UI Journal of Civil Engineering and Technology Vol. 1, No. 1; December, 2019

Analysis and Design of Intersection for Improved Traffic flow at Awolowo Junction, Bodija Ibadan, Nigeria

[1]Adigun, T., [2]Akintayo, F. O. and [3]Okunlola, O.

[1,2,3]Department of Civil Engineering, University of Ibadan, Ibadan, Nigeria

Corresponding Author: lekeadigun@gmail.com

ABSTRACT

Traffic Congestion is inevitable for residents of economically dynamic cites therefore city authorities have to devise means of managing congestion to ease commuters of constrains imposed upon them by traffic congestion. The need for improvement of traffic flow at Awolowo Junction Bodija Ibadan is germane due to traffic congestion at this intersection. The aim of this study is to improve traffic flow at Awolowo Junction Bodija Ibadan. Traffic survey was carried out at the intersection, the peak hour factor and the design hourly volume were determined then the saturation flow rate and the cycle length (using the concept of volume-to-capacity ratio) were determined following the steps outlined in the Highway Capacity Manual, thereafter the yellow interval and the green times were computed. The peak hour was between 4:00 pm - 5:00 pm with a flow of 2989 vehicles per hour and a factor of 0.94 with design hourly volume of 539, 1464 and 1177 vehicles per hour for North, West and East approach respectively. The data collected was checked against the traffic signal warrants of the Manual on Uniform Traffic Control Device and yielded positive result with warrant 3. The saturation flow rate was computed to be 2618, 4320 and 3913 vehicles per hour for the North, West and East approach respectively with a flow ratio of 0.21, 0.34 and 0.3 for North, West and East Approach respectively. A pre-timed traffic control signal was designed to improve traffic flow at Awolowo Intersection of UI/secretariat Road.

Keywords: Traffic Congestion, Road Intersection, Pre-Timed Control Signal, Traffic flow

1. INTRODUCTION

Traffic congestion occurs when a city's road network is unable to accommodate the volume of traffic that traverses it. Urban traffic congestion can be contributed by a number of factors including rapid increase in urban population, economic growth, increase in employment opportunities, increase in traffic volume, low capacity of transport infrastructure and poor traffic management. The Organisation for Economic Co-operation and Development (OECD) and European Conference of Ministers of Transport (ECMT) defined congestion as the relative phenomenon that is linked to the difference between the roadway system performance that users expect and how the road actually performs. Road traffic congestion which is one of the acclaimed indicators of a city's socio-economic vibrancy has continually challenged the efforts of transportation planners in terms of choosing longer travel time and delays over time and space (Popoola *et al.*, 2013)

Rodrique *et al.*, (2009) stated that congestion can be seen as unavoidable consequence of deficient transport facilities such as road space, parking area, road signals and effective traffic management. They argued that urban congestion mainly concerns two domains of circulation, passengers and freight which share the same infrastructure. Thus, traffic congestion condition on road networks occurs as a result of use of road infrastructure beyond capacity, and it is characterised by slower speeds, longer trip hours and increased vehicular queuing. Downie (2008) also stated that traffic congestion occurs when the volume of vehicular traffic is greater than the available road capacity, a point commonly referred to as saturation. Basiru and Waziri (2008) listed the causes of traffic congestion in Lagos to include the following: presence of pot holes/bad road, roadside trading activities, on-street parking, loading and discharging of passengers at illegal bus stops, flooding/poor drainage, vehicle breakdown, narrow road sections, religious activities, high volume of traffic, lack of parking space and lack of traffic signal at some road intersections.

Zhang and Yue (2001) reported in the proceedings of the Eastern Asia Society for Transportation Studies that urban traffic congestion is a significant and growing menace in some parts of the world. Furthermore, they pointed out that as congestion continues to increase, the typical approach of 'building more roads' does not always work for a variety of political, financial and environmental reasons in fact building new roads may compound congestion, in some cases by inducing greater demands for vehicle travel that quickly eat away the additional capacity. Against this backdrop of existing and growing congestion, traffic control techniques and information systems are needed that can substantially increase capacity and improve traffic flow efficiency. Cities that are economically productive will rarely be free from traffic congestion. Congestion has become an everyday part of life and that it is the city authorities that have to devise measures to help manage it at an affordable basis to relief road users of the difficulties imposed upon them by traffic congestion (May and Marsden, 2007).

Kayode *et al.*, (2012) in the official conference proceedings of the Asian conference on the social sciences noted that while examining the causes of traffic congestion , the average time spent on traffic by road users due to traffic congestion, time occurrence and the spatial pattern of congestion in Agbowo, Bodija, Agodi areas of Ibadan North Local Government with the use of a well-structured questionnaire that traffic congestion is very high in the three neighbourhoods in the evening and morning period compared to afternoon. However, there are variations across the neighbourhoods. Traffic flow studies assists traffic Engineers maximize roadway capacity minimize vehicle delays and improve traffic safety (Akintayo and Agbede, 2015). A pre-timed traffic control signal serves as a means of upgrading an existing system of using a traffic warden to control the flow of vehicles and pedestrians (Akintayo and Lafinhan, 2015).

The traffic of the highway system in Nigeria (most especially the central business district) is in a bleak situation caused by daily congestion. Therefore, it is necessary that solutions are provided to this problem so as to alleviate the magnitude of its occurrence. The main objective for improving traffic flow is to enhance the efficiency of the existing roadway system and to reduce traffic congestion and related problems. The amelioration of traffic flow depicts those operations that can be implemented to augment person-carrying capability of the roadway system without adding to the width of the roadway. Most traffic flow improvements are implemented with a focus on the peak period work trip. The aim of this project is to improve traffic flow at Awolowo Junction Bodija Ibadan, Nigeria.

2. METHODOLOGY

2.1 Reconnaissance Survey

Reconnaissance survey was carried out for the purpose of getting acquainted with the study area and to access the situation on ground before a detailed survey. It involved the study of the geographical area where the survey was carried out and evaluation of facility types available in the study area. Figure 1 shows the geographical location of the study area. Figure 2 shows the CAD representation of the intersection

2.2 Traffic Volume Count

The traffic volume count was conducted so as to know the total number and movement of vehicles and pedestrians movement at the study area. The data collected were used to determine the critical flow time periods. The study was conducted between (6:45hrs - 8:45hrs) and (15:45hrs - 17:45hrs) during the week.

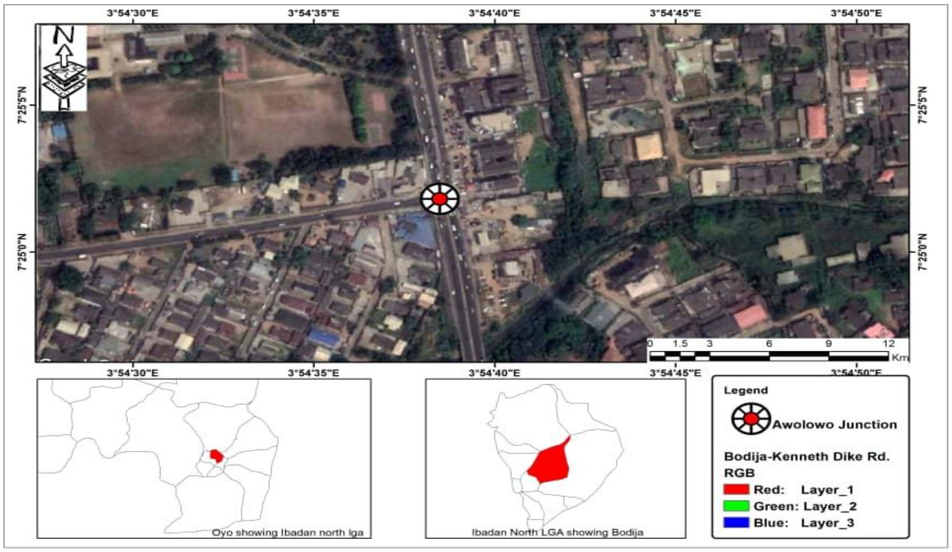

Figure 1: Geographical Location of the Awolowo Intersection

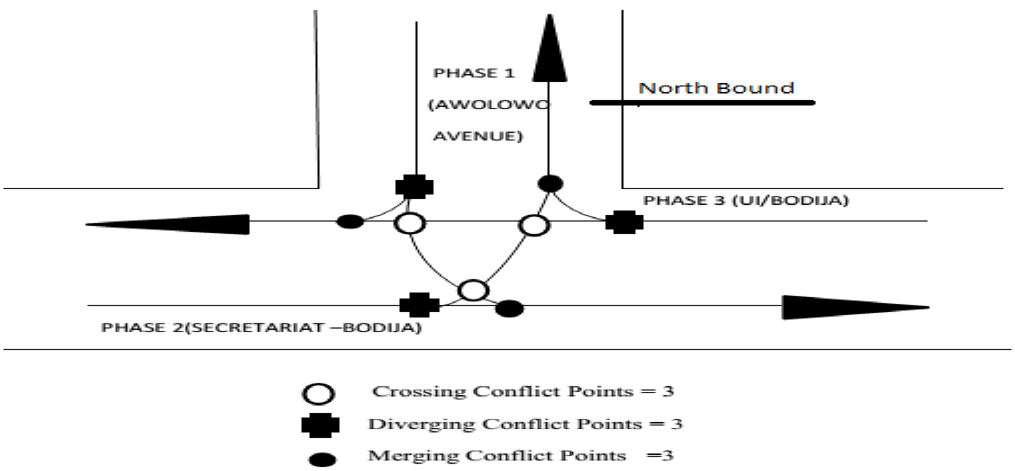

Figure 2: CAD of Awolowo Intersection

2.3 Traffic Count Method

An electronic counting board which is in the form of a mobile application was used for traffic count for the first four days (Tuesday 29th January – Friday 1st February 2019). The mobile application is called "Traffic Abacus". The mobile application captures different directions of a four legged intersection and it is operated manually. This mobile application is identical to mechanical counting board which consists of counter placed on a board that record each direction of travel. The traffic Abacus supported input of observed traffic movement using its internal clock to separate data by time intervals. Screen shot of the application was made every fifteen (15) minutes during the traffic count period. This method was selected due to the available manual method of conducting the count Figure 3 Shows the overview of the mobile application. Automatic counting was carried out for the last four days using a video camera (Tuesday 12th February – Friday 15th February 2019). The video camera technique which seemed to give the most accurate and precise result was used for the analysis. After the completion of the traffic count, the data collected and recorded in the traffic abacus was extracted and tabulated. The video camera was played and the data collected was also extracted and tabulated.

Figure 3: Traffic Abacus

2.4 Peak Hour Factor and Design Hourly Volume

Peak hour factor refers to as the measure of the viability of demand during the peak hour and is also the ratio of the volume during peak hour to the maximum rate of flow during a given time period within the peak hour. The peak hour factor is given as

$$\text{PHF} = \frac{Volume\ during\ peak\ hour}{4 \times volume\ during\ peak\ 15\ minutes\ within\ peak\ hour} \tag{1}$$

Design hourly volume (DHV) was obtained using

$$\text{DHV} = \frac{Peak\ Hour\ Volume}{PHF} \tag{2}$$

2.5 Traffic Signal Warrant

The manual for uniform traffic control devices (MUTCD 2003) contains the traffic signal warrant and establishes the minimum criteria for traffic signal installation. Analysis of the applicable factors relating to traffic signals was done

2.6 Phase Determination

The design of phase in this study was guided by the geometry of the intersection as shown in Figure 2, the flow pattern especially turning movements and the magnitude of flow. Considering this and other relevant factors, a three phase signal is therefore selected for the intersection

2.7 Saturation Flow Rate

The saturation flow rate for the intersection was determined from direct field measurement following the procedures in the highway capacity manual (HCM 2000).

The saturation flow was determined from the equation

$$\frac{3600}{(t_n - t_4/(n-4)} \quad (3)$$

Where t_n= time of the last vehicle surveyed t_4 = time of the fourth vehicle surveyed

n = numbers of vehicles

2.8 Determination of Cycle Length using Highway Capacity Manual Method

The highway capacity method was used to determine the cycle length based on the capacity (the maximum flow based on the available effective green time) of a lane group. The saturation flow rate which is the maximum flow rate on an approach or lane group when 100 per cent effective green time is available, the capacity of an approach or lane group depends on the percentage of the cycle length that is given to that approach or lane group.

The approach or lane group capacity is given as

$$C_i = S_i(g_i/C) \quad (4)$$

Where

C_i= Capacity of lane group i (veh/h) S_i= Saturation flow rate for lane group or approach I (veh/h of green or veh/h/g) g_i/C = Green ratio for lane group or approach i , g_i= effective green for lane group is or approach I C= Cycle length

The ratio of flow to capacity (*v/c*) is usually referred to as degree of saturation which is expressed as

$$(v/c)_i = X_i = \frac{V_i}{S_i(g_i/C)} \quad (5)$$

Where

X_i= (v/c) ratio for lane group or approach i V_i= actual flow rate for lane group or approach i(veh/h) S_i= Saturation flow for lane group or approach i (veh/h) g_i= effective green for lane group i or approach i

The overall intersection was evaluated with respect to its geometry and the total cycle time using the concept of critical volume-to-capacity ratio (X_c) .The critical v/c ratio for the whole intersection is given as

$$X_C = \sum_i (v/s)_{ci} \frac{C}{C-L} \quad (6)$$

Where

X_C = critical (v/c) ratio for the intersection

$\sum_i (v/s)_{ci}$= summation of the ratios of actual flows to saturation flow for all critical lanes, groups, or approaches.

C= cycle Length (sec)
L= lost time per cycle computed as the sum of the lost time $l_i$for each critical signal phase.
Re arranging Equation 6 so as to be used in determining the cycle length, it becomes

$$C = \frac{X_C}{\sum_i (v/s)_{ci}} \times C - L \quad (7)$$

2.9 Yellow Interval

The main purpose of the yellow indication after the green is to alert motorists to the fact that the green light is about to change to red and to allow vehicles already in the intersection to cross it. A bad choice of yellow interval may lead to the creation of a dilemma zone, an area close to an intersection in which a vehicle can neither stop safely before the intersection nor clear the intersection without speeding before the red signal comes on. The required yellow interval is the time period that guarantees that an approaching vehicle can either stop safely or proceed through the intersection without speeding.

The equation below is used for the determination of sufficient yellow interval τ_{min} for the intersection

$$\tau_{min} = \delta + \frac{W+L}{U_O} + \frac{U_O}{2(a+Gg)} \quad (8)$$

Where δ= perception reaction time (sec) W= Width of Intersection L= Length of vehicle

U_O =Speed Limit (m/s) a= Constant rate of braking deceleration (m/s²) G = Grade of the approach

g = Acceleration due to gravity (m/s²)

2.10 Allocation of Green Times

The total effective green time available per cycle was determined using

$$G_{te} = C\text{-}L \quad (9)$$

Where

G_{te} = Total effective green time per cycle C= Cycle Length (sec) L= Total Lost Time (sec)

The minimum overall delay was obtained by distributing the total effective green time among the different phases in proportion to their saturation flow values.

The actual green time for each phase was obtained using equation 6 which was re arranged to become

$$G_{ai}=G_{ei}+l_i - \tau_i \quad (10)$$

Where the effective green $G_{ei} = \frac{(v/s)_i}{\sum_i (v/s)_{ci}} \times G_{te}$

3. RESULTS AND DISCUSSION

3.1 The Intersection

It was observed that the study area is a 3 legged intersection and the intersection is formed as a result of the road stretching from Awolowo Avenue, UI-Bodija road and Secretariat Road. Traffic at the intersection as at the time of the survey was controlled by traffic wardens. It was also observed that the major traffic generators are the Bodija market, the Oyo State Secretariat and the University College Hospital. The Road stretching from Awolowo Avenue was taken as the North Approach, while the road stretching from Secretariat was taken as the West Approach and the road stretching from UI-Bodija was taken as the East Approach.

3.2 Traffic Count

The result of the vehicular count used for the analysis is shown in Table 1. From the table, the North Approach represents 15.04% of the total volume, West Approach represents 46.51% of the total volume and the East Approach represents 38.45% of the total volume Figure 4 shows the typical flow of traffic during the morning and afternoon peak periods.

Table 1: Vehicular Count for Afternoon Peak Period (Wednesday 13th February 2019)

START TIME	NORTH APPROACH(N.A) (AWOLOWO ROAD)			WEST APPROACH(W.A) (SECRETARIAT-BODIJA ROAD)				EAST APPROACH(E.A) (UI/SECRETARIAT ROAD)				N.A+W.A+E.A
	L	R	Total	L	S	U	Total	R	S	U	Total	TOTAL
15:45	35	35	70	85	224	1	310	29	184	-	213	593
16:00	48	55	103	103	253	3	359	23	221	-	244	706
16:15	57	56	113	81	254	7	342	24	272	2	298	753
16:30	59	63	122	109	242	4	355	20	238	4	262	739
16:45	84	85	169	99	219	2	320	36	264	2	302	791
17:00	63	34	97	94	214	3	311	24	236	2	262	670
17:15	42	30	72	64	117	2	183	14	202	1	217	472
17:30	30	15	45	66	200	1	267	12	212	1	225	537
												∑=**5261**

Where L =Left Turn Movement R= Right turn movement S=Straight movement U = U-turn movement

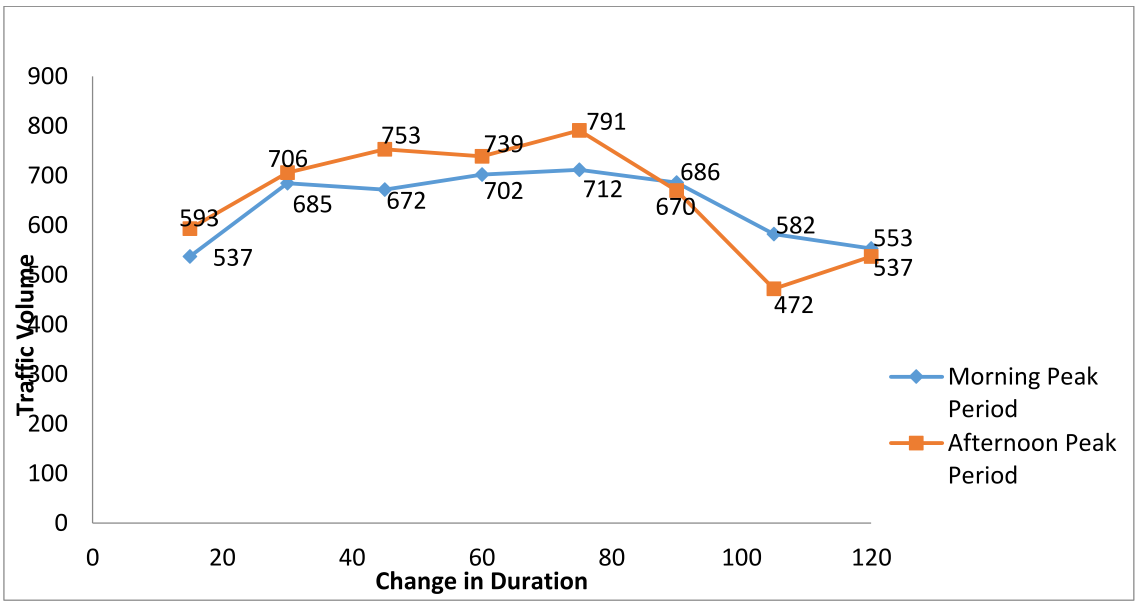

Figure 4: Typical flow of traffic during the morning and afternoon peak periods.

From Figure 4, it is observed that the highest 15 minutes volume with 791 vehicles falls on the 80th minute which is between 4:45pm -5:00pm.

3.2.1 Determination of peak hour

The peak hour of the intersection was determined by adding the highest four consecutive fifteen minutes period of the traffic count which gave the hour with the highest volume of traffic. The highest four consecutive fifteen minutes count is shown in Table 2. From the table 2, it can be concluded that the peak hour period is between 16:00hrs - 17:00hrs with a flow of 2989 veh/hr.

Table 2: Vehicular Count for Peak Hour

TIME (PM)	TOTAL
16:00-16:15	706
16:15-16:30	753
16:30-16:45	739
16:45-17:00	791
TOTAL	2989veh/hr.

Determination of Peak Hour Factor

$$\text{PHF} = \frac{\textit{Volume during peak hour}}{4 \times \textit{volume during peak } 15 \textit{ minutes within peak hour}}$$

$$= \frac{2989}{4 \times 791}$$

$$= 0.94$$

3.2.2 Design hourly volume

The peak hour volume for each lane of the intersection was determined following the procedure used in section 2.4. The peak hour volumes were divided by the peak hour factor to determine the design hourly volume.

Peak Hour for the North Approach

$$103+113+122+169 = 507\text{veh/hr}$$

$$\text{Design Hourly Volume} = {}^{507}/_{0.94}$$

$$= 539 \text{ veh/hr.}$$

Peak Hour for West Approach

$$359+342+355+320 = 1376\text{veh/hr}$$

$$\text{Design Hourly Volume} = {}^{1376}/_{0.94}$$

$$= 1464 \text{ veh/hr.}$$

Peak Hour for East Approach

$$244+298+262+302 = 1106\text{veh/hr}$$

$$\text{Design Hourly Volume} = {}^{1106}/_{0.94}$$

$$= 1177\text{veh/hr.}$$

3.2.3 Traffic signal warrant

To justify the installation of an upgraded traffic control signal at Awolowo Intersection of UI/Secretariat Road, the result of traffic count was checked against the traffic signal warrant of the manual on uniform traffic control devices. Due to the length of the study, selected warrant (Warrant 3 and 4) were analysed with the data collected. Warrant 3 (peak Hour) and Warrant 4 (Pedestrian Volume) were analysed, but it was observed that the pedestrian volume was unable to meet the criteria for warrant 4. Therefore, the traffic volume was checked against Only Warrant 3 which yielded positive.

3.2.4 Phase determination

This was guided by the geometry of the intersection, the flow pattern especially turning movement and magnitude of flow as there is no definite method for the design of phases. Following this, a three phase signal is needed for the intersection.

3.2.5 Determination of saturation flow rate

Following the procedures outlined in HCM, the data below were extracted from the video coverage at the intersection.

Saturation Flow Rate for the North Approach

$$n = 20 \quad t_4 = 3 \quad t_n = 25$$

$$= 2618 \text{ veh/hr.}$$

Saturation Flow Rate for West Approach

$$n = 34 \quad t_4 = 5 \quad t_n = 30$$

$$= 4320 \text{ veh/hr.}$$

Saturation Flow Rate for East Approach

$$n = 30 \quad t_4 = 4 \quad t_n = 28$$

$$= 3913 \text{ veh/hr.}$$

Flow Ratio

The flow ratio was used in the determination of the cycle length of the proposed pre-timed traffic signal
The flow Ratio was calculated by dividing the Flow Rate by the Saturation Flow Rate;
The flow ratio For Phase 1(North Approach), For Phase 2(West Approach) and for Phase 3 (East Approach) were computed as 0.21, 0.34 and 0.3 respectively

$$\text{Sum of the Flow Ratios} = 0.21 + 0.34 + 0.3$$

$$= 0.85$$

3.2.6 Determination of cycle length

Following the equation given in the methodology

Where $(X_C) = 0.95$ L=4 seconds $(\sum_i (v/s)_{ci}) = 0.85$

Cycle Length = 112 seconds

≡115 seconds (Cycle Lengths are usually multiples of 5 and 10 seconds)

3.2.7 Determination of Yellow Interval

The equation below is used for the determination of sufficient yellow interval τ_{min} for the intersection

$$\tau_{\min} = \delta + \frac{W+L}{U_O} + \frac{U_O}{2(a+Gg)} \quad (11)$$

Where δ =2.5 seconds, W= 31 m, L = 4.5m, U_0 = 13.89m/s, a=3.4 m/s², g = 9.81m/s² G=1

≈ 5.6 seconds

Therefore, a yellow interval of 5.6 seconds is needed for the intersection.

3.2.8 Allocation of green times

First, the total effective green time is required and is determined using;

$$G_{te} = C\text{-}L$$

Where C=Cycle Length L=Total Lost Time

G_{te}=115-12 G_{te}

=103 seconds

Therefore the total effective time required for the intersection is 103 seconds.

Actual Green Time

The equation for determining the actual green time for each phase is given as

$$G_{ai}=G_{ei}+l_i-\tau_i$$

Where yellow time(τ_i) is 5.6 seconds as calculated above

Where the effective green $G_{ei} = \frac{(v/s)_i}{\sum_i (v/s)_{ci}} \times G_{te}$

Actual Green Time for Phase 1 (North Approach)

$= (\frac{0.21}{0.86} \times 103) + 4 - 5.6$

=23.5 seconds

≈ 24 seconds

Actual Green Time for Phase 2 (West Approach)

$= (\frac{0.34}{0.86} \times 103) + 4 - 5.6$

=39.1 seconds

≈39 seconds

Actual Green Time for phase 3 (East Approach)

$= (\frac{0.3}{0.86} \times 103) + 4 - 5.6$

=34.3 seconds

≈34 seconds

4. CONCLUSION

Traffic volume study was conducted at Awolowo Intersection of UI/Secretariat Road to validate the establishment of a pre-timed traffic control signal for the improvement of traffic flow at the intersection, It can be drawn from the study that;

The peak hour period for the intersection is between 16:00hrs - 17:00hrs with a traffic flow of 2989 veh/hr. having 1106 veh/hr. at the East Approach,1376 veh/hr. at the West Approach and 507 veh/hr. at the North Approach. It can be concluded that the west approach has the highest vehicular flow. The analysis of the factors related to traffic control signals as seen in the manual on uniform traffic control devices carried out showed that warrant 3 (peak hour check) was satisfied. The signal timing parameters computed for the design of the pre-timed traffic control signal are;

i. The saturation flow: The saturation flow rate was computed as 4320veh/hr. for west approach, 3913veh/hr. for east approach and 2618veh/hr. north approach

ii. Cycle length: The cycle length was calculated to be 115 seconds

iii. Yellow Interval: The yellow interval was computed to be 5.6 seconds

iv. Effective green time: This was computed to be 103 seconds

v. The actual green time for phase one, two and three were calculated to be 24 seconds, 39 seconds and 34 seconds respectively.

REFERENCES

Akintayo, F. O. and Agbede, O. A. (2015). Vehicle Headway Distribution Modelling of Free-flowing Traffic on Two-lane Single Carriageways. *Journal of Research Information in Civil Engineering*, 12(1): 609 – 619.

Akintayo, F. O and Lafinhan, O. O. (2015). Design of a pre-timed traffic signal at the University of Ibadan Main Gate Intersection. *Journal of Civil Engineering and Architecture Research,* 2(12): 1207-1212

Basiru, A. R and Wazari, O. O. (2008). *Analysis of Intra-Urban Traffic Problems in Nigeria: A study of Lagos Metropolis.* Indonesian Journal of Geography 40(1): 31-35.

Downie, A. E. (2008). The world worst Traffic Jam Times. Retrieved July 3rd 2019 from http://www.time/world/articles/0.8599,1733872,00.html.

Highway Capacity Manual (2000). USA: Transportation Research Board.

Manual on uniform control devices for street and highways 2003.

Kayode, A. O., Yusuf, O. G., Edward, E. D., Musibau, A. A., Stephen, E. E., Wellington, D. T. and Arham. A. (2012). Traffic Congestion, Causes and Effect on Residents of Urban Cities in Nigeria. *Official conference proceedings of the Asian conference on the social sciences 2012.*

May, A. and Marsden, G. (2011). Urban Transport and mobility: Transport and innovation unleashing the potential. International Transport Forum. Retrieved July 4th 2019 from www.internationaltransportforum.org/pub/pdf/10FP05

Organisation for economic co-orperation and development (OECD), European Conference of Ministers of Transport (ECMT) (2006). Managing Urban Traffic Congestion.

Popoola, M. O., Abiola, S. O. and Aseniji, W. A. (2013). Traffic Congestion on Highways in Nigeria Causes, Effects and Remedies. *International journal of civil, Architectural, structural and construction Engineering,* 7(11): 524 – 529.

Rodrique, J. P., Comtois, C. and Slack, B. (2019). The Geography of Transportation System. New York: Routledge Retrieved July 3rd 2019 from www.en.wikibooks.org/wiki/Gravity of migration

Zhang, W. A. and Yue, W. L. (2001). Alternative Solutions for traffic congestion. *Proceedings of the Eastern Society for Transportation Studies volume 3, No 2 October 2001*