DESIGN AND ANALYSIS OF TRAFFIC SIGNAL AT SIGNALIZED JUNCTION

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Abstract:

Traffic volume studies are conducted to determine the number, movements, and classifications of roadway vehicles at a given location. These data can help to identify critical flow time periods, determine the influence of large vehicles or pedestrians on vehicle traffic flow. The length of the sampling period depends in the type of count being taken and the intended use of the data recorded. Webster method is a rational approach for signal design. The design is simple and is totally based on formulas laid down by Webster, in this method, the total cycle of the signal is determined which forms a total least delay occurring at signal and timing involves deciding how much green time the traffic lights shall provide at an intersection approach. How long the pedestrian walk signal should be, and many numerous other factors. The design of traffic signal nowadays has become an important factor for major intersections of towns and cities. Traffic signal controls the movement of traffic and not only reduces accidents but enables the road safety users to effectively use the area of road at intersection. The important parameters in the planning, design and control of a signalized intersection are saturation flows, lost times and passenger car units (PCU).

Keywords - Signal Design, Webster method, Traffic control, PCU, Intersection, Simulation, Traffic field studies.

1.0 INTRODUCTION

The city of Hyderabad is one of the fastest growing metropolitan cities with a decadal growth rate of 32%. The urban agglomeration of Hyderabad spread over an area of 650sq. km which comprises Hyderabad, and twelve other municipal entities surrounding it. Regionally, Hyderabad lies on the convergence of national highways, state highways, rail routes and air routes which link it's with other metropolitan Centre's and key centers of importance in the country. The city is experiencing rigorous changes in its infrastructure which is due to rapid urbanization, service- oriented activities and industrial development. This indicates a potential demand for investment in transport infrastructure. Such need-based developments include determination of the required capacity expansion, provision of additional road infrastructure, improvement of existing roads, prioritization of different development phases and forecasting of which is possible upon collection of traffic data. This is done in order to eliminate bottlenecks in both international and local inter-urban road transport towards providing an efficient and effective road transport system. The techniques used have become almost standard in both developing and developed countries. The accuracy of traffic data collection and the subsequent predictions are of paramount importance in the fulfillment of an appropriate planning, design, maintenance monitoring and management of the road network. In the past, routine collection of traffic data in this country was not considered important for the development and management of the road network. In the early 1970's it was realized that a wide variety of information is required in respect of traffic characteristics for proper maintenance, planning, design, maintenance and management of the national road network. This realization emanated from concerns raised with regard to the amount of traffic, the composition of the different types of vehicles, their speed, and total gross weight, number of axles, axle loads and origin and destination of the journeys. Most of this information result in assessment of progressive or rapid deterioration of the road network towards estimating additional cost required to sustain it. As a result, attempts are now being made to adopt suitable road traffic methodologies for conducting road traffic surveys, which are both technically and scientifically sound, and operationally convenient to execute under the country's prevailing conditions. During the planning, design, construction and maintenance period of the road network, traffic data becomes an essential element in decision-making, and therefore the format and the accuracy of data collection and analysis is critical. Most of the urban roads in Hyderabad are static in behavior during peak hours. This is leading to traffic congestion and in-turn to endless transportation gridlocks which has a direct impact on economy. It is with this view that this guideline on traffic data collection and analysis has been prepared.

2.0 LITERATURE REVIEW

Udit Batra, Mandar V. Sarode (2013):

Rapid Industrialization and the consequent urbanization have brought about an unprecedented revolution in the growth of motor vehicles all over the world and India

is no exception. This created scope for increase in travel and transportation analysis. The growing urbanization, combined with rising number of vehicle ownership, has led in recent years to an increased demand of traffic survey and analysis, for both long term and short- t e r m period. Traffic analysis is basically the process of intercepting and examining the number of vehicles on the road and deducing the pattern of traffic moment.

Dr. Awari Mahesh Babu (2017):

Road traffic delay and overcrowding have become recurrent problems worldwide.This is mainly since transportation growth is sluggish compared to increase in quantity of vehicles, owing to gap and expenditure restriction. Traffic being non-lane based and disordered, is mainly unusual with different types of vehicles. Metropolitan region roads are under mixed traffic conditions. The road user physiological behavior also causes delay and congestion.

Adepu Ramesh, Kumar Molugaram (2018):

In our country traffic flow is heterogeneous and is governed by traffic characteristics as driver behavior, road geometry etc. Increase in traffic volume and limited road way width should be promptly addressed by traffic engineers who shall provide solutions which shall be more competent than traditional signalized designs. The recommendations suggested by the traffic engineer for improving signalized intersection shall be less expensive than providing interchanges. Metropolitan cities like Hyderabad are also experienced with delay and congestion due to ineffective traffic signal operation. Non- l a n e - b a s e d traffic behavior, varying pavement width and driver characteristics are a few reasons for delay and congestion on our city roads Improvement in the above context can be achieved through lane prioritization, alternative routes etc. These improvements will certainly reduce the impact on fuel consumption, improves safety and Level of Service at signalized intersection.

Samrat Mukhopadhyay, Pramod M.J (2015):

Mixed vehicular traffic comprising small cars and two-wheeled vehicles arrive at a lane of a signalized road intersection. The traffic does not follow lane-discipline, in that the arriving vehicles do not necessarily queue up one behind the other. The motorcycles are small enough to stand side-by-side with cars or other motorcycles, so as to fill up the width of the lane. With such queue joining behavior, the waiting vehicles form batches, comprising motorcycles and at most one car. During the green signal period the vehicles in the head-of- the-line batch exit the intersection together. In this paper, assuming a Poisson point process model for vehicle arrivals, we have provided an approximate analysis of such a queuing system. Our approach is to use an assembly queue model for the batching process. The batches generated by the assembly queue enter an interrupted M/Semi Markov/1 (or M/SM/1) queue. By analyzing the assembly queue, we characterize the batch input process for the interrupted M/SM/1 queue. We then develop an extension of the Webster mean delay formula for obtaining the approximate mean delay in the interrupted M/SM/1 queue. Numerical results from the analysis are compared with simulation

3.0 METHODOLOGY

The equations developed by Webster in his famous 1958 report are still the basis of traffic signal planning today. They are being used in handbooks like the HCM and similar instruments world-wide. However, the handbook approach typically works with approximations to the original equations which have stood the test of time, but may nevertheless not be the best to be done today. This work analyzes Webster's approach and advocates a more modern use of it which utilizes the tremendous advances in computer hardware and software. This is being done by comparing approximations to exact solutions, and by a comparison between various models and Webster's equations itself. It is shown that there can be significant differences in the calculation of optimal cycle times and consequent delay times. Webster published his famous report in which the working of a fixed cycle traffic signal is analyzed in depth. Especially the formula for the optimum cycle time of an n-phase intersection is still used in every day's work and is put into handbooks like the Highway Capacity Manual and similar works. A large amount of research has been put into the comparison of Webster's equations with micro-simulation tools and to comparing them to real data and into the theoretical description of what happens at a signal-controlled intersection. Nevertheless, there are still open questions in this field, a few of them will be highlighted in the current study. In this study we compare Webster's theory with results obtained from a micro-simulation model. The deterministic model by Webster fits fairly well with a host of different deterministic modeling approaches. For the stochastic part, however, differences between theory and simulation reality have been found. It is shown that there can be significant differences in the calculation of the optimal cycle times and the resulting delay times

Webster's Method of Traffic Signal Design

It has been found from studies that the average delay and the overall delay to the vehicles at a signalized intersection vary with the signal cycle length. The average delay per vehicle is high when the cycle length is very less, as a sizable proportion of vehicles may not get cleared during the first cycle and may spill over to subsequent cycles. As the signal cycle time is increased, the average delay per vehicle decreases up to a certain minimum value and thereafter the delay starts increasing, indicating that there is an 'optimum signal cycle time' corresponding to least overall delay. The optimum cycle time depends on the geometric details of the intersection and the volume of traffic approaching the intersection from all the approach roads during the design hour. Webster's method of traffic signal design is an analytical approach of determining the optimum signal cycle time, corresponding to minimum total delay to all the vehicles at the approach roads of the intersection.

The field work consists of determining the following two sets of values on each approach road near the intersection:

1) The normal flow, q on each approach during the design hour and

2) The ‘saturation flow’, S per unit time. The normal flow values, and on roads 1, 2 and 3 are determined from field studies conducted during the design hour or the

Traffic during peak 15 – minute’s period. The saturation flow of vehicles is determined from careful field studies by noting the number of vehicles in the stream of compact flow during the green phases and the corresponding time intervals precisely. Based on the selected values of normal flow, the ratio and are determined on the approach roads 1, 2 and 3. In the case of mixed traffic, it is necessary to covert the different vehicle classes in terms of suitable PCU values at signalized intersection; in case these are not available they may be determined separately. The normal flow of traffic on the approach roads may also be determined by conducting field studies during off – peak hours to be design different sets of signal timings during other periods of the day also, as required so as to provide different signal settings. The optimum signal cycle time is given by relation, Where L = total lost time per cycle, i.e., 2n + R, n = is the number of phases, R = all red time or red amber time, Y = Here, and Then, Similar procedure is followed when there are more number of signal phases.

Optimum Signal Cycle:

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

Where L= Lost time per cycle, sec=2n+R

Steps Involved in Webster Method

Step 1 - Identify Traffic Flow Volumes, Traffic flow volumes are identified, including turning movements.
Step 2 - Identify Junction Layout, Lane Geometry and Site Characteristics The junction layout, including lane geometry and site characteristics are identified. It may be necessary, if revealed in Step 4 or Step 7, to modify the layout to cater for turning movements, pedestrians or to enhance capacity and/or safety.
Step 3 - Identify Signal Phasing and Method of Control The method of control to be used for analysis is identified.
Step 4 - Check Turning Movements and Pedestrians Adequate provision for turning movements and pedestrians should be checked. It may be identified at this stage that the assumed method of control would need adjustment before continuing. Adequate allowance in calculations for parallel pedestrian minimum green crossing times should be made.
Step 5 - Estimate Saturation Flows The saturation flows for various approaches/movements are identified. In critical cases the saturation flows for important movements may have to be measured on site.
Step 6 - Compute Y, L, the lost times, flow factors and sum of the critical flow factors are computed.
Step 7 - Compute Reserve Capacity The maximum reserve capacity of the intersection is then calculated as a measure of operating performance. If this is not satisfactory, then it may be necessary to go back to Step 2, modify data and layouts and recalculate. A minimum provision of 25% reserve capacity should be provided wherever possible for new junctions. A lower standard may be adopted for existing junctions where further improvement is restricted by space limitations.
Step 8 - Compute Co, Cm, and Cp. The optimum, s and practical cycle times for operating the junction are then computed for further analysis, if necessary.

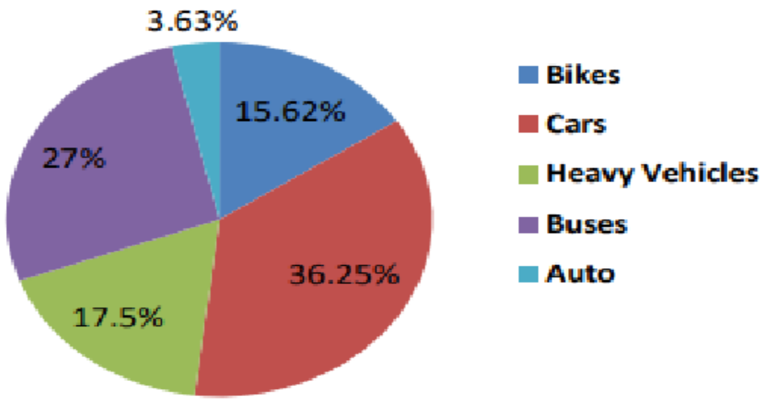
Step 9 - Select C It is then necessary to select a cycle time for operating the intersection. Sometimes, for reasons of linking, the selected cycle time may be different from the values Calculated in the previous step.
Step 10 - Compute Green Times, Degree of Saturation The green times of the various phases are then computed. Degree of saturation may be computed as well if detailed analysis of signal operation is required. If good linking to other junctions requires a cycle
time that results in very low degree of saturation and a very high reserve capacity, consideration should be given to double cycling this junction within the linking group, i.e. running it at half the linking cycle time.
Step 11 - Prepare Documentation for record purposes, drawings showing the junction layout, method of control, stage/phage diagram, traffic flow, etc. need to be prepared and maintained. Standard symbols should be used wherever applicable.

4.0 TEST RESULTS AND ANALYSIS

NON-PEAK HOURS

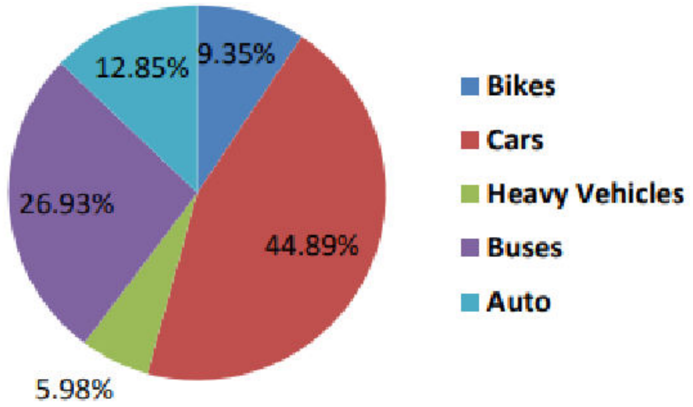
1) VEHICLES APPROACH ON ROAD-1

Bikes - 760×0.25 = 190 PCU (15.62%)
Cars - 434×1.0 = 434 PCU (36.25%)
Heavy Vehicles - 74×2.8 = 208 PCU (17.5%)
Buses - 90×3.6 = 324 PCU (27%)
Auto - 70×0.6 = 42 PCU (3.63%)
Total =1198 PCU



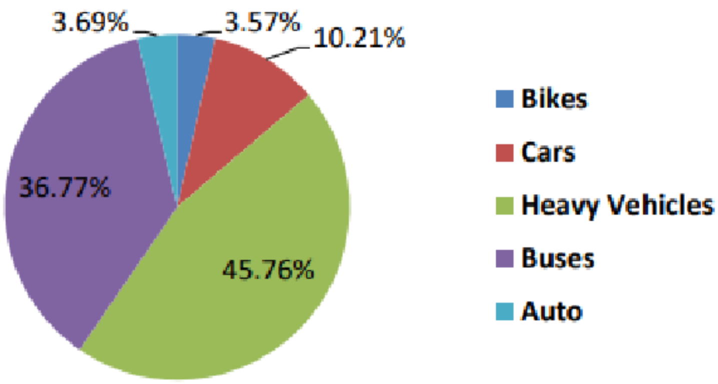
2) VEHICLES APPROACH ON ROAD-2

Bikes - 520×0.25 = 130 PCU (9.35%)
Cars - 623×1.0 = 623 PCU (44.89%)
Heavy Vehicles - 29×2.8 = 83 PCU (5.98%)
Buses - 104×3.6 = 374 PCU (26.93%)
Auto - 295×0.6 = 177 PCU (12.85%)
Total =1387 PCU

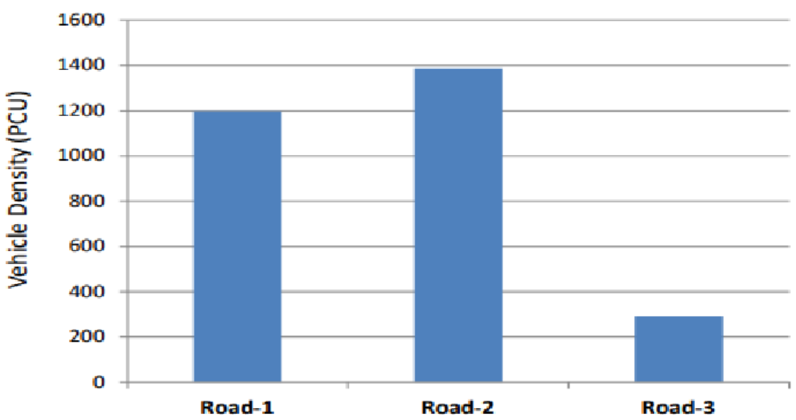


3) VEHICLES APPROACH ON ROAD-3

Bikes - 44×0.25 = 11 PCU (3.57%)
Cars - 30×1.0 = 30 PCU (10.21%)
Heavy Vehicles - 48×2.8 = 134 PCU (45.76%)
Buses - 30×3.6 = 107 PCU (36.77%)
Auto - 17×0.6 = 10 PCU (3.69%)
Total =292 PCU



Approach volume on road-1 = 1198 (q1)
Approach volume on road-2 = 1387 (q2)
Approach volume on road-3 = 292 (q3)



Width of road-1 (w1) = 7.5m
Width of road-2 (w2) = 7.5m
Width of road-3 (w3) = 7.5m

Saturation flow on road-1 (s1) = 525 × w1 =525 ×7.5 = 3937.5
Saturation flow on road-2 (s2) = 525 × w2 =525 ×7.5= 3937.5
Saturation flow on road-3 (s3) = 525 × w3 =525 × 3.75 = 3937.5

$$y1=\frac{q1}{s1}=\frac{1198}{3937.5}=0.30$$
$$y2=\frac{q2}{s2}=\frac{1387}{3937.5}=0.35$$
$$y3=\frac{q3}{s3}=\frac{292}{3937.5}=0.074$$

Y = y1+y2+y3 = 0.30+0.35+0.074=0.724
L = 2n+R = 2×3+12 = 18

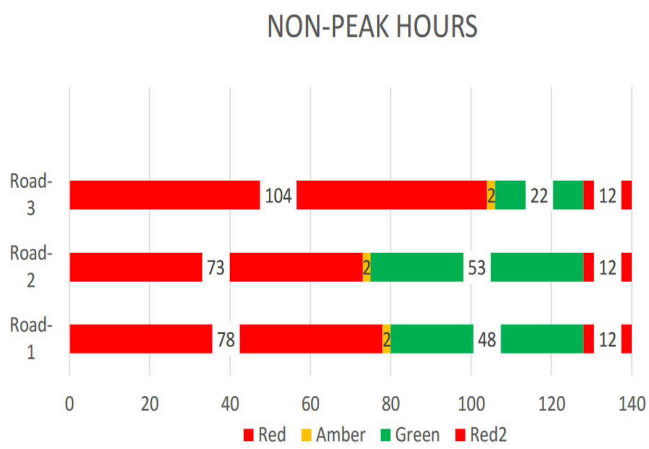
$$C_0=\frac{1.5L+5}{1-Y}=\frac{1.5*18+5}{1-0.72}=115.94\cong 116$$

Total Cycle Time = 116 Seconds

$$G1=\frac{y1}{Y}(C_0\text{-L})=\frac{0.30}{0.724}(116\text{-}18) = 40.60 \cong 41 \text{ Sec}$$

$$G1=\frac{y2}{Y}(C_0\text{-L})=\frac{0.35}{0.724}(116\text{-}18) = 47.37 \cong 48 \text{ Sec}$$

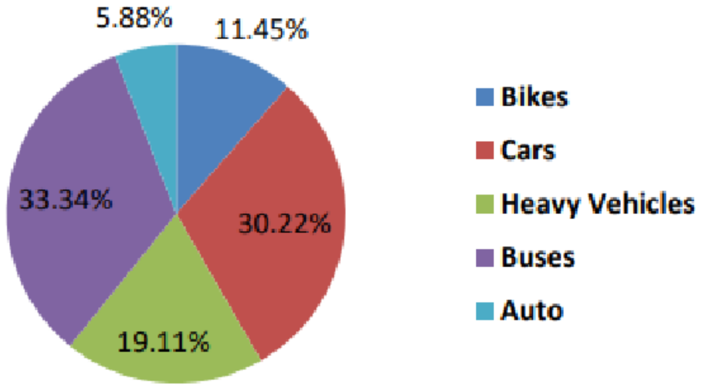
$$G1=\frac{y3}{Y}(C_0\text{-L})=\frac{0.074}{0.724}(116\text{-}18) = 10.04 \cong 10 \text{ Sec}$$



PEAK HOURS

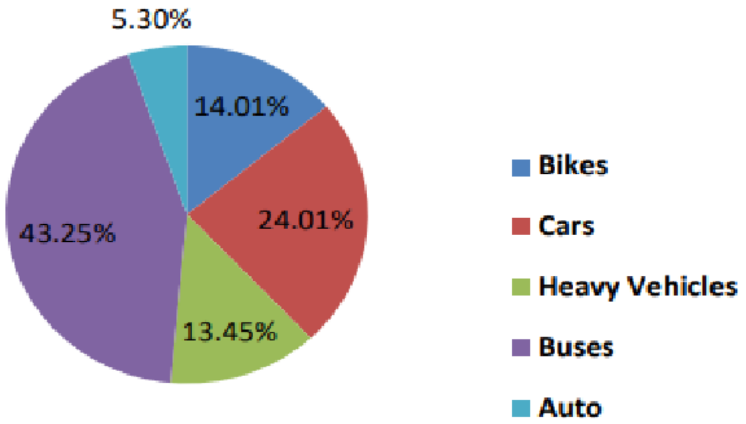
1) VEHICLES APPROACH ON ROAD-1

Bikes - 736×0.25 = 184 PCU (11.45%)
Cars - 486×1.0 = 486 PCU (30.22%)
Heavy Vehicles - 109×2.8 = 308 PCU (19.11%)
Buses - 148×3.6 = 537 PCU (33.34%)
Auto - 156×0.6 = 94 PCU (5.88%)
Total =1610 PCU



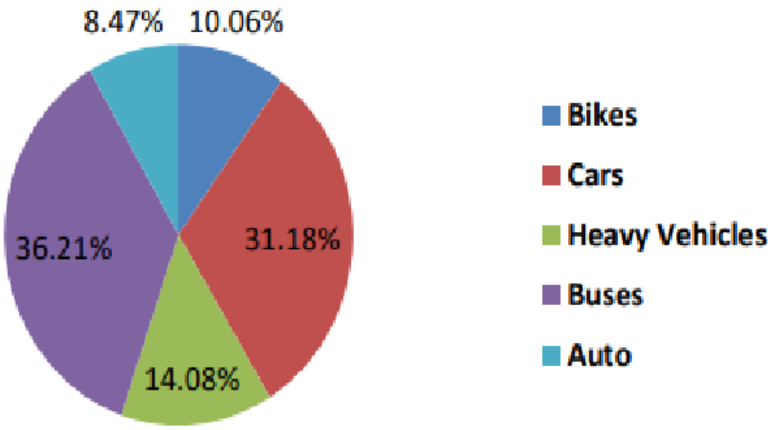
2) VEHICLES APPROACH ON ROAD-2

Bikes - 976×0.25 = 244 PCU (14.01%)
Cars - 418×1.0 = 418 PCU (24.01%)
Heavy Vehicles - 84 ×2.8 = 235 PCU (13.45%)
Buses - 209×3.6 = 754 PCU (43.25%)
Auto - 153×0.6 = 92 PCU (5.30 %)
Total =1743 PCU

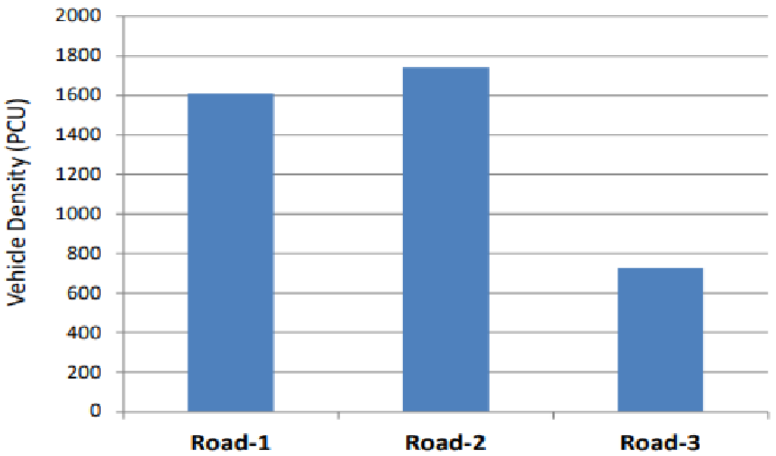


3) VEHICLES APPROACH ON ROAD-3

Bikes - 296×0.25 = 74 PCU (10.06%)
Cars - 226×1.0 = 226 PCU (31.18%)
Heavy Vehicles - 36×2.8 = 102 PCU (14.08%)
Buses - 72×3.6 = 262 PCU (36.21%)
Auto - 103×0.6 = 62 PCU (8.47%)
Total =726 PCU



Approach volume on road-1 (q1) = 1610
Approach volume on road-2 (q2) = 1743
Approach volume on road-3 (q3) = 726



Width of road-1 (w1) = 7.5+2.5 = 10
Width of road-2 (w2) = 7.5+2.5 = 10
Width of road-3 (w3) = 7.5+2.5 = 10

Saturation flow on road-1 (s1) = 525 × w1 = 525 ×10 = 5250
Saturation flow on road-2 (s2) = 525 × w2 = 525 ×10 = 5250
Saturation flow on road-3 (s3) = 525 × w3 = 525 × 10= 5250

$$y1=\frac{q1}{s1}=\frac{1610}{5250}=0.306$$
$$y2=\frac{q2}{s2}=\frac{1743}{5250}=0.332$$
$$y3=\frac{q3}{s3}=\frac{726}{5250}=0.138$$

Y = y1+y2+y3 = 0.306+0.332+0.138=0.77
L = 2n+R = 2×3+12 = 18

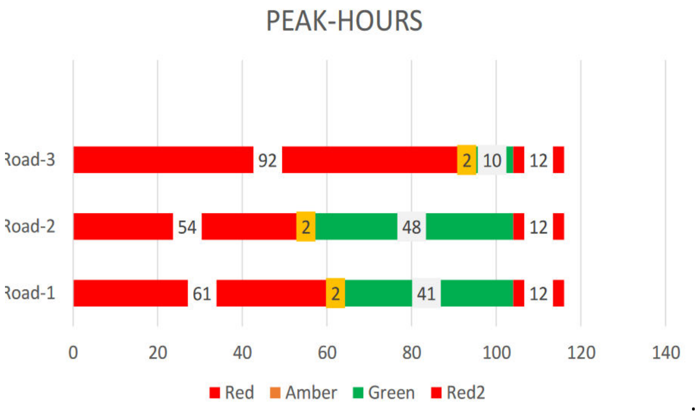
$$C_0=\frac{1.5L+5}{1-Y}=\frac{1.5*18+5}{1-0.77}=139.13\cong 140$$

Total Cycle Time = 140 Seconds

G1=$\frac{y1}{Y}$ $(C_0$-L) =$\frac{0.306}{0.77}$(140-18) = 48 Sec

G1=$\frac{y2}{Y}$ $(C_0$-L) =$\frac{0.332}{0.77}$(140-18) = 52.28 ≅ 53 Sec

G1=$\frac{y3}{Y}$ $(C_0$-L) =$\frac{0.138}{0.77}$(140-18) = 21.86 ≅ 22 Sec



5.0 RESULTS AND DISCUSSION

The paper proposes the modified Webster's model to estimate delay for heterogeneous traffic conditions at pre-timed signalized intersections. Traffic volumes approaching the signalized intersection are classified into four groups: Motorized two-wheeler, Car, Minibus, and Bus. The passenger car unit (PCU) is estimated by using the linear multiple regression analysis. The regression function expresses the relationship between the saturated green time and the total number of vehicles of all groups passing the approach. Saturation flows are estimated with the consideration of different types of vehicles traveling together. Distributions of saturation flow are, computed to follow the normal distribution at all observed intersections. Then, an expectation function method and Taylor series expansion are utilized to estimate the mean and the variance of delay. The model is evaluated at three pre-timed signalized intersections, then compared with the conventional Webster's and observed delays. The results identify that the output of the proposed methodology is close to the observed data and better than that of the conventional Webster's, especially when the degree of saturation is close to 1.

6.0 CONCLUSION

Intersections are the critical component of roadway system and frequently act as a choke point on the transport system.

The current data shows the increment in traffic as well as site constraints. The engineer needs to design methods and criteria based on fundamental relationship between capacities, flow of traffic, geometry design, safety that will enable users to get directly from proposed geometry to the realistic estimates of operating conditions. The result of this study gives the idea that what measures are suggested to remove such kind of problems and the precautions to be used to remove congestion at intersection. The traffic study and analysis at the Panama intersection reveals the conclusion as following:

• The numbers of bikes travelling are more when compared to cars. • The number of cars is more when compared to buses.

• So, if numbers of buses are increased, then the dependency on public transports increase.

• This will make decrease in number of personal vehicles.

• Thus, the traffic situation in the Panama intersection is critical in the peak hours as the optimum cycle length is about to expand and escalate the standard value of optimum.

• It is very essential to recommend an alternative transportation infrastructure in the Panama intersection so as to abate the delay in the traffic and thereby congestion gets reduced and free Flow of Traffic shall be achieved

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