DESIGN OF A TRAFFIC SIGNALISATION SCHEME AT OLA-OLU INTERSECTION, ILORIN, NIGERIA

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Abstract

Ola-Olu intersection in Ilorin metropolis, Nigeria, is a 3-legged intersection in a typical urban centre of a developing economy. It is presently traffic warden controlled at morning peak period on weekdays and occasionally in the evening when there’s an event in a neighbouring public event centre that is expected to increase the traffic at the intersection. It is observed that the delay experienced at the intersection is quite high and traffic crashes at the intersection is a weekly occurrence. The study thereby aims at ameliorating the hazards by designing a fixed-time traffic signalization for the intersection. The objectives are to i. determine the geometric layout of the intersection ii. determine the traffic volume and vehicular turning movement pattern and iii. design and provide the signal timings at the T-intersection. Traffic volume survey and geometric layout survey were carried out at the intersection and analyzed to determine the optimum cycle length and signal setting using the Webster’s method. A 3-phase fixed time traffic signalization of 155 seconds cycle length was designed for an effective signal traffic control. The green time for phases 1, 2 and 3 are 102 seconds, 16 seconds and 22 seconds respectively. The implementation of the traffic signal will enhance both traffic flow and safety at the intersection.

Keywords: Urban intersection, Congestion, Traffic signals, Crashes, Safety

1.0 INTRODUCTION

Most urban centres in Nigeria, including Ilorin where the studied Ola-Olu intersection is located do not have efficient mass public transit system where High Occupancy Vehicles are used for commuting. What is prevalent resulting from this urban infrastructure deficiency is the use of private cars, tricycles, motorcycles and light buses (14-seater and 10-seater) for commuting. This contributes to the high incessant traffic congestion often experienced in urban centres in the country with the intersections being the bottleneck from which most urban centres’ congestions radiate (Reddy and Reddy, 2016). Ilorin metropolis with a population of 814,192 and an annual growth rate of 2.60 % (Worldometers, 2020) is a fast growing city and the capital city of Kwara State, Nigeria, a developing economy. The city’s Central Business District road network experiences traffic congestions between 7.30 am and 6.30 pm on weekdays with the attendant negative impacts on the socio-economic activities and health of the citizens. Traffic controls are presently done manually at all the intersections in Ilorin except two, by traffic control officers with the accompanying inherent disadvantages in manual traffic control exhibited (Adeleke, 2010). With the increasing traffic jam on the metropolis urban roads and high traffic crashes at the intersections, traffic engineers are looking for new approaches to ameliorate the problem (Wang, 2016).
The Ola-Olu intersection is one of such intersections needing effective traffic management as delay experienced at the intersection is quite high and traffic crashes at the intersection is a weekly occurrence. Traffic signals are one of the most effective and flexible active control of traffic that is widely used in several cities worldwide to ensure safe and orderly traffic flow; the conflicts arising from movements of traffic in different directions is solved using time sharing principle. Traffic signals when justifiably provided, improve on the movement and safety of vehicle users and pedestrians and aid to obtain the most efficient use of available road space (Zegeer, 2002; Matthew, 2014; Patil, 2015; Wang, 2016). Hence the aim of the study is to design a traffic signalization scheme at Ola-Olu intersection. The objectives of the study are to i. determine the geometric layout of the intersection ii. determine the traffic volume and vehicular turning movement pattern and iii. design and provide the signal timings at the T-intersection.

2.0 METHODOLOGY

2.1 Study Area

The study area is the Ola-Olu T-intersection in Ilorin, Nigeria. The intersection is situated at longitude 4˚ 34’ 04.2” E and latitude 8˚ 28’ 10.9” N on the Ilorin-Ajasse-Ipo Road which is one of the four transect routes linking the Kwara State capital city Ilorin from other parts of Nigeria. The Ilorin-Ajasse-Ipo road on which the intersection is situated is also the major inlet from the South Western part of the metropolis to the city’s Central Business District. The intersection is three-legged; the major road which intersects the minor is a dual carriageway while the minor road is a 2-lane single carriageway. The approaches on the major road are Gaa-Akanbi and A-Division while Gaa-Imam is on the minor road.

2.2 Preliminary Considerations and Warrants

Before a traffic control signal is designed it must be determined if the signal is warranted and needed. The positioning of the signalization at Ola-Olu intersection is justified as it satisfies traffic signals Warrant 1 on 8-hour Vehicular Volume, Warrant 7 on Crash Experience and Warrant 8 on Road Network (Manual on Uniform Traffic Control Devices, 2009; North Star Highways, 2019).

2.3 Determination of the Geometric Layout

The geometric layout of the intersection was determined using surveying instruments that include Total Station and tapes. The geometric parameters determined included the approach width and approach slopes that were used to determine the saturation flow used in the design of the signalisation.

2.4 Volume Study

A 12 hour, 15 minutes interval classified traffic count was conducted manually for 7 days at the Ola-Olu intersection from 7 am – 7 pm on each day, in the month of May, 2019 with three observers at each approach. The data were then converted to Passenger Car Unit (PCU) using Nigerian standard (Federal Ministry of Works, 2013; Sanganaikar et. al., 2018). The traffic count data were used for the determination of the prevailing traffic volume trend, peak hour timings and flow rate, movement patterns and the traffic signalization characteristics.

3.0 RESULTS AND DISCUSSION

3.1 Geometric Layout of the Intersection

The measured geometric parameters of Ola-Olu intersection are shown in Table 1. Figure 1 is the schematic diagram of the intersection layout.

| Approach     | Width (m) | Slope (%) | No of lanes |
|--------------|-----------|-----------|-------------|
| A-Division   | 11.0      | 3.42      | 3           |
| Gaa-Akanbi   | 11.2      | -3.42     | 3           |
| Gaa-Imam     | 3.65      | 4.5       | 1           |

**Table 1 Geometric parameters of Ola-Olu intersection**

![Figure 1 Intersection layout and critical volumes (pcu/hr)](image-url)
3.2 Traffic Count and Analysis

The 12-hour traffic volume is presented in Tables 2, 3 and 4 for A-Division, Gaa-Akanbi and Gaa-Imam approaches respectively. Five different vehicle types were observed at the intersection; cars and light vans (including taxis and pick-up), motorcycles, buses and coaches, tricycles and heavy trucks. The critical volumes at the intersection in pcu/hr are presented in Figure 1.

| Table 2 Traffic volume- A-Division approach |
|--------------------------------------------|
| Days                        | Through movement (pcu) | Right turn movement (pcu) | U-turn movement (pcu) |
|-----------------------------|------------------------|---------------------------|-----------------------|
|                            | CL MC TR BC HT        | CL MC TR BC HT            | CL MC TR BC HT       |
| Monday                      | 10084 4942 2026 907 217 1174 1086 8 47 26 | 387 190 79 35 8         |                        |
| Tuesday                     | 8457 4691 2128 842 171 1102 942 10 39 27 | 325 180 82 32 7         |                        |
| Wednesday                   | 4856 2970 1803 794 125 904 1002 6 41 9 186 114 69 30 5 |                        |                        |
| Thursday                    | 4514 2768 1040 527 124 591 870 3 27 14 | 173 106 40 20 5         |                        |
| Friday                      | 6637 3929 1940 657 135 772 774 7 32 17 255 151 74 25 5 |                        |                        |
| Saturday                    | 7866 3384 1558 828 162 881 996 10 16 5 302 130 60 32 6 |                        |                        |
| Sunday                      | 6746 3603 1656 706 116 765 900 5 15 7 259 138 64 27 4 |                        |                        |

*Through movement: A-Division-Gaa-Akanbi; Right turn movement: A-Division-Gaa-Imam; U-turn movement: A-Division*

| Table 3 Traffic volume- Gaa-Akanbi approach |
|--------------------------------------------|
| Days                        | Through movement (pcu) | Left turn movement (pcu) |
|-----------------------------|------------------------|-------------------------|
|                            | CL MC TR BC HT        | CL MC TR BC HT          |
| Monday                      | 6895 3628 1438 625 99 546 588 19 35 17 |                        |                        |
| Tuesday                     | 5012 3114 1242 642 90 502 602 22 34 9    |                        |                        |
| Wednesday                   | 5180 2891 1139 518 102 623 574 14 20 13   |                        |                        |
| Thursday                    | 4974 3080 1089 502 73 487 503 11 23 10    |                        |                        |
| Friday                      | 5842 3214 1214 587 81 364 387 22 18 8     |                        |                        |
| Saturday                    | 5254 2089 1069 505 141 743 857 25 24 4     |                        |                        |
| Sunday                      | 4899 2241 1142 487 104 689 840 32 19 7     |                        |                        |

*Through movement: Gaa-Akanbi - A-Division; Left turn movement: Gaa-Akanbi - Gaa-Imam*

| Table 4 Traffic volume- Gaa-Imam approach |
|--------------------------------------------|
| Days                        | Left turn movement (pcu) | Right turn movement (pcu) |
|-----------------------------|------------------------|---------------------------|
|                            | CL MC TR BC HT        | CL MC TR BC HT            |
| Monday                      | 878 928 4 30 8 549 930 11 30 10 |                        |                        |
| Tuesday                     | 678 781 4 31 6 487 814 9 24 14    |                        |                        |
| Wednesday                   | 602 821 7 27 8 504 702 9 28 13    |                        |                        |
| Thursday                    | 512 800 3 19 6 272 547 4 18 6     |                        |                        |
| Friday                      | 301 741 5 22 5 314 683 10 17 20    |                        |                        |
| Saturday                    | 748 828 9 36 23 580 854 15 41 33   |                        |                        |
| Sunday                      | 714 800 11 20 4 487 740 11 22 18   |                        |                        |

*Left turn movement: Gaa-Imam - A-Division; Right turn movement: Gaa-Imam - Gaa-Akanbi*

3.3 Design of Proposed Phase Plan using Webster Method

3.3.1 Saturation Flow Rate

A 3-phase plan was proposed for the intersection (Federal Highway Administration, 2013; Matthew, 2014; Environment, 1996; Federal Highway Administration, 2017; Koonce et al., 2008; Maki, 1999). Phase 1 comprises of the 2 non-conflicting through movements from A-Division approach and Gaa-Akanbi approach, phase 2 is provided for the left turn movement from Gaa-Akanbi approach and vehicles on A-division approach making U- turn while phase 3 is for the left turn movement from Gaa-Imam approach. All the right turn movements in the scheme are non-conflicting movements, Nigeria being a right-hand drive country. The phase diagram is presented in Figure 2. The saturation flow rate for each of the approaches was obtained using the Highway Capacity Manual model shown in Eq. (1) (Transport Research Board, 2000; Jimoh et al., 2012). The results are summarized in Table 5.

\[ S = S_0Nf_wf_hV_f_gf_pbf_s_f_R_f_L \]  

Eq. (1)

Where

\[ S = \text{Total saturation flow rate for lane group (vphg)} \]
$S_0$ = Ideal saturation flow rate per lane usually taken to be 1900 pcp/h
$N$ = Number of lanes in the lane group
$f_w$ = Adjustment factor for lane width
$f_{HV}$ = Adjustment factor for heavy vehicle presence
$f_g$ = Adjustment factor for grade
$f_p$ = Adjustment factor for parking conditions
$f_{bb}$ = Adjustment factor for local bus blockage
$f_{RT}$ = Adjustment factor for right turning vehicles
$f_{LT}$ = Adjustment factor for left turning vehicles

The adjustment factors are as given in Transport Research Board (2000).

### 3.3.2 Determination of Optimum Cycle Length And Signal Settings

The main consideration in selecting cycle length should be that the least delay is caused to the traffic passing through the intersection. The optimum cycle length ($C_0$) proposed is obtained using the Webster’s equation as given in Eqn. (2) (Reddy and Reddy, 2016, Jimoh et al., 2012):

$$ C_0 = \frac{1.5L + S}{1 - Y} \quad \text{Eqn (2)} $$

where, $L$ = Total lost time per cycle
$Y = \gamma_1 + \gamma_2 + \ldots + \gamma_n$
where, $\gamma_1, \gamma_2, \ldots, \gamma_n$ are the critical flow ratios for phases $1, 2, \ldots, n$.

$L$ is given as

$$ L = n(t + R) \quad \text{Eqn (3)} $$

where
$n$ = number of phases
$t$ = amber time for each phase
$R$ = all-red clearance time provided for each phase

Applying the value of $t = 3$ seconds of amber time and 2 seconds of all-red clearance time for each phase (MUTCD, 2009; Federal Highway Administration, 2008) and $n = 3$ (number of phases) in Eqn (2):

$$ L = 3(3 + 2) = 15 \text{ seconds} $$

The critical flow ratios $\gamma_1, \gamma_2$ and $\gamma_3$ as shown in Table 7 are 0.602, 0.090 and 0.129 respectively, thus

$$ Y = \gamma_1 + \gamma_2 + \gamma_3 \quad \text{Eqn (4)} $$

which is obtained as

$$ Y = 0.602 + 0.090 + 0.129 = 0.821 $$

Therefore,

$$ C_0 = \frac{1.5(15) + 5}{1 - 0.821} = 153.6 \text{ sec} $$

### Calculation of Green Time:

The flow ratios were used to estimate the proportion of the total green time that was allocated to each phase. This was obtained from Eqn (5).

$$ G_i = \frac{\gamma_i}{\sum \gamma_i} (C_0 - L) \quad \text{Eqn (5)} $$

where $G_i$ = green time for $i^{th}$ phase
$\gamma_i$ = critical flow ratio of the $i^{th}$ phase
$C_0$ = optimum cycle length
$L$ = total lost time per cycle

thus for

Phase 1: $G_1 = \frac{\gamma_1}{Y} (C_0 - L) = \frac{0.602}{0.821} (153.6 - 15) = 101.9 \text{ secs} (102 \text{ secs is used for design})$

Phase 2: $G_2 = \frac{\gamma_2}{Y} (C_0 - L) = \frac{0.090}{0.821} (153.6 - 15) = 15.2 \text{ secs} (16 \text{ secs is used for design})$
Phase 3: 
\[ G_3 = \frac{y^3}{Y} \left( C_0 - L \right) = \frac{0.129}{0.821} \left( 153.6 - 15 \right) = 21.8 \text{ secs} \] 
(22 secs is used for design)

Table 6 is a summary of timings of proposed signalization scheme while Figure 3 is the Signal timing diagram. The signal phase, actual capacity and group lanes are presented in Table 7.

Comparing the actual capacity (C) of each lane group with the corresponding critical volume as shown in Table 7 reveals that the capacity of each lane group can accommodate the corresponding maximum hourly volume, therefore the proposed phase plan is okay. Also the summation of the critical flow ratios (v/s) gave 0.821 < 1, this confirms the adequacy of the intersection geometry. Hence, the proposed phase plan is adequate and there is no need for additional lanes to the critical lane groups (Zakariya and Rabia, 2016; Palmer, 2009; Roess et al., 2004).

### Table 7 Signal phase, actual capacity and group lanes

| Phase | Movement                          | Critical volume(v) | Saturation flow rate(s) | Flow ratio(v/s) | Flow ratio for critical lane group(y=v/s) | Proposed green time | g/C | C = sg/C Capacity of lane group | Remarks               |
|-------|----------------------------------|--------------------|-------------------------|-----------------|------------------------------------------|---------------------|-----|-------------------------------|-----------------------|
| 1     | Through traffic from A-Division  | 1901               | 3159                    | 0.602           | 0.602                                    | 102                 | 0.662| 2079                         | OK/ under saturated  |
|       | Through traffic from Gaa-Akanbi | 1316               | 3389                    | 0.388           |                                          |                     | 0.662| 2230                         | OK/ under saturated  |
| 2     | Left turn from Gaa-Akanbi        | 152                | 1694                    | 0.090           | 0.090                                    | 16                  | 0.104| 175                          | OK/ near capacity    |
|       | U-turn from A-Division           | 73                 | 1579                    | 0.046           |                                          |                     | 0.104| 163                          | OK/ under saturated  |
| 3     | Left turn from Gaa-Imam          | 185                | 1429                    | 0.129           | 0.129                                    | 22                  | 0.143| 203                          | OK/ under saturated  |

### 4.0 CONCLUSION

#### 4.1 Conclusion

A 3-phase traffic signal control scheme with an optimum cycle length of 155 seconds is designed for the Ola-Olu intersection for an effective signal traffic control. The green time for phases 1, 2 and 3 are 102 seconds, 16 seconds and 22 seconds respectively, an amber time of 3 seconds and an all-red clearance time of 2 seconds was utilised for each of the phases in the design. Phase 1 allows movement simultaneously for the through movements on Gaa-Akanbi and A-Division approaches. Phase 2 is for both the U-turn movement on A Division approach and the left turn movement on Gaa-Akanbi approach. Phase 3 is for left turn movement on Gaa-Imam approach. By providing traffic signal at the Ola-Olu intersection, there will be reduction in the conflicts experienced at the intersection that would consequently yield to orderly movement of traffic and reduction in the frequency of crashes. There will also be no further need for traffic wardens to control the traffic at the intersection.
4.2 Recommendations

Based on the findings of this study, the following recommendations are made:

i. Further research and design should be carried out for other identified critical intersections in Ilorin metropolis.

ii. Implementation of pavement markings to guide drivers and improve lane discipline for efficient use of the intersections as pavement markings and stop lines are presently not provided at the metropolis intersections.

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