[1.] J.I. OZULIGBO, [2.] O.J. OKOH

COMPARATIVE ANALYSIS OF THE PREDICTIVE MODELS AND DAILY TRAFFIC COUNTS OF TWO SELECTED HIGHWAYS WITHIN IBADAN METROPOLIS, NIGERIA

[1,2]Department of Civil and Water Resources Engineering, Faculty of Engineering, University of Delta, PMB 2090, Agbor, Delta State, NIGERIA

Abstract: The efficiency of traffic flow on two–lane highways is crucial for urban mobility and economic activities, particularly in rapidly growing cities such as Ibadan, Nigeria. This study presents a comparative analysis of the predictive models and daily traffic counts on two selected highways within the Ibadan metropolis: the Ojoo–Mokola Road and the Mokola–Agodi Road. Traffic flow surveys were conducted through videographic data collection during peak hours over a five–day period, capturing hourly vehicle counts across seven traffic categories. The study also explored the speed–density relationship by developing predictive models for traffic volume forecasting. The results revealed distinct traffic patterns on both highways. The Mokola–Agodi Road exhibited significantly higher traffic volumes than the Ojoo–Mokola Road, particularly during evening peak hours. The predictive speed–density model for the Ojoo–Mokola Road showed a strong correlation ($R = 0.9333$) with a high coefficient of determination ($R^2 = 0.9876$), indicating that traffic speed variations were highly dependent on density. In contrast, the Mokola–Agodi Road revealed a lower correlation ($R = 0.8762$, $R^2 = 0.7863$), signifying a more complex interaction between traffic density and speed due to road conditions and disruptions. Key findings show that while both roads experience congestion, Mokola–Agodi Road faces higher traffic loads, necessitating improved traffic management strategies. The study's predictive models provide valuable insights into traffic behavior, offering a foundation for policy recommendations aimed at mitigating congestion and enhancing road efficiency in Ibadan. These findings contribute to urban transport planning and support evidence–based infrastructure improvements for better road utilization and traffic safety.
Keywords: Speed–density relationship, traffic volume forecasting, regression analysis, space–mean speed, Ibadan

1. INTRODUCTION

The highway network is a fundamental aspect of any transportation system, particularly in developing countries like Nigeria, where it serves as the primary means of transportation (Patience et al., 2020). In Nigeria, two-lane highways, or single carriageways, constitute a significant part of the road infrastructure, supporting both local and interstate travel (Nemanja et al., 2023). These roads are pivotal for the efficient movement of people and goods, directly influencing the socio-economic activities of the population. The efficiency of traffic flow on these highways is essential for the optimal operation of the transportation system, and maintaining an effective flow is vital for ensuring that these roads can meet the demands placed on them. In this context, the study of traffic flow becomes essential in managing the capacity of the road network, especially in urban areas such as Ibadan, Nigeria's third-largest city.

Traffic flow is the interaction between vehicles, drivers, and the infrastructure itself, and can be classified as either free-flowing or constrained (Abdulsattar et al., 2020; Al-Turki et al., 2021). The free-flow condition occurs when traffic moves without significant delay or hindrance, whereas constrained flow happens when congestion sets in, reducing speed and efficiency (Sougata, 2017). Traffic volume refers to the number of vehicles passing a given point within a set time period, usually expressed in vehicles per unit of time. The Average Daily Traffic (ADT) metric quantifies the volume of vehicles over a 24-hour period, providing a clearer understanding of the traffic demands on a road segment (Acheampong, 2020).

Traffic volume data are crucial for making informed decisions about road design, maintenance, and planning. On highways, congestion is a common issue, particularly when traffic density increases, causing a decline in the speed of vehicles. This scenario is prevalent on secondary roads, where an influx of vehicles leads to slower speeds and increased interaction between road users, ultimately resulting in traffic congestion. As density increases, the road becomes congested, and the traffic speed decreases, making it essential to understand the relationship between speed and density to better manage congestion (Afrin & Yodo, 2020). Several models have been proposed to explain this relationship, notably the seminal studies by Drličiak et al. (2020) and Karbasi et al. (2022), which primarily examined expressways. However, these studies are often limited in scope, focusing on specific road sections or time periods, and may not be directly applicable to urban areas with varying traffic conditions.

Traffic engineering, as a discipline, applies engineering principles to improve the safe and efficient movement of vehicles and pedestrians on roadways. Understanding traffic flow, which is influenced by three key parameters volume, speed, and density is essential for effective traffic management and planning (Nemanja et al., 2023). In the absence of adequate planning and traffic management, the current road infrastructure may fail to meet the growing needs of the city (Ariyo et al., 2023). Over the years, increased pedestrian and vehicular volumes, driven by changes in the socio-economic dynamics of the middle class, have exacerbated congestion in urban areas like Ibadan (Salisu et al., 2020).

The objective of this study is to comparatively analyze the predictive models and daily traffic counts of two-lane highways in Ibadan: the Ojoo to Mokola roundabout section and the Mokola to Agodi Gate road, by conducting primary traffic flow surveys. The study aims to compare the daily traffic counts and model variables of the roads.

This study uses the Linear Speed-Density Regression Model due to its simplicity, ease of application, and strong theoretical grounding (Lighthill & Whitmann, 1955). It also aligns with studies that observed good predictive strength in urban two-lane road scenarios (Stepanović, Tubić, & Zdravković, 2003).

The problem of traffic congestion in Ibadan has been particularly pronounced during peak hours, where increased vehicle numbers and limited road capacity result in slower traffic movement and longer travel times. Several traffic volume models have been proposed in previous studies to analyze congestion; however, these models often fail to account for the varying conditions of different roadways, traffic types, and control measures. To address this issue, dynamic traffic data capturing and analysis systems are necessary to support civil engineers in implementing improvement schemes (Wegener, 2021). The development of speed-density models for the selected two-lane highways in Ibadan is essential for understanding and estimating traffic volume under varying conditions, particularly in areas with heavy traffic. This study, therefore, aims to contribute to the development of a predictive speed-density model that can be used for traffic volume forecasting and congestion management on Ibadan's two-lane highways.

This study seeks to make a comparative analysis between the two-lane highways in Ibadan metropolist, Nigeria. This work is crucial for making comparison and enhancing the efficiency of traffic flow in Ibadan, thereby contributing to better road usage and improved road safety, which is an urgent need for urban areas experiencing rapid growth and congestion (Zhu et al., 2023).

2. METHODOLOGY

Traffic Survey

Traffic survey was conducted on two selected roads within Ibadan metropolis, Oyo State. The roads selected for the survey include:

- Ojoo - Mokola Roundabout (Old Oyo Road)
- Mokola - Agodi (Queen Elizabeth) Dual CW, Mokola bound

These roads were chosen based on the frequent traffic congestion experienced on certain segments during peak traffic hours: morning peak (7:00 AM to 9:00 AM) and evening peak (4:00 PM to 6:00 PM). The Old Oyo Road features two lanes with a carriage width of 7.3 meters and an existing shoulder width of 1.5 meters. The road begins at the Ojoo Market junction, passes through the Ibadan Toll Gate, and extends to the Ogun State border. This highway is known for frequent accidents involving heavy trucks and trailers, including skidding and head-on collisions.

Data Collection

Traffic data on the selected roads was collected through videographic recording using a Canon Vixia HF R800 video camera, capturing traffic flow during the morning and evening peak periods from 7:00 AM to 7:00 PM, between August 26 and September 6, 2019. The study considered seven traffic categories: Motorcycles, Tricycles, Cars, Taxis, Buses, Light Trucks, and Heavy Trucks. Hourly traffic counts were conducted over five consecutive weekdays, with the total count for each period systematically recorded by playing back videos.

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

Model Formation and Calibration

The relationship between space mean speed and density was modeled using a linear equation, as shown below:

$$y = b + cx \tag{1}$$

Where: y is the Flow (q), x is the density (k), R is the correlation coefficients b and c is the constants to be determined,

$$R = \frac{\sum[(x-\dot{x})(y-\bar{y})]}{\sqrt{\sum(x-\dot{x})^2}\times\sqrt{\sum(y-\bar{y})^2}} \tag{2}$$

$$c = \frac{n(\sum xy)-(\sum x)(\sum y)}{n\sum x^2-(\sum x)^2} \tag{3}$$

$$b = \bar{y} - c\dot{x} \tag{4}$$

Where: $\bar{y}$ and $\dot{x}$ are the average values of y and x respectively.

Calculation of Flow, Speed, and Density

Traffic flow q is defined as the number of vehicles n passing a given point on the highway during a time interval t, as expressed in Equation 5:

$$q = \frac{n}{t} \tag{5}$$

Where q is the traffic flow (veh/hr), n is the number of vehicles, and t is the time interval in hours.

Traffic density k is defined as the number of vehicles per unit length of highway, calculated using Equation 6:

$$k = \frac{n}{L} \tag{6}$$

Where L is the length of the highway under study (in kilometers) and n represents the number of vehicles passing through a given section.

3. RESULTS AND DISCUSSION

Daily Traffic Counts Along Ojoo - Mokola Road

Table 1 shows the traffic volume data across five days highlights key trends in vehicle movement. The highest congestion occurred between 17:00 - 18:00, with a total of 12,800 vehicles, followed by 16:00 - 17:00 (12,311) and 15:00 - 16:00 (11,991). Morning peak hours, particularly 7:00 - 8:00 and 8:00 - 9:00, also recorded significant volumes, averaging over 10,000 vehicles each. A sharp drop was observed on Thursday morning (especially from 7:00 - 9:00), suggesting potential road restrictions or unusual conditions. The data indicates that late afternoons and early evenings experience the highest traffic flow, necessitating targeted congestion management strategies during these peak periods.

Table 1: Daily Traffic Counts Along Ojoo – Mokola Road

Time Interval (hrs.)	Monday (26/08/19)	Tuesday (27/08/19)	Wednesday (28/08/19)	Thursday (29/08/19)	Friday (30/08/19)	Total
7:00 – 8:00	2739	2137	2410	40	2943	10269
8:00 – 9:00	1471	2829	2863	35	3050	10248
9:00 – 10:00	1038	2580	2336	845	2626	10425
10:00 – 11:00	972	2660	2165	2608	2717	11122
15:00 – 16:00	658	3134	2533	2970	2660	11991
16:00 – 17:00	766	2926	2945	2871	2803	12311
17:00 – 18:00	1077	2975	3182	2687	2879	12800
18:00 – 19:00	943	2671	2232	2456	2305	10607

Figure 1 depicts the hourly traffic counts recorded along the Ojoo-Mokola Road for five weekdays (August 26, 2019, Monday through August 30, 2019, Friday).The horizontal axis shows the hourly intervals from 7:00 - 8:00 to 18:00 - 19:00, while the vertical axis shows the number of vehicles passing each hour. Each colored bar represents a specific day of the week, and the green bar labeled indicates the combined traffic count for all five days in that hour.

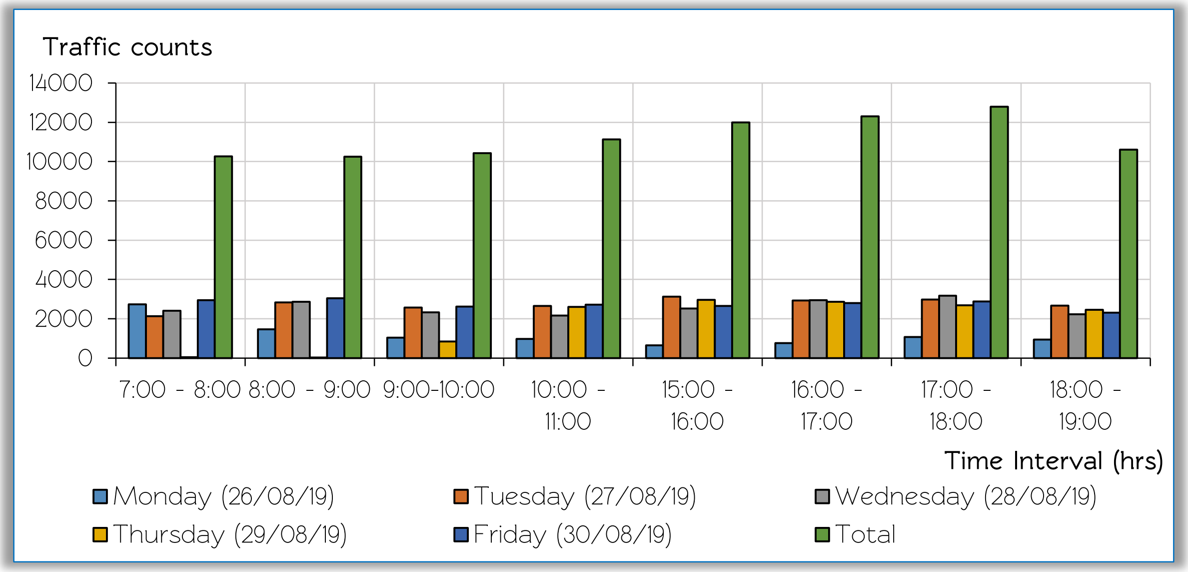

Figure1: Daily Traffic Counts Along Ojoo – Mokola Road

The shorter bars in figure 1, show that traffic volumes varies from one day to another, indicating some fluctuation in demand or travel behavior across the weekdays. Morning hours (7:00–10:00), exhibit moderate traffic, reflecting commuters heading to work or school. Midday (10:00–14:00), traffic may ease or fluctuate based on lunch breaks or errands. While late afternoon to early evening (14:00–19:00): Bars in these intervals generally reach their highest points, suggesting a strong evening peak when people return from work or school. The Total bar (green) consistently surpasses individual daily counts, indicating the combined hourly flow across all five days. The highest total typically appears in the late afternoon/early evening (e.g., 16:00–17:00 or 17:00–18:00), underscoring a pronounced peak period. For the vertical scale (up to 14,000 vehicles) highlights that the busiest hours can see well over 10,000 vehicles across the five days combined. This large cumulative volume suggests heavy usage of the Ojoo-Mokola corridor during specific peak times. Conclusively, figure 1, reveals a distinct morning and more noticeable evening peak, varying daily traffic volumes, and significant cumulative flows toward the end of the day. This information is essential for transport planning and peak-hour management, helping to guide decisions on road improvements, public transit strategies, or travel demand measures.

Daily Traffic Counts Along Mokola - Agodi Road

Table 2 depicts the traffic volume data for the week of September 2 to 6, 2019 indicates peak congestion during afternoon and early evening hours, with the highest traffic recorded between 15:00 - 16:00 (20,701 vehicles). The morning rush hours (7:00 - 11:00) also experienced significant traffic, particularly on Monday and Friday, with vehicle counts exceeding 4,000 in some slots. Thursday had notably lower traffic in the early morning hours (7:00 - 9:00) but showed an increase later in the day. The 17:00 - 18:00 period saw a significant drop in traffic on Wednesday compared to other days. The overall trend suggests heavier traffic in the afternoons and early evenings, highlighting the need for congestion management strategies during these peak times.

Table 2: Daily Traffic Counts Along Mokola – Agodi Road

Time Interval (hrs.)	Monday (02/09/19)	Tuesday (03/09/19)	Wednesday (04/09/19)	Thursday (05/09/19)	Friday (06/09/19)	Total
7:00 – 8:00	4236	3876	4116	468	4203	17415
8:00 – 9:00	3801	3397	3950	534	4776	15885
9:00 – 10:00	3582	3062	3388	3554	3410	16996
10:00 – 11:00	3401	2964	2988	4472	3578	17403
15:00 – 16:00	3612	4378	3559	4003	4548	20701
16:00 – 17:00	3666	3067	3236	4423	3406	16157
17:00 – 18:00	4454	4604	2775	3866	3604	16978
18:00 – 19:00	3339	2754	2229	3455	2691	14468

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

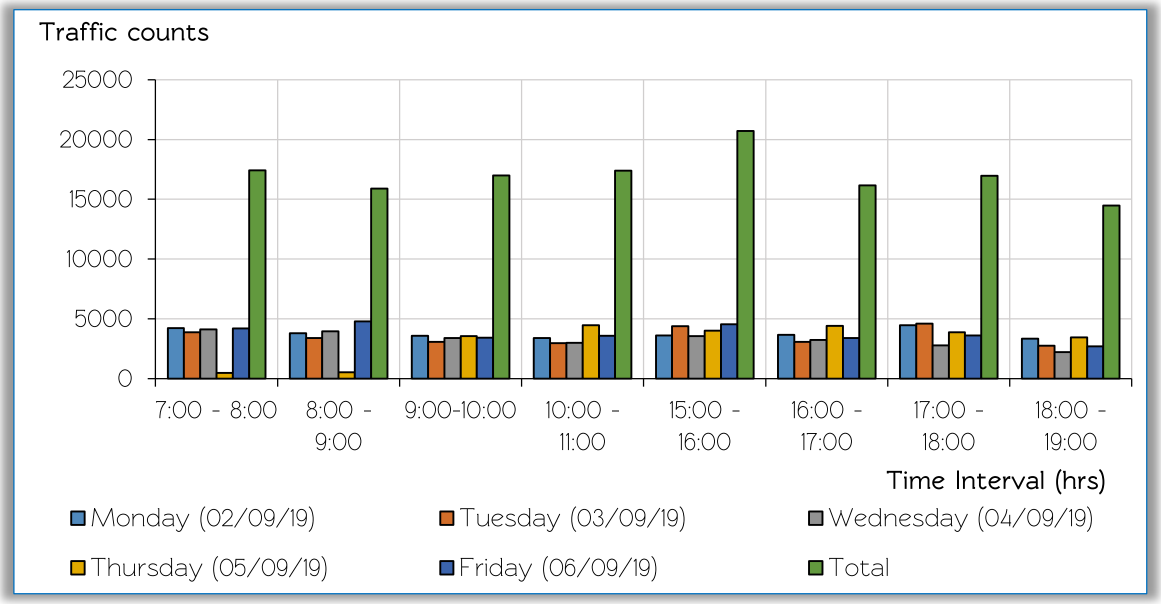

Figure2: Daily Traffic Counts Along Mokola – Agodi Road

Figure 2 illustrates hourly traffic counts along the Mokola-Agodi Road for five weekdays (Monday, September 2, 2019, through Friday, September 6, 2019). The horizontal axis shows time intervals from 7:00–8:00 up to 18:00–19:00, and the vertical axis represents the number of vehicles recorded during each hourly slot. Each color-coded bar corresponds to a specific day, and the green bar labeled combines the traffic from all five days for that particular hour. The shorter bars depict day-to-day differences in traffic flow, reflecting changing travel patterns throughout the workweek. Monday (blue bar) may display a certain trend, while Tuesday (orange), Wednesday (gray), Thursday (yellow), and Friday (light blue) can each show unique peaks or troughs based on daily routines or external factors. Morning Hours (7:00–10:00): These intervals often show moderate to increasing traffic as commuters travel to work, school, or other engagements. Midday (10:00–14:00): Traffic volumes may stabilize or fluctuate depending on lunchtime movements and errands. Late Afternoon to Early Evening (14:00–19:00): Bars in this timeframe typically grow taller, indicating an evening peak as individuals head home or run after-work errands. The Total bar (green) generally surpasses the daily bars, representing the sum of traffic across all five days in each hourly interval. Highest totals commonly occur late in the day (e.g., 16:00–17:00 or 17:00–18:00), suggesting a prominent evening rush with high vehicle counts. The vertical scale extends to 20,000 vehicles, showing that combined traffic can exceed 15,000 vehicles per hour during peak times. Such volume underscores the significant usage of the Mokola-Agodi corridor and the need for careful planning to accommodate high-demand periods.Conclusively, figure 1, reveals distinct morning and stronger evening peaks, varied daily flows, and notably high cumulative volumes in the late afternoon, making it a valuable reference for transport policy and operations on Mokola-Agodi Road.

Comparative analysis of the Daily Traffic Counts between Ojoo - Mokola Road and Mokola - Agodi Road

The overall traffic volumes Ojoo-Mokola Road (Figure 1) Indicates moderate to high traffic volumes but on a smaller scale compared to Mokola-Agodi Road (Figure 2) reflecting higher peak volumes, suggesting that Mokola-Agodi Road experiences heavier traffic flow during certain hours. In conclusion Mokola-Agodi Road exhibits significantly higher total hourly volumes than Ojoo-Mokola Road, possibly due to differences in road capacity, land use, or commuter patterns.

For the Peak Periods and Hourly Patterns both roads experience a strong evening peak, but Mokola-Agodi consistently shows larger total counts in the same time intervals.

In terms of day-to-day variation, both roads exhibit day-to-day variability, but Mokola-Agodi's daily volumes are higher. This may indicate that Mokola-Agodi serves more trips or is a busier corridor during weekdays.

Conclusively, these differences highlight the relative significance of Mokola-Agodi Road in handling higher traffic demands, while Ojoo-Mokola Road, though still busy, accommodates a smaller traffic volume during the same hourly intervals.

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

Comparative Analysis of the predictive model of Ojoo - Mokola Road and Mokola - Agodi Gates

The predictive speed-density models for both roads were compared in Table 3, highlighting differences in key traffic characteristics.

Table 3. key differences in traffic characteristics for Ojoo – Mokola Road and Mokola – Agodi Gates.

Name of Road	Number of Lanes	Correlation Coefficient, R	Coefficient of Determination, R^2	Model Equation	Jam Density (veh/km)k_j	Free Flow Speed (km/hr)
Ojoo – Mokola	2	0.9333	0.9876	u= 1.286k + 58.67	45.62	58.67
Mokola – Agodi	2	0.8762	0.7863	u= 29.76 + 0.1268k	234	29.76

The study on the predictive speed-density relationship for traffic volume forecasting on two-lane highways in Ibadan, Nigeria, focused on two primary roads: Ojoo - Mokola Expressway and Mokola - Agodi Gates (Queen Elizabeth Road). The research aimed to explore the correlation difference between traffic density (k) and space-mean speed (u), and their predictive models. The results suggest strong linear relationships between speed and density, although with varying degrees of fit and traffic flow characteristics across the two roads.

For the Ojoo - Mokola Expressway, the model produced a high correlation coefficient (R = 0.9333) and a high coefficient of determination (R^2 = 0.9876), indicating that 98.76% of the variation in space-mean speed could be explained by the traffic density on the road. This road's higher R value suggests that the data has minimal variation, thus allowing for a more accurate prediction of traffic speed based on density. The model derived, u = 1.286k + 58.67, reveals that traffic speed decreases as density increases, a trend confirmed in the literature (e.g., Lighthill and Whitham, 1955), which correlates with findings that a congested roadway causes slower vehicle speeds. The free flow speed (58.67 km/hr) on this road corresponds to the design speed, where density is zero.

For the Mokola - Agodi Gates, the regression analysis revealed a moderate correlation (R = 0.8762) with a lower R^2 of 0.7863, indicating that 78.63% of the variation in speed is explainable by the density. This road's relatively lower correlation is attributed to its physical and operational characteristics, such as the presence of dilapidated road sections and frequent traffic disruptions, which reduce traffic flow. The derived model, u = 29.76 + 0.1268k, suggests a lower free flow speed of 29.76 km/hr, likely influenced by the substantial presence of heavy-duty trucks and accident-prone zones, which often slow down the overall traffic speed. This is consistent with the observations of other studies (Greenberg, 1959), where composition traffic significantly impacts flow and speed dynamics.

The traffic flow, which is higher on the Mokola - Agodi Road, can be attributed to alternative route options available to commuters. This road also has higher traffic volume, possibly due to its proximity to business hubs and the high frequency of commercial vehicles.

4. CONCLUSION

This study demonstrates that the speed-density relationship can be effectively used to predict traffic flow and optimize highway management. The research highlights the significant role of road conditions and traffic composition in shaping this relationship, with implications for better traffic forecasting and infrastructure planning. The differences observed between the two roads underscore the need for context-specific traffic models that account for local road features and vehicle types. The comparison revealed that the Ojoo-Mokola road has a higher R value, indicating a better fit for the speed-density model, and the free-flow speed is higher compared to the Mokola-Agodi road, which is influenced by several factors such as road conditions and traffic composition. The coefficient of determination (R^2) for the Ojoo-Mokola road (0.9876) suggests that a significant proportion (98.76%) of speed variation can be explained by the density, while for the Mokola-Agodi road, R^2 is 0.7863, indicating that only 78.63% of the variation in speed is explained by the density.

Recommendations:

- The study suggests the need for improved traffic management strategies, especially on roads like Mokola - Agodi, where heavy-duty vehicles and road conditions limit flow. Measures such as road repairs and dedicated lanes for trucks could improve traffic speeds.
- Efforts should focus on maintaining the road surface quality and addressing conflict zones on roads like Mokola - Agodi, which would help improve speed consistency and reduce congestion.

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

- Future studies should explore the impact of other variables, such as weather and traffic signals, on the speed-density relationship. Additionally, expanding the study to cover more diverse road types in Ibadan could provide a more comprehensive model for the region.
- Implementing real-time traffic monitoring and adaptive signaling could help reduce congestion and optimize traffic flow on both highways, especially during peak hours.

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ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665