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Adequacy of Traffic Signal at Intersection

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ABSTRACT - Traffic congestion is a major issue in this world, time is an important aspect. The significance of time is at odds or in other words totally different for each individual. Some of them may be workers, school-college students or people in emergency situation and so on the value of time is salient for each individual. It is an engineer's responsibility to make an efficient traffic signal which is safe, ideal and less confusing for the people. The intersection traffic signal control problem has become even more important as traffic congestion has been more intractable. The intersection traffic signal control problem seeks an efficient schedule for traffic signal settings at intersections with the goal of maximizing traffic flow while considering various factors such as real-time strategies, signal timing constraints, rapid developments in traffic systems, and practical implementation.

I. INTRODUCTION

Traffic congestion is an extensive global phenomenon resulting from high population density, growth of motor vehicles and their infrastructure, and proliferation of rideshare and delivery services. Researchers have defined congestion from different perspectives. The most common definition of congestion in the state of traffic flow is when the travel demand exceeds road capacity. From the delay-travel time perspective, congestion occurs when the normal flow of traffic is interrupted by a high density of vehicles resulting in excess travel time. Congestion can also be defined by the increment of the road user's cost due to the disruption of normal traffic flow. A variety of reasons are responsible for creating congestion in most urban areas. Depending on these different reasons, congestion can be classified into recurring and nonrecurring congestion. Recurring congestion occurs regularly, mostly due to the excessive number of vehicles during peak hours. On the other hand, unpredictable events-such as weather, work zones, incidents, and special events-are the causes of nonrecurring congestion. According to the United States Department of Transportation Federal Highway Administration (DOT-FHWA), nonrecurring congestion contributes to more than 50% of all traffic congestion, where 40% of congestion is caused by recurring congestion. Main reason for traffic congestion is that every single person moves at the same time every single day. In spite of many of the remedies tested to reduce the traffic congestion there has not been any major improvement in this aspect. The traffic is only getting worse with every passing year.

Traffic congestion is a global issue that challenges the development of a resilient and sustainable transportation system. The long-term goal of this project is to contribute to the development of a sustainable and resilient transportation management system that aims to minimize the negative impact of congestion by making sure the traffic signal at the junctions are efficient based on the traffic flow in that respective junction. . To find out whether the traffic signal is efficient in that respective junction analysis of traffic flow from different perspectives must be conducted. Monitoring the traffic flow in an area is one of the initial steps in establishing a proper traffic management system or mitigating congestion. If the traffic signals are not efficient it will lead to congestion and cause man hour delay.

II. OBJECTIVE

- To estimate the field saturation flow in PCU/hr. and compare it with theoretical estimation of saturation flow.
- To estimate the adequacy of existing traffic signal at 3- arm intersection at Paruthippara and Ulloor Junctions.

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III. METHODOLOGY

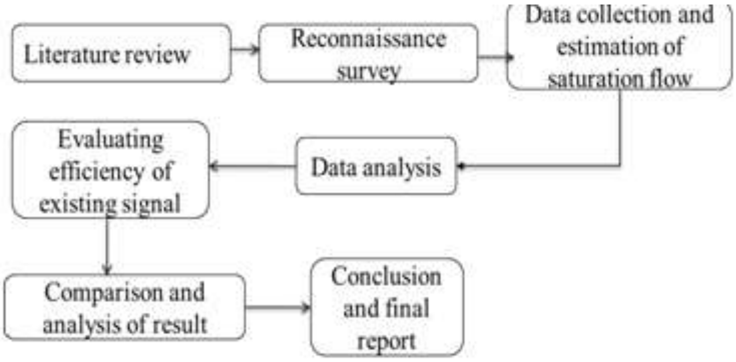

Fig -1: Methodology flow chart

3.1 LITERATURE REVIEW

The journals related to the topic were referred and collected. It helped to understand the various aspects and hence lead to the progress of the project. The proper foundation of knowledge about the topic was acquired and identified the need for additional research.

3.2 RECONNAISANCE SURVEY

The study area selection of our group was under the external guidance of Salini P N, Senior Scientist, KSCSTE-NATPAC. To find the adequacy of traffic signal at intersection two 3 arm intersections at Thiruvananthapuram the capital city of Kerala was selected. The selected 3 arm intersections are Paruthippara and Ulloor junctions.

3.3 DATA COLLECTION AND ESTIMATION OF SATURATION FLOW

Data were collected based on Videographic survey and real time saturation flow were estimated. To obtain saturation flow from video we must be aware about the phases, signal time for each direction, and stop line.

3.4 DATA ANALYSIS

The saturation flow based on movement groups were calculated by observing the movements and were analysed

3.5 EVALUATING EFFICIENCY OF EXISITING SIGNAL

Saturation flow is estimated and analysed based on movement group and the optimum cycle length for the same is calculated and evaluated and hence efficiency is determined

3.6 COMPARISON AND ANALYSIS OF REPORT

A comparison is done between the existing and the proposed signal design and the report is made

3.7 CONCLUSION AND FINAL REPORT

Conclusions are obtained from the study and a final report is made.

IV. STUDY AREA

The study for the adequacy of traffic signal is conducted on two, three arm intersections in the capital city of Kerala, Thiruvananthapuram, namely Ulloor and Paruthippara.

Paruthippara is one of the quite residential areas in Thiruvananthapuram District, Kerala. It lies between Kesavadasapuram and Nalanchira. The place is around 7 km from East Fort and 3 km from Pattom. Ulloor, Muttada, Pananvila, Parottukonam and Vayalikkada are within a short distance from Paruthippara. M G College situated here is a major landmark. Medical College is easily accessible from here. Regular bus services connect Paruthippara with East Fort and Peroorkada. Trivandrum International Airport and Thiruvananthapuram Central Railway Station are the nearest airport and railhead respectively.

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Fig 2: Paruthippara junction

The geometric details of Paruthippara are it consist of 3 approaches Kesavadasapuram, Nalanchira, and peroorkada approach. Kesavadasapuram and Nalanchira consisit of 2 lanes and Peroorkada approach consist of 1 lane. The approach width of kesavadasapuram, nalanchira and peroorkada are as follows 9.3m, 8.5m, 3.5m.

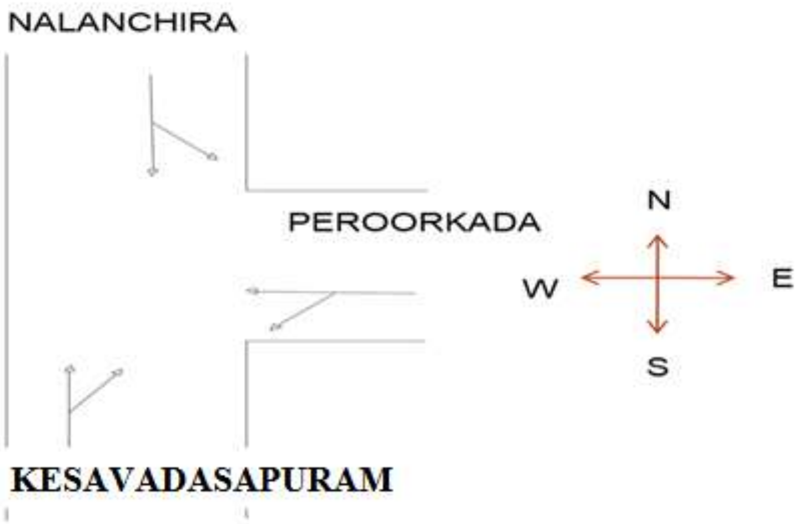

Fig 3: Schematic representation of Paruthippara junction

As shown in figure Nalanchira arm is in North direction, peroorkada arm is in east direction and kesavadasapuram is in south direction. Paruthippara junction consist of 5 phases.

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Fig -4: Existing phasing diagram Paruthippara junction

Ulloor is the second study area where we are analyzing the traffic signal. Ulloor junction is a 3-arm intersection which consist of medical college approach, sreekaryam approach, and akkulam approach.

Fig 5: Ulloor junction

All these 3 approaches consist of 2 lanes with an approach width of 6.2m,7.7m,7.4m respectively for medical college, sreekaryam and akkulam approach. A schematic representation of ulloor junction is shown below:

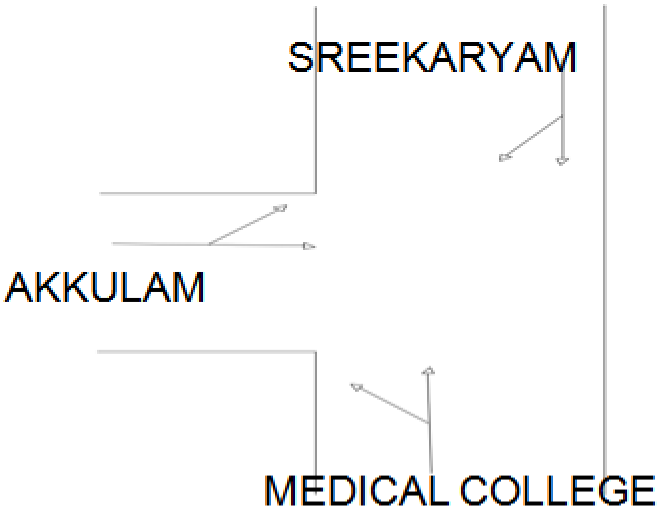

Fig -6: Schematic representation of ulloor junction

Ulloor junction consist of 4 phases. As shown in the figure sreekaryam approach is in north direction akkulam in west and medical college approach in south direction respectively. The existing phasing diagram of ulloor junction is given below:

Fig -7: Existing phasing diagram ulloor junction

V. SURVEYS AND DATA COLLECTION

Surveys and data were accumulated and collected on two ways, manually and videographic survey. Manually the data were collected for determining the queue length. Queue length is the number of units or vehicles waiting in a queue or present in a system. For determining the queue length, the data is collected based on how many vehicles are waiting in queue for each 5 second interval for the red time.

Videography survey was another mode which was used for the survey and data accumulation for saturation flow. Through this survey turning movement counts at the intersection is calculated based on vehicle arrival rate.

VI. PASSENGER CAR UNIT (PCU)

Passenger car equivalent or passenger car unit is a metric used in transportation engineering, to assess traffic-flow rate on a highway. Passenger Car Unit (PCU) values is important for traffic capacity analysis, level of service measures, signal design and coordination, saturation flow rate determination and development of traffic flow models. Due to these wide applications, accuracy of PCU values is considered to have significant influence on traffic flow analysis. In developed countries, various methods were devised for estimating PCU values. But these methods are not completely applicable for mixed traffic because of the presence of wide variety of vehicle types, non-lane discipline and intra-class variability of vehicles

Traffic on Indian roads is heterogeneous in nature with a wide variation in static and dynamic characteristics. Hence, one vehicle type cannot be considered equal to the other type. The only way for accounting for this non-uniformity in traffic stream is to convert all vehicles into a common unit. The common unit for this purpose is PCU. In Indo-HCM, dynamic PCU is estimated. Highway Capacity Manual (HCM) defines PCU as “the number of passenger cars that are displaced by a single heavy vehicle of a particular type under prevailing roadway, traffic and control conditions”. The values of dynamic PCU given in Indo-HCM are given below:

Vehicle type	PCU Values
2-Wheeler	0.4
Car	1
Auto	0.5
Bus	1.6
LCV	1.1
HCV	1.6
Bicycle	0.3
Other	1.8

Table-1: Dynamic PCU values

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VII. MOVEMENT GROUP

On each approach during green interval, the operation of movements may happen in a shared manner or in an exclusive manner. In shared operation, all the movements from an approach that are permitted in the same phase and are in equilibrium need to be considered as one entity or movement group in the analysis. In the signalized intersection the traffic movements are in shared manner and the operation of typical approaches are shown in Table.

Approach	Operation of movements	Representation	No.of movement group
North bound	Left turn and Through shared approach operation		1
East bound	Left turn and Right turn shared approach operation		1
West bound	Left turn and Right turn shared approach operation		1
South bound	Left turn and Through shared approach operation		1

Table-2: Illustration of Movement group at signalized intersection as per INDO HCM

Movement groups at both the junctions namely paruthippara and ulloor junctions were analysed, obtained and results were collected in Microsoft excel sheets based on the movements.

VIII. SATURATION FLOW

Saturation flow is a very important road traffic performance measure of the maximum rate of flow of traffic. It is used extensively in signalized intersection control and design. It describes the number of passenger car units (PCU) in a dense flow of traffic for a specific intersection lane group. In traffic engineering, saturation describes the maximum traffic flow which can be handled by a junction. The saturation flow is thus described as the rate at which a continuous flow of vehicles can pass through a constant green signal, typically expressed in vehicles per hour or PCUs per hour. The following factors affect the saturation flow rate: lane width, heavy vehicles in traffic stream, approach grade, parking lane and parking activity adjacent to lane group, bus stop within intersection area, lane utilization in lane group, turning traffic in lane group, pedestrians crossing turning.

Saturation flow can be obtained in different ways such as:

- ✓ Field saturation flow
- ✓ Theoretical saturation flow

8.1 FIELD SATURATION FLOW

Video recorded data was used to measure the field saturation flow. The observation point selected was stop line. The data was retrieved separately for straight on, left and right turning traffic streams, by playing the video repeatedly. The saturation flow was then measured by making classified count of all the vehicles crossing the stop line, during the effective green time of a signal phase. The counting was started when the vehicle starts to move and the counting was stopped when the continuity in the flow of vehicles broke. The duration of the green time over which the counting was done and the classified count of vehicles, were recorded in the data sheet. Considering the non-lane based mixed traffic operation in Indian context, the flow profile method suggested by TRL (UK) is a suitable field method for measurement of saturation flow. Its principle is that the number of vehicles passing the stop line during green is counted at fixed short time intervals. The length of time interval can be chosen to reflect local conditions. Here 5 second was taken. As it was not possible to count all classified vehicles at a time, video was replayed a number of times. The same procedure was repeated for each cycle of recorded duration.

Measurements should ideally be made at sites which are free from all obstructions. If any obstruction occurs within a cycle, the observations for that cycle should be discarded. For unobstructed traffic conditions, the saturation flow of each approach is simply the average flow for all saturated intervals i.e., once the initial start-up period has been completed, and

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while flow is still being supplied from a queue. If the flow in the first 5second interval is higher than that in the other intervals when initial surge of vehicles, saturation flow is worked out as the average flow for all intervals including the initial interval. i.e., the average of all the flow values excluding the ones with obstruction but including the ones with surge is the field observed saturation flow. If initial surge is not present, the first interval in each cycle should be omitted while computing the average. The flow in PCU/hour for the observed traffic flow parameters is worked out as

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

Were,

S = Flow in PCU/hour crossing the stop line

n_i = No. of vehicles of type 'i' crossing the stop line during the Count Interval (CI)

P_i = Passenger car unit of vehicle type 'i'

CI = Count Interval in seconds

Obtained field saturation flow for each approach of the signalized intersection at both the junctions are given below:

Approach	**Vehicle from**	**Field saturation flow (PCU/Hr)**
North bound	Nalanchira	8102
South bound	Kesavadasapuram	7332
East bound	Peroorkada	3351

Table-3: Field Saturation flow at paruthippara junction.

Approach	**Vehicle from**	**Field saturation flow (PCU/Hr)**
North bound	Sreekaryam	12001
South bound	Medical college	14007
East bound	Akkulam	5138

Table-4: Field Saturation flow at paruthippara junction.

8.2 THEORETICAL SATURATION FLOW

Saturation flow values can be obtained theoretically based on the width of the road, as mentioned in IRC93-1985. If the width of the road is in between 5.5m to18m, then saturation flow is obtained by multiplying 525 by the width of the road. For lesser widths the value may be obtained from the table:

Width W in meters	3.0	3.5	4.0	4.5	5.0	5.5
Saturation flow PCU per hour	1850	1890	1950	2250	2550	2990

Table-5: Theoretical saturation flow-IRC

The theoretical saturation flow based on the width for paruthippara junction is:

Approach	Approach width (m)	saturation flow (PCU/hr/m)
North bound	8.5	4463
South bound	9.3	4883
East bound	3.5	1890

Table-6: Theoretical saturation flow-Paruthippara

The theoretical saturation flow based on the width for ulloor junction is:

Approach	Approach width (m)	saturation flow (PCU/hr/m)
North bound	7.7	4043
South bound	6.2	3255
West bound	6.4	3360

Table-7: Theoretical saturation flow-Ulloor

8.3 COMPARISON AND REPRESENTATION OF FIELD AND THEORETICAL SATURATION FLOW BY CHARTS

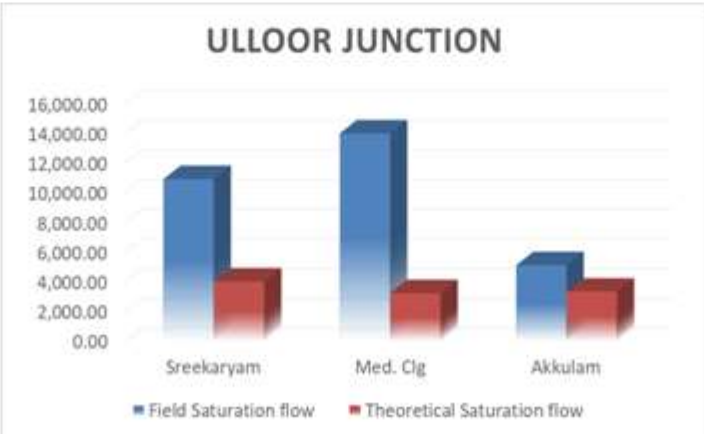

Fig.-7: Chart Representation- Ulloor Junction

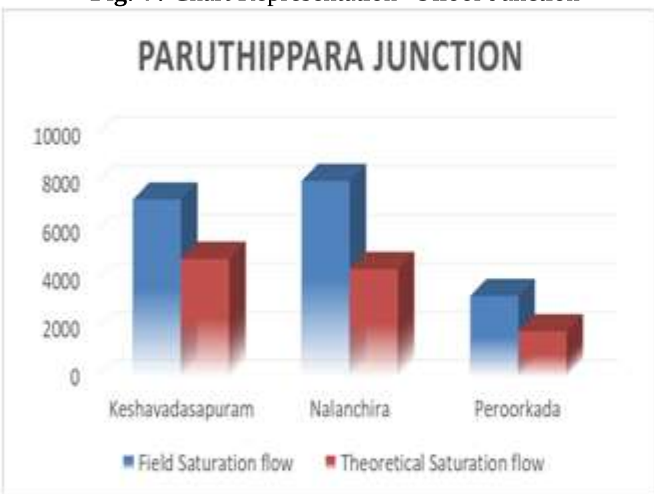

Fig.-8: Chart Representation- Paruthippara Junction

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IX. TRAFFIC WARRANTS

A traffic signal is used as an instructing device that indicates the road user to act according to the displayed sign. Following the traffic signal ensures road safety and to make things simple to understand, these signals have been using a universal color code such as red, green and yellow. How can we decide in which intersection a traffic signal must be installed? The answer for this question is that there are specific warrants for traffic signal installation which has been provided in IRC:93-1985. A warrant is a condition that an intersection must meet to justify a signal installation. For a traffic signal to be an asset instead of a liability, traffic engineers must evaluate the warrants for traffic signal.

There are 4 warrants that are given in IRC: 93-1985 namely:

- ❑ WARRANT 1- MINIMUM VEHICULAR VOLUME
- ❑ WARRANT 2- INTERRUPTION OF CONTINOUS TRAFFIC
- ❑ WARRANT 3-MINIMUM PEDESTRIAN VOLUME
- ❑ WARRANT 4-ACCIDENT EXPERIENCE
- ❑ WARRANT 5-COMBINATION OF WARRANTS

9.1 WARRANT 1- MINIMUM VEHICULAR VOLUME

Warrant is satisfied when for each of any 8 hours of an average day, traffic volume given in table exist on major Streets on higher volume, minor street approach to intersection. In here they evaluate whether the volume of vehicles entering an intersection creates confusion or congestion.

Number of lanes for moving traffic on each approach		Motor vehicles per hour on major street (total both approaches)	Motor vehicles per hour on higher volume minor street approach (one direction only)
Major street	Minor street		
1	1	650	200
2 Or more	1	800	200
2 or more	2 or more	800	250
1	2 or more	650	250

Table-5: – Minimum vehicular volume for warrant-1

9.2 WARRANT 2- INTERRUPTION OF CONTINOUS TRAFFIC

Applied when traffic volume on a major street is so heavy that traffic on minor intersecting street suffers excessive delay in entering or crossing major street. The warrant is satisfied when for each of any 8 hours of an average day the traffic volume given in table exist and signal installation will not seriously disrupt progressive traffic flow. Here the engineers evaluate whether the vehicle volume on main street is so heavy that diversion side street will try to cross when it is not safe.

Number of lands for moving traffic on each approach		Motor vehicles per hour on major street (total of both approaches)	Motor vehicles per hour on higher volume minor street approach (one direction only)
Major street	Minor street		
1	1	1000	100
2 or more	1	1200	100
2 or more	2 or more	1200	150
1	2 or more	1000	150

Table-6: - Minimum vehicular volume for warrant 2

9.3 WARRANT 3-MINIMUM PEDESTRIAN VOLUME

In this warrant the engineers evaluate whether the number of pedestrians trying to cross a busy main street creates confusion, congestion or hazardous conditions.

9.4 WARRANT 4-ACCDENT EXPERENCE

Accident warrant is satisfied when 5 or more reported accidents, of types susceptible of correction by traffic signal control have occurred within a period of 12 months, each accident involving personal injury or property damage to an apparent extent of 2000 or more.

9.5 WARRANT 5 – COMBINATION OF WARRANTS

This condition is satisfied when warrant 1,2,3 are satisfied up to 80% or more of stated volume. Adequate trial or other measures which causes less delay and inconvenience to traffic should precede installation of signals under this warrant.

X. TRAFFIC SIGNAL DESIGN PROCEDURE

A traffic signal setup includes controller, traffic lights and detection. The controller works as the 'brain' of the entire setup and has the information that is required to make sure the lights work as per the required sequences. Traffic signals can run under a variety of different modes which can be dependent on location and time of day. A traffic signals optimum cycle length should not be more than 120 sec.

The traffic signal design procedure is shown below:

- Green interval required for pedestrian to cross the carriageway is calculated by Width of carriageway /assumed walking speed (1.2)
- To the above value 7 sec (reaction time) is added to obtain the total pedestrian phase.
- The green time required for the vehicular traffic on the major road is increased in proportion to the traffic on the two approach roads.
- The cycle time is calculated after allowing amber time of 2 secs each.
- The minimum green time required for clearing vehicles arriving a cycle. is determined by assuming 1st vehicle -6 sec subsequent queue will be cleared-2 sec.
- Optimum cycle length is calculated using Webster's formula

$$C_0 = \frac{1.5L + 5}{1 - Y}$$

- Saturation flow is obtained from IRC: 93-1985 for width above 5.5m saturation flow-525pcu per hour per meter width.

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- The total lost time is calculated from amber time, inter green time and initial delay of 4 sec for first vehicle on each leg.
- Optimum cycle length is designed in such a way that the delay at all approaches will be minimized
- Maximum cycle length recommended is 120 sec considering all delays of drivers of vehicles and pedestrians.
- Not more than a maximum of 4 phases in any given cycle.

XI. PROPOSED SIGNAL DESIGN

Traffic signal design should be efficient to reduce the traffic congestion in those areas. First of all, we have to find the optimum cycle length for the junction based on the field saturation flow obtained. To find the optimum cycle length we are using Webster's Equation.

$$C_0 = \frac{1.5L + 5}{1 - Y}$$

To find the optimum cycle length we need to know about the following factors:

- ✓ Walking speed
- ✓ Reaction time
- ✓ Approach width for major road
- ✓ Minimum pedestrian crossing for major road
- ✓ Approach width for minor road
- ✓ Minimum pedestrian crossing for minor road
- ✓ Design traffic for major road
- ✓ Design traffic for minor road
- ✓ No. of lanes of major road
- ✓ No. of lanes of minor road
- ✓ Critical lane volume for major road (Vc1)
- ✓ Critical lane volume for minor road (Vc2)
- ✓ Minimum green time for vehicle in minor road (g2)
- ✓ Minimum green time for vehicle in major road (g1)
- ✓ Minimum cycle time
- ✓ Loss time
- ✓ Saturation flow for major road
- ✓ Saturation flow for minor road
- ✓ Critical flow ratio for major road (y1)
- ✓ Critical flow ratio for minor road (y2)
- ✓ Optimum Cycle Length by Webster's Equation
- ✓ Calculated min. green time (g1)
- ✓ Calculated min. green time (g2)

To find the optimum cycle length the walking speed and reaction time are assumed to be 1.2 m/s and 7s respectively based on IRC 93:1985. Design traffic is the highest value obtained as the sum of vehicles corresponding to each 15 min interval for the observed approach. Critical lane volume is obtained by dividing design traffic to the number of lanes respectively for major and minor road. Critical flow ratio is obtained by dividing design traffic to the saturation flow respectively for the major and minor road. After obtaining the cycle length, amber time and green time we can find out the red time. The obtained red time should be atleast or more than the minimum pedestrian

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time obtained through calculation, because that is when the pedestrians are crossing the road.

Based on the calculations the optimum cycle length for both the junctions were calculated and the signal design were proposed. The proposed signal design for Paruthippara and Ulloor junctions are provided below:

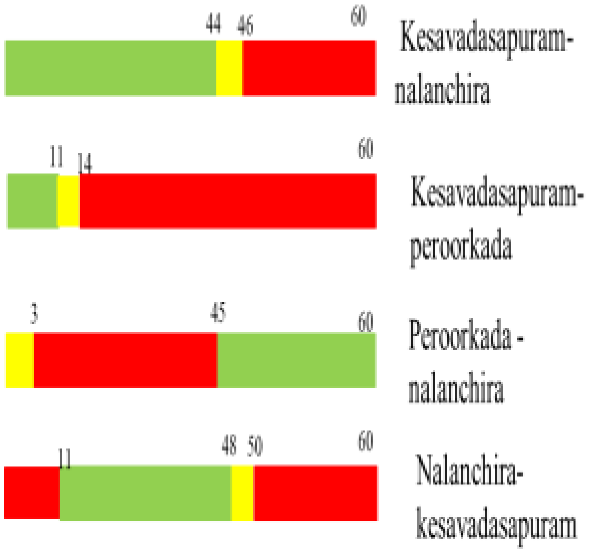

Fig.- 9: Proposed Signal Design of Paruthippara Junction

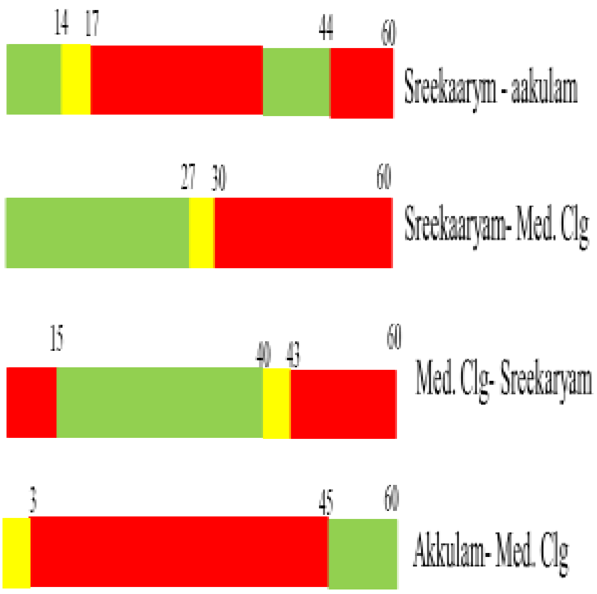

Fig. -10: Proposed Signal Design of Ulloor Junction

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XII. COMPARISON OF EXISTING AND PROPOSED SIGNAL DESIGN

12.1 PARUTHIPPARA JUNCTION

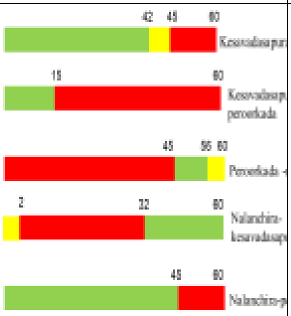
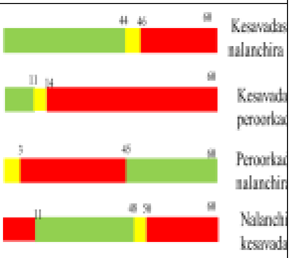
EXISTING SIGNAL DESIGN	PROPOSED SIGNAL DESIGN
	
• No. of phases= 5	• No. of phases= 4
• Free left is not provided	• Free left is provided
• Approach width is less	• Approach width has been increased as per the IRC sp-41 guidelines
• Optimum cycle length= 60s	• Optimum cycle length= 60s
• Conflict exists	• Conflict resolved

Table-7: Comparison of existing and proposed signal at Paruthippara

12.2 ULLOOR JUNCTION

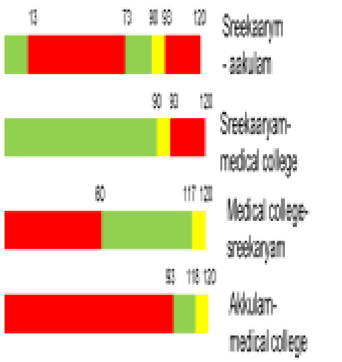
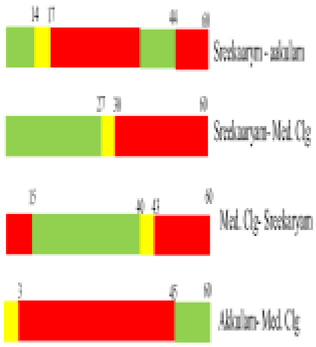
EXISTING SIGNAL DESIGN	PROPOSED SIGNAL DESIGN
	
• Optimum cycle length= 120s	• Optimum cycle length= 60s
• Queue length is more	• Queue length is less
• Man hour delay is high	• Man hour delay is less

Table- 8: Comparison of existing and proposed signal at Ulloor

XIII. CONCLUSIONS AND RECOMMENDATIONS

- The outcome of the whole study is the fact that the widening of the road needs to be done at the intersection. The road widening will cater for a lot of traffic and would handle the high volume of traffic efficiently.
- Traffic signal is redesigned according to the present traffic flow and hence the signal works efficiently.

- Adaptive traffic signal can be implemented in order to reduce the congestion.

OUTCOME

• Compared and evolved existing and desirable phasing diagram.

• Estimated Saturation flow in PCU/hr. and compared it with Theoretical Saturation flow.

• Inspected the efficiency of existing signal, since it is not efficient, we redesigned the signal and suggested adequate measures.

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