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Estimation of capacity at Un-Signalized intersections under mixed traffic flow conditions

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Abstract
The methodology for the analysis of capacity at unsignalized intersections has been established where identical traffic conditions are depending upon the present traffic scenario. There are several attempts made to develop different approaches for the analysis of unsignalized intersections under Mixed, Major and Minor traffic conditions. Conflict technique is a recent development, which is based on practically simplified concept, considering interaction and impact between flows at intersection and using different mathematical models by calibrating their accuracy. In present study, capacity of unsignalized intersection was calculated from Capacity. Surveys were conducted in Nellore, to measure Capacity by empirical methods. Movement capacities were evaluated by using UK method German method, HCM (2000) method capacity comparison with approach wise capacities obtained different directions on the study area.

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

1. Introduction

Were first introduced in the early 1960s in England. These facilities were introduced in order to solve the problems of the existing rotaries and traffic circles. Using the principal that entering traffic yields to circulating traffic, or the "give way" rule, roundabouts proved to be a much more efficient intersection than the rotaries, and in many cases, signalized intersections. Roundabout is a junction with a central island where the conflicting traffic streams are separated in time by the priority rules, i.e. the entry vehicles should give way to the circulating vehicles.

1.1 Basic concepts of Round About

- **Offside priority or yield-at-entry:** Roundabouts give vehicles in the circulating roadway the right of way. This is different than other uncontrolled, yield controlled or multi-way-stop controlled intersections that give priority to vehicles approaching from the left.
- **Approach flare:** Most roundabout approaches flare out at the entries and allow more vehicles to enter the circulating roadway at a more obtuse angle. This improves capacity, and allows entering vehicles to enter at similar speeds as the circulating vehicles unless a queue has developed at the entry. The size and angle of the flare is generally controlled by a Raised Splitter Island that separates the entering and exiting traffic at an approach.
- **Deflection:** This characteristic is the geometry of the facility that requires vehicles to slow down as they man oeuvre through the roundabout. The size of the Centre Island and angle of approach determine the deflection and potential speeds of entering and circulating vehicles. In addition to these three primary requirements, there are other attributes common to roundabouts. Unlike traffic circles, where there can be pedestrian access to the centre island, crosswalks for roundabouts are located on the approach legs, behind the yield lines. Also, parking is not allowed within the circulating roadway or at the entries of the approach legs, and all entering traffic is required to proceed around the roundabout in a clockwise direction.
- **Volume Count Study:** To determine the number, movement and classification of roadway vehicles at a given location. The number of observers needed to count the vehicles depends upon the number of lanes in the highway on which the count is to be taken and the type of information desired. The indications in table can be used as rough guides. It is perhaps more desirable to record traffic in each of travel separately and past separate observer for each direction enumerators should be literate persons with preferably middle or matriculation level for the purpose.
- **Gap Acceptance Study:** Pedestrians preparing to cross the roadway must access the gaps in conflicting traffic determine whether sufficient length is available for crossing & decide to cross the road. Following experiments presents a method for collecting field data to identify the minimum usable gap. As if any traffic engineering analysis recognition & definition of the difference between the standard values of the observed values & the observed values increase the accuracy.

1.2 Concept of roundabout capacity

The capacity of each entry to a roundabout is the maximum rate at which vehicles can reasonably be expected to enter the roundabout from an approach during a time period under prevailing traffic and roadway (Geometric) conditions.

The maximum flow rate that can be accommodated at a roundabout entry depends on two factors; the circulating flow on the roundabout that conflicts with the entry flow, and the geometric elements of the roundabout.

When the circulating flow is low, drivers at the entry are able to enter the roundabout without significant delay. The large gaps in the circulating flow are more useful to the entering drivers and more than one vehicle may enter each gap. As the circulating flow increases, the size of the gaps in the circulating flow decrease and the rate at which vehicles can enter also decreases.

The geometric elements of the roundabout also affect the rate of entry flow. The most important geometric element is the width of the entry and circulatory roadways, or the number of lanes at the entry and on the roundabout. Two entry lanes permit nearly twice the rate of entry flow as doe's one lane. Wider circulating roadways allow vehicles to travel alongside or follow, each other in tighter bunches and so provide longer gaps between bunches of vehicles. The flare length also affects the capacity. The inscribed circle diameter and the entry angle have minor effects on capacity.

As at other forms of un-signalized intersection, when traffic flows on an approach exceed approximately 85 percent of capacity, delays and queue lengths very significantly about their mean values (with standard deviations of similar magnitude as the means). For this reason, the analysis procedures in some countries recommend that roundabouts be designed to operate at no more than 85 percent of their estimated capacity (FHWA 2000) [8].

1.3 Need for the study

Traffic behavior in developing countries is largely differ from those or developed countries. Traffic composition of each type of vehicles is slightly different with different static and dynamic characteristics called as fast-moving vehicles and slow-moving vehicles. Exclusive lanes, especially for un-motorized or slow-moving vehicles are very uncommon. Impact from large different in speed could be serious problem in traffic operation, safety and capacity. Furthermore, typical roadside activities have a very significant effect in reducing the capacity, ex. Pedestrian, stopping and parking vehicle and entering / leaving vehicles.

1.4 Objectives of the study

The objectives of the present study are as follows:

- To find the capacity of roundabout intersection from various methods.
- To compare the results obtained by the various methods.

2. Literature Review

This chapter deals with various methods and models developed to find the capacity of roundabout intersections. General types of capacity analysis models have been used for TWSC intersections, gap acceptance methods and empirical methods.

Various models have been developed based on the gap acceptance theory and different assumptions of gap acceptance process. Empirical models were developed using regression Techniques.

2.1 Definitions

a) **Capacity:** The capacity of each entry to a roundabout is the maximum rate at which vehicles can reasonably be expected to enter the roundabout from an approach during a time period under prevailing traffic and roadway (Geometric) conditions.

b) **Level of service:** The level of service is defined as a qualitative measure describing the operational conditions within a traffic stream, and their perception by motorist and/or passengers.

c) **Service Time:** The time period that customer spends in service facility. At un-signalized intersection the time period during which a vehicle not blocked by vehicles ahead and blocks the vehicle behind from reaching the stop/yield line.

d) **Critical Gap:** Critical gap is the minimum time needed for a vehicle in the minor road to enter safely the major road stream. The critical gap is the median of the minimum accepted gaps. The median divides the data set into two parts of equal size. Another definition given by Raff and Hart (Salter, 1974) defines the critical gap as that gap of which the number of accepted gaps shorter than it is equal to the number of rejected gaps longer than it.

e) **Follow-up Time:** Time between the departure of one minor stream vehicle and the departure of the next vehicle, using same gap, under condition of continuous queuing.

2.2 Empirical Capacity Models

2.2.1 The U.K. Capacity Formula

The UK roundabout capacity formula is based on Kimber's study in 1980. Kimber's equation could be used for both large and small roundabouts. The first approach is a linear approximation used to determine the entry capacity of a roundabout. Kimber's capacity formula is (Kimber, 1980):

$$Q_e = F - fcQ_c \qquad (2.1)$$

Where: Q_e =entrycapacity,pcu/h
Q_C = circulating flow, pcu/h
F, fc =Parameters defined by roundabout geometry

2.2.2 Germany's Formula

Germany uses an approach similar to that of the U.K. Germany investigated both regression and gap theory and decided to utilize the U.K. regression analysis. However, in contrast with the U.K. linear approximation, an exponential regression line was used to describe the entry/circulating flow relationship because of the better agreement with the gap acceptance capacity formula developed by Siegloch (1973) [3]. Germany's formula:

$$Qe = A*e-BQc/1000 \qquad (2.9)$$

Where:
Q_e = entering capacity (pcu/h)
Q_c = circulating flow (pcu/h)
A, B = defined parameters

Several types of roundabouts were investigated. The parameters A and B in this equation have been determined separately from the measurements by regression calculation for different number of entries. The values of A and B are shown in Table 1.

Table 1: Coefficients of Calculating the Capacity of Roundabout

Number of Lanes			
Entry	**Circulating Roadway**	**A**	**B**
1	1	1089	7.42
2-3	1	1200	7.3
2	2	1553	6.69
3	2	2018	6.68

The German results are between 0.7 and 0.8 of the English values. In Birgit Stow's opinion (Stowed 1991), this difference can be explained by different driver behaviour. It is assumed that drivers in England are more familiar with roundabouts because this type of intersection control has been in place in England for a long time. In Germany, however, at the time of this study, roundabouts are still an exotic solution.

Recently, continuing research from the federal government in Germany shows that the linear function instead of an exponential function has a better agreement of the variance of data (Briton, Wu and Bonze 1997) [5]. The new capacity formula is:

$$Qe = C+DQc \qquad (2.10)$$

Table 2: Coefficients for Linear Regression

No. of Lanes Entry/Circle	C	D	N (Sample Size)*
1/1	1218	-0.74	1504
1/2 or 1/3	1250	-0.53	879
2/3	1380	-0.5	4574
2/3	1409	-0.42	295

2.2.3 HCM-2000 method

2.2.3.1 Introduction

The unique characteristics of roundabout capacity are introduced along with terminology. For ease of reference, the following terms are defined:

c_a = approach capacity
v_e= entry flow rate, and
v_c = conflicting flow rate.

Roundabouts have been used successfully throughout the world and are being used increasingly in the United States, especially since 1990. A recently completed study provides a comprehensive database of roundabout operations for U.S. conditions based on a study of 31 sites. The capacity and level of service analysis procedures that follow were developed in that study. The procedures allow the analyst to assess the operational performance of an existing or planned roundabout given traffic demand levels.

Intersection analysis models generally fall into two categories. Empirical models rely on field data to develop relationships between geometric features and performance measures such as capacity and delay; these are commonly regression models. Analytical models rely on field measures of driver behavior and an analytic formulation of the relationship between those field measures and performance measures such as capacity and delay.

2.2.3.2 Methodology

The capacity of an approach on a roundabout can be estimated using gap acceptance theory with parameters of critical headway and follow-up time. It is generally assumed that the performance of each approach can be analyzed independently of the other approaches. The three flows of interest, the entering flow, the circulating flow, and the exiting flow, are shown in Figure 1.

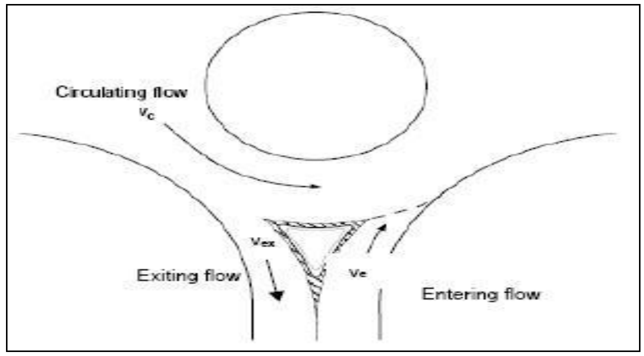

Fig 1: Analysis on one roundabout leg

2.2.3.3 Capacity

The capacity of a given approach is computed using the following process:

- Adjustment of the flows to account for vehicle stream characteristics.
- Determination of the entry and conflicting flows for each approach. For multilane approaches, evaluation of the approach will be done to determine the flow in each lane on an approach and identify the critical lane on the approach.
- Computation of the maximum possible entry flow will be done by using the appropriate model (single-lane model or multilane critical lane model).

Computation of the performance measures for each entry lane.

2.2.3.4 Capacity for round About Entries

The capacity of a roundabout is based on the conflicting flow, the critical headway, and the follow-up time. The equation for estimating the capacity is given as.

$$c_{e,x} = \frac{v_{c,x} e^{-v_{c,x} t_c / 3600}}{1 - e^{-v_{c,x} t_f / 3600}}$$

Where: $c_{e,x}$ = entry capacity for entry x, veh/h;
$v_{c,x}$= conflicting flow in front of entry x, veh/h;
t_c = critical headway, s; and
t_f = follow-up time, s.

The capacity model given above reflects observations made at U.S. roundabouts in 2003. As noted previously, it is expected that capacity at U.S. roundabouts will increase over time with increased driver familiarity. In addition, communities with higher densities of roundabouts may experience a higher degree of driver familiarity and thus potentially higher capacities. Therefore, local calibration of the capacity models is recommended to best reflect local driver behavior.

The single-lane capacity model has two parameters for calibration: the critical headway, t_c, and the follow-up time, t_f. If field measurements cannot be made, recommended values are given in Table 2. For reference, the minimum and maximum observed values for these parameters are also given in this Table

Table 3

	t_c s	t_f s
Recommended value	5.1	3.2
Minimum measured value	4.2	2.6
Maximum measured value	5.9	4.3

3. Study Methodology

Comprehensive literature on capacity estimation of roundabout has been presented in the previous chapter. In the present chapter study methodology is being presented.

3.1 Background

A suitable form of capacity and delay equations from the available equations is selected so that they can be modified in order to suite to Indian condition. Basically, two main approaches can be seen among the various approaches currently practicing in the world to acquire capacity estimations. They are:

(i) Gap acceptance approach, and

(ii) Empirical approach.

In U.K. (Kimber method) and Germany (Briton method), the empirical approach has been used while in Australia (Trout beck method), Akcelik method and the HCM 2000 method, the gap acceptance approach has been used.

The difference between these two methods can be described in terms of methodology, data collection, reliability of prediction and the appropriate situations. The gap acceptance approach is mainly based on theory and driver behavior represented by vehicle-to-vehicle interaction. The empirical approach is based on statistical regression and driver behavior is represented by the relation between geometric elements and road performance.

Although an extensive amount of data with sufficient variation of geometric parameters is required in empirical approach, few roundabouts are currently

Operated and fewer data can be obtained on the relationship between driver behavior and geometric elements. On the other hand, driver behavior through vehicle-to-vehicle interaction can be monitored sufficiently even with few available roundabouts. The reliability of the later method is dependent on the developed model and assumptions used for the model. In terms of appropriate situations, former approach is easy for planning purposes but the latter one is convenient in geometric design purposes. Thus, the empirical approach is considered to be more suitable for capacity estimation for Indian conditions.

The U.K. and Germany method use empirical approach. In order to choose the most appropriate equation from these two, first, the U.K. method and Germany method are compared. Germany method is suitable for roundabouts, which have typical inscribed circle diameters in up to 30 m. Their design allows lower speeds at the entry, on the circulatory roadway, and at the exit.

U.K. method is suitable for roundabouts, which have typical inscribed circle diameters up to 40 m and somewhat more tangential entries and exits, resulting in higher capacities. Their design allows slightly higher speeds at the entry, on the circulatory roadway, and at the exit. Considering these aspects, U.K. capacity formula is selected to represent the realistic traffic behavior.

3.2 Overview of the methodology

3.2.1 Selection of Location

Before collecting the data, intersections that represent the objectives of the study are chosen after reconnaissance survey. The surveys were conducted in the city of Madurai (dt) in Tamil Nadu. To fulfil the specified objectives of the study two roundabouts have been chosen.

1. Madurai Junction
2. Rameswaram Junction

3.2.2 Survey and Data Collection

Surveys will be carried out to get the reliable data at the chosen intersection consisting of heterogeneous traffic. Different modes of traffic such as Buses, Trucks, cars, auto rickshaws, cycles and low commercial vehicles etc. ply on these roads. The following surveys will be conducted.

Roundabout Inventory survey Traffic Volume Count Survey

3.2.2.1 Roundabout inventory survey

Inventory data is a collection of the physical characteristics of the roundabout. The inventory details of the roundabout are collected by the team of enumerators. The inventory details constitute the following parameters.

1. Entry width
2. Approach half width
3. Effective flare length
4. Inscribed circle diameter
5. Entry angle
6. Entry radius
7. Sharpness of flare

3.3 Capacity Estimation by Various Methods

Generally the capacity of the roundabout has been estimated by using the empirical approach and gap acceptance approach. In the present study the capacity will be estimated by two empirical methods namely:

- The U.K. capacity method
- Germany’s method

And also under the gap acceptance approach the HCM 2000 method will be used.

3.3.1 Comparison of the Capacity Estimation by Various Methods

Finally the comparison will be made between the various methods for the capacity estimation of roundabout.

4. Summary and conclusions

4.1 Summary

The main objective of the study was to estimate the capacity of the roundabout by various methods. In this study two roundabouts have been considered to carry out the traffic volume study and roundabout inventory survey. The summary of the present study is summarized as follows. To fulfill the specified objectives of the study two roundabouts have been chosen.

- Nellore Junction
- KVR Petrol bunk Junction
- The concerned surveys were conducted to fulfill the specified objectives of the study.
- The data collected from the field is analyzed to study the variation of traffic, peak hour, and traffic composition.

- In the present study the capacity has been estimated by two empirical methods and one gap acceptance approach namely:
- The U.K. capacity method
- Germany's method
- HCM 2000 method

4.2 Conclusion

Based on the study carried out the following conclusions have been made:

- The capacities estimated by the Germany's method and HCM 2000 method are nearly equal.
- The estimated capacity by the U.K. method is quite grater then the Germany's method and HCM 2000 method. Hence capacity estimated by U.K. method can be considered for the design purpose.

4.3 Limitations of the study

- Following are the limitations of the present study: In the present study only two roundabout intersections have been considered.
- In H.C.M. 2000 method the data regarding with the follow-up time and the critical headway is directly collected by the previous studies, as the special surveys required for that.

4.4 Scope for the future work

The presented study work can be extended further as suggested below. The variation of driver's behavior and roundabout geometry is important in the outcome of the capacity formula. Therefore, the research is essential which orients toward the driver's behavior. Basic parameters i.e., critical gap, follow-up time, and headway distribution can be collected from field experiments

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