of lane changing, the headway distribution of confluence vehicles, and vehicles on circulating lanes, as well as the application of accepted headways. Besides, some conclusions were drawn, for example, the vehicle velocity of outer circulating lane is larger than the inner circulating lane; the confluence vehicle velocity is smallest; the influence operation occurs later than the confluence operation; the confluence vehicle velocity has a tendency to increase with the accepted headway increase; the posterior gap is usually larger than the frontal gap in one accepted headway; the equivalent critical gap of multilane roundabouts is smaller than the critical gap of single-lane roundabouts.

2. CONFLICT

A conflict occurs whenever the paths followed by vehicles diverge, merge or cross.

Types of Conflicts: Conflicts at an intersection are different for different types of intersection.

a) Diverging: It is traffic operation when the vehicles moving in one direction is separated into different streams according to their destinations.
b) Merging: Merging is the opposite of diverging. Merging is referred to as the process of joining the traffic coming from different approaches and going to a common destination into a single stream.
c) Weaving: Weaving is the combined movement of both merging and diverging movements in the same direction. It is accomplished by a merging maneuver followed by a diverging maneuver.

Figure 2: Conflicts in a traffic signal
3. CLEARANCE AND GAP

a) Clearance: Clearance is similar to spacing, except that the clearance is the distance between the rear bumper of the leading vehicle and the front bumper of the following vehicle. The clearance is equivalent to the spacing minus the length of the leading vehicle. Clearance, like spacing, is usually reported in units of feet or meters.

b) Critical gap: Critical gap can be defined as the average minimum gap that the drivers of minor stream vehicles (entry vehicles) are willing to accept to merge with the major stream vehicles (circulating vehicles). It mainly describes the gap acceptance behavior of the driver. Critical gap is not directly observable only the gaps rejected or accepted can be determined. It is generally assumed that the driver of minor vehicle will reject the gaps lower than the critical gap.

- Correspond to parameters of spacing (m) and headway (sec)

Figure 4: Headway and Gap Concept

Models for determining Critical Gap

The value of critical gap depends upon the flow condition whether it is saturated or unsaturated. Hence there are two different approaches for the same.

Sieloghe gave model for critical gap which can be used only when the queue is formed that is in case of saturated flow in minor stream.
\[ c = qp \int h(t)g(t)dt \]  

Where  
- \( qp \) is volume in major stream 
- \( h(t) \) is Statistical density function of all gaps 
- \( G(t) \) is Gap of size \( t \) 

The saturated flow in minor stream is not a standard condition and hence various researchers had carried out work and gave various models for determining the critical gap for the condition of unsaturated flow condition. Those are as follows:

i. **Lag method:** This method depends upon Lag time which is the time from arrival of minor vehicle until the arrival of next major vehicle  

Here,  
Critical gap  
\[ t_c = \sum a_i \cdot \frac{(F_c \cdot 0) - (F_c \cdot 1)}{(F_c \cdot 1) - (F_c \cdot 0)} \]  

Where:  
\( F_c \cdot 0 = a_i \)  
\( a_i = A_i/N_i \)  
\( A_i = \) number of accepted lags within interval \( i \)  
\( N_i = \) Number of all observed lags within interval \( i \)  
\( t_i = \) Time at the centre of interval \( i \)  

ii. **Raff’s method:**  

Here \( t_c \) is that value of \( t \) at which the functions  
1- \( F_r(t) \) and \( F_a(t) \) intercepts  
Where, \( F_a(t) \) is empirical statistical distribution function of accepted gaps  
And \( F_r(t) \) is empirical statistical distribution function of rejected gaps.  

iii. **Ashworth Method:**  

\[ t_c = \mu_a - P \sigma_a^2 \]  

Where, \( \mu_a \) is the mean of accepted gaps  
\( P \) is major stream traffic volume  
\( \sigma_a^2 \) is standard deviation of accepted gaps.  

iv. **Millers method:**  

\[ t_c = \mu_a - P \sigma_c^2 \]  

\[ \sigma_c = \sigma_a \cdot \frac{t_c}{\mu_a} \]  

v. **Harders Method:**  

Based on Lag method but here lag is not to be considered as sample and hence \( A_i \) is number of accepted gaps and \( N_i \) is number of all gap of size \( i \) provided to minor vehicle  

\( a_i = A_i/N_i \)  

vi. **Logit Models:**  

Assumes two decision i.e Accepted Gaps(i) and rejected Gap (j)  
Therefore Utility \( U_{id} = V_{id} + \varepsilon_{id} \)  
\( U_{jd} = V_{jd} + \varepsilon_{jd} \)  

vii. **Probit Method**  

\[ t_{cd} = t_c + \varepsilon_d \]  

Where \( t_{cd} \) is Critical gap for driver \( d \)  
\( t_c \) is average critical gap for whole population of driver  
\( \varepsilon_d \) is deviation of critical gap for driver \( d \) from \( t_c \)
4. A Decision Model for Gap Acceptance and Capacity at Intersections

The authors presented a microscopic decision model for driver gap-acceptance behavior when waiting at an unsignalised intersection on the secondary road and also to estimate the resulting intersection capacity. The model is based on evaluation of the risk associated with not accepting small gaps against the potential benefit of their acceptance, which has saved time as a result of shorter waits at the entry line. The model takes into account individual preferences by defining individual critical gap, which is different from the traditional macroscopic critical-gap approach. The latter estimates the critical gap for the entire population of drivers. The paper presents the difference between different driver populations (risk loving vs. cautious) and shows how this difference actually results in different capacities on the minor road.

5. Total Capacity of Unsignalized Intersections under Mixed Traffic Flow

Studies for capacity under mixed traffic situations have been done, especially in developing countries e.g. India and Indonesia where vehicles are categorized as fast–moving vehicles and slow–moving vehicles where the static and dynamic characteristics of these vehicles vary widely. Ramanayya (1988) has done a simulation model which was developed and tested with a number of times for different traffic volumes and a different percentage mix of vehicles. Traffic stream models (speed – flow, speed – density and flow – density) under mixed traffic conditions are essential to the formulation.

Chandra & Sinha (2001) and Chandra & Kumar (2003) stated that the capacity on two–lane roads was influenced by directional split of traffic. The capacity reduces as split moves away from 50/50. The capacity of a two–lane road also increases with total width of the carriageway. IHC M (1997) determined the capacity of a road segment based on basic capacity with various adjustment factors such as carriageway width, kerb and shoulders, median and directional split, side friction and city size. In such a case, it is very difficult to measure the capacity due to poor lane discipline which exists including a tendency to “cut corners” while drivers making right–turn which results in a blockage of other traffic movements. Studies of the driver’s behavior in China showed that only 40% of the vehicles that had a choice between ”gapping” and ”pushing” actually waited for a gap in the major road flow, i.e., gap acceptance models could not be used to predict intersection performance for unsignalized intersections.

CONCLUSIONS & RECOMMENDATIONS

Based on the experimental analysis, the following conclusions can be made:

i. The data like Volume, Flow, and Capacity of each type of vehicle can be obtained from the field study whereas for gap acceptance models.

ii. Based on the traffic flow measurements, the maximum flow of a stream, the total capacity of an intersection can be calculated by Comparing all the 3 T-intersections.

REFERENCES


