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Evaluation and Improvement of Traffic Flow and Delay at Eko-Ende Intersection in Ikirun, Osun State, Nigeria

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Abstract: *The rapid increase in traffic volume in Ikirun has led to rising congestion across the town's road network. Stop delay, a significant indicator of intersection performance, is commonly used to assess the level of service (LOS) and capacity. This study investigated delays at the Eko-Ende intersection, a critical point in Ikirun's traffic system that connects commercial hubs such as Ikirun Garage, Osogbo-Ilorin Road, Monday Market, and Alamisi Market. A geometric evaluation of the intersection showed approach widths of 7.2 m for Moshadek, 7.0 m for Kereje, 10.73 m for Sawmill, and 14.8 m for Nazeem. Traffic volume assessments revealed Sawmill as the busiest approach, with a weekly average peak-hour volume of 1,773 vehicles, followed by Moshadek and Kereje with 1,553 and 1,362, respectively, while Nazeem had the lowest volume at 876. The average peak-hour volume across the intersection was 5,566 vehicles. Delay studies indicated Sawmill had the highest delay (14.7 s), while Moshadek had the lowest (8.8 s), with an overall intersection LOS of B.*

Keywords: Traffic congestion, intersection performance, stop delay, traffic volume.

1. INTRODUCTION

Traffic congestion is a widespread issue impacting regions globally, with significant economic, environmental, and social repercussions. Defined by the [1] as a situation where traffic demand surpasses a roadway's capacity, congestion forces vehicles to travel at reduced speeds, leading to unpredictable and inconsistent travel times. As urban populations grow, pressure on transportation networks intensifies, exacerbating congestion. This phenomenon also has spatial and temporal dimensions, as slower travel times spread through road networks, resulting from complex interactions between vehicles and road infrastructure [2].

Rapid urbanization has led to imbalanced urban land use and insufficient public transportation, significantly impacting public health, air quality, and economic productivity [3]. Despite various traffic management efforts, traffic congestion remains a critical challenge, driven by the global surge in motor vehicle numbers [4]. Congestion contributes to extended travel times, increased fuel consumption, transportation-related emissions, and poses major obstacles to sustainable urban development within transport networks [5].

Traffic congestion also has serious health implications. Many vehicles, especially diesel-powered buses, trucks, and other heavy-duty vehicles, emit nitrogen oxides and particulate matter, which pollute urban air. In dense city environments, these pollutants can become trapped due to high traffic volumes and tall buildings that inhibit air circulation, leading to respiratory illnesses among urban populations.

Beyond public health, traffic congestion also affects economic interests, including those of commercial enterprises. While specific data on financial losses due to congestion in Nigeria is limited, studies from the United States and Europe highlight the substantial economic costs of traffic congestion [3].

2. LITERATURE REVIEW

2.1 Intersection

An intersection is where two or more roads meet or cross, playing a critical role in urban planning and the effectiveness of transportation networks. Intersections use a mix of traffic signals, signs, and road markings to regulate vehicle and pedestrian flow, enhancing safety and efficiency [6]. The primary purpose of intersection design is to promote smooth, convenient, and safe movement for drivers and pedestrians alike [7].

2.1.1 Types of intersection

Intersections are tailored to accommodate diverse traffic patterns while promoting traffic efficiency and safety. Common types include:

i. **Four-Way Intersections:** These intersections occur when two roads meet at a right angle, creating a crossroad. Their design minimizes conflict points and improves visibility, contributing to smoother traffic flow and reduced congestion [8].

ii. **Three-Way Intersections:** Also known as T-intersections, these join three roads, offering a simpler design that usually requires less space. The straightforward layout can reduce confusion and promote smoother traffic flow [8].

iii. **Roundabouts:** Also referred to as traffic circles, roundabouts guide vehicles in a circular pattern around a central island, enabling continuous movement and reducing the likelihood of high-speed collisions. Roundabouts help alleviate congestion, minimize severe crashes, and improve air quality by reducing vehicle idling time [9].

2.1.2 Benefits of intersections

i. Enhancing traffic flow and operational efficiency.
ii. Reducing collision risk and improving road safety.
iii. Increasing the accessibility of transportation networks.
iv. Lowering fuel consumption, which in turn improves air quality [10].

2.2 Delay

Delay refers to the additional time drivers and passengers experience beyond what is expected in free-flow conditions. Delays occur when traffic volume nears or exceeds roadway capacity and may be caused by various factors such as traffic signals, accidents, and road geometry [11, 12]. Table 1 summarises of recent studies on intersection traffic flow and delay improvement (2020-2024)

2.3 Congestion

Traffic congestion happens when demand exceeds the capacity of a roadway, leading to slower speeds and less predictable travel times [13].

2.3.1 Causes of traffic congestion

Factors contributing to congestion include area design, geographical constraints, adverse weather, accidents, vehicle breakdowns, and the level of infrastructure investment [14].

i. **Road Space:** There would always be a greater demand for road space than there is supply, particularly in the existing central town districts, due to competing needs for available land, which results in congestion even in the event that the required financial resources were available [15].

ii. **Planning of Land-use**: Human land use determines the need for transport facilities, and conversely, the availability of transport facilities frequently encourages land-use activities. Many cities experience traffic congestion, particularly in developing nations, as a result of planning processes that ignore the relationship between land use and transportation planning [15].

iii. **Use of Vehicles:** According to [16], there were over 2.6 billion people on the planet at the middle of the 20th century, and between them, they owned roughly 50 million cars. The transition from buses to private vehicles has resulted in a massive increase in the demand for necessary transportation network, which has caused traffic congestions and inevitably slowing down traffic [15]. The number of vehicles occasionally increased as a result of economic development and urbanization in urban areas throughout the world [17].

iv. **Income:** Vehicle ownership is mostly dependent on income in both developed and developing nations, traffic volumes and congestion are projected to increase with income [18].

Table 1: Summary of recent studies on intersection traffic flow and delay improvement (2020-2024)

Authors	Focus Area	Key Findings
[19]	Urbanization's Impact on Intersection Efficiency I	Rapid urban growth without adequate transport planning significantly increases delays at intersections, adversely impacting air quality.
[20]	Adaptive Traffic Signal Systems	Adaptive traffic signals led to a 25% reduction in intersection delays, enhancing overall traffic flow and level of service (LOS).
[21]	Sustainable Design for Intersection Improvements	Use of roundabouts and additional lanes improved traffic flow and reduced fuel consumption, supporting sustainable urban traffic solutions.
[22]	Intersection Geometric Modifications	Implementing wider approaches and adding turning lanes reduced average delay times by 35% in high-traffic intersections.
[23]	AI and Smart Technologies in Traffic Management	AI-driven traffic monitoring optimized signal timing, reducing peak-hour intersection delays by 30% and improving efficiency.

3. METHODOLOGY

3.1 Description of the Study Area

The study focused on the Eko Ende Intersection in Ikirun, Osun State, situated along the Osogbo–Ilorin highway as shown in Plate 1. This cross-type intersection features four main approaches: sawmill approach, Kereje furniture approach, Moshadek filling station approach, and Nazeem filling station approach. It is an at-grade intersection, with each approach consisting of a single carriageway.

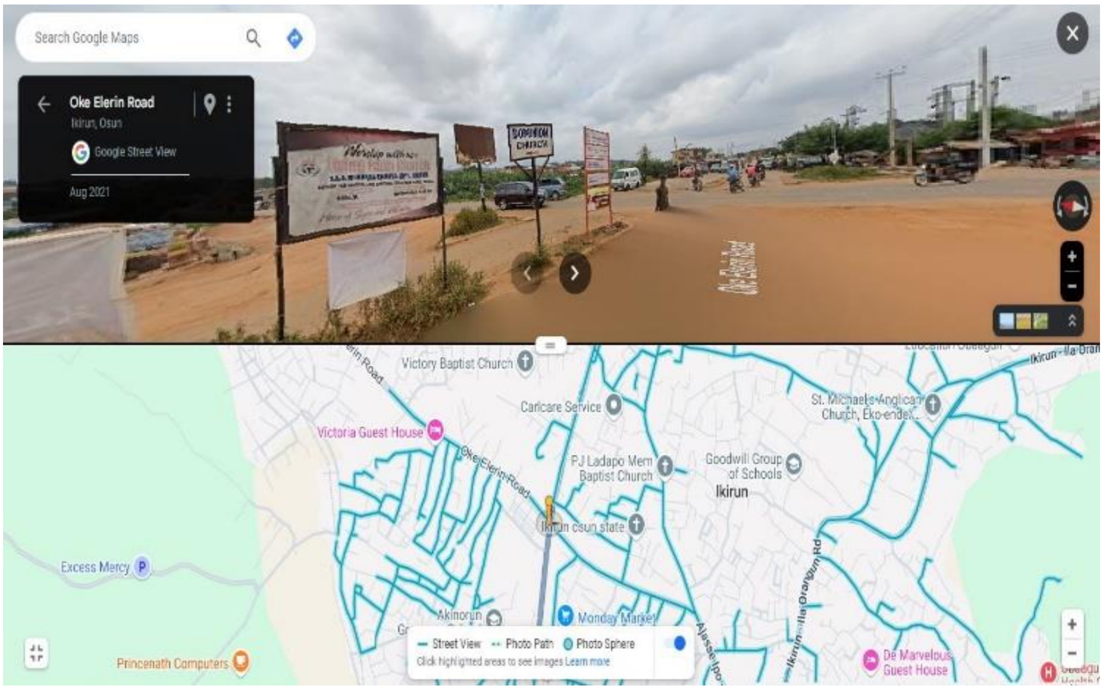

Plate 1: Eko Ende intersection in Ikirun, Osun State, situated along the Osogbo–Ilorin highway [24]

3.2 Traffic Data Collection at the Intersection

Video recordings were conducted using a digital camera to capture essential data on traffic patterns and identify interruptive factors at the intersection. The footage was reviewed to assess traffic volumes for each approach. Camera placement was optimized to minimize obstructions from other vehicles, ensuring clear visibility for accurate data analysis.

Data collection occurred during peak hours in the morning (7:00–9:00 a.m.) and evening (4:00–6:00 p.m.) from Monday through Sunday. To determine the daily average traffic volume, the total volume recorded in the morning and evening.

The weekly average traffic volume was calculated by summing daily averages from Monday to Sunday and dividing by seven. This method ensured an accurate representation of average traffic flow at the intersection.

3.3 Stop Delay Study

The stop delay study aimed to analyse factors contributing to traffic delays at the Eko-Ende intersection. Data was collected via video recordings, which were reviewed to count the number of stopped and non-stopped vehicles at each approach in 15-second intervals.

Equations (1) – (4) were used to quantify total delay, average delay per stopped vehicle, average delay per approach vehicle, and the percentage of stopped vehicles:

$$\text{Total Delay} = \text{Total Number of Stopped Vehicles} \times \text{Sampling Interval} \quad (1)$$

$$\text{Average Delay per Stopped Vehicle} = \text{Total Delay} / \text{Number of Stopped Vehicles} \quad (2)$$

$$\text{Average Delay per Approach Vehicle} = \text{Total Delay} / \text{Approach Volume} \quad (3)$$

$$\text{Percentage of Vehicles Stopped} = \text{Number of Stopped Vehicles} / \text{Approach Volume} \quad (4)$$

3.4 Level of Service (LOS)

Level of Service (LOS) is a qualitative assessment that reflects the operational conditions of a traffic stream as perceived by drivers and passengers [25]. For an intersection, LOS is determined by calculating the average delay per approach vehicle, which is evaluated for each individual lane rather than for the intersection as a whole. The criteria for categorizing LOS are summarized in Table 2.

Table 2: Level of service

Average Delay per Approach Vehicle (s)	Level of Service
0 - 5.0	A
5.1 - 15.0	B
15.1 - 25.0	C
25.1 - 40.0	D
40.1 - 59.9	E
60 and above	F

Source: [25]

4. RESULTS AND DISCUSSION

4.1 A Benchmark for Evaluating Future Traffic Performance at the Eko-Ende Intersection and other similar Urban Traffic Nodes

i. Geometric Characteristics

Approach Lane Widths: Record and evaluate the lane widths of each approach. Use the measured values at Eko-Ende as reference benchmarks:

Moshadek Filling Station: 7.2 m.
Kereje Furniture: 7.0 m.
Sawmill: 10.73 m.
Nazeem Filling Station: 14.8 m.

Adequacy of Pedestrian Walkways: Evaluate the adequacy of walkways in relation to pedestrian and vehicular interactions. The issues identified at Kereje and Moshadek approaches (inadequate pedestrian walkways and vehicle offloading zones) should serve as baseline issues to address.

ii. Interrupting Features

Road Surface Quality: Track the presence and impact of features like potholes. The current state of hindrances at the Eko-Ende intersection highlights a need for regular maintenance schedules and performance metrics.

iii. Traffic Volume Benchmarks

Peak Hour Traffic Patterns**:**
Morning Peak (7:00 AM - 9:00 AM).
Evening Peak (4:00 PM - 6:00 PM).

Use the recorded average traffic volumes:
Sawmill Approach: 1,773 vehicles/hour (highest traffic flow).
Nazeem Filling Station Approach: 876 vehicles/hour (lowest traffic flow).
Intersection Average: 5,566 vehicles/hour.

This benchmark provides a systematic method to monitor and evaluate the Eko-Ende intersection's traffic performance and serves as a replicable model for other urban intersections. It can also guide infrastructure improvements and traffic management interventions to meet future demands effectively.

4.2 Evaluation of Geometry and Interrupting Features at Eko-Ende Intersection

The physical characteristics of each approach at the Eko-Ende Intersection were assessed through direct measurements of the approach lanes. The Moshadek filling station approach has a road width of 7.2 m, functioning as a single carriageway. The Kereje furniture approach measures 7.0 m and is also a single carriageway. The sawmill approach is wider, at 10.73 m, while the Nazeem filling station approach is the broadest, with a width of 14.8 m, and is similarly designed as a single carriageway.

The evaluation of interrupting features at the intersection revealed several issues. Potholes present at the intersection hinder traffic flow, while pedestrian walkways on two of the four approaches (Kereje and Moshadek filling station) are inadequate, as vehicles frequently stop to offload passengers. This situation is exacerbated by traffic entering Sawmill motor park and Kereje furniture, further obstructing pedestrian movement.

4.3 Evaluation of Traffic Data

Traffic volume studies focused on peak hour periods, specifically the morning peak from 7:00 AM to 9:00 AM and the evening peak from 4:00 PM to 6:00 PM. Data collection was conducted over seven consecutive days, including Monday through Sunday. The data presented in Table 3 indicates that the sawmill approach experiences the highest average traffic volume, recorded at 1,773 vehicles. This significant traffic flow is likely due to the concentrated movement of individuals heading to various destinations such as offices, markets, and shops. The sawmill approach serves a densely populated residential area and lacks alternative routes, compelling residents to use this approach to access the Eko-Ende intersection as they navigate the town. In contrast, the Nazeem filling station approach exhibits the lowest traffic volume, with an average of 876 vehicles. This reduced volume can be attributed to the availability of multiple alternative routes that allow drivers to bypass the intersection entirely. Overall, the average traffic volume across the intersection is 5,566 vehicles per hour. The average traffic volume results for these peak hours are presented in the Table 3.

Table 3: Summary of traffic flow distribution for the approaches

Approach	Left Turn	Through Turn	Right Turn	Total Traffic Volume	Average Hourly Volume	Percentage of Total Traffic Volume (%)
Kereje	3,014	4,282	2,236	9,532	1,362	24.5
Moshadek	3,572	4,763	2,552	10,887	1,555	27.9
Sawmill	2,939	4,481	4,989	12,409	1,773	31.9
Nazeem	2,344	1,661	2,119	6,134	876	15.7
Total	11,869	15,187	11,896	38,962	5,566	100

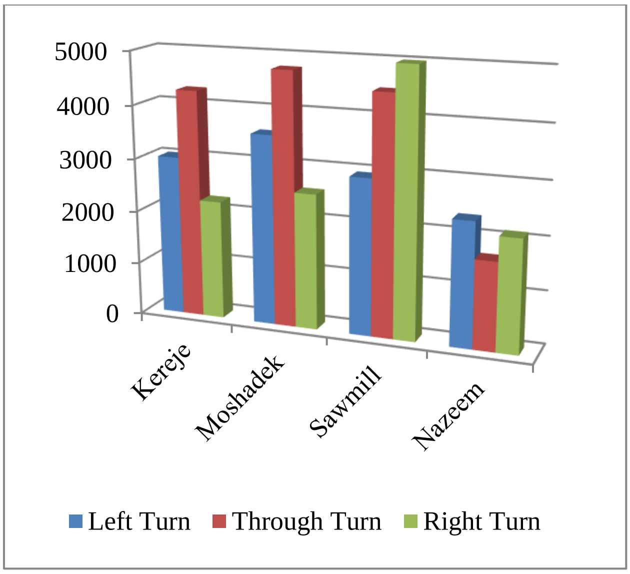

Figure 2: Average traffic distribution from Day 1 to Day 7 of the traffic studies

4.4 Traffic Delay, Level of Service and Vehicle Stoppage at Eko-Ende Intersection

The results summarized in the Table 4, indicate varying levels of delay and vehicle stoppage percentages across the different approaches at the Eko-Ende intersection, all of which fall within level of service (LOS) B. This classification signifies that the intersection operates with acceptable delay levels, although there is room for improvement.

The Sawmill approach experiences the highest average delay per vehicle, recorded at 14.7 s, which correlates with a substantial percentage of vehicles stopped at 97%. This indicates significant congestion in this approach, likely due to its high traffic volume and possibly limited capacity to accommodate the flow. The high stoppage rate suggests that vehicles are frequently halted, leading to longer wait times for drivers.

In comparison, the Kereje approach shows an average delay of 11.2 s and a stoppage percentage of 74%. This approach is also moderately congested but experiences less delay than Sawmill. Similarly, the Nazeem approach records an average delay of 11.6 s, with 77% of vehicles stopping, indicating that while delays are present, they are not as severe as those at the Sawmill approach.

The Moshadek approach has the lowest average delay of 8.8 s and a stoppage percentage of 59%, reflecting a more efficient traffic flow compared to the other approaches. Overall, the total average delay across all approaches is calculated at 9.9 s, with an average stoppage rate of 76.8%. This data underscores the need for targeted interventions to alleviate congestion, particularly at the sawmill approach, while also suggesting that the intersection's overall performance is within acceptable parameters as indicated by its LOS B rating. Figure 3 illustrates the average stop delays.

Table 4: Relationship between the averages stopped delay and level of service for each approach.

Approach	Average Delay per Approach Vehicle (s)	Percentage of Vehicles Stopped (%)	Level of Service
Kereje	11.2	74	B
Moshadek	8.8	59	B
Sawmill	14.7	97	B
Nazeem	11.6	77	B
Total	46.3	307	
Overall Average	39.53/4 = 9.9	76.8	B

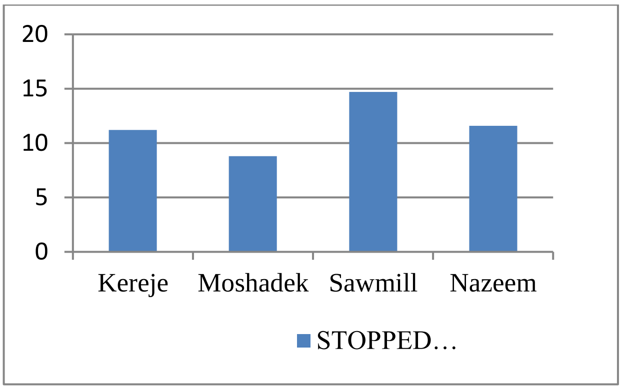

Figure 3: Average stopped delay at the intersection

5. CONCLUSION

Encroachment, parked vehicles, and commercial activities significantly reduce lane capacity and disrupt traffic flow, but these challenges can be mitigated with a combination of infrastructure upgrades, regulatory enforcement, behavioural interventions, and smart traffic management systems. Implementing these measures will optimize the use of available road space, reduce congestion, and enhance safety and efficiency at the Eko-Ende intersection. This study showed that in accordance with the [26], the minimum required lane width for highways is 3.5 m. All approaches at the intersection surpass this standard, with widths measuring 7.2 m for the Moshadek approach, 7.0 m for Kereje, 10.73 m for Sawmill, and 14.8 m for Nazeem. However, guidelines from the [27] suggest that high-speed highways should feature a minimum lane width of 4 m, highlighting the need for potential expansions of the Kereje and Moshadek approaches to enhance traffic accommodation. The analysis showed that the Eko-Ende intersection currently operates below saturation levels. Traffic volume is highest along the Sawmill approach, with 1,773 vehicles, followed by Moshadek and Kereje, which record volumes of 1,553 and 1,362 vehicles, respectively. The Nazeem approach, by contrast, has the lowest volume, accommodating 876 vehicles. The overall traffic volume at the intersection averages 5,566 vehicles. Some lane capacity at the intersection has been compromised due to factors such as parked vehicles, commercial unloading activities, and encroachments by nearby shops and vendors. Additionally, a prevalent disregard for traffic regulations among local drivers affects lane discipline, further disrupting the flow of traffic. The study finds that all approaches currently function at an average level of service (LOS) rating of B. However, improvement to an LOS of A remains achievable if certain conditions are addressed—specifically, filling potholes, widening single carriageways, and encouraging better driver behaviour. These adjustments could meaningfully enhance both traffic flow and safety at the Eko-Ende intersection.

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