https://doi.org/10.3311/PPtr.18018

Periodica Polytechnica Transportation Engineering, 51(2), pp. 166–171, 2023

Improving Traffic Flow in Emerging Cities: A SIDRA Intersection Based Traffic Signal Design

Oyetunde Oluwafemi Adeleke[1], Daniel Oluwafemi Oguntayo[2], Iyunade Tiwalade Ayobami[1], Gabriel Ayobami Ogunkunbi[3*]

[1] Department of Civil Engineering, Faculty of Engineering and Technology, University of Ilorin, 240102 Ilorin, P. O. B. 1515, Nigeria
[2] Civil Engineering Department, College of Science and Engineering, Landmark University, 251103 Omu-Aran, P. O. B. 1001, Nigeria
[3] Department of Transport Technology and Economics, Faculty of Transportation Engineering and Vehicle Engineering, Budapest University of Technology and Economics, Műegyetem rkp. 3., H-1111 Budapest, Hungary
[*] Corresponding author, e-mail: ogunkunbi@edu.bme.hu

Received: 10 February 2021, Accepted: 08 January 2023, Published online: 26 January 2023

Abstract

Intersections in urban centers, especially those without any form of signalization, are accident hotspots. This, therefore, calls for effective and efficient traffic management at the intersections for improved safety and efficient traffic flow. This study aimed to improve traffic flow at the Gaa-Akanbi intersection in Ilorin, Nigeria, using a traffic signal scheme. A traffic volume study and geometric features survey was carried out at the intersection. The traffic volume study was performed to determine the number, movement, and classification of vehicles at this intersection using the manual method of traffic count, while the geometric survey of the intersection was done using tape and Total Station. A 3-phase traffic signal was proposed. The optimum cycle length and signal setting were determined using SIDRA Intersection software by adopting the maximum average passenger car unit on the intersection and targeted level of service (LOS) "D". A traffic signal plan with a cycle length of 150 seconds was designed for the intersection. The amber time was considered to be 2 seconds for all phases, and green time of 48, 46 and 38 seconds was gotten for phases 1, 2 and 3, respectively; this timing ensures that minimum delay occurs at the intersection. The proposed traffic signal should be adopted at the intersection by the metropolitan traffic management agency to improve traffic management.

Keywords

traffic signal, traffic flow, safety, intersection, SIDRA, critical movement, Nigeria, Ilorin

1 Introduction

Road transportation network is a significant backbone of the society with the increasing demand for mobility. It is an essential and most used means of transportation that carries all classes of vehicles (trucks, vans, cars, motorcycles, bicycles, and tricycles) and pedestrians. If this demand on road transportation is not adequately managed and effectively controlled, the apparent outcome is always delay, congestion, accidents and their attendant adverse effects on human health and socioeconomic activities. Congestion, for example, negatively affects the economic and social health of nations, imposing costs on society equal to 2 to 3% of the gross domestic product and, if not addressed, will leave future generations without a reasonable level of mobility (Bertini, 2005; Cervero, 2020; Transportation Research Board, 2005).

An intersection is a part of the road or a point of interchange; it is a conflicting point on the road network where traffic competes for space. Its primary purpose is to allow road users to change their route direction, making it a vital section of the road transportation network (Abdulhafedh, 2018; Sharma and Gupta, 2015). Their performance significantly determines the effectiveness and ability of city traffic. When an intersection cannot efficiently discharge the traffic demand entering it, there is bound to be congestion (Adeke et al., 2018). Therefore, for the best performance of intersections, movements into them need to be optimized.

Due to high volumes of traffic in the metropolitan areas coupled with absent, non-functional or poorly timed traffic signals, it is a frequent act in Nigeria during peak periods for

Cite this article as: Adeleke, O. O., Oguntayo, D. O., Ayobami, I. T., Ogunkunbi, G. A. (2023) "Improving Traffic Flow in Emerging Cities: A SIDRA Intersection Based Traffic Signal Design", Periodica Polytechnica Transportation Engineering, 51(2), pp. 166–171. https://doi.org/10.3311/PPtr.18018

traffic wardens or police officers to manually control traffic at unsignalized intersections or even seen to be overruling traffic signals at signalized intersections (Adeleke et al., 2020; Bichi, 2018). This scenario calls for proper control or channelization of traffic at intersections to increase the efficiency of the roads in traffic performance. Traffic signals are now used at intersections in the global north for traffic management by time-sharing of the right of way, thereby enhancing road traffic performance (Ikporo and Ume, 2017).

Traffic signals are control devices most commonly installed at arterial roadway intersections to designate when it is safe to drive, ride, or walk using a universal color code, and also to carry traffic from local streets to highways. They are standardized devices for regulating and controlling traffic at signalized intersections and at locations where the efficient movement of traffic flow is required (Meszaros and Torok, 2014; Yulianto and Setiono, 2012). They alternately direct traffic to stop and proceed at intersections using red and green light signals as per the pre-determined time settings (Dutta and Dan, 2020). The purpose of the traffic signal, therefore, is to assign the right-of-way to road users and thus facilitate safety by ensuring the orderly and predictable movement of all traffic on the roadways (Adeleke et al., 2016; Demir and Demir, 2020; Krishna et al., 2018; Mathur and Mathur, 2018; Sipos et al., 2015).

Traffic signalization is often the recommended traffic management measure to solve the congestion problem at intersections and improve traffic flow. Therefore, this study aims to design a traffic signal at a Traffic Warden Controlled intersection to improve safety and ease congestion often experienced at the intersection. The objectives include to:

- determine the geometric layout of the Gaa-Akanbi intersection,
- conduct a traffic impact study at the intersection to assess the need for a traffic signal, and
- design a fixed-time traffic signal control system for the intersection.

2 Methodology

2.1 Selection of the intersection

There are many intersections in the Ilorin metropolis, which vary with respect to geometric design, traffic flow, traffic management measures and degree of traffic law enforcement. Gaa-Akanbi intersection was selected for this study as vehicles experience undesirable but preventable long delays, and efforts are now being made to install traffic signals at such critical intersections in the metropolis. Furthermore, positioning a traffic signal at this intersection is justified as it satisfies traffic signals Warrant 1 on 8-hour Vehicular Volume, Warrant 3 on peak hour volume, Warrant 5 on school crossing, and Warrant 8 on Road Network (Minnesota Department of Transportation, 2019).

2.2 Study intersection

The study area is a T-intersection situated in the Central Business District (CBD) of Ilorin. The approaches at the intersection are namely: Ola-Olu approach, Offa Garage approach and Gaa-Akanbi approach. The intersection operates as a priority intersection with traffic on Gaa-Akanbi road, yielding to Offa-Garage and Ola-Olu approaches. However, volunteers occasionally control it manually whenever there is a lock jam at the intersection. All the approaches are paved with asphalt, and the surfacing is in good condition.

2.3 Geometric layout of the intersection

Intersection geometry is an essential element of traffic signal design. The geometric features of the intersection approaches were determined with the aid of a total station and measuring tape. The features considered include:

- roadway width in meters,
- number of lanes,
- distance between the intersection and the nearest intersection.

2.4 Traffic impact study

A 12-hour classified traffic count was conducted manually at 15-minute intervals for seven days at the intersection from 7 am–7 pm in May 2019 with three observers at each approach. The data were then converted to Passenger Car Units (PCU) using the specifications of the Nigerian highway manual (Federal Ministry of Works, 2013; Wani et al., 2018). The traffic count data was used to determine the prevailing traffic volume trend, peak hour timings and flow rate, movement patterns and traffic signalization characteristics.

2.5 Traffic signal design

This study employed SIDRA Intersection 8.1 software to design the traffic signal. The data requirement in SIDRA Intersection software for this analysis is shown in Table 1 (Akmaz and Çelik, 2016).

The traffic design was based on the Highway Capacity Manual (Transportation Research Board, 2010) method targeted under the level of service (LOS) D using the minimum delay method. The analysis was performed based on the optimum cycle time.

Table 1 Data needs for analysis in SIDRA intersection 8.1 (Akmaz and Çelik, 2016)

Type of condition	Parameter
Geometric conditions	Site name
	Area type
	Lane number 'N'
	Average lane width 'W' (m)
	Grade 'G' (%)
	Existence of exclusive left turn (LT) or right turn (RT) lanes
	Parking
	Length of storage bay (m)
	Left or right turn lane 'L' (m)
Traffic conditions	Traffic volume by movement 'V' (veh/h)
	Peak Hour Factor (PHF)
	Percentage of heavy Vehicles 'HV (%)
	Pedestrian flow rate 'Vped' (p/h)
	Approach speed 'SA' (mile/h)
	Parking activity, 'Nm' (maneuvers/h)
Signalization conditions	Phase plan
	Actuated/pre-timed operation
	Green time, 'G' (s)
	Cycle length, 'C' (s)
	Amber-plus-all-red change-and-clearance interval, 'Y' (s)
	Pedestrian push button
	Analysis period, 'T' (h)

3 Results and discussions

3.1 Geometric layout of the intersection

The intersection's geometric features are shown in Fig. 1, and the measured parameters of the intersection are shown in Table 2. These features are critical, given their potential impact on intersection safety and performance. Geometrics directly impact sight distance, vehicle separation, operations, and capacity (Minnesota Department of Transportation, 2019).

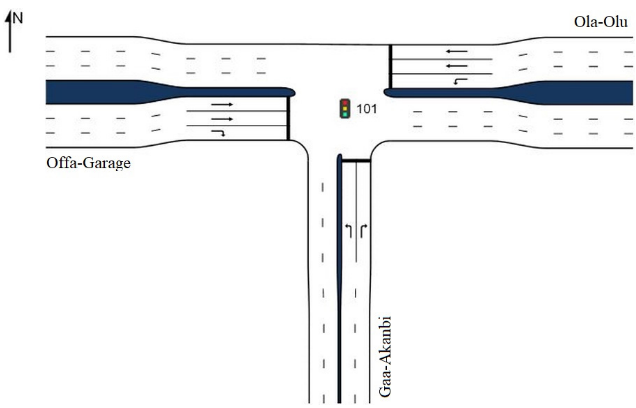

Fig. 1 Gaa-Akanbi intersetcion layout

Table 2 Geometric features of the intersection

Features	Approaches		
	Gaa-Akanbi	Offa Garage	Ola-Olu
Lane width (m)	6.7	11.24	11.24
Number of lanes	2	3	3

3.2 Traffic volume study

The results of the traffic survey conducted at Gaa-Akanbi intersection recorded at every 15 minutes interval are shown in the Appendix (Tables A1 to A3), and they are categorized under five different vehicle classes (motorcycle, tricycle, light vehicles, buses and heavy vehicles) according to the specifications of Federal Ministry of Works (2013). The peak hour volume, timing and movement obtained from the traffic survey and used as inputs to design the signal phases are presented in Table 3. Expectedly and as shown in the data, the traffic volume observed is more significant on weekdays as compared to weekends, with the daily peaks occurring at the periods of the day when people are commuting between work and their places of residence. It was observed as shown in Fig. 2 that the predominant mode of transport plying the

Table 3 Peak hour volume, timing and movement at Gaa-Akanbi

Approach	Day	Time	Movement pattern			Total hourly volume (pcu/hr)
			RT	LT	TT	
Gaa-Akanbi	Wed	3.15–4.15 pm	513	277	–	790
Offa-Garage	Tue	7.45–8.45 am	192	–	1729	1921
Ola-Olu	Mon	5.30–6.30 pm	–	640	1538	2178

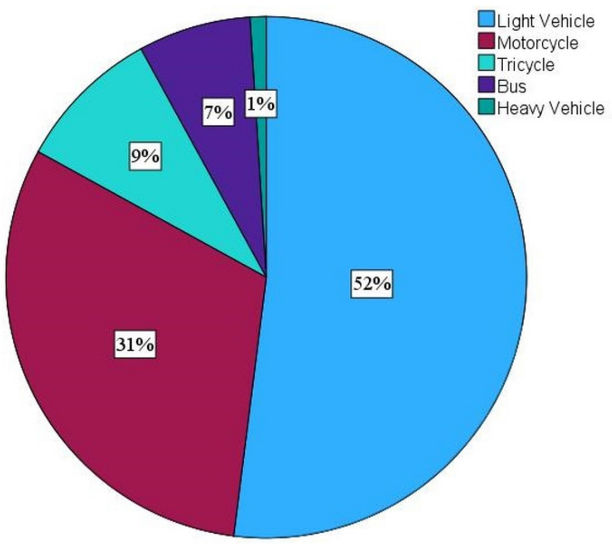

Fig. 2 Traffic composition at Gaa-Akanbi intersection

intersection is light vehicles which make up about 52% of the total vehicular flow at the intersection. The result also indicates the proportion of heavy vehicles in the traffic composition is significant because they impose physical and psychological effects on surrounding traffic flow (Moridpour et al., 2015). In addition, due to differences in the vehicle characteristics and maneuvering requirements compared with other classes of vehicles, heavy vehicle drivers tend to behave differently at an intersection controlled by traffic signal, especially at the onset of an amber indication (Bryant et al., 2015).

3.3 Design of the proposed phase plan

A 3-phase traffic signal plan is proposed for efficient traffic flow due to the geometry of the intersection. As seen in Fig. 3, the two non-conflicting through movements from the Ola-Olu approach and the Offa garage approach and the right turn movement on the Offa garage approach are sorted into Phase 1. Phase 2 admits both left turn and right turn movements from the Gaa-Akanbi approach and right turn movement from Offa garage, while Phase 3 is for the conflicting left turn movement from the Ola-Olu approach. Phase 1 allows permissible right-turn movement from Gaa-Akanbi. Table 4 and Table 5 show the phasing of the proposed traffic signal scheme, while Fig. 4 and Fig. 5 show the phase movement and timing and the critical movement diagrams, respectively. The optimum signal cycle length for the signal was found to be 150 seconds. This will ensure

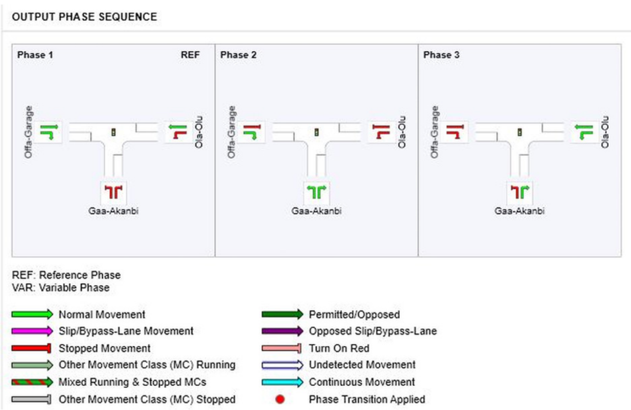

Fig. 3 Phase sequence of proposed signal

Table 4 Phase information

Optimal cycle time (sec)					150 sec	
Phase	Change time (sec)	Green start (sec)	Displayed green (sec)	Amber (sec)	Phase end (sec)	Phase time (sec)
1	0	0	62	6	68	68
2	68	68	21	6	95	27
3	95	95	49	6	150	55

Table 5 Intersection performance

Performance measure	Value
Degree of saturation	0.983
Level of service	D
Average delay	97.5 sec
Effective stop rate	1.48
Maximum back of queue (worst lane; Veh.)	138.9
Effective intersection capacity (Veh/h)	3533

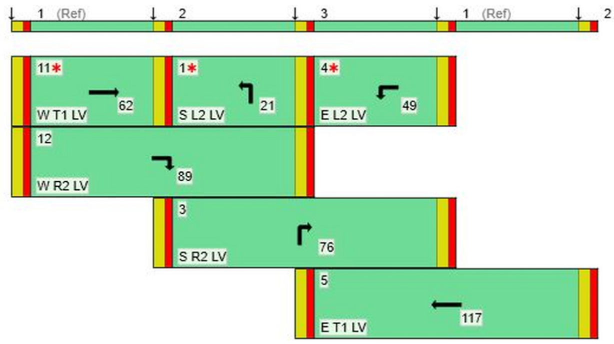

Fig. 4 Phase movement and timing

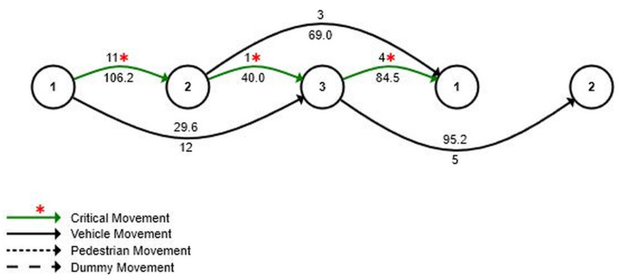

Fig. 5 Critical movement and timing

minimal delay due to the traffic at the intersection. As seen in Fig. 4, the phase movement timings displayed the green time for vehicle movements. This phasing movement characterized the essential manner by which a traffic signal at an intersection accommodates the various users securely and efficiently. The green time would ensure that minimum delay is experienced at the intersection. As seen in Table 5, the LOS, which is a measure of driver discomfort, frustration, fuel consumption, and lost travel time, is 'D'. This LOS of D will give a comfortable experience to the road user, especially car drivers.

The critical movement diagram shows the required movement time in seconds. This movement determines the intersection's capacity and timing requirements, as is the movement or lane for a given phase that requires the maximum green time. As seen in Fig. 5, this intersection's critical movement is 1↔2, 2↔3 and 3↔1.

4 Conclusion

Signalization of an intersection is vital in its traffic management as it will help reduce delays and accidents. Based on the traffic study conducted at the Gaa-Akanbi intersection, which presently operates as a priority intersection, a traffic signal scheme was proposed for safety and efficient traffic flow using SIDRA Intersection 8.1 software. A 3-phase traffic signal plan with a cycle length of 150 seconds was designed for the intersection. The amber time was 6 seconds for all phases, and green time of 48, 46 and 38 seconds was designed for phases 1, 2 and 3, respectively. The proposed traffic signal will improve mobility, reduce delays, and decrease fuel consumption and pollutants. Hence, it should be adopted by the metropolitan traffic management agency for efficient traffic management at the intersection.

References

Abdulhafedh, A. (2018) "How to Design Traffic Signals at Multiple Coordinated Intersections", International Journal of Automation, Control and Intelligent Systems, 4(3), pp. 29–35.

Adeke, P. T., Atoo, A. A., Zava, A. E. (2018) "Traffic Signal Design and Performance Assessment of 4-Leg Intersections Using Webster's Model: A Case of 'SRS' and 'B-Division' Intersections in Makurdi Town", International Research Journal of Engineering and Technology, 5(5), pp. 1253–1260.

Adeleke, O. O., Jimoh, Y. A., Yusuf, I. T. (2016) "Modified Traffic Signal Phasing at Traffic Warden Controlled Intersection to Accommodate Pedestrian Traffic in Ilorin Metropolis, Nigeria", Nigerian Journal of Technology, 35(1), pp. 25–30.
https://doi.org/10.4314/njt.v35i1.4

Adeleke, O. O., Adeogun, K. A., Kolo, S. S. (2020) "Design of A Traffic Signalisation Scheme At Ola-Olu Intersection, Ilorin, Nigeria", Malaysian Journal of Civil Engineering, 32(2), pp. 23–28.
https://doi.org/10.11113/mjce.v32n2.639

Akmaz, M. M., Çelik, O. N. (2016) "Examination of Signalized Intersections According to Australian and HCM (Highway Capacity Manual) Methods Using Sidra Intersection Software", Journal of Civil Engineering and Architecture, 10, pp. 246–259.
https://doi.org/10.17265/1934-7359/2016.02.013

Bertini, R. L. (2005) "Congestion and Its Extent", In: Levinson, D. M., Krizek, K. J. (eds.) Access to Destinations, Emerald Group Publishing Limited, pp. 11–38. ISBN 978-0-08-044678-3
https://doi.org/10.1108/9780080460550-002

Bichi, A. H. (2018) "Evaluation of Traffic Flow at Signalized Intersections: A Case Study of Kano City, Nigeria", Masters dissertation, Near East University.

Bryant, C. W., Rakha, H. A., El-Shawarby, I. (2015) "Study of truck driver behavior for design of traffic signal yellow and clearance timings", Transportation Research Record: Journal of the Transportation Research Board, 2488(1), pp. 62–70.
https://doi.org/10.3141/2488-07

Cervero, R., (2020) "Chapter 7 - The transit metropolis: a 21st century perspective", In: Deakin, E. (ed.) Transportation, Land Use, and Environmental Planning, Elsevier, pp. 131–149. ISBN 978-0-12-815167-9
https://doi.org/10.1016/b978-0-12-815167-9.00007-4

Demir, H. G., Demir, Y. K. (2020) "A comparison of traffic flow performance of roundabouts and signalized intersections: a case study in Nigde", The Open Transportation Journal, 14, pp. 120–132.
https://doi.org/10.2174/1874447802014010120

Dutta, K., Dan, A. (2020) "Approximate Methods for Two-Phase Traffic Signal Design At Road Intersections", EPRA International Journal of Multidisciplinary Research (IJMR), 6(4), pp. 138–144.
https://doi.org/10.36713/epra2013

Federal Ministry of Works (2013) "Highway Manual Part 1: Design, Volume 1: Geometric Design", [pdf] Federal Ministry of Works, Abuja, Nigeria. Available at: https://worksandhousing.gov.ng/fmw_training/management/uploads_images/1569359724.pdf [Accessed: 07 January 2023]

Ikporo, S. C., Ume, L. E. (2017) "Sensor-Based Intelligent Traffic Light Control System: A Panacea to Traffic Congestion in Nigerian Motorways", Computer Engineering and Intelligent Systems, 8(6), pp. 14–20.

Krishna, K. H., Kumar, K. V., Rao, D. C. H. (2018) "Signal design using Webster's method (4 legged intersections)", Indian Journal of Scientific Research, 17(2), pp. 113–119.

Mathur, B., Mathur, D. (2018) "Traffic Study and Design of Traffic Signal at Identified Intersections in Mansarovar, Jaipur", International Journal of Recent Trends in Engineering and Research, 4(12), pp. 66–76.
https://doi.org/10.23883/ijrter.2018.4424.wezcx

Meszaros, F., Torok, A. (2014) "Theoretical investigation of emission and delay based intersection controlling and synchronizing in Budapest", Periodica Polytechnica Transportation Engineering, 42(1), pp. 37–42.
https://doi.org/10.3311/PPtr.7183

Minnesota Department of Transportation (2019) "MnDOT Traffic Signal Timing and Coordination Manual", [pdf] Minnesota Department of Transportation, Minneapolis, MN, USA. Available at: https://dot.state.mn.us/trafficeng/publ/signaloperations/signal-timing-manual.pdf [Accessed: 07 January 2023]

Moridpour, S., Mazloumi, E., Mesbah, M. (2014) "Impact of heavy vehicles on surrounding traffic characteristics", Journal of Advanced Transportation, 49(4), pp. 535–552.
https://doi.org/10.1002/atr.1286

Sharma, I., Gupta, P. K. (2015) "Study on automatic traffic signal system for Chandigarh", International Journal of Engineering Sciences & Research Technology, 4(7), pp. 26–33.

Sidra Solutions "Sidra Intersection (8.1)", [computer program] Available at: https://www.sidrasolutions.com/software/sidra-intersection [Accessed: 06 September 2020]

Sipos, T., Tanczos, K., Torok, A. (2015) "Economical Analysis of low cost road safety infrastructure investments", In: Proceedings of the International Scientific Conference on Modern Safety Technologies in Transportation, (MOSATT 2015), Kosice, Slovakia, pp. 182–185. ISBN 9788097143220

Transportation Research Board (2005) "Integrating Sustainability into the Transportation Planning Process", Transportation Research Board. ISBN 0-309-09418-6
https://doi.org/10.17226/13878

Transportation Research Board (2010) "HCM2010: Highway Capacity Manual", Transportation Research Board, National Research Council, Washington, DC, USA.

Wani, F. M., Sanganaikar, R. S., Leekha, V., Khan, R., Hussain, A. (2018) "Design of Traffic Signal at Kundahallli Junction, Bengaluru Karnataka", International Journal of Scientific & Engineering Research, 9(6), pp. 1688–1695.

Yulianto, B., Setiono (2012) "Traffic Signal Controller for Mixed Traffic Conditions", IOSR Journal of Mechanical and Civil Engineering, 4(1), pp. 18–26. https://doi.org/10.9790/1684-0411826

Appendix

Table A1 Traffic volume for Gaa-Akanbi approach

Days	Left turn movement (pcu)						Right turn movement (pcu)					
	Motorcycle	Tricycle	Bus	Light vehicle	Heavy vehicle	Total	Motorcycle	Tricycle	Bus	Light vehicle	Heavy vehicle	Total
Mon	539	103	100	2480	4	3226	1785	502	242	3582	4	6115
Tue	493	96	92	2362	5	3048	1637	459	2104	3410	5	7615
Wed	514	97	89	2351	3	3054	1712	464	189	3396	3	5764
Thur	525	98	97	2481	3	3204	1748	482	232	3581	3	6046
Fri	396	97	98	2232	5	2828	1323	445	234	3224	5	5231
Sat	484	96	112	1557	2	2251	1608	447	256	2259	2	4572
Sun	264	48	86	1309	2	1709	873	240	190	1893	2	3198

Table A2 Traffic volume for Offa Garage approach

Days	Through traffic (pcu)						Right Turn Movement (pcu)					
	Motorcycle	Tricycle	Bus	Light vehicle	Heavy vehicle	Total	Motorcycle	Tricycle	Bus	Light vehicle	Heavy vehicle	Total
Mon	6781	1588	1306	10465	152	20292	359	101	175	1649	7	2291
Tue	6202	1453	1144	9943	184	18926	322	96	157	1571	9	2155
Wed	6494	1477	1031	9926	128	19056	346	97	144	1568	64	2219
Thu	6633	1546	1269	10464	133	20045	353	98	168	1657	7	2283
Fri	5023	1418	1239	9253	186	17119	267	97	170	1456	6	1996
Sat	6094	1425	1389	6599	87	15594	322	96	187	1044	4	1653
Sun	3302	759	1017	5522	88	10688	177	48	140	877	4	1246

Table A3 Traffic volume for Ola-Olu approach

Days	Through traffic (pcu)						Left turn movement (pcu)					
	Motorcycle	Tricycle	Bus	Light vehicle	Heavy vehicle	Total	Motorcycle	Tricycle	Bus	Light vehicle	Heavy vehicle	Total
Mon	5710	1891	1099	8832	184	17716	2680	799	518	3305	21	7323
Tue	5228	1728	963	8374	244	16537	2454	726	450	3142	28	6800
Wed	5466	1757	873	8361	160	16617	2554	741	409	3133	19	6856
Thu	5584	1839	1066	8811	166	17466	2621	778	504	3305	20	7228
Fri	4231	1677	1062	7632	231	14833	1986	705	500	2922	28	6141
Sat	5047	1697	1170	5559	119	13592	2408	717	548	2084	13	5770
Sun	2778	899	869	4650	110	9306	1307	378	408	1744	13	3850