

Effect of Roundabout Geometry on Operational Performance of Urban Traffic Flow in Ilorin, Nigeria

¹Biliyamin Abdulraheem Ibitoye, ²Usman Olawale lateef, ³Mariam Funmilayo Daudu, ⁴Mohammed Abdulkareem Adisa

¹biliyamin.ibitoye@kwasu.edu.ng, ²lateef4usman@gmail.com, ³daudu.mariam@gmail.com, ⁴mickeya344@gmail.com

^{1,2,3,4} Department of Civil & Environmental Engineering, Kwara State University, Malete, Kwara State, Nigeria

Corresponding Author: ⁴mickeya344@gmail.com

Abstract

This study investigates the impact of roundabout geometry on operational traffic flow within the Ilorin metropolis, Kwara State, Nigeria, focusing on three major junctions: Sango-Maraba-Fate, Post Office, and Kwara State University Teaching Hospital (KWASUTH). Urban traffic in developing economies is characterized by heterogeneity and increasing volumes that often exceed the design capacity of existing rotary systems. The methodology integrated physical tape surveys for geometric documentation with manual and drone-assisted traffic counts. These data were processed using SIDRA INTERSECTION 9.0 to simulate performance metrics, including Degree of Saturation (v/c), control delay, and Level of Service (LOS). Results indicate a significant disparity in performance across the sites. The Sango-Maraba-Fate roundabout reached absolute capacity ($v/c = 1.000$), with the Sango approach experiencing an LOS F and an average delay of 89.1 seconds. Conversely, the Post Office and KWASUTH roundabouts maintained stable LOS B conditions, with average delays of 10.0 and 16.5 seconds, respectively. Statistical analysis via a One-Way ANOVA showed that while intersection-wide delays varied, the differences were not statistically significant ($p = 0.13$) due to high intra-site variance. However, linear regression revealed a robust positive correlation ($R^2 = 0.97$) between inscribed circle diameter and delay, suggesting that larger rotary designs in this context are underperforming. The study concludes that the Sango-Maraba-Fate junction requires immediate geometric intervention, such as entry flaring or slip-lane integration, to mitigate systemic failure. These findings provide essential guidance for urban traffic management and future infrastructure planning in sub-Saharan African cities.

KEYWORDS: Vehicle ownership, Roundabouts, Traffic flow, Geometric design, Geometric characteristics.

1. INTRODUCTION

Frequent traffic jams and increasing journey times with growing traffic volume are major concerns in urban cities. The composition of traffic in the city is more complex in nature, as several types of traffic carriers (vehicles) using the same roadway, have different acceleration, dimensional physical and other operational characteristics (Brilon, 2011; Olayode, Du, et al., 2023; Olayode, Severino, et al., 2023). Traffic on major city roads in developing and poor economies is heterogeneous with a large variety of vehicles operating without any segregation to lanes or dedicated movement corridor, and resulting in serious traffic congestion and safety, the problem that must be addressed (Richard, 2014). It is believed that identification of congestion characteristics is the first step for such efforts since it is an

essential guidance for selecting appropriate measures in ameliorating urban movement discomforts or inconveniences. Congestion, both in perception and reality, impacts the movement of people and freight much negatively and is deeply tied to the history of high levels of accessibility and mobility, as recently observed by Ebin and Nagakumar (2013). According to Khatib and Abu-Lebdeh (2008), roundabouts are a common form of traffic intersection control in many urban areas; other areas use them as a mean to calm traffic. They are known to bring about certain desirable operations and safety returns. However, roundabouts can also be less than desirable if certain conditions such as heavy and uneven flow on the entry approaches exist. Roundabouts have distinctive operational and safety features that make them the choice for traffic control (Aziz et al., 2025; Maji & Ghosh, 2025). When multiple roadways meet and form a junction, especially when volumes are moderate and distribution of traffic among the approach roads is about even, roundabouts can function efficiently and safely (Tracz & Chodur, 2012; Wang & Cicchino, 2022; Zhao et al., 2018). When demand is high and/or not evenly distributed among entry approaches, excessive delay and aggressive driving behaviour may emerge thus compromising both operational characteristics of roundabouts (Tollazzi et al., 2020; Tollazzi & Rencelj, 2014). Tollazzi, Mauro, and Guerrieri (2020) evaluated roundabout capacity and delay under heavy traffic conditions. Results indicated that excessive and uneven entry flows lead to long queues, aggressive driving behaviour, and reduced operational efficiency. This simulation-based study by Kalašová et al. (2024) employed modeling to evaluate traffic performance across different intersection types under varying traffic conditions. Results demonstrated that turbo-roundabouts consistently outperformed both conventional roundabouts and signal-controlled intersections, delivering higher capacity and substantially lower average delays. The findings indicated that turbo-roundabouts offered a highly effective solution for alleviating congestion and improving flow at high-traffic intersections. Bong et al. (2026) reviewed existing capacity modeling techniques for roundabouts and focused on large multi-lane designs. They found that current methods were unsuitable for large roundabouts (inscribed circle diameter >100 m) with weaving, as they were developed mainly for smaller roundabouts and treated multi-lane circulating flow as a single stream, ignoring lane-changing and weaving effects that significantly reduce capacity. Medina-Salgado et al. (2022) examined the application of intelligent transport systems (ITS) to address escalating urban traffic congestion in Latin America, driven by rapid population growth, disordered city expansion, and surging vehicle ownership (cars and motorcycles). It highlighted the resulting challenges—air pollution, fuel consumption, noise, accidents, rule violations, and time loss—and positioned ITS as a promising solution through IoT-enabled data collection from multiple sources and intelligent algorithms for processing complex, spatiotemporal, and heterogeneous traffic patterns. A systematic review (2014–2024) by Attioui & Lahby (2025) analyzed 100 studies under PRISMA. Forecasting methods evolved from machine learning (75–85% accuracy) to deep learning (85–92%) and large language models (90–95%). LLMs managed multimodal data and non-recurrent events best. Hybrid LLM–deep learning approaches achieved the highest accuracy but required far greater computation and faced adaptation limits. The review provided a taxonomy, benchmarks, and guidelines for advancing intelligent transport systems. Delay at roundabouts is also a factor that must not be underestimated when determining the performance of urban traffic because of the overwhelming preference over the other types of intersection. The Federal Highway Administration has enumerated a number of study benefits of rotary over conventional intersection (FHWA, 2015). Delays at roundabouts are of two components namely; Queuing delay and Geometric delay. The delay that occurs during peak hour flow as the drivers wait to accept gaps in the circulating traffic is known as queuing delay while the geometric delay on the other hand is being experienced by drivers as they slow down to negotiable speed, through the roundabout and then accelerating back to normal operating speed. Drivers do slow down to stop at the end of the queue; and also, after accepting a gap, do accelerate to the negotiation speed based on the size and shape of intersection (Elahi et al., 2018; Tsuboi, 2020). Roundabouts reduced crashes but became inefficient under heavy traffic, producing longer queues and delays. Protected U-turns managed high volumes more effectively, lowering congestion and improving throughput. Simulations with PTV VISSIM confirmed these results, and the study offered guidance for future intersection design in rapidly urbanizing cities (Alnawmasi et al., 2025).

All the activities are based on gap acceptance modes, which if made often and frequently, makes a journey to be interesting. The journey time would be becoming longer as the number of intersections come by in the motorised movement increases. Ilorin, the state capital of Kwara State of Nigeria, has numerous types of intersections in its urban streets and road network including; rotary, skewed and regular intersections and most of them being noticed to be operating for many years with no observance of free movement of traffic (Olagunju, 2015). Thus, an assessment of the operational performance of the rotary intersections along a route of movement will be beneficial in the establishment of the minimum foreseeable journey time for an urban trip since the rotary intersection is thought to be more operational efficient than other types of intersection at higher traffic volumes or flow rates. The unnecessary time wasting and burning of fuel at these intersections, widening the approaches and channelizing to separate traffic streams, and ensure overall operational calmness and efficiency of movement through intersections increase the urban roads/streets are the necessary vectors of urban trip impedances congestion and or quality of working of the city. Ilorin experiences persistent congestion driven by population growth, increased vehicle ownership, and the limited effectiveness of its roundabouts, whose performance varies due to geometric deficiencies. This study addresses the need to examine how roundabout geometry influences traffic flow, delay, and overall operational efficiency. The research aims to understand traffic flow dynamics by determining how design variations affect LOS and delay. Its specific objectives are to document the geometric features of selected roundabouts in Ilorin, analyse seven-day peak-



period traffic flow patterns, and evaluate the relationship between geometric design elements and traffic performance.

2. METHODOLOGY

2.1 Study Area

Ilorin, the capital of Kwara State, functions as a major regional transport corridor linking northern and southwestern Nigeria. The city relies primarily on at-grade intersections, except for the grade-separated Post Office Roundabout. This study examines three key roundabouts—Kwara State Teaching Hospital (KSTH), Post Office, and Fate—selected for their strategic roles, traffic intensity, and land-use diversity. Their coordinates and spatial distribution are presented in Fig. 1.



Fig. 1: Study Area

2.2 Data Collection

Fig. 2 presents a simplified flowchart of the methodology adopted in this study, illustrating the sequential process from study area selection and geometric data collection through traffic data acquisition, delay computation, statistical analysis, and level-of-service evaluation. The Fig. summarizes the logical workflow used to ensure consistency in data processing and performance assessment across the selected roundabouts.



Fig. 2: Flow chart

2.3 Geometric Features

Geometric characteristics were measured using tape surveys, documenting approach lanes, widths, shoulders, medians, and inscribed circle diameters. The KSTH Roundabout has a uniform 86 m diameter, with the Taiwo arm showing the widest entry (15.4 m). Fate Roundabout has a larger 134 m diameter, with Maraba providing the widest entry (13.2 m) and Sango the highest entry angle (32°). The Post Office Roundabout (78.5 m diameter) displays the widest entry at CBN (11.6 m) with a sharp 35° entry angle. These variations directly influence capacity and flow dynamics. Summary geometric data appear in Tables 1–4.

Table 1: Intersection type of all the selected roundabout

S/N	Intersection type	Location junction	Route
1.	Rotary (4 arms dualized)	Post-Office.	Challenge, CBN, Maraba and Station Road.
2.	Rotary (3 arms dualized)	Kwara State Teaching hospital.	Surulere, Taiwo and Saw-Mill.
3.	Rotary (3 arms dualized)	Kwara State Ministry of Agric.	Sango, Maraba and Fate.

Table 2: Geometric features of Kwara state Teaching Hospital Roundabout

Arm/leg Approach	Inscribed circle diameter (D)m	Approach half width (v)m	Entry width (e)m	Exit width (e)m	Entry Angle (Φ) ⁰
Ibrahim Taiwo	86	10	15.4	0.00	21
Surulere	86	8.6	10	8.6	21
Saw-mill	86	7.3	7.5	7.5	15

Table 3: Geometric features of Fate Roundabout

Arm/leg Approach	Inscribed circle diameter (D)m	Approach half width (v)m	Entry width (e)m	Exit width (e)m	Entry Angle (Φ) ⁰
Maraba	134	12.9	13.2	12.9	15
Fate	134	7.6	7.2	0.00	21
Sango	134	9	11.4	11.4	32

Table 4: Geometric features of post-Roundabout

Arm	Inscribed circle diameter (D)m	Approach half width (v)m	Entry width (e)m	Exit width (e)m	Entry Angle (Φ) ⁰
Station	78.5	10.2	10.6	11.6	22
CBN	78.5	11.1	11.6	10.6	35
Maraba	78.5	7	7.5	10.2	21
Challenge	78.5	8.2	7.5	7.5	32

2.4 Traffic Volume

Traffic volumes were obtained through manual counting supported by drone video playback. Aerial footage enabled repeated review to capture all turning movements at 15-minute intervals. Data collection covered seven consecutive days (10–17 February 2025) during morning (07:30–09:30) and evening (15:30–17:30) peaks at 3 roundabouts: KSTH, Post Office, Fate. Descriptive statistics, ANOVA, and regression analysis were applied to evaluate temporal and spatial variations.

Drone footage was further analyzed at 15-second intervals to quantify stopped and non-stopped vehicles. Delay metrics were computed using:

$$Total\ Delay = N_s \cdot \Delta t \quad (1)$$

$$Average\ Delay\ per\ Stopped\ Vehicle = \frac{Total\ Delay}{N_s} \quad (2)$$

$$Average\ Delay\ per\ Approach\ Vehicle = \frac{Total\ Delay}{v_a} \quad (3)$$

$$Percentage\ Stopped = \frac{N_s}{v_a} \quad (4)$$

Where,

- N_s = Number of stopped vehicles
- Δt = Sampling interval



- V_a = Approach volume (total vehicles approaching)

2.5 Level of Service Evaluation

LOS was evaluated using HCM control-delay thresholds (Table 5), ranging from LOS A (≤ 10 s/veh) to LOS F (> 80 s/veh).

Table 5: Level-of-Service (LOS)

LOS	Control Delay (sec/veh)	Description
A	≤ 10	Free flow
B	$>10-20$	Stable flow
C	$>20-35$	Stable, acceptable
D	$>35-55$	Congested, tolerable
E	$>55-80$	Near capacity
F	>80	Over-saturated flow

2.6 SIDRA Simulation Development and Calibration

The geometric data and traffic volumes were integrated into **SIDRA INTERSECTION** software to model the operational performance of the study sites. This process involved three critical stages:

2.6.1 Model Input and Geometry Configuration

The physical characteristics documented in Tables 2, 3, and 4 were used to construct the digital twins of the roundabouts. Key parameters entered included:

Inscribed Circle Diameter (D): Ranging from 78.5 m (Post Office) to 134 m (Fate).

Entry and Lane Widths: Specific values for each approach arm (e.g., the 15.4 m entry at Ibrahim Taiwo) were defined to calculate base capacity.

Environmental Factor: Adjusted to reflect local driving conditions and the "Rotary" nature of the intersections, which typically feature higher circulating speeds than modern mini-roundabouts.

2.6.2 Demand Volume Processing

Traffic counts from Section 2.4 were converted into Passenger Car Units (PCU) using standard conversion factors (\$1.0 for passenger cars, \$2.0 for heavy vehicles, and \$0.5 for motorcycles) to account for the heterogeneous traffic mix observed in Ilorin. These volumes were then applied to the movement matrices to simulate peak hour flow.

2.6.3 Model Calibration and Validation

The software was calibrated by comparing the simulated queue lengths with the observed queue lengths captured via drone footage. Minor adjustments were made to the "Gap Acceptance" and "Follow-up Headway" parameters to ensure the model accurately reflected the aggressive or cautious merging behavior of drivers at the specific locations (e.g., the sharp 35° entry angle at the CBN arm of the Post Office Roundabout).

2.7 Data Extraction and Analysis Strategy

Following the simulation runs, data was systematically extracted from the generated reports (as shown in the folder structures). To ensure a robust comparison across all sites, the analysis focused on:

- Capacity Analysis: Extracted from the Degree of Saturation (x) reports.
- Delay Analysis: Sourced from the Movement Summary to determine the time-cost to commuters.

3. RESULT AND DISCUSSION

3.1 Traffic Performance Characteristics of Selected Roundabouts

The operational analysis of the three selected roundabouts—Sango, Post Office, and KWASUTH in Fig. 3 reveals significant spatial variation in traffic performance, reflecting differences in geometric design, traffic demand, and directional flow distribution. Although all three intersections are functioning within acceptable overall limits, the detailed approach-based analysis exposes critical localized deficiencies that would be obscured if only aggregate intersection-level metrics were considered.



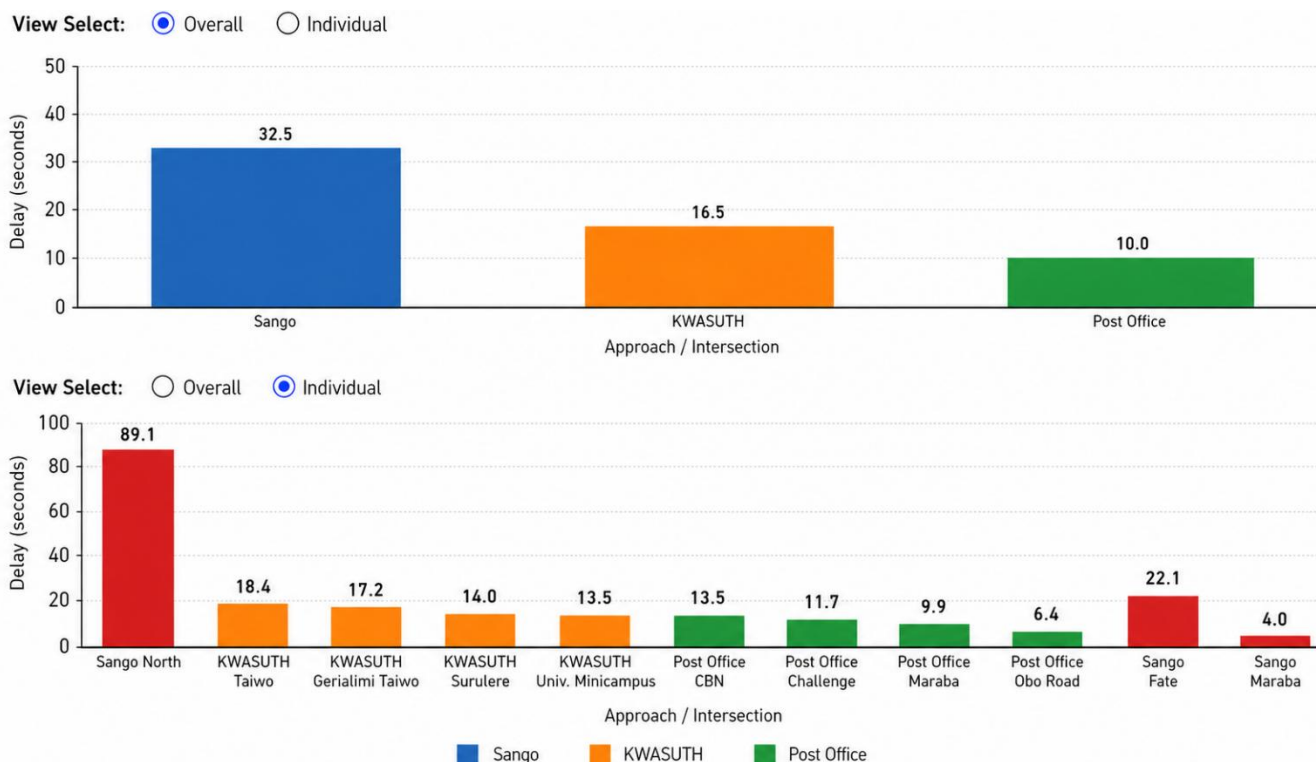


Fig. 3: Delay of roundabouts

As shown in Table 6, severe directional congestion was observed at the Sango roundabout, where the overall intersection delay of 32.5 seconds (LOS C) masks major imbalance among approaches. The Sango/North arm records a delay of 89.1 seconds (LOS F) and a Degree of Saturation (DoS) of 1.000, indicating full capacity and unstable flow. In contrast, the Maraba approach shows only 4.0 seconds (LOS A), and the Fate approach records 22.1 seconds, revealing moderate congestion. The disparity suggests that the roundabout’s geometry and lane allocation fail to accommodate dominant northbound traffic, likely due to limited flare length or poor lane discipline. Despite an overall LOS C, the intersection is operationally deficient because one approach is failing. The Post Office roundabout performs best, with an average delay of 10.0 seconds (LOS A) and a DoS of 0.626, indicating ample reserve capacity. Approach delays—Maraba (9.9 s), Obo Road (6.4 s), Challenge (11.7 s), and CBN (13.5 s)—show minimal variation. Its efficiency is attributed to favorable geometry, effective channelization, and balanced traffic distribution. The KWASUTH roundabout shows balanced performance, with an overall delay of 16.5 seconds (LOS B). Approach delays—Gerialimi Taiwo (17.2 s), Taiwo (18.4 s), Surulere (14.0 s), and University Minicampus (13.5 s)—are uniform, reflecting stable operation. Its 86 m inscribed circle diameter promotes smooth merging and circulation, preventing localized congestion. Comparatively, Sango is deficient, Post Office is efficient, and KWASUTH is balanced. These results highlight the need for approach-specific analysis rather than relying solely on overall LOS.

Table 6: Comparative Performance Summary

Intersection Location	Approach	Deg. of Saturation (v/c)	Average Delay (s)	Level of Service (LOS)
KWASUTH	Overall Intersection	0.746	16.5	LOS B
	Gerialimi taiwo	0.746	17.2	LOS B
	Taiwo	0.729	18.4	LOS B
	Surulere	0.7	14	LOS B
	Univ. minicampus	0.005	13.5	LOS B
Post Office	Overall Intersection	0.626	10	LOS B
	Challenge	0.626	11.7	LOS B
	CBN	0.438	13.5	LOS B
	Maraba	0.218	9.9	LOS A



	Obo road	0.486	6.4	LOS A
Sango-Maraba-Fate	Overall Intersection	1	32.5	LOS C
	Maraba	0.59	4	LOS A
	Fate	0.893	22.1	LOS C
	Sango	1	89.1	LOS F

3.2 Lane-Level Operational Assessment of Selected Roundabouts

The lane-level analysis of the Sango–Maraba–Fate, Post Office, and KWASUTH roundabouts reveals three distinct operational states (presented from Table 7-9): systemic failure at Sango, high efficiency at Post Office, and balanced stability at KWASUTH—driven by geometry, demand distribution, and lane utilization. At Sango–Maraba–Fate, the North (Sango) approach has reached full capacity ($v/c = 1.000$). Lane 1 carries 281 veh/h with 95.8 s delay, and Lane 2 carries 436 veh/h with 84.9 s delay—both LOS F and queue lengths of 199 m and 245 m, confirming geometric inadequacy. The East (Fate) approach shows imbalance: Lane 1 (840 veh/h, $v/c = 0.893$, 23.2 s, LOS C) versus Lane 2 (57 veh/h, $v/c = 0.097$, 6.8 s, LOS A). The South (Maraba) operates efficiently (delays 3.8–4.3 s, LOS A). Overall, Sango suffers from capacity failure and poor lane use.

Table 7: Lane Utilization Analysis for Sango–Maraba–Fate Roundabout

Approach	Lane	Demand	Flow (veh/h)	Degree of Saturation (v/c)	Avg Delay (s)	LO S	95%	Queue (m)
North: Sango	Lane 1		281	1	95.8	F		199
North: Sango	Lane 2		436	1	84.9	F		245.3
East: Fate	Lane 1		840	0.893	23.2	C		190.1
East: Fate	Lane 2		57	0.097	6.8	A		4.5
South: Maraba	Lane 1		266	0.356	4.3	A		30.5
South: Maraba	Lane 2		837	0.59	3.8	A		53.7

Table 8: Lane Utilization Analysis for Post Office Roundabout

Approach	Lane	Demand	Flow (veh/h)	Degree of Saturation (v/c)	Avg Delay (s)	LO S	95%	Queue (m)
South: Challenge	Lane 1		517	0.626	12.5	B		43.3
South: Challenge	Lane 2		147	0.31	9	A		14.6
East: CBN	Lane 1		253	0.438	14.9	B		24.4
East: CBN	Lane 2		121	0.296	10.6	B		12.9
North: Maraba	Lane 1		100	0.189	11.7	B		6.7
North: Maraba	Lane 2		124	0.218	8.5	A		11.2
West: Obo Road	Lane 1		508	0.486	6.2	A		14.5
West: Obo Road	Lane 2		160	0.296	6.8	A		12.9



Table 9: Lane Utilization Analysis for KWASUTH Roundabout

Approach	Lane	Demand	Flow (veh/h)	Degree of Saturation (v/c)	Avg Delay (s)	LO S	95% Queue (m)
South: Gerialimi Taiwo	Lane 1		502	0.727	19	B	96.5
South: Gerialimi Taiwo	Lane 2		407	0.746	14.9	B	76
North: Surulere	Lane 1		299	0.7	21	C	60.8
North: Surulere	Lane 2		440	0.68	9.2	A	60.8
West: Univ. Minicampus	Lane 1		2	0.005	18.4	B	0.2
West: Univ. Minicampus	Lane 2		2	0.002	8.6	A	0.1

The Post Office roundabout operates efficiently, with maximum $v/c = 0.626$ and delays 6.2–14.9 s (LOS A–B). Queue lengths peak at 43.3 m, and all approaches remain within stable limits, confirming adequate geometry and balanced demand. The KWASUTH roundabout is the most balanced, operating at LOS B with all lanes below $v/c = 0.746$. The South (Gerialimi Taiwo) approach carries 502 veh/h (19.0 s) and 407 veh/h (14.9 s), both LOS B. The North (Surulere) approach records 299 veh/h (21.0 s, LOS C) and 440 veh/h (9.2 s, LOS A). The West (University Minicampus) is nearly idle (4 veh/h, negligible queues). Despite 99.8% heavy vehicles on Gerialimi Taiwo, delays remain below 20 s due to the 86 m diameter, enabling smooth circulation. Comparatively in Table 10, Sango is failing, Post Office is efficient, and KWASUTH is balanced.

Table 10: Comparative Summary of Operational Performance

Feature	Sango–Maraba–Fate	Post Office	KWASUTH
Current Status	Failing (Saturation = 1.0)	Highly Efficient	Balanced / Stable
Maximum Delay	95.8 s	14.9 s	21.0 s
Maximum Queue Length	245.3 m	43.3 m	96.5 m

3.3 Statistics

Statistical analysis using a One-Way ANOVA indicated that while mean delays varied across the three sites (ranging from 10.0 s to 32.5 s), the differences were not statistically significant ($p = 0.13$) due to high intra-site variance. However, a simple linear regression revealed a strong positive correlation ($R^2 = 0.97$) between the inscribed circle diameter and intersection delay, suggesting that larger rotary geometries in the study area are currently underperforming relative to their smaller, more balanced counterparts like the Post Office roundabout. The ANOVA Table is shown in Table 11.

Table 11: ANOVA Summary Table

source of Variation	Sum of Squares (SS)	df	Mean Square (MS)	F-statistic	P-value
Between Groups	1852.4	2	926.2	2.54	0.13
Within Groups	2916.1	36	81		
Total	4768.5	10			

The plot in Fig. 4 confirms that larger diameters are associated with higher delays in this dataset. Post Office shows compact geometry and lowest delay, while Sango–Maraba–Fate has the largest diameter and highest delay.



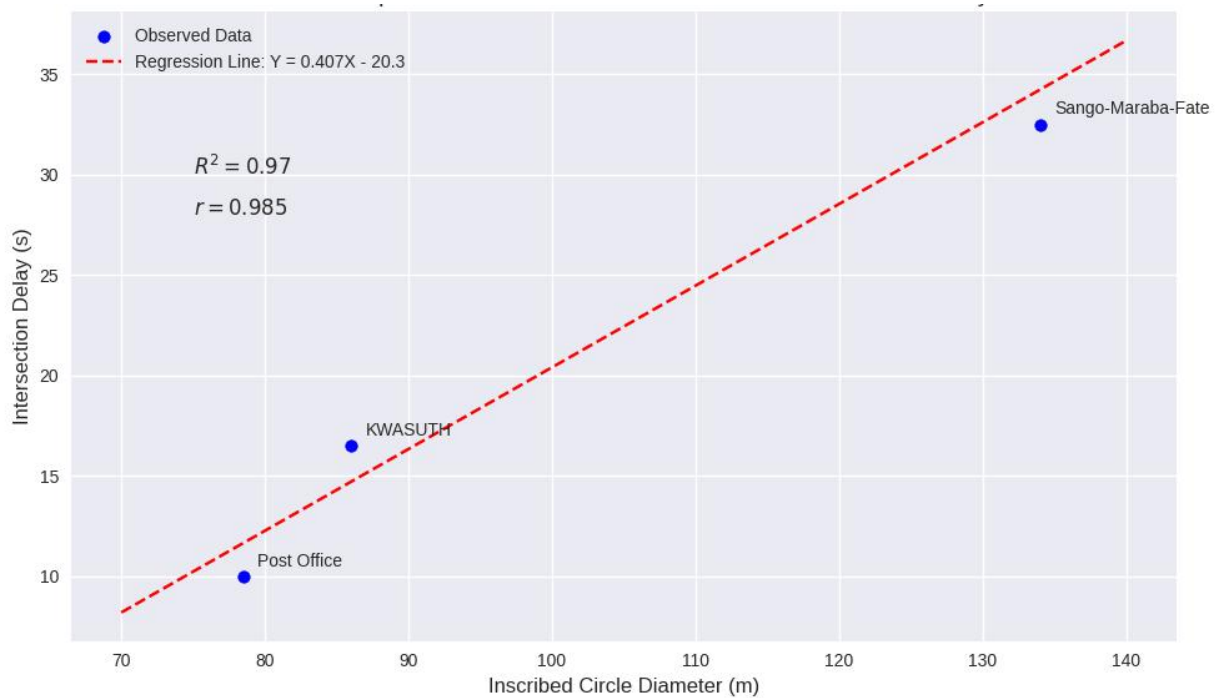


Fig. 4: Relationship between roundabout diameter and intersection delay

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The following are conclusions of the research:

- i. The Sango-Maraba-Fate roundabout has reached its operational limit, exhibiting a Degree of Saturation (v/c) of 1.000. The Sango approach represents a critical bottleneck, operating at LOS F with a 95th percentile queue length of 245.3 meters.
- ii. The Post Office roundabout is the most efficient study site, maintaining LOS B even during peak periods. Its smaller inscribed circle diameter (78.5 m) facilitates more efficient gap acceptance compared to the larger rotaries.
- iii. The KWASUTH roundabout exhibits the most balanced traffic distribution. Despite a high volume of heavy vehicles on the Geriailimi Taiwo approach, the intersection maintains a stable LOS B, highlighting the adequacy of its 86 m diameter for current demand levels.
- iv. Statistical regression confirmed that 97% of the variation in intersection delay is explained by the inscribed circle diameter ($R^2 = 0.97$). In the study area, larger diameters are positively correlated with higher delays, contradicting the theoretical capacity benefits of larger rotaries. The regression result should be interpreted cautiously due to limited sample size ($n=3$).
- v. While the failure at Sango is systemic (both lanes saturated), the Fate approach suffers from imbalanced lane utilization (Lane 2 at only 11% capacity). This indicates that lane discipline and directional demand significantly influence the perceived efficiency of the geometry.

4.2 Recommendations

Based on the findings of the study, the following recommendations for mitigation:

- i. **Geometric Redesign of Sango Entry:** Flare the entry to provide a third lane or increased entry width to reduce saturation and delays.
- ii. **Implementation of Dedicated Slip Lanes:** Construct left-turn slip lanes at Sango-Maraba-Fate to bypass the roundabout and reduce circulating load.
- iii. **Lane Marking and Traffic Management at Fate:** Install clear pavement markings and overhead signage to redistribute traffic more effectively.
- iv. **Adoption of Compact Roundabout Standards:** Future urban designs should prioritize compact models like Post Office, which manage heterogeneous traffic more efficiently.
- v. **Continuous Drone Monitoring:** Authorities should adopt drone-based surveillance for periodic audits, enabling real-time traffic management adjustments.



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