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

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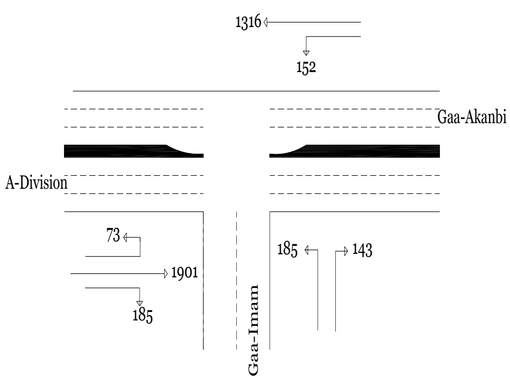

Abstract

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.

Table 1 Geometric parameters of Ola-Olu intersection

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

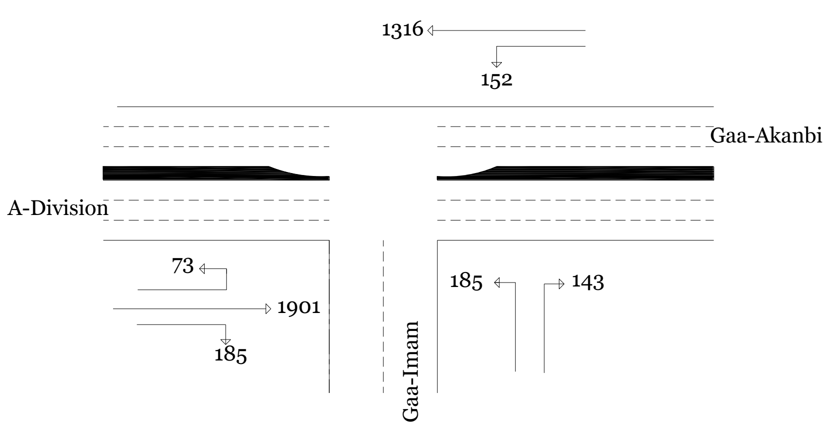

Figure 1 Intersection layout and critical volumes (pcu/hr)

3.2 Traffic Count and Analysis

The 12-hour traffic volume is presented in Tables 2, Table 3 and Table 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;
Left turn movement: U-turn movement to A-Division
CL - Cars and Light vans MC – Motorcycles TR – Tricycles BC – Buses and Coaches HT – Heavy Trucks

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
CL - Cars and Light vans MC – Motorcycles TR – Tricycles BC – Buses and Coaches HT – Heavy Trucks

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
CL - Cars and Light vans MC – Motorcycles TR – Tricycles BC – Buses and Coaches HT – Heavy Trucks

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.

$$S = S_0 N f_w f_{HV} f_g f_p f_{bb} f_a f_{RT} f_{LT} \quad \text{Eq. (1)}$$

Where

S = Total saturation flow rate for lane group (vphg)

S_o = Ideal saturation flow rate per lane usually taken to be 1900 pcphpl
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_a = Adjustment factor for area type
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_o) proposed is obtained using the Webster's equation as given in Eqn. (2) (Reddy and Reddy, 2016, Jimoh *et al*., 2012):

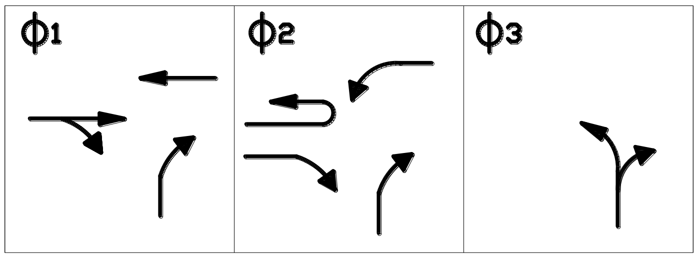

Figure 2 Phase Diagram

Table 5 Saturation flow rate computation

Approach	S_o (pcphpl)	N	f_w	f_{HV}	f_g	f_p	f_{bb}	f_a	f_{RT}	f_{LT}	S (pcu/h)
Gaa-Akanbi	1900	3	1.0	1.0	1.02	0.93	0.94	1.0	1	1	5083
A Division	1900	3	1.0	0.99	0.98	0.93	0.94	1.0	0.98	1	4738
Gaa-Imam	1900	1	1.10	1.0	0.98	0.75	1.0	1.0	0.93	1.0	1429

$$C_0 = \frac{1.5L+5}{1-Y} \qquad \text{Eqn (2)}$$

where, L = Total lost time per cycle
$Y = y_1 + y_2 + \ldots + y_n$
where, $y_1, y_2, \ldots, y_n$ are the critical flow ratios for phases 1,2,...,n,.

L is given as
$$L = n(t+R) \qquad \text{Eqn (3)}$$
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 y_1, y_2 and y_3 as shown in Table 7 are 0.602, 0.090 and 0.129 respectively, thus
$$Y = y_1 + y_2 + y_3 \qquad \text{Eqn (4)}$$

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 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).

$$G_i = \frac{y_i}{\sum_i^n y_i}(C_o - L) \qquad \text{Eqn (5)}$$

where G_i = green time for i[th] phase
y_i = critical flow ratio of the i[th] phase
C_0 = optimum cycle length
L = total lost time per cycle

thus for
Phase 1: $G_1 = \frac{y1}{Y}(C_0 - L) = \frac{0.602}{0.821}(153.6 - 15)$ = 101.9 secs (102 secs is used for design)

Phase 2: $G_2 = \frac{y2}{Y}(C_0 - L) = \frac{0.090}{0.821}(153.6 - 15)$ = 15.2 secs (16 secs is used for design)

Phase 3: $G_3 = \frac{y3}{Y}(C_0 - L)$ = $\frac{0.129}{0.821}(153.6 - 15)$ = 21.8 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.

Table 6 Summary of timings of proposed signalization scheme

Phase	1	2	3
Green time (sec)	102	16	22
Total lost time (sec)	15		
Cycle length (sec)	155		

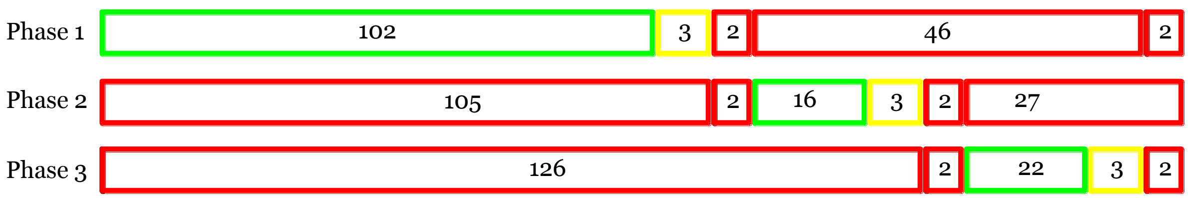

Figure 3 Signal timing

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_o	$C = sg/C_o$ 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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