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Research Article

EVALUATING TRAFFIC OPERATIONS AT AN URBAN ROUNDABOUT IN A DEVELOPING CITY: EVIDENCE FROM GAA AKANBI, NIGERIA

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Abstract

Efficient operation of urban roundabouts is critical for managing traffic flow, particularly in rapidly growing cities characterized by heterogeneous traffic conditions. This study evaluates the operational performance of Gaa Akanbi Roundabout using established traffic engineering metrics, including average control delay, queue length, and Level of Service (LOS), in accordance with Highway Capacity Manual (HCM) standards. Field data were obtained through direct geometric measurements and video-based traffic surveys conducted during peak periods over seven consecutive days. Traffic volumes and turning movements were manually extracted from recorded footage, while performance indicators such as delay and queue length were computed using standard analytical procedures.

The results indicate that the roundabout operates at an overall average delay of 34.5 seconds per vehicle, corresponding to LOS C, which reflects stable but moderately delayed traffic conditions. However, significant disparities were observed across individual approaches. The western approach exhibited the poorest performance, with a delay of 46.2 seconds per vehicle (LOS E), indicating oversaturation largely due to limited entry capacity and inadequate geometric design. The southern and northern approaches recorded delays of 38.5 seconds and 30.2 seconds per vehicle, respectively, both operating at LOS D, suggesting moderate congestion with relatively stable flow conditions. In contrast, the eastern approach demonstrated comparatively efficient

operation, with a delay of 23.1 seconds per vehicle (LOS C), characterized by lower conflict levels and shorter queues.

Keywords: Traffic flow; Level of Service; Nigeria; delay; volume; congestion.

Introduction

An intersection is a critical area where two or more roads meet, either at the same or different elevations. It is a point of potential conflict, where traversing traffic can lead to discomfort, delays, inconvenience, and even accidents if not properly managed. Intersections are designed to allow vehicles to turn in various directions to reach their intended destinations. There are two primary types of intersections: controlled and uncontrolled. Controlled intersections, typically found in areas with high traffic volumes, use traffic signals to manage the flow of traffic from different approaches. In contrast, uncontrolled intersections operate without traffic signs or signals, relying on the discretion of drivers to navigate the intersection (Daniel, 2016).

Evaluating the capacity of an intersection is essential because it directly impacts delays, levels of service, accidents, operational costs, and environmental factors. Rotary intersections, commonly known as roundabouts, have proven to be effective in managing traffic at intersections worldwide for over three decades. Roundabouts reduce delays and offer superior safety compared to traditional intersections. Moreover, they lower vehicle operating costs and reduce conflict points, which significantly decreases accident rates (Federal Ministry of Works, 2013).

A roundabout is a type of channelized intersection where vehicles are directed onto a one-way circulatory road around a central island. Entry to the roundabout is controlled by give-way markings, with priority given to vehicles circulating in an anti-clockwise direction in Nigeria. These circular intersections are designed for varying traffic volumes and approaches, with geometric curvature that ensures travel speeds on the circulatory roadway remain below 50 km/h. As a subset of various circular intersection forms, roundabouts are designed to deflect vehicles' paths, promoting slower speeds and yielding to other road users at the intersection. The entry lanes are typically flared to help slow down approaching vehicles.

Determining the capacity of a traffic facility provides crucial insights into the number of vehicles and passengers the facility can accommodate, which is vital for the planning, design, and operation of intersections. The capacity of an intersection also allows for the estimation of other traffic performance measures, such as level of service, degree of saturation, and delays. The analysis of roundabout capacity is based on empirical relationships that consider both traffic characteristics and the geometry of the facility. The capacity of the entry or approach lanes is determined by factors such as traffic on conflicting approaches, the interaction between these traffic streams, and the overall geometry of the intersection (HCM, 2010).

The Signalized and Unsignalized Intersection Design and Research Aid (SIDRA) is an advanced traffic analysis tool used for the design and evaluation of both individual intersections and networks of intersections. It allows for the modeling of various vehicle types, such as light vehicles, heavy vehicles, buses, bicycles, and large trucks, among others. SIDRA provides estimates for queue lengths, vehicle and pedestrian stops, as well as fuel consumption, pollutant emissions, and operating costs at intersections. It has been widely used to analyze various types of intersections, including signalized (fixed-time/pretimed and actuated), unsignalized intersections, roundabouts (signalized and unsignalized), pedestrian crossings, and different types of interchanges. Additionally, SIDRA is applicable for uninterrupted traffic flow conditions and merge analysis, making it a versatile tool for traffic planning and optimization.

The socio economic and environmental sustainability of urban and semi urban towns and cities are heavily dependent on the operational efficiency and effectiveness of the urban transportation system, especially at critical corridors segments and traffic scenarios. Thus transportation has been considered as important for the survival of the fabric of modern society without which there would be no life in the city. However, complete and total goal of transportation is not limited to only the old classical definition of safe, convenient and comfortable movement of goods and services alone but also extended to the need for assurance of environmental sustainability, fair health and promotion of economic activities (Ogunsanya, 2009, O' Sullivan et al., 2000). Public transport (mass transit) service helps in curbing the menace of transportation by ensuring timely movement of large population of passengers, with less or tolerable delays, either while awaiting arrival of transit vehicles or in motion, and their after-effects. Public transport is so diversified that each of its components must be well articulated in order to have a vibrant and sustainable urban system with desired synergy between transportation and land use. Among the factors that needed to be considered for effective implementation of public transport system are proper design and location of bus stops, bus stations or terminals (Olowosegun and Okoko, 2012), which alongside with the street intersections constitute the critical features of trip movement operation in urban settings. Bus stop design is recognised as a crucial element in the drive to improve the quality of bus services and public transport in general and hence in accomplishing the main objectives of commuters in the urban transportation system with respect to Total Journey Quality concept (BPT, 2006).

International migration is a central component of contemporary demographic change, influencing population distribution, labour-market dynamics, household welfare, and development trajectories across regions (UN DESA, 2024). In sub-Saharan Africa, as averred by Castles, et al. (2020), migration is deeply embedded in socio-economic survival strategies and youth aspirations, particularly in contexts characterized by rapid population growth and limited domestic employment absorption. Nigeria, Africa's most populous country, occupies a prominent position within global migration systems, with the United States emerging as one of the most significant destinations for its migrants (Migration Policy Institute, 2022).

Statement of Problem

The major arterial intersections in Ilorin, kwara state, Nigeria, metropolis significantly hinder intra-city movement, particularly along high-traffic routes such as the Kwara Polytechnic and University of Ilorin corridors. These intersections experience high vehicle volumes, resulting in frequent traffic congestion that disrupts the flow of traffic. The persistent traffic jams not only cause delays but also contribute to environmental issues, including littering, pollution, increased vehicle emissions, and heightened noise levels, which negatively affect both motorists and local residents. The growing number of vehicles on the roads, coupled with inadequate road planning, on-street parking, and suboptimal intersection geometry, exacerbates the congestion. Therefore, there is an urgent need for comprehensive assessments of the major arterial roads in the city to evaluate the relationship between road capacities and traffic volumes. Such evaluations would help in identifying effective solutions to mitigate traffic delays, ultimately improving the efficiency of transportation and supporting local commercial activities.

Objectives

The aim of this study is to investigate the performance metrics of selected arterial road intersection due to their geometric characteristics and traffic flow.

The objectives of the study are to:

(i) assess the operational performance of selected intersections based on geometric design and traffic flow characteristics during peak-hour conditions.

(ii) develop and implement dynamic traffic flow simulations by SIDRA for quantifying intersection performance under real-world urban operating conditions.

(iv) formulate performance-based criteria and guidelines to support evidence-driven improvements in intersection design and operational planning.

4. Literature Review

Table 1.0: Review of literature

S/N	AUTHOR	YEAR	TITLE OF RESEARCH	METHODOLOGY	RESULT	RESEARCH GAP
1	Okafor, C. et al.	2022	Optimizing Cycle Lengths for Congested Urban Signals	SIDRA calibration with field counts	Control delay cut by 12–16% at critical v/c	Seasonal demand variability not tested
2	Li, Y. & Kumar, P.	2022	Turning Ratio Sensitivity at 3-Leg Intersections	SIDRA sensitivity analysis	High right-turn share degraded minor-street LOS	No pedestrian interaction modelling
3	Adeyemi, T. et al.	2022	Queue Spillback Prediction for Closely Spaced Signals	SIDRA network + video validation	Offset coordination reduced spillback by 18%	Incident surges and lane closures unmodeled
4	Rahman, S. et al.	2022	Roundabouts vs Signals under Peak Variability	Comparative scenarios in SIDRA	Roundabouts better at mid-range flows	Heavy-vehicle profiles not calibrated

5	Gonzalez, R. & Silva, J.	2022	Saturation Flow Calibration for Heterogeneous Traffic	SIDRA with adjusted s-values	Improved DoS and delay accuracy	Transferability to non-arterials unclear

5. Methodology

5.1 Geometric Characteristic

The characteristics of intersection geometry involved the measurement of physical features of the intersection that influence its capacity, safety, and operational performance. These include elements such as lane width, number of lanes, turning radii, approach gradients, sight distances, and the lengths of turn bays. Accurate measurement and documentation of these characteristics are essential for intersection design, performance evaluation, and the development of effective traffic management strategies.

In this study, the geometric data were obtained through direct field measurements using a standard measuring tape. The process was conducted manually due to the relatively small scale of the intersection and the need for its accuracy and real-world dimensional assessment. Key steps considered in this process include: physical inspection and demarcation of intersection legs, measurement of lane widths and lengths, recording of turn radii and turn bay dimensions, and identification of structural elements such as medians, pedestrian islands, and roadside obstructions.

5.2 Traffic Flow Data Collection

A digital video camera was used to capture traffic flow at the intersection. The camera was strategically mounted at a safe place to ensure that all approaches and turning movements (straight, left-turn, right-turn) were clearly visible with no obstruction to vehicle paths by other vehicles or roadside objects, and no interaction with the points of entire field of view. Video recording was conducted during the morning peak period from 07:30 am to 09:30 am for seven days. This traffic counts enabled the identification of dominant approaches with high demand, turning movement imbalances that could contribute to delays or operational inefficiencies, and potential for congestion and conflict during simultaneous movements

The collected footage was reviewed and played back to count traffic volume which involved vehicle movement on each leg of the intersection, including through movements, left-turns, and right-turns. Counts were conducted manually from the recorded footage to ensure precision, particularly in cases of congestion or overlapping vehicle movements. Each leg's demand profile was established to assess traffic distribution and turning behaviours.

5.3 Descriptive / Operational Analysis

These methods are used to describe and compare the observed performance of intersections in terms of traffic engineering standards (mainly the Highway Capacity Manual, HCM). They include:

Performance metric assessment: Queue length, average delay, and Level of Service (LOS) were calculated and compared across intersection types.

Queue lengths were estimated using the formula:

Queue Length = Total Number of Vehicles in Queue × Average Vehicle Length

Average delays for selected sample vehicles across all movements, entry time (when a vehicle reached the queue or stop line) and exit time (when the vehicle completed its movement and cleared the intersection) were noted. The delay per vehicle was then calculated using the formula:

Delay = (Exit Time − Entry Time) − Free Flow Travel Time

where free-flow travel time was estimated based on normal travel time through the intersection without delay.

The following thresholds were adopted to classify average delays into performance grades

Performance Measure	Description	Formula / Method	Data Source	Procedure / Standard
Average Traffic Flow (veh/h)	Demand intensity	Q = N \ T * 3600	Video counts	Aggregated across all approaches
Queue Length (m)	Congestion	QL = Nq * Lv	Video & field	Average across

	indicator		measurement	cycles
Delay (s/veh)	Operational efficiency	D = (T exit -T entry)-Tff	Video travel time	Averaged per vehicle
Free-Flow Travel Time (s)	Baseline travel	Tff = L / Vff	Field-measured distances	During uncongested periods
Level of Service (LOS)	Qualitative performance	Based on HCM delay thresholds	Derived from delay	A (≤10s), …, F (>80s)

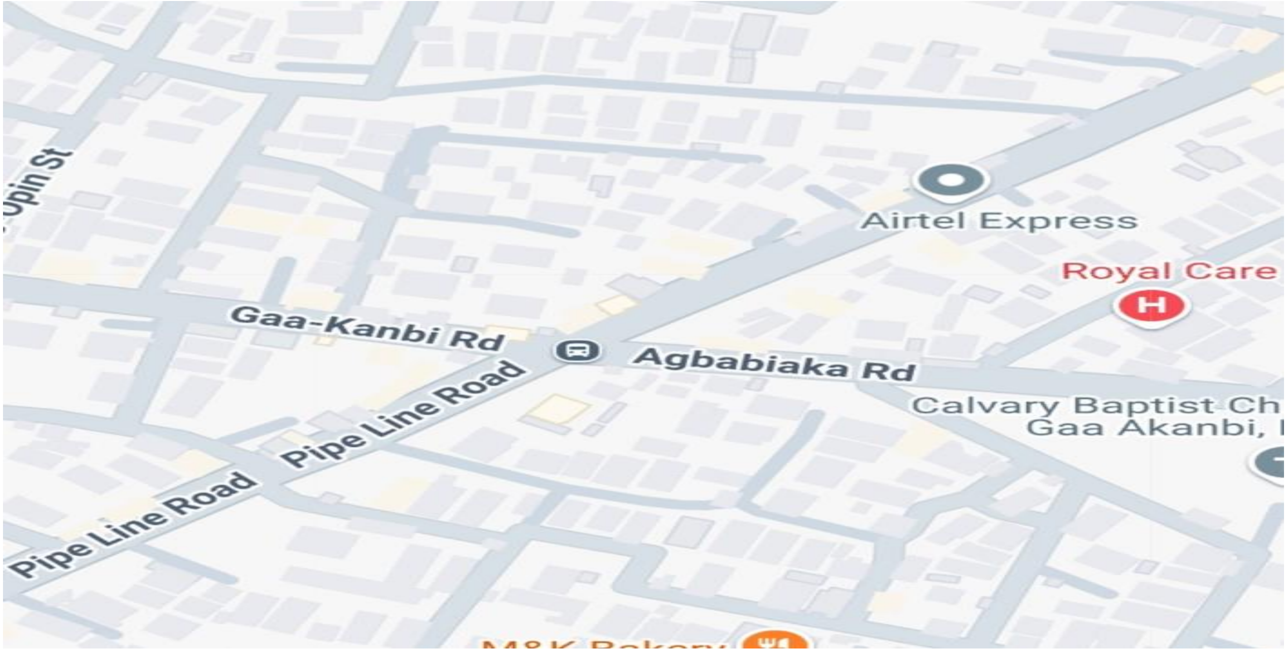


Figure 1: Map of Gaa-akanbi Roundabout, Ilorin, kwara state, Nigeria (Source: Google earth)

6. Result

MOVEMENT SUMMARY

Site: 101 [GAA AKABI ROUNDABOUT]

New Site

Site Category: (None) Roundabout

Movement Performance - Vehicles

Mov ID	Turn	Demand Flows Total veh/h	Demand Flows HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance m	Prop. Queued	Effective Stop Rate	Aver. No. Cycles	Average Speed km/h
South: OFFA GARAGE												
1u	U	38	1.4	1.021	41.5	LOS D	29.3	133.2	1.00	1.58	2.43	32.9
1	L2	224	0.5	1.021	39.9	LOS D	29.3	133.2	1.00	1.58	2.43	27.3
2	T1	609	0.5	1.021	38.1	LOS D	29.3	133.2	1.00	1.58	2.45	28.2
3	R2	186	1.4	1.021	47.6	LOS D	12.4	52.4	1.00	1.61	2.57	25.9
Approach		1057	0.7	1.021	40.3	LOS D	29.3	133.2	1.00	1.59	2.47	27.7
East: AGBABIAKA												
4u	U	5	0.0	1.070	23.8	LOS C	0.0	0.0	0.00	0.15	0.00	28.6
4	L2	179	0.9	1.070	23.2	LOS C	0.0	0.0	0.00	0.15	0.00	28.1
5	T1	217	0.5	1.070	21.0	LOS C	0.0	0.0	0.00	0.15	0.00	26.8
6	R2	112	1.4	1.070	21.0	LOS C	0.0	0.0	0.00	0.15	0.00	26.8
Approach		513	0.8	1.070	21.8	LOS C	0.0	0.0	0.00	0.15	0.00	27.3
North: TIPPER GARAGE												
7u	U	27	1.9	0.981	39.2	LOS D	20.3	108.4	0.89	1.52	2.33	29.6
7	L2	77	1.4	0.981	37.5	LOS D	20.3	108.4	0.89	1.52	2.33	30.1
8	T1	596	0.8	0.981	34.7	LOS C	20.3	108.4	0.88	1.51	2.33	31.4
9	R2	129	2.4	0.981	52.6	LOS E	5.5	27.9	0.72	1.46	2.33	21.8
Approach		829	1.1	0.981	37.9	LOS D	20.3	108.4	0.86	1.51	2.33	29.6
West: GAA AKANBI												
10u	U	2	0.0	1.207	31.2	LOS C	0.0	0.0	0.00	0.00	0.00	18.7
10	L2	142	1.5	1.207	31.2	LOS C	0.0	0.0	0.00	0.00	0.00	18.7
11	T1	225	1.2	1.207	31.2	LOS C	0.0	0.0	0.00	0.00	0.00	18.7
12	R2	392	0.4	1.207	31.2	LOS C	0.0	0.0	0.00	0.00	0.00	18.7
Approach		761	0.8	1.207	31.2	LOS C	0.0	0.0	0.00	0.00	0.00	18.7
All Vehicles		3160	0.9	1.207	34.5	LOS C	29.3	133.2	0.56	0.95	1.44	25.3

LANE SUMMARY

Site: 101 [GAA AKABI ROUNDABOUT]

New Site

Site Category: (None) Roundabout

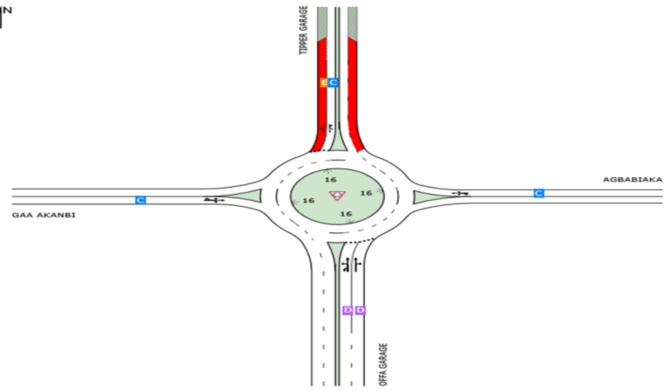
Lane Use and Performance

	Demand Flows Total veh/h	Demand Flows HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Veh	95% Back of Queue Dist m	Lane Config	Lane Length m	Cap. Adj. %	Prob. Block. %
South: OFFA GARAGE													
Lane 1[d]	765	0.5	749	1.021	100	37.5	LOS D	29.3	133.2	Full	500	-35.0	0.0
Lane 2	293	1.1	287	1.021	100	47.4	LOS D	12.4	52.4	Full	500	-65.0	0.0
Approach	1057	0.7		1.021		40.3	LOS D	29.3	133.2				
East: AGBABIAKA													
Lane 1[d]	513	0.8	479	1.070	100	21.8	LOS C	0.0	0.0	Full	500	-87.0	0.0
Approach	513	0.8		1.070		21.8	LOS C	0.0	0.0				
North: TIPPER GARAGE													
Lane 1[d]	662	0.9	675	0.981	100	34.2	LOS C	20.3	108.4	Full	300	-30.0	0.0
Lane 2	167	2.1	170	0.981	100	52.6	LOS E	5.5	27.9	Short (P)	200	-70.0	NA
Approach	829	1.1		0.981		37.9	LOS D	20.3	108.4				
West: GAA AKANBI													
Lane 1[d]	761	0.8	631	1.207	100	31.2	LOS C	0.0	0.0	Full	300	-84.0	0.0
Approach	761	0.8		1.207		31.2	LOS C	0.0	0.0				
Intersection	3160	0.9		1.207		34.5	LOS C	29.3	133.2				

Lane Level of Service

Site: 101 [GAA AKABI ROUNDABOUT]
New Site
Site Category: (None) Roundabout

	Approaches				Intersection
	South	East	North	West	
LOS	D	C	D	C	C



7. Conclusion

The operational performance of Gaa Akanbi Roundabout was evaluated using delay and Level of Service (LOS) indicators. The overall average control delay at the intersection was estimated at 34.5 seconds per vehicle, corresponding to LOS C. This indicates a moderate level of efficiency, where traffic flow is stable but experiences noticeable delays, especially during peak periods.

A directional analysis reveals variations in performance across the approaches. The western approach (Gaa Akanbi axis) recorded the highest delay of 46.2 seconds per vehicle, operating at LOS E. This suggests oversaturation conditions, which can be attributed to the restricted approach width and limited capacity to accommodate traffic demand. Consequently, this leg experiences significant congestion and longer queues.

The southern approach (Fate axis) exhibited a delay of 38.5 seconds per vehicle, corresponding to LOS D. This reflects moderate congestion characterized by noticeable queuing. The performance of this approach could be improved through geometric enhancements, particularly at the entry point, to facilitate smoother vehicle movement.

8. Policy Recommendations

Recommended Improvement Measures for Gaa Akanbi Roundabout

i. Based on the observed operational deficiencies, several engineering interventions are proposed to enhance the performance and safety of the Gaa Akanbi Roundabout. Priority should be given to capacity improvement on the western approach, where widening of the carriageway is necessary. The introduction of an additional flare lane or a properly designed entry taper would increase entry capacity and reduce congestion levels experienced on this leg.

ii. Furthermore, optimization of pavement markings and refinement of entry geometry are essential. Clear and properly aligned road markings, combined with improved entry curvature, would enhance driver guidance, minimize conflicts, and promote smoother merging behavior at the roundabout.

iii. The installation of splitter islands at each approach is also recommended. These features would serve to channelize traffic, reduce vehicle entry speeds, and improve overall safety by minimizing conflict points and enhancing pedestrian refuge where applicable.

iv. Finally, to address peak-period congestion, the implementation of partial signal control should be considered. Signalization during high-demand periods can regulate traffic inflow, balance delays among approaches, and improve overall intersection efficiency without compromising off-peak performance.

v. Collectively, these measures are expected to improve traffic flow, reduce delays, and enhance operational stability at the roundabout.

References

1. Bus Priority Team. (2006). Bus stop design and quality standards: Total journey quality approach. UK Department for Transport.
2. Castles, S., de Haas, H., & Miller, M. J. (2020). The age of migration: International population movements in the modern world (6th ed.). Guilford Press.
3. Daniel. (2016). Traffic engineering fundamentals and applications.
4. Federal Ministry of Works. (2013). Highway manual: Design of at-grade intersections. Federal Ministry of Works.
5. Gonzalez, R., & Silva, J. (2022). Saturation flow calibration for heterogeneous traffic.
6. Li, Y., & Kumar, P. (2022). Turning ratio sensitivity at 3-leg intersections.
7. Migration Policy Institute. (2022). Nigerian immigrants in the United States. Migration Policy Institute.
8. Olowosegun, & Okoko. (2012). Public transport system planning and bus stop design considerations.
9. O'Sullivan, Morrall, & Shearer. (2000). Urban transportation systems and sustainability.
10. Ogunsanya. (2009). Transportation planning and policy in Nigeria. [Publisher not specified].
11. Okafor, C., et al. (2022). Optimizing cycle lengths for congested urban signals.
12. Rahman, S., et al. (2022). Roundabouts vs signals under peak variability.
13. Transportation Research Board. (2010). Highway capacity manual (5th ed.). Transportation Research Board.

14. United Nations Department of Economic and Social Affairs. (2024). International migration report 2024. United Nations.
15. Adeyemi, T., et al. (2022). Queue spillback prediction for closely spaced signals.