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Capacity Analysis of Signalized Intersection in Urban Areas

Salini P N[1], Ancy Genu C George[2], Anitta Babu[3], Anna Mariya Joseph[4], Krishna Priya S[5], Lakshmi P Shaji[6]

[1]Senior Scientist, KSCSTE-National Transportation Planning And Research Centre, Kerala, India
[2] Assistant Professor, Dept. of Civil Engineering, Viswajyothi College of Engineering and Technology, Kerala, India
[3,4,5,6]B.Tech Scholar, Dept. of Civil Engineering, Viswajyothi College of Engineering and Technology, Kerala, India

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Abstract - *Signalized intersections are the most complex locations in urban networks. A good road system is essential to the well-being of the surface transportation of goods and passengers in cities, where social, economic, recreational, and other activities rely on them. Managing and improving urban traffic systems involves evaluating the status and performance of road intersections. Signalized intersections must be evaluated based on the level of service as well as their capacity. The current study is aimed at estimating the current traffic capacity prevailing at Pattom and Palayam Junctions in Kerala, facilitated through means of surveys which shall be conducted. The performance of the junction shall be checked following the results of the survey. The study mainly focuses on finding the level of service of these intersections by analyzing the Degree of saturation, Control Delay Estimation and incorporating these results for adopting improvement measures to ensure a smoother flow of traffic along the junction.*

Key Words **:** Signalized Intersection, Level of Service, Degree of Saturation

1. INTRODUCTION

Highways' visible characteristics, such as their horizontal and vertical alignments, sight distances, and intersections, are scaled and laid out according to a geometric design. Highway geometry involves aspects such as vertical alignment details, intersection elements, cross-section elements, horizontal alignment details, and sight distance considerations. The concerns for pavement width, formation, and land, as well as its surface qualities and cross slope, are included under cross-sectional elements. The safe movement of cars is governed by the sight distance, or clear distance, visible ahead of a driver at horizontal and vertical bends and crossings. By incorporating horizontal curves, it is possible to alter the direction of the road. In order to partially offset the centrifugal force created on a vehicle travelling a horizontal curve, the super elevation is provided by raising the outer edge of the pavement relative to the inner edge. Extra pavement width is also provided on horizontal curves. Transition curves are added between the straight and circular curves in order to progressively introduce the centrifugal force and superelevation. On a highway's vertical alignment, slopes and vertical curves are first introduced. The topography of the terrain through which the highway is being aligned, the locale, traffic patterns, and design speed requirements all have a significant impact on highway geometry. Speed, road user and vehicle characteristics, design traffic, traffic capacity, and benefit-cost considerations are the variables that influence geometric design requirements.

2. OBJECTIVES

The main aim of our study are:

- To estimate saturation flow of a given signalized intersection
- To find the degree of saturation
- To find the control delay
- To predict the level of service of the given signalized intersections
- To find out capacities of the given signalized intersections by considering effects of various parameters:
  - (a) Geometric Characteristics
  - (b) Traffic Characteristics

3. STUDY AREA

Pattom Junction

Thiruvananthapuram in Kerala State, India, contains a spot called Pattom Junction. It is around 4 kilometres to the north of Thampanoor's core. One of Thiruvananthapuram's busiest junctions, it connects four routes, including NH 66 to North Kerala and a road to Kowdiar Palace. Thiruvananthapuram Central Railway Station is 4 km distant, while Trivandrum International Airport at Shanghumugham is 7 km away.

Palayam Junction

In India's Kerala state, in the Thiruvananthapuram District, lies Palayam Junction. Palayam is locally known, one of the busiest localities in Thiruvananthapuram. It is a

part of Kerala's South Division. Due to its location in the city's core. A religious confluence at Palayam, which includes a Palayam Juma Masjid, a Palayam Ganapathy Temple, and St. Joseph Church is another of the city's well-known attractions.

4 DATA COLLECTION

The first stage in the Data Collection process is the Reconnaissance also known as the Preliminary Survey. As part of Reconnaissance, the site at Pattom and Palayam Junctions were visited by the team on 11 November 2021. Initial visual observations pertaining to the situation prevailing at the junctions in terms of the traffic, signalling and the geometry were studied.

Saturation flow was measured using video data. The stop line was chosen as the observation point. By repeating the footage repeatedly, the data was extracted individually for the straight-on, left- and right-turning traffic streams. The saturation flow was then determined by classifying and tallying every vehicle that crossed the stop line simultaneously during a signal phase. For each cycle with a recorded duration, the same process was performed. At the completion of each period during the green phase, a table listing the categorised traffic data is prepared.

The observed traffic flow metrics are used to calculate the flow in PCU/hour as

$$S = n_i \times P_i \times \frac{3600}{CI}$$

Where,
S = Vehicle flow (PCU per hour) passing the stop line
n_i= No. of vehicles passing the stop line of type 'i' throughout the Count Interval
P_i = PCU of vehicle type 'i'
CI = Count Interval (sec)

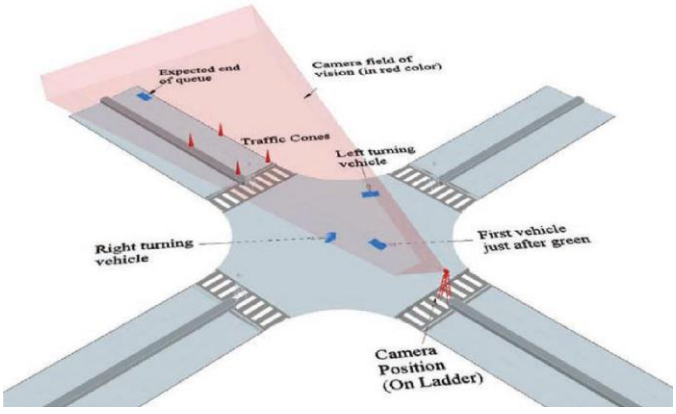

Fig-1: Camera Position Arrangement for Data Collection, (Indo HCM)

4.1 Estimation Of Saturation Flow

To conduct the study, it is necessary to convert each type of vehicle's volume into an equal volume of passenger car units (PCUs). The PCUs have been determined for all vehicle types using saturation flow as the baseline. In order to get the steady rate of saturation flow, It is suggested that these PCUs be used to convert multiple vehicle volume combinations into similar passenger car volumes.

Table -1: Field saturation flow of Pattom Intersection

Approach	Vehicle from	Field saturation flow (PCU/Hr)
Northbound	Thampanoor	6780
Eastbound	Medical College	5690
Westbound	Kowdiar	5092
Southbound	Kesawadasapuram	5230
Southbound	Kesawadasapuram	6202

Table -2: Field saturation flow of Palayam Intersection

Approach	Vehicle from	Field saturation flow (PCU/Hr)
Northbound	Thampanoor	5040
Eastbound	General Hospital	2066
Westbound	Bakery Junction	5232
Southbound	LMS Junction	5005

4.2 Estimation Of Capacity

The highest vehicle count (measured in PCUs) that can flow through a signalised intersection in one unit of time under the current traffic, geometric, and control conditions is known as the approach capacity. This capacity is typically represented in passenger car units per hour (PCU/hr).

A moving group's ability to approach a signalised intersection can be stated as

$$C_i = SF_i\left({}^{g_i}/_{C}\right)$$

Where,

C_i = Movement group 'i' capacity (PCU per hr)

SF_i = Current movement group saturation flow (PCU per hour)

g_i = Movement group 'i' effective green time (sec)
C = Overall Cycle time (sec)

Table -3: Capacity for Pattom Intersection

Approach	Vehicle from	Effective green time (s)	Capacity (PCU/Hr)
Northbound	Thampanoor	30	1695
Eastbound	Medical College	15	711
Westbound	Kowdiar	33	1400
Southbound	Kesawadasapuram	62	2688
Southbound	Kesawadasapuram	30	1550

Table -4: Capacity for Palayam Intersection

Approach	Vehicle from	Effective green time (s)	Capacity (PCU/Hr)
Northbound	Thampanoor	70	2940
Eastbound	General Hospital	27	465
Westbound	Bakery Junction	27	1177
Southbound	LMS Junction	70	2920

5. LOS ASSESSMENT

5.1 Control Delay

The control delay is made up of three parts: the uniform delay (d1), which is the time when vehicles arrive at a predictable uniform rate, the incremental delay (d2), which partially takes into account the randomness of arrivals, and the initial queue (d3), which is the time before the analysis period begins.

$$d = 0.9 \times d_1 + d_2 + d_3$$

Where,

d = control delay, (in seconds / PCU)

$$d_1 = 0.50C \frac{(1 - \frac{g}{CY_{Time}})^2}{(1 - \frac{g}{CY_{Time}} min(X, 1))}$$

$$d_2 = 900T[(X-1) + \sqrt{(X-1)^2 + \frac{4X}{C_{SI}T}}\ ]$$

$$d_3 = \{0, Q_b = 0 \frac{1800Q_b(1+u)t}{C_{SI}T}, Q_b \neq 0$$

Equations provide the values of the parameters "t" and "u".

$$t = \{0\ , Q_b = 0 \left(T, \frac{Q_b}{C_{SI}(1-(1,X))}\right),\ \ Q_b \neq 0$$

$$u = \{0, t < T1 - \frac{CT}{Q_b(1-(1,X))},\ \ otherwise$$

Where,

g = Effective green period (sec)
CY_Time = Overall cycle time (sec)
T = Analysis period (hrs)
X = Degree of saturation
Q_b = At the beginning of the time period "T," the initial queue (PCU).
t = Time for which the requirement was satisfied throughout the analysis period "T" (hrs)
u = Demand parameter
C_{SI} = Capacity of the signalized intersection (PCU per hour)

Table -5: Control Delay of Pattom Intersection

Vehicle from	d1	d2	d3	Control delay(d) (sec/PCU)
Thampanoor	40.95	2.47	0	43.42
Medical College	51.91	19.05	0	70.95
Kowadiar	40.34	4.69	0	45.02
Kesawadasapuram	24.36	2.98	0	27.35
Kesawadasapuram	42.67	5.52	0	48.19

Table -6: LOS of Pattom Intersection

Vehicle from	Control Delay (sec/PCU)	LOS
Thampanoor	43.42	C
Medical College	70.95	D
Kowadiar	45.02	C
Kesawadasapuram	27.35	B
Kesawadasapuram	48.19	C

Table -7: Control Delay of Palayam Intersection

Vehicle from	d1	d2	d3	Control delay (d) (sec/PCU)
Thampanoor	23.48	0.17	0	21.31
General Hospital	37.70	0.95	0	34.78
Bakery Junction	40.40	1.40	0	37.77
LMS Junction	14.49	0.57	0	13.62

Table -8: LOS of Palayam Intersection

Vehicle from	Control Delay (sec/PCU)	LOS
Thampanoor	21.31	A
General Hospital	34.78	A
Bakery Junction	37.77	B
LMS Junction	13.62	A

5.2 Volume To Capacity Ratio

A movement group's degree of saturation (X) can be calculated as,

$$X_i = (\frac{v}{c})_i = \frac{v_i}{SF_i(\frac{g_i}{CY\_Time})}$$

Where,

X_i= Movement group 'i' degree of saturation
c_i = Movement group 'i' capacity (PCU per hour)
v_i = Movement group 'i' volume
SF_i = Current movement group saturation flow (PCU per hour)
g_i = Movement group 'i' effective green time (sec)
CY_Time =Overall cycle time (sec)

Table -9: Volume to Capacity Ratio of Pattom Intersection

Approach	Vehicle from	Degree of Saturation
Northbound	Thampanoor	0.7032
Eastbound	Medical College	0.9201
Westbound	Kowdiar	0.7930
Southbound	Kesawadasapuram	0.8220
Southbound	Kesawadasapuram	0.8363

Table -10: LOS of Pattom Intersection

Vehicle from	Degree of Saturation	LOS
Thampanoor	0.7032	B
Medical College	0.9201	C
Kowdiar	0.7930	C
Kesawadasapuram	0.8220	C
Kesawadasapuram	0.8363	C

Table-11: Volume to Capacity Ratio of Palayam Intersection

Approach	Vehicle from	Degree of Saturation
Northbound	Thampanoor	0.2209
Eastbound	Medical College	0.1965
Westbound	Kowdiar	0.4804
Southbound	Kesawadasapuram	0.4820

Table -12: LOS of Palayam Intersection

Vehicle from	Degree of Saturation	LOS
Thampanoor	0.2209	A
General Hospital	0.1965	A
Bakery Junction	0.4804	B
LMS Junction	0.4820	B

6. RESULTS AND DISCUSSIONS

The control delay model and v/c ratio are used to estimate the degree of service offered by the various techniques. The results are displayed in the table below.

Table -13: Pattom Intersection

Approach	Vehicle from	LOS Based on Control Delay	LOS Based on v/c ratio
North bound	Thampanoor	C	B
East bound	Medical College	D	C
West bound	Kowdiar	C	C
South bound	Kesawadasapuram	B	C
South bound	Kesawadasapuram	C	C

Table -14: Palayam Intersection

Approach	Vehicle from	LOS Based on Control Delay	LOS Based on v/c ratio
North bound	Thampanoor	A	A
East bound	General Hospital	A	A
West bound	Bakery Junction	B	B
South bound	LMS Junction	A	B

Table -15: Estimate of the Service Level at the Pattom Intersection

Phase	1	2	3		4
Access	WB	EB	NB	SB	SB
g/C ratio	0.28	0.125	0.25	0.52	0.25
Degree of Saturation	0.79	0.92	0.70	0.82	0.84
Approach Delay in sec/PCU	45.02	70.95	43.42	27.35	48.19
Approach LOS	C	D	C	B	C
Intersection Delay in sec/PCU, D	41.92				
Intersection LOS based on Delay	C				

Table -16: Estimate of the Service Level at the Palayam Intersection

Phase	1	2	3	4
Access	SB	WB	NB	EB
g/C ratio	0.58	0.23	0.58	0.23
Degree of Saturation	0.48	0.48	0.22	0.196
Approach Delay in sec/PCU	13.61	37.70	21.31	34.78
Approach LOS	A	A	B	A
Intersection Delay in sec/PCU, D	21.159			
Intersection LOS based on Delay	B			

7. CONCLUSIONS

A qualitative metric called level of service (LOS) is used to assess how well motor vehicle traffic services are provided. By traffic flow classification and quality rating based on performance indicators like vehicle speed, density, congestion, etc., LOS is used to study roads and crossings. LOS aids in determining traffic quality levels based on performance indicators like speed, density, etc.

From the analysis, it is concluded that,

Table -17: LOS ofPattom Intersection

Movement Groups	LOS	
1	C	**LOS OF PATTOM INTERSECTION: C**
2	D	
3	C	
4	C	
5	C	

Table -18: LOS of Palayam Intersection

Movement Groups	LOS	
1	A	**LOS OF PALAYAM INTERSECTION: B**
2	A	
3	B	
4	B	

From the above results, Pattom Intersection has more congested condition than the intersection of Palayam. So all the approach arms of Pattom require further treatment to alleviate the congested movements and ensure better operational efficiency and level of performance.

The LOS analysis of Pattom concludes that the approach arms of Pattom are having overcrowded conditions than the Palayam intersection because Pattom has LOS C and D. Comparatively, the Palayam intersection has better operational efficiency with estimated LOS A and B for different movement groups.

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