DEVELOPMENT OF DELAY MODELS FOR ROUNDABOUT WITH HETEROGENEOUS TRAFFIC FLOW CONDITION

K. Shashi Kumar[1] Mohammed Ibrahim [2], Prof. R. Srinivasa Kumar[3]

[1,2]Student M.E (Transportation Engineering),

[3]Assistant Professor, Department of Civil Engineering,

University College of Engineering,

Osmania University, Hyderabad, Telangana, (India)

ABSTRACT

The purpose of this research was to develop a model for estimating roundabout delay as a function of the influencing traffic and geometric factors. Three roundabouts were selected in Hyderabad.

a) A 4-legged roundabout intersection named as "Prasad Imax Junction"

b) A 4-legged roundabout intersection named as "Narayanguda Junction"

c) A 4-legged roundabout intersection named as "Barkathpura Junction"

Circulating volume, entry volume, and entry delay were measured during peak and off-peak periods using video cameras. Data on geometric design elements including circulating width, entry width, and roundabout diameter were measured through field survey. An empirical approach was used to develop a delay model as a function of the influencing factors based on a time interval of 15 min. The analysis indicated that geometric variables have significant effects on the roundabout entry delay. The entry width has the greatest influence, whereas the circulating width has the least influence. A comparison between delay models produced using different time intervals showed that, as time interval increases, the stronger the correlation.

Key Words: ***Intersections; Hyderabad; Delay Time; Traffic Flow.***

I. INTRODUCTION

The traffic performance of a roadway network is greatly influenced by the traffic flow through intersections. Many types of traffic control are being used worldwide at intersections, including yield signs, stop signs, roundabouts, and signals. Transportation is an infrastructure facility for the economic, social, cultural and administrative development of a nation. But in order to see that interaction materialize in practice, a provision of suitable transportation system is imminent. The rapid urbanization and growth of private ownership have caused an increase in road traffic congestion and delays in most of the urban areas in India. Generally road network links in the urban areas frequently intersect thus leading to conflicts between opposing flows of traffic and to delays and accidents.

Roundabouts are widely used in Europe, Australia, and recently have received more acceptances in the United States and other countries. Roundabouts work than traffic signals at intersections with low to medium traffic volumes. They reduce the overall delay, better handle intersections with high volumes of left turns, reduce fatal and injury accidents, reduce the speeds of approaching vehicles to the intersection, have lower maintenance costs, and provide an opportunity for landscaping inside the central island.

1.1 Delays at Roundabout Intersection

Roundabout intersections are the intersections which function without any priority assigned to the traffic on any of the intersecting roads, no control (neither STOP signs nor Police-controlled) and the traffic is of heterogeneous nature. These intersections are vital nodal points on urban roads, the performance of which will influence the traffic flow on entire network.

1.2 Need for the Study

The recent steep growth of traffic in and around urban areas in India created an urgent need for better management of vehicles movements along the main streams, in general, through uncontrolled intersections, in particular. In India, the problem of traffic congestion, delay, and queuing are more complex than that in western countries. This is mainly due to

- Heterogeneity of traffic flow
- Unrestricted mixing of various vehicles without their physical segregation
- Irregular lateral and longitudinal spacing among the vehicles while in queue.
- Lack of lane discipline
- Haphazard movement of vehicles and pedestrians.

The various factors affecting the delay caused to the vehicles approaching the intersections are:

- **Physical factors**: Number of lanes, width, grades, access control, channelization and transit stops
- **Traffic factors**: Volume on each approach, turning movements, vehicle classification, driver characteristics, approach speeds, parking and pedestrians.
- **Traffic controls**: Type of control (Signals/Stop-Yield signs/police control/uncontrolled), parking regulations, prohibition of certain turning movements.For this purpose, it is necessary to develop a model which will be useful to analyze the traffic delay and apply the results to evolve appropriate traffic management measures for safe, fast and economic movement of traffic.

1.3 Objectives of the Study

Based on the above discussion, the present study was taken up with the following objectives:

- To identify the study area
- To collect data on
- Geometric characteristics

- Traffic volume study for delay studying using video photography.
- To develop a model for estimating roundabout delay as a function of the influencing traffic and geometric factors.
- An empirical approach was used to develop a delay model as a function of the influencing factors based on a time interval of 15 min.

II. OVERVIEW OF LITERATURE

Kimber and Hollis (1979) conducted a comprehensive research on traffic delay and queues at road junctions in Great Britain. They estimated vehicle delay as a function of entry capacity, entry degree of saturation, and distribution of arrivals and services.

Troutbeck (1986) utilized a dichotomized distribution to represent the roundabout headway distribution and developed a group of models for roundabout capacity and delay.

The Institute of Transportation Engineers (ITE) Technical Council Committee (Yagar 1992) has summarized the current practice related to the use and analysis of roundabouts based on the U.K. and Australian procedures. The U.K. procedure estimates vehicle delay as a function of entry capacity, entry degree of saturation, and distribution of arrivals and services.

Akcelik and Troutbeck (1991) developed a comprehensive Australian method for analysis of the capacity and performance of roundabouts. The method allows for the effects of circulating flows, entry flows, and roundabout geometry on gap acceptance parameters. The method was implemented in the SIDRA package. SIDRA was developed by Australian Transport Research Ltd.

Flannery and Datta (1997) used 16 h of field data collected by video camera to determine the critical gap for roundabout entry based on the graphical method as 3.7 s, and that based on the likelihood technique method as 3.89 s. They also derived the probability density function for the gap acceptance of roundabouts in the United State.

Flannery et al. (1998) Made a before-and-after study to compare the entry delay for five intersections converted from stop control to roundabouts, and they found that roundabouts caused significant reductions in the entry delays.

Garder (1999) investigated the effect of converting intersection control from a two-way stop to a roundabout at a main junction in the United States. The results indicated that the construction of the roundabout reduced the average minor streets delay by about 83% in the morning peak and by 76% in the afternoon peak.

Oh and Sisiopiku (2001) made a comparison between the performance of different types of intersection control-roundabouts, yield, and two- and four-way stop control—using the SIDRA(Southwestern Idaho Desert Racing Association.) package for various volume levels, turning volume splits, number of approach lanes, and lane widths. They concluded that ‘‘roundabouts are the best alternative design for intersections with two lane approaches that carry heavy through and/or left turning traffic volumes”

Thamizh Arasan (2005) described a modeling methodology adopted to simulate the flow of heterogeneous traffic with vehicles of wide ranging static and dynamic characteristics. Satish Chandra et al. (2009) introduced a service delay model, based on microscopic analysis of delay data under mixed traffic conditions. Service delay (or Service time) is mainly depends upon the conflicting traffic volume and the priority of the movement. Satish Chandra and Ashalatha (2010) developed a simulation model capable of simulating heterogeneous traffic flow conditions at a TWSC intersection. Driver behavior was incorporated in the model through intersection clearing time distributions. This simulation model is used for studying the effect of conflicting traffic as well as its composition on the service delay of various priority movements.

III. PROPOSED METHODOLOGY

The suggested methodology is presented below through a flow chart, as shown in Figure-3.0 .

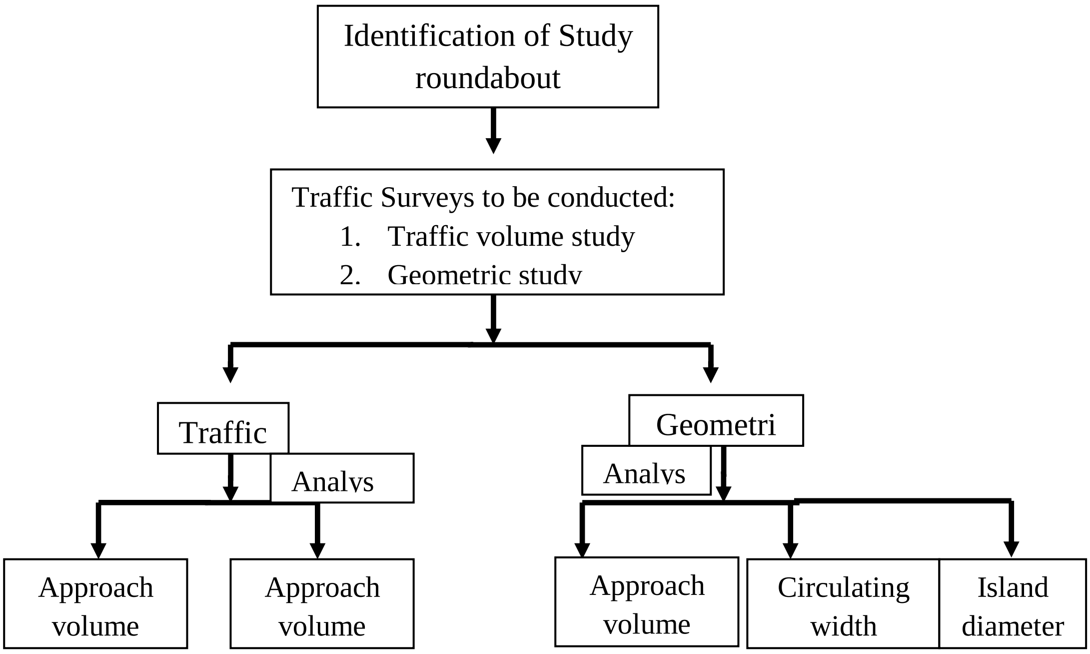


Fig 3.0 Proposed Methodology

3.1 Case Study Area

Figure 3.1 Site image of Prasad Imax Junction

Figure 3.2 Site Image of Narayanguda Junction

Figure 3.3 Site Image of Barkatpura Junction

3.2 Generation of Vehicle Characteristics

The dimensions of the vehicle, acceleration and deceleration characteristics and the mode of operation of the vehicle very much influence its behavioral properties. The traffic at these intersections in most Indian cities is highly heterogeneous comprising vehicles with different static and dynamic characteristics falling on the wide range. For the purpose of the study, the vehicles based upon the size, speed and acceleration or deceleration characteristics were grouped into the following types:

i. Cars (car/jeep/passenger van)	iv. Heavy vehicles (bus/truck/tractor/mini-bus)
ii. Motor cycles (motorcycle/scooter/moped)	V. Non-motorized vehicles (cycle/cycle-rickshaw)
ii. Auto-rickshaws	

The average dimensional attributes of the five proposed vehicle categories are given in the Table-3.1.

Table 3.1 Dimensions of the vehicles

S.NO	Vehicle Type	Length(m)	Width(m)
1	Heavy Vehicles (Bus/Truck)	7.5	2.4
2	Cars	4.4	1.65
3	Auto-rickshaws	2.5	1.25
4	Motorcycles	2.0	0.7
5	Bicycles	1.9	0.5

3.3 Delay Study at roundabout Intersection

The volumes of traffic on the subject entry and circulating roadways were counted while observing the videotapes. At the same time, the queue length (number of vehicles between the entry stop line and the end of the standing queue) for the subject approach was measured based on a time interval of 15 s. A vehicle was considered as having joined the queue when it approached within one car length of a stopped vehicle and was itself about to stop (TRB 2000). The counting process was repeated every 15 s during the study period using a countdown-repeat timer on a digital watch to signal the count time. Observations were then averaged for each one minute (four observations per minute) to calculate the average queue length. Also, the average queue lengths for other time intervals were estimated by grouping the 1 min data to obtain the 15min interval data. The average stopped delay was then calculated using the followingThe average stopped delay was calculated using the following little's formula (Salter and Okezue 1988). This formula has proved (Zonghong et al. 1997) to give reliable delay estimates at unsignalized intersections.

Let D=stopped delay time (s); L=queue length (veh); and λ=mean arrival rate (veh/s). $D=L/\lambda$

The data of interest for each approach are the entry flow and the circulating flow. Entry flow is simply the sum of the through, left, and right turn movements on an approach. Circulating flow is the sum of the vehicles from different movements passing in front of the adjacent upstream splitter island. At existing roundabouts, these flows can simply be measured in the field. Right turns are included in approach volumes and require capacity, but are not included in the circulating volumes downstream because they exit before the next entrance

VEB,circ = VWB,LT + VSB,LT + VSB,TH + VNB,U-turn + VWB,U-turn + VSB,U-turn

VWB,circ = VEB,LT + VNB,LT + VNB,TH + VSB,U-turn + VEB,U-turn + VNB,U-turn

VNB,circ = VEB,LT + VEB,TH + VSB,LT + VWB,U-turn + VSB,U-turn + VEB,U-turn

VSB,circ = VWB,LT + VWB,TH + VNB,LT + VEB,U-turn+ VNB,U-turn + VWB,U-turn

IV. DATA COLLECTION

The data set pertaining to the independent variable and the dependent variable were obtained by conducting the traffic surveys at study intersections. Classified turning movement volume counts of vehicles of each groups i.e., two-wheelers, cars, auto, buses, trucks, tractors, mini-bus/tempo vans) and, for each direction of movements (LT, RT,TH and U-turn) at each of the approaches were done simultaneously for 1hours in the morning session at 10 AM.

It was observed that the traffic volume and vehicular composition of individual vehicles remained varied slightly during the survey period. The video camera was placed at a suitable vantage point near the intersection to record an unobstructed view of all approaches and turning movements and data were recorded for about 1hr to 2 hr depending upon the significant sample of vehicle type. The recorded video file was played in the laboratory several times to get the conflicting traffic volume count and the queue length experienced by each subject vehicle.

4.1 Data Extraction

The average stopped delay was then calculated using the following

Little's formula (Salter and Okezue 1988): $D = L/\lambda$

Where D=stopped delay time (s); L=queue length (veh); and λ=mean arrival rate (veh/s).

4.2 Passenger Car Units Considered for the Analysis

As per IRC: 106-1990, "Guidelines for Capacity of Urban Roads in Plain areas", urban roads are characterized by mixed traffic conditions, resulting in complex interaction between various kinds of vehicles. To, cater to this, it is usual to express the capacity of urban roads in terms of a common unit. The unit generally employed is the 'Passenger Car Unit' (PCU), and each vehicle type is converted into equivalent PCUs based on their relative interference value. Considering all these factors, the conversion factors as shown in Table 4.3 are recommended for adoption.

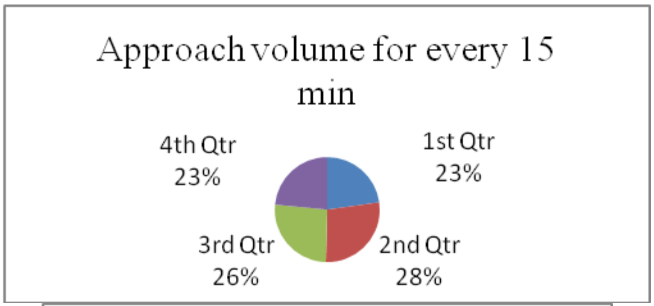
Table 4.1 Recommended PCU factors for various types of vehicles on urban roads (IRC: 106-1990)

Vehicle Type	Equivalent PCU Factors	
	Percentage Composition Of Vehicle Type In Traffic Stream	
	5%	10% and above
Fast Vehicles		
2w	0.5	0.75
3w/Auto	1.2	2.0
Car/Van	1.0	1.0
LCV	1.4	2.0
Truck/Bus	2.2	3.7
Tractor	4.0	5.0
Slow Vehicles		
Cycles	0.4	0.5
Cycle Rickshaws	1.5	2.0
Tonga	1.5	2.0
Hand Cart	2.0	3.0

4.3 Approach volume and Circulating volume and Stopped Delay Time

Traffic volume from khairatabad signal. Table 4.2 entryflow from khairatabad for every 15 min

TIME	2W	AUTO	TRUCKS	BUS	CAR	TOTAL	AV	CV	SDT
00-15	640	186	12	6	515	1359	1274	477	2.43
15-30	721	241	10	3	425	1450	1546	792	1.76
30-45	684	192	8	0	534	1418	1461	842	2.28
45-60	573	154	0	1	570	1298	1312	507	2



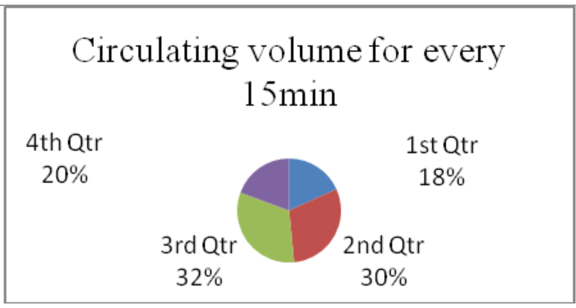


Fig 4.1 Indira Gandhi statue circle Google map

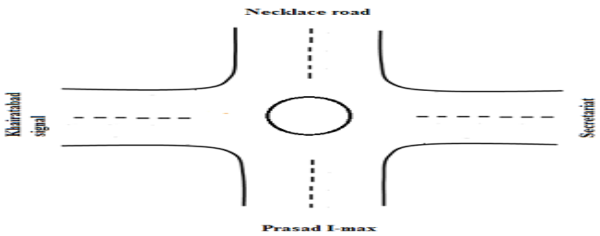


Fig 4.2 Indira Gandhi Statue Circle

4.4 Model Development of Average Stopped Delay

The analysis was done separately for five categories of approach based parameters like Entry width, circulating width, Island diameter, approach volume and circulating volume. Correlation is a statistical measure for finding out degree of association between two or more variables. The extent or degree of relationship between two variables measured in terms of another parameter is called the coefficient of correlation. It is denoted by r. Let X and Y denote two variables and r denote the coefficient of correlation between X and Y. depending on the value of r.

$$\mathbf{Y = a_0+a_1X_1+a_2X_2+......+a_nX_n}$$

Y = dependent variable ao = regression constant xl, x_2 = independent variables a_l , a_2 = regression coefficients, we can classify correlation as follows

(a) If r = 1 both the variables X and Y increase or decrease in the same proportion. In this case we say that there is perfect positive correlation.

(b) If r = -1 both the variables X and Yare inversely proportional to each other. We say that there is perfect negative correlation.

(c) If r = 0 we say that there is no relation between X and Y.

(d) If 0< r < 1 , there is moderate (partial) positive correlation between X and Y

(e) If -1< r < 0 , there is moderate (partial) negative correlation between X and Y

Data showing Average stopped delay models, Entry width, Circulating width, Island diameter, Approach volume and Circulating volume of three roundabout delay for 15min time interval are in the below table 5.1

Table4.3 Total Data for Model Development

S No.	ASD	EW	CW	Is-Dia	AV	CV	S No.	ASD	EW	CW	Is-Dia	AV	CV
1	2.43	10.5	13.5	60	1273	477	25	2.26	9.5	11.2	17	762	1350
2	1.76	10.5	13.5	60	1545	792	26	0.19	9.5	11.2	17	601	1128
3	2.28	10.5	13.5	60	1460	842	27	2.72	9.5	11.2	17	695	1263
4	2	10.5	13.5	60	1311	507	28	2.9	9.5	11.2	17	823	1370
5	1.6	10.5	13.5	60	1460	768	29	2.7	9.5	11.2	17	808	1456
6	1.65	10.5	13.5	60	1412	794	30	3.22	9.5	11.2	17	865	1402
7	1.71	10.5	13.5	60	1263	627	31	2.98	9.5	11.2	17	879	1290
8	2.12	10.5	13.5	60	1318	622	32	3.26	9.5	11.2	17	914	1523
9	3.27	9.5	13.5	60	838	1466	33	3.86	6	12.6	42	1241	300
10	3.49	9.5	13.5	60	748	1746	34	3.02	6	12.6	42	1368	361
11	3.76	9.5	13.5	60	771	1535	35	3.62	6	12.6	42	1215	356
12	2.41	9.5	13.5	60	780	1372	36	2.72	6	12.6	42	1225	331
13	1.97	9.5	13.5	60	871	1667	37	3.15	6	12.8	42	834	440
14	3	9.5	13.5	60	810	1826	38	4.04	6	12.8	42	760	463
15	2.85	9.5	13.5	60	762	1729	39	3.36	6	12.8	42	835	432
16	2.53	9.5	13.5	60	748	1646	40	3.5	6	12.8	42	753	457
17	2.45	12	11.6	17	1500	628	41	3	4.5	12	42	633	742
18	2.37	12	11.6	17	1408	704	42	3.75	4.5	12	42	578	722
19	2.41	12	11.6	17	1275	702	43	3.58	4.5	12	42	601	762
20	2.76	12	11.6	17	1465	744	44	2.9	4.5	12	42	580	732
21	1.91	11.2	11	17	1299	701	45	3.8	4.5	12.8	42	264	1388
22	1.98	11.2	11	17	1322	721	46	4.61	4.5	12.8	42	237	1561
23	1.6	11.2	11	17	1268	820	47	3.91	4.5	12.8	42	208	1374
24	1.61	11.2	11	17	1339	866	48	4.81	4.5	12.8	42	242	1367
							Avg	2.787	8.6	12.4	39.667	961.8	977

Multiple correlations were done for the above following data in Microsoft excel 2010 and following is the output data.

Table 4.4 Correlation

Predictor	Delay	EW	CW	AV	CV	Is-Dia
Delay	**1**					
EW	**-0.681**	1				
CW	**-0.146**	-0.136	1			
AV	**0.588**	0.678	-0.010	1		
CV	**0.172**	0.102	0.061	-0.547	1	
Is-Dia	**-0.105**	-0.177	0.970	-0.032	0.062	1

Based on the 15 min time interval, as can be seen from the correlation matrix in table 5.1, the subject approach width has the greater linear association with delay time, with correlation coefficient -0.681.We see graph between Average stopped delay and entry width showing the relation

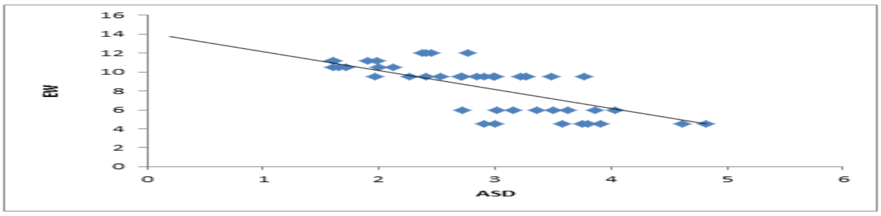


Fig 5.1 Graph Showing EW vs ASD

- Whereas the Island diameter and circulating width has less linear association with delay, with correlation coefficient of -0.105 and -0.146.
- Above correlation coefficient values show how the estimated average stopped delay depends geometric and traffic volume parameters.

Regression Model The following regression model was produced for estimation of the stopped delay time by using above data. The stepwise regression was used to find the most influencing variables on the stopped delay.

It was found that the entry traffic volume, circulating traffic volume, roundabout island diameter, circulating width, and entry width had significant effects on the stopped delay, and none of them could be excluded from the model. By using Microsoft excel tools this regression model was generated.

$$D_s = -7.816 + 0.00708V_s + 0.00818V_c - 0.067D_i + 0.8048W_c - 0.383W_e$$

With an adjusted R^2 of 60.2% and a Standard error of Estimate(SEE) of 0.55.

V. CONCLUSIONS

Based on the field studies and the modelling process, the following conclusions have been drawn:

- Using 15 min time intervals, an empirical model was developed to estimate the entry stopped delay time as a function of the entry traffic volumes, circulating traffic volumes, roundabout island diameter, circulating width, and entry width.
- It was found that the entry traffic volume, circulating traffic volume, roundabout island diameter, circulating width, and entry width had significant effects on the stopped delay.
- It was found that entry delay increases with an increase in entry volume, circulating volume, and circulating width, and with a decrease in island diameter and entry width.
- Entry width has the greatest influence on the estimated entry stopped delay time, while circulating width has the least influence.

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