Improvement Of Traffic Operations In Congested Signalized Intersections - A Case Study In Bangalore City

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Abstract

Intersections are usually considered as the critical points within the network and the evaluation of their performance provides valuable understanding and useful indication about the performance of the system. The capacity of signalized intersection is of more significant because such intersections often control the ability of the city streets to accommodate traffic. In Bangalore city, most of the signalized intersections are congested and operate in LOS E or F. The objective of the present study is to improve the performance operation of the signalized intersections by investigating the proper alternatives to enhance the traffic capacity. To achieve this objective, Bilekahalli signalized intersection in Bangalore city, along the Bannerghatta road, were selected.

The required data for the study purpose like Road Inventories and Traffic Volume Counts were collected. Traffic Volume Counts were collected by the video footages through the cameras installed at the signalized intersections by the Traffic Management Centre, Bangalore City Traffic Police Department.

The results of this study revealed the selected traffic facility currently undergoes serious degradation causing breakdown conditions. Thus, urgent considerations must be given regarding the upgrading in the LOS by suggesting many alternatives.

1.0 Introduction

Bangalore, the capital city of Karnataka, is one of the fifth largest metropolitan cities in the country. It has an area of 741 Sq.km, with a population of 6.8 million. The population of Bangalore is growing day by day. The intensity of the traffic and pedestrians crossing has increased significantly and there is requirement of augmentation of capacity for safe and efficient means to cross over roads especially at junctions in multiple directions.

Signalized intersections are key elements in the urban transportation network and carry heavy movement of motorized, non-motorized vehicles and pedestrians, which in turn generate many conflicts among crossing, turning and merging maneuvers. For a variety of reasons such as population, economic and auto ownership growth, increasing traffic demand can exceed the carrying capacity of the intersection during peak periods. As a consequence, traffic condition deteriorates and safety risk worsens. The congested and hazardous traffic conditions in the city increase fuel consumption of the vehicles, exhaust emission from the vehicles, accidents and noise, therefore a city's quality of life, world energy resources and global atmospheric conditions deteriorate.

Capacity of a road is represented by the maximum rate at which vehicles can pass through a given point in an hour under prevailing operational conditions. The number and width of lanes, grades, and lane use allocations, as well as signalization conditions ascertains the capacity of the road. The measures of effectiveness, which are commonly used to evaluate the signalized intersection operations, are Capacity and volume-to-capacity ratio, delay, and queue behavior of the vehicles. Intersection capacity or volume-to-capacity ratio is one of the operational measures of effectiveness used in measuring signalized intersection LOS.

1.1 Objectives

The objectives of the present study are as follows:

- To study the existing traffic situation for the selected signalized intersections of Bangalore City.
- To study the level of service for selected signalized intersections.
- To evaluate the traffic performance operation in selected congested signalized intersections.

- To propose the traffic improvement measures for the selected signalized intersections.

1.2 Scope of Studies

The studies were limited to identify the congested intersections in Bangalore city and to carry out the, investigations to reason out the causes for the congestion and suggesting improvement measures to improve the traffic operation using Highway Capacity Manual 2000.

2.0 Literature Review

Xin Yu and **Goro Sulijoadikusumo** made an effort to assess the capacity of signalized intersection. Here they used HCM method for the analysis, because HCM method doesn't take account for the effect of queue spillback from a downstream signal and is unable to provide accurate estimation if the spillback is present, recent practices in signalized intersection capacity analysis. The selected intersection was on the urban arterial road. The eastbound (EB) and westbound (WB) of the subject intersection have been experiencing heavy congestion during peak periods, resulting in frequently observed queue spillback from downstream intersection because of the short intersection spacing and long peak hour cycle length. In order to simplify the case study process, only the capacity of EB and WB through lane groups and morning peak hour traffic condition are considered. They collected the additional information's such as intersection spacing between signals, downstream approach lane configuration, downstream cycle length, saturation flow rates, number of lanes, road segment posted speed and green time allocation.

Because of the complexity involved in the formulation of the improved capacity assessment method and in order to reduce the chances of error if attempting to calculate by hand, an interactive spreadsheet tool was developed by using Microsoft Excel 2007 to quickly execute the process. The spreadsheet user was taken through this computerized tool where above traffic and geographic information at intersections is collected and the calculation is automatically processed. The spreadsheet tool had a one-page worksheet containing Input and Output. User was required to select lane group and enter data including the intersection geographic and signal timing information in the boxes of the input section and the capacity assessment analysis was done by using some equations.

Yusria Darma, Mohamed Rehan Karim et al. [r] made a research work to determine the set of variables that affect control delay at signalized intersection using capacity software's SIDRA and Transyt-7F based on Highway Capacity Manual methods. The study involved the selection process for the variables to be considered and the levels at which they will be considered. Their selection process is a key step in identification of those variables that have an effect on the control delay. Each of the potential variables that were identified was submitted to a test using SIDRA and TRANSYT-7F to determine the magnitude of its impact on the control delay. The variables selected for testing were chosen based on systematic and practical reasons. The Potential Explanatory Variables considered are Cycle length, Effective Green Time, Capacity, Volume to Capacity ratio, Saturation Flow Rate, Turning Movements, Signal Phasing Plan and Sequence, Speed Limit and Geometric Conditions such As Number of Lanes, Lane Widths, approach lengths etc. The first step that was done in testing the variables was to develop the basic test junction because it is important to understand the characteristics of the test junction. The basic test junction is the intersection with basic layout and parameters. Thus, the testing of all potential variables was done by substituting the test junction variables with the testing variables. Each of the potential variables was submitted to a test using TRANSYT-7F and SIDRA to determine the magnitude of its impact on the control delay. The disparities of the control delay values after executing the testing variables were the main target of the measurement in this study. The paired samples t-test method was utilized in this test to determine the significant variables that affect the control delay at signalized intersection.

I.N.Askerzade (Askerbeyli), **Mustafa Mahmood** made an effort to propose automated traffic signals at a junction. This paper uses the Fuzzy logic traffic lights control, which is an alternative to the present conventional traffic lights control and can be used for a wider array of traffic patterns at an intersection. A fuzzy logic controlled traffic light uses sensors that count vehicles instead of proximity sensors. This provides the controller with traffic densities in the lanes and allows a better assessment of changing traffic patterns. They used two electromagnetic sensors placed on the road for each lane. The first sensor behind each traffic light counts the number of vehicles passing the traffic lights, and the second sensor D from the lights. The number of vehicles between the traffic lights is determined by the difference of the reading between the two sensors. The distance between the two sensors D, is determined accordingly following the traffic flow pattern at that particular intersection. Finally they concluded, the fuzzy logic traffic lights controller performed better than the fixed-time controller or even vehicle actuated controllers due to its flexibility. Also a simulation experiment was carried out to compare the performance of the fuzzy logic controller with a fixed-time conventional controller. The flow density of the simulation was varied according to real life traffic conditions. They observed from the results that the fuzzy logic control system provided better performance in terms of total waiting time as well as total moving time. which is located behind the first sensor counts the number of vehicles coming to the intersection at distance

3.0 Methodology

3.1 General

This chapter includes the details of the methodology adopted and the field studies used for the present study. The details of the Signalized intersections, field studies such as Road Inventory and Turning Movement Counts and LOS have been discussed in the chapter.

3.2 Selection of Study Intersections

As mentioned earlier, two different signalized intersections of Bangalore city along the Bannerghatta road were considered for the study by limiting the general criteria in the selection of the study intersections:

- The selected intersections are flexible pavements and the pavement condition at the intersection and between the intersections are deteriorated.
- The selected intersections carry different categories of traffic from slow, medium to heavy trucks of single axle, two-axle and multi axle loads.
- The volume of traffic on the selected intersections is reasonably high causing congestion and delays.

3.3 Road Inventory Data

Inventory surveys of the selected intersections and road were undertaken initially. The purpose of the road inventory studies was to obtain the necessary information regarding the existing intersection features of the selected signalized intersections, existing pavement condition and existing conditions of the drainage structures and other ancillary road features like footpath, medians, kerbs, Road Furniture's etc. The following information was collected as part of the survey.

- Presence of crossing traffic (vehicular, pedestrian)
- Width of the Carriage Way and Shoulders
- Surface type of carriageway and shoulders
- Location, type and condition of side drains
- Location and type of road access and roadside features (parking bays, bus stops, and all major and minor commercial establishments, Road Furniture's etc.) Roadside land use
- Pedestrian Facilities
- Traffic Signal and Road Marking Details

3.4 Turning Movement Counts

Any traffic study requires accurate traffic counts. Determining how many vehicles use a section of roadway is necessary for analyzing, designing the signals, determining capacity and estimating the level of service that will be needed. Accurate counts of current traffic flow provide a departure point for estimates of future traffic volume data. Moreover, the effectiveness of various traffic control measures, geometric modifications, or maintenance practice is governed by traffic volume data.

The turning movement counts at the intersections were collected by the video footages through the cameras installed at the signalized intersections by the Traffic Management Centre, Bangalore City Traffic Police Department. This way of approach reduced the requirement of the man power for the traffic volume count survey.

3.5 Level of service

There are several methods to find out the level of service at signalized intersections. Some of the methods are:

- Highway Capacity Manual method.
- Webster's method.
- Normann method etc.

Highway Capacity Manual Method

The HCM 2000 contains a methodology for analyzing the capacity and level of service (LOS) of signalized intersections. The analysis must consider a wide variety of prevailing conditions, including the amount and distribution of traffic movements, traffic composition, geometric characteristics, and details of intersection signalization.

The methodology addresses the capacity. Capacity is evaluated in terms of the ratio of demand flow rate to capacity (V/c ratio), whereas LOS is evaluated on the basis of control delay per vehicle (in seconds/vehicle). Control delay is the portion of the delay attributed to traffic signal operation for signalized intersections.

By considering the above parameters HCM defines the levels of service for intersections as described in Table 1.

Table-1: Level of Service for intersections

LOS	Signalized intersection (seconds/ vehicle)	Unsignalized intersection(seconds/ vehicle)
A	<=10	<=10
B	10-20	10-15
C	20-35	15-25
D	35-55	25-35
E	55-80	35-50
F	>80	>50

Level of Service Criteria for Signalized Intersections:

The delay experienced by motorists in a signalized intersection is affected by a number of factors related to geometrics, traffic, control, and incidents. The Table 2 summarizes the ***Highway Capacity Manual's*** description of the six LOS's for a signalized intersection.

Table- 2: LOS Criteria for Signalized Intersections

LOS	Average Delay per Vehicle
A	Very low control delay 10 or less seconds per vehicle; progression is very favorable; most vehicles arrive during green signal; most vehicles do not stop. Short cycle lengths may also contribute to low delay.
B	Control delay greater than 10 and up to 20 seconds per vehicle; progression is good and /or cycle lengths are short. More vehicles stop than for LOS A, causing higher levels of average delay.
C	Control delay greater than 20 and up to 35 seconds per vehicle; progression is fair and/or cycle lengths are longer. Individual cycle failures may begin to appear at this level. The number of vehicles stopping is significant, though many vehicles still passthrough without stopping
D	Control delay greater than 35 and up to 55 seconds per vehicle; progression is unfavorable, cycle lengths are long, or has a high flow rate to capacity ratio. Many vehicles stop, and the proportion of vehicles not stopping diminishes. Individual cycle failures are obvious.
E	Control delay greater than 55 and up to 80 seconds per vehicle; progression is poor, cycle lengths are long, and has a high flow rate to capacity ratio. Individual cycle failures are frequent occurrences
F	Control delay greater than 80 seconds per vehicle; progression is very poor, cycle lengths are long. Many individual cycle failures. Arrival flow rates exceed the capacity of the intersection. This level is considered unacceptable to most drivers.

3.5.1 Determining Capacity and v/c Ratio

Capacity at signalized intersection is based on the concept of saturation flow and saturation flow rate. The flow ratio for a given lane group is defined as the ratio of the actual or projected demand flow rate for the lane group (v_i) and the saturation flow rate (s_i). The capacity of a given lane group is stated as shown in equation 1

$c_i = s_i\ (g/C)$ ……….. (*Equation 16-6 HCM, 2000)*

Where, c_i= Capacity of lane group I (veh/hr),

s_i= Saturation flow rate for lane group I (veh/hr), and

g/C= Effective green ratio for lane group.

v/c ratio, often called as volume to capacity ratio, is given symbol X in intersection analysis. It is typically referred to as degree of saturation. For a given lane group I, X is computed using the equation 2.

$X = (v/c)_i$ ……….. (*Equation 16-7 HCM, 2000)*

Where, X = (v/c) ratio for lane group,

v_i = Actual flow rate for the lane group i (veh/hr)

s_i = Saturation flow rate for lane group i (veh/hr)

3.5.2 Determining Delay

The values determined from the delay calculations represent the average control delay experienced by all the vehicles that arrive in the analysis period, including delays incurred beyond the analysis period when the lane group is saturated.

The average control delay per vehicle for a given lane group is given by the equation 3.

$d = d_1.PF + d_2 + d_3$ . . . . (*Ref: Equation16-9HCM, 2000)*

Where, d = control delay per vehicle, s/veh;

d_1 = uniform control delay assuming uniform arrivals, s/veh;

PF = uniform delay progression adjustment factor, which accounts for effects of signal progression

d_2 = incremental delay to account for effect of random arrivals and over saturation queues, adjusted for duration of analysis period and type of signal control; this delay component assumes no initial queue for a lane group at the start of analysis period, s/veh; and

d_3 = initial queue delay, which accounts for delay to all vehicles in analysis period due to an initial queue at the start of analysis period, s/veh. A zero initial queue is assumed in this study.

3.5.2.1 Uniform Delay

Equation 4 gives an estimate of delay assuming uniform arrivals, stable flow, and no initial queue. It is based on the first term of Webster's delay formulation and is widely accepted as an accurate depiction of delay for the idealized case of uniform arrivals.

$d_1 = [0.5\ C\ (1- g/c)^2]/ [1-(\min(1, X)\ g/c]$… (*Equation 16-11 HCM, 2000)*

Where, d_1 = average delay per vehicle due to uniform arrivals in seconds,

C = cycle length in seconds,

g = effective green time for lane group in seconds, and

X = volume/capacity (v/c) ratio for lane group.

3.5.2.2 Incremental Delay

Equation 5 is used to estimate the incremental delay due to non uniform arrivals and temporary cycle failures as well as delay caused by sustained periods of oversaturation. It is sensitive to the degree of saturation of the lane group (X), the duration of the analysis period (T), the capacity of lane group (c) and the type of signal control, as reflected by the controlled parameter (k**).**

$d_2 = 900T\ [(X - 1) + ((X - 1)2 + 8kIX/cT)^{0.5}]$ …

(*Equation 16-12 HCM, 2000)*

Where, d_2 = average delay per vehicle due to random arrivals in seconds,

T = duration of analysis period in h=0.25,

X = v/c ratio for lane group,

k = delay adjustment factor that is dependent on signal controller (0.5)

I = upstream filtering/metering adjustment factor (1.0)

c = lane group capacity, in veh/h.

The model is adjusted for traffic-actuated control with factor k depending on unit extension and degree of saturation. For pretimed signals k = 0.5 and I = 1.0. Control delay is used as the basis for determining LOS.

4.0 Data Collection And Analysis Of Data

4.1 General

The various data collected for the studies are:

- Geometrical condition of the road: This part includes in collecting the lane width and shoulder width up to a certain distance from the intersection. The road width was measured at night time.

- Volume count for diverting traffic: The required data was collected by conducting vehicle turning movement survey.
- Signal timings: This includes in collecting the cycle length, green phase of the signals of the roads

The traffic volume data of the four selected intersections along the Bannerghatta road for 24 hours (6:00 am to 6:00 am) during the workdays on 06th March 2013 were collected from the video footages.

4.2 Data Collection and Data analysis of Bilekahalli Intersection

It is a three legged signalized intersection, located to the southern part of Bangalore city. It interlinks Outer ring road (Mysore Road) and Bannerghatta road. The Google map of Jeedimara Intersection is shown in Fig.1.The three legged intersection has six different directions of movement of traffic. The directions of each arm of the intersection are tabulated in the Table 3.

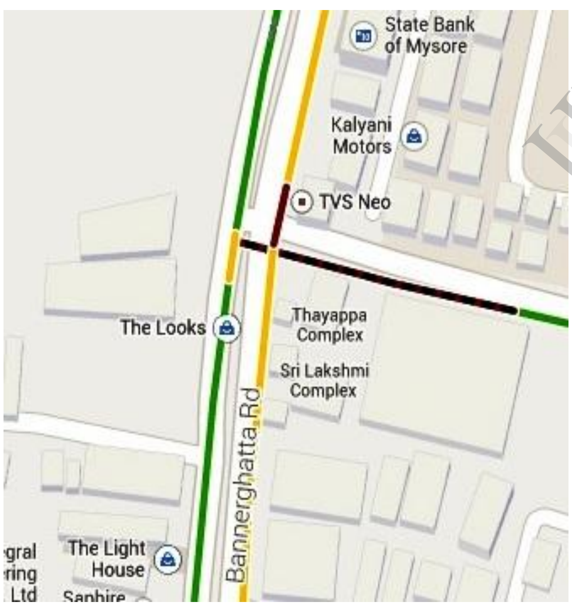

Fig.1 Google Image of Bilekahalli Intersection

Table-3: List of directions of Bilekahalli Intersection

Direction	Name of the road/ Connectivity
Direction 1	Dairy Circle to Bannerghatta
Direction 2	Dairy Circle to Bilekahalli
Direction 3	Bannerghatta to Dairy Circle
Direction 4	Bannerghatta to Bilekahalli
Direction 5	Bilekahalli to Bannerghatta
Direction 6	Bilekahalli to Dairy Circle

Table 4 shows the total vehicles for all approaches at Bilekahalli Intersection.

Table-4: Traffic Volume Data of Bilekahalli Intersection

Direction	Left	Straight	Right
From Dairy Circle	13082	37775	-
From Bannerghatta	-	28491	1198
From Bilekahalli	1026	-	14233

4.2.1 Vehicle Movements

To evaluate the level of service (LOS) at intersections it is very important to specify the number of lanes in addition to the direction of each movement. The volume of vehicles moving along the respected directions is shown in Table 5.

Table-5: Volume of Vehicles in all Directions

Sl.No	Directions	Volume, veh/day
1	Dairy Circle to Bannerghatta and Bilekahalli to Bannerghatta	38801
2		
3	Bannerghatta to Dairy Circle and Bilekahalli to Dairy Circle	42724
4		
5	Bannerghatta to Bilekahalli and Dairy Circle to Bilekahalli	14280
6		

4.2.2 Analysis

The data required to determine the LOS is tabulated in Table 6.

Table-6: Data required for analysis

Road/ Direction	Volume, veh/hr (Refer Annexure)	Cycle length, sec	Green time, sec	Road width, m
Direction 1, 2	2119	420	275	8.0
Direction 3,4	1237	420	240	8.0
Direction 5,6	6356	420	120	4.25

The level of service for the junction is calculated using the data collected and tabulated in the Table 7.

Table-7: Obtained LOS for Bilekahalli Intersection

Roads / directions	s=525*W	c=s*g/C	V, veh/hr	X= v/c	d1 s/veh	d2 s/veh	d, s/veh	LOS
Direction 1, 2	4200	2750	2119	0.77	78	5	145	F
Direction 3,4	4200	2400	1237	0.52	36	0.5	55	E
Direction 5,6	4200	637	636	0.99	151	3.3	187	F

5.0 Discussion and Conclusions

From the results of the traffic analysis of Bilekahalli intersection, it is noticed that the problem is concentrated in all the directions of the intersection.
To improve the traffic performance operation of these squares, it is important to adopt several alternatives to reduce the stopped delay time and improve the level of service.
The carriage width of the road approaching the intersection from Bannerghatta and Dairy Circle are to be widened. The drains provided here are of open RCC type. Therefore the drains are to be closed and the same shall be used as footpaths. The existing footpath width along this stretch is 1.0 m to 2.5 m, hence the carriage way width can widened to a width of 1.5 m. so this reduces the volume to capacity ratio thereby decreasing the delay time of the vehicles.

The level of service of the junction was studied and following conclusions can be made:

- The level of service of the direction 1, 2 (from Dairy Circle) was found to be “F” as the delay was 145 s/ vehicle.
- The level of service of the direction 3,4 (from Bannerghatta) was found to be “E” as the delay was 55 s/ vehicle.
- The level of service of the direction 5,6 (from Bilekahalli) was found to be “F” as the delay was 187 s/ vehicle.

6.0 Recommendations

To attain a better LOS we can recommend the following:

- The presence of pot holes & cracks on the surface layer of the pavement should be treated so that the operating speed at the junction can be increased.
- Wherever necessary overlaying of the surface layer should be done.
- As mentioned in chapter 5.0 the carriage way should be widened. This can reduce the delay and congestion of vehicles at the studied intersection resulting in improving traffic movement.

7.0 References

1. J.C. Golias. "Effects of Signalization FourArm Urban Junction Safety". National Technical University of Athens, Greece, Vol.29, No.2, pp.181-190, 1997.
2. Transportation Research Board, *Highway Capacity Manual*, 2000.
3. IRC SP-41. "Guide Lines for the Design of At Grade Intersections in Rural and Urban Areas",-1994.
4. IRC: 83-1985. "Guidelines on Design and Installation of Road Traffic Signals".
5. IRC: 86- 1983. "Geometric Design Standards for Urban Roads In Plains".
6. Dr. L.R. Kadyali. "Traffic Engineering and Transportation Planning". Khanna Publishers, Seventh Edition 2007.
7. S K Khanna, C E G Justo. "Highway Engineering". Nem Chand & Bros Publishers.