2025 Scienceline Publication

Journal of Civil Engineering and Urbanism

Volume 15, Issue 3: 112-129; September 25, 2025 ISSN-2252-0430

DOI: https://dx.doi.org/10.54203/jceu.2025.7

Assessment of the Level of Urban Traffic Congestion for Improved Mobility: Case Study of Selected Intersections in Ibadan, Nigeria

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RESEARCH ARTICLE
PII: S225204302400007-14
Received: May 05, 2025
Revised: September 20, 2025
Accepted: September 22, 2025

ABSTRACT

The traffic problems in Ibadan can be primarily attributed to inadequate road infrastructure and a shortage of traffic control personnel. The objective of this study is to assess and analyze the current level of urban traffic congestion at specific intersections in Ibadan. A comprehensive traffic survey was conducted using a manual methodology for counting traffic volume. The volume to capacity ratio was employed to assess the levels of service at the Sango – Polytechnic Ibadan Road intersection, while the Kimber empirical regression technique was utilized to evaluate the capacity of the Iwo Road Intersection. The results indicated that the volume to capacity ratio at the Sango-Polytechnic Road Intersection ranges from 0.71, 0.72 and 0.74, resulting in consistent Levels of service classified as C. In contrast, the volume to capacity ratio at the Iwo Road Intersection ranges from 0.73, 0.77, 0.76, 0.90 and 0.96, corresponding to Levels of service classified as C, D and E. A questionnaire survey data was analyzed utilizing the Relative Important Index (RII) to ascertain the ranking of factors that contribute to and influence congestion at the selected intersections. The main factors contributing to congestion identified by the respondents are presence of a roadside market with RII of 0.888, lack of parking facilities resulting to on street parking with RII of 0.878, increased population with RII of 0.820, peak hour congestion with RII of 0.810 and poor driving behaviors with RII of 0.807. Binary logistic regression analysis shows that factors with RII ≥ 0.80 have high rating and R-square Nagelkerke of the model shows 95% of the variance in explanatory variables indicating that the overall model fit is good. The analysis demonstrated that well-designed and accessible pedestrian walkways can significantly reduce congestion caused by the factors, thereby fostering a more vibrant urban environment.

Keywords: Traffic congestion, Intersection, Level of service

INTRODUCTION

Traffic congestion can result from various sources, including traffic incidents, work zones, weather, special events, recurring congestion, and nonrecurring congestion (Jilani et al., 2023). Bad roads, poor traffic management, weak traffic rules, and not enough traffic control staff are some of the main reasons for traffic issues. Therefore, an effective traffic management system is no longer merely a desirable enhancement, it has become a necessary component for addressing traffic related issues in a systematic manner (Aleksander et al., 2016). The ability to navigate urban environments is essential for fostering social connections, as there is a growing need for individuals to travel within cities (Getu et al., 2019). Traffic congestion poses considerable economic challenges, as it can adversely affect businesses and render a city less attractive Naveed et al. (2024). In response to these concerns, a substantial number of studies have been conducted to investigate the business implications of urban traffic congestion, revealing its significant impact on commuters, which often manifests in wasted time and lost business opportunities (Choudhary et al., 2022). Lwesya et al. (2021) found that traffic congestion restricts mobility, interferes with city business, and reduce productivity, collectively affecting local and national economics which poses a significant threat to urban quality of life. Peak traffic in urban areas typically occurs during morning and evening hours, primarily attributed to the committing patterns of individuals travelling to and from their workplaces. As the demand for transportation services increasing at an unprecedented rate, there is a pressing necessity for the development of efficient transit infrastructure (Patience and Chidinma, 2020). Cities frequently encounter traffic congestion, which can be attributable to a range of factors, including the inefficiency of public transportation systems, thereby leading to an increased reliance on private vehicles; in addition, the existing street networks often prove insufficient in accommodating the increasing demand for urban traffic (Lu et al., 2021). Furthermore, the adverse impacts of traffic congestion on societal and economic stability have increased in recent years (Almatar and Almulhim, 2021).

An intersection is a key part of urban roads where two or more roads meet with a provision for changing route of directions and a well-designed intersections help make the whole road system safer and work better (Atomode, 2013). Basically, intersections can be classified into three categories: At grade, Grade – separated without ramps and Grade – separated with ramps intersections (Garber and Hoel, 2009). An example of the strained infrastructure is the road network, which plays a crucial role and has numerous dependencies, as it is the most economical mode of transportation (Udoakah and Okure, 2017). Designing an intersection well and maintaining traffic is important for better traffic flow and safety on the roads (Lee and Chiu, 2020). Muhammad et al. (2025) emphasizes the critical role of road maintenance in minimizing travel delays. Similarly, Xiaofeng and Zhenshun (2020) propose that the implementation of efficient public transport systems can significantly alleviate traffic congestion. In the context of Ibadan, the advancement of public transportation has been recognized as the most promising solution with challenges related to institutional frameworks and funding continue to pose significant obstacles (Julius et al., 2020).

Level of Service (LOS) was conceptualized in the second volume of the Highway Capacity Manual (HCM) 2010. LOS is defined as "a quality measure describing operational conditions within a traffic stream, generally in terms of such service measures as speed and travel time, freedom to maneuver, traffic interruptions, comfort, and convenience (HCM, 2010). The conventional HCM methodology uses six LOS classes: A to F. LOS A defines the 'best' riding condition while LOS F defines the 'worst'. Laoye et al. (2016) studied how congestion happen on the main roads in Akure, Nigeria. They gathered information on how many vehicles used certain parts of the roads, and recorded the speed, numbers of cars, delays and time between cars at intersections. And from the data analysis they found the following key measurements: volume – capacity ratio, minimum speed allowed, jam density and critical delay and all these were used to assess traffic congestion and the finding concluded that certain routes exhibited moderate congestion, while others experienced severe congestion.

Dukiya et al. (2011) investigated the factors contributing to delays, wasted time, and traffic issues at city intersections in Lagos, Nigeria, utilizing congestion index parameters to assess congestion levels. The finding indicated that the intersections were classified into service levels B, C, D and E, with the most significant delays occurring in the evening when traffic wardens were directing vehicles.

The objective of this research is to assess and analyze the current level of urban traffic congestion at specific intersections in Ibadan. A comprehensive Traffic survey was conducted, utilizing a manual methodology for traffic volume counting and the volume to capacity ratio was employed to assess the levels of service (A – F) at the Sango – Polytechnic Ibadan Road intersection. Additionally, the Kimber empirical regression technique which is a statistical approach employed in transportation engineering to examine the relationships between various variables, especially in relation to traffic flow and congestion. This method was utilized to generate a dataset evaluation that aids in predicting traffic patterns, capacity and the level of service based on the empirical data collected from traffic studies conducted at the Iwo Road Intersection. This data is important for decision – makers and city planners so they can use the right methods to mitigate problems at the selected intersections in Ibadan.

MATERIALS AND METHODS

Description of the study area

This research focused on Sango – Polytechnic Ibadan Road intersection and the Iwo Road intersections. Figure 1 shows the Sango – Polytechnic Ibadan Road intersection where many roads meet. It is located in the Ibadan North – west area of Ibadan, Oyo state at a latitude of 7.4307°N and a longitude of 3. 8872°E. The Intersection is a three legged type with Eleyele – Polytechnic Road serving as the minor Road and Sango – Mokola Road serving as the major Road.

The approach Legs for the purpose of the study, the intersection was referred to as;

- Leg A is for Sango – Ojoo Road
- Leg B is for Sango – Mokola Road
- Leg C is for Eleyele – Polytechnic Ibadan Road

Figure 2 shows the Iwo Road intersection, which is a very busy and well – known spot in Ibadan. The intersection is located in the Ibadan North – West area of Ibadan, which is in Oyo state and a latitude of 7.3775°N and a longitude of 3.8964°E. It has two ramps, and it is the largest roundabout in the state that connects five main roads (Salami, 2021). It also joins two highways coming from Ife and Iwo towns in Osun state, as well as the road from Lagos, Ibadan, and Ojoo at the Lagos – Ibadan Expressway. The parameters considered to determine the performance of the intersection, are generally traffic flow and geometric characteristics. The reconnaissance carried out offers an opportunity to gather sufficient information including location, description, traffic flow, density, headway and nature and condition at the roundabout. The approach roads for the purpose of the study, the Iwo road roundabout was referred to as:

- Leg A is for Lagos Road
- Leg B is for Gate Road
- Leg C is for Ojoo Road
- Leg D is for Iwo Road
- Leg E is for Ife Road

Figure 1. Geographical view of Sango- Polytechnic Ibadan Road Intersection

Figure 2. Geographical view of Iwo Road Intersection

Materials used for field survey and traffic count

Materials for this research work include, measuring tape, field book, pen/pencils and camera.

- Measuring tape: This tool is essential for accurately measuring distances, widths of roads and lane dimensions.
- Field book: This is an essential tool for ensuring accurate data collection and documentation during traffic counts and surveys, enabling thorough analysis and informed decision-making.
- Pens / pencils: These instruments are necessary for taking notes, recording observations and documenting measurements during field surveys.
- Camera: This instrument is used to document visual aspects of the traffic environment such as conditions, traffic patterns and any unusual occurrences.

Method used for the collection of traffic parameters along the selected intersections

A) Survey of the Sango - Polytechnic Ibadan road intersection and Iwo road intersection

A manual traffic count was done with ten observers. The types of vehicles were recorded and the directions of the vehicles using hand tally counters for five consecutive days (Monday to Friday) and for ten hours each day (8 am to 6 pm). At each counting spot vehicles going to and fro was recorded, as well as those turning right, left and going straight. Composition of traffic such as Motorcycles, Tricycles, Cars, Buses, 2 wheeler and Truck ply the intersections. The passenger car equivalents were used to convert the traffic volume to passenger car units per hour (Pcu/hr). The study focused on three key aspects of traffic flow at selected intersections: vehicle composition, hourly share of vehicles, and volume variation of traffic. Vehicle composition involves categorizing the types of vehicles that pass through the intersections, hourly share of vehicles examines the distribution of different vehicle types over the course of an hour and volume variation evaluate the changes in the number of vehicles using the selected intersections over time. The data collection process involved manually counting traffic flow, headway and density at various intersections. This involved observing and recording the number of vehicles passing a specific point within a designated time frame (traffic flow), the time interval between successive vehicles (headway), and the number of vehicles present in a given length of roadway (density). This comprehensive approach allowed for an accurate assessment of traffic patterns and conditions at the intersections being studied.

B) Detailed procedure for measuring and analyzing traffic density at the intersection location

A segment of the intersections was selected and measured during the traffic survey and equation 1 below was used to determine the speed of the vehicle at the intersections.

$$q = uk \tag{1}$$

Where q is traffic flow rate(vehicles/time), u is average speed of vehicles (distance/time) and k is traffic density(vehicles/distance). To perform the analysis, a systematic counting of vehicles occupying the selected segment was conducted. This involved tallying the number of vehicles that traversed the segment within a specified time frame. The total count of vehicles was then divided by the length of the segment that was measured, providing a quantitative representative of traffic flow dynamics. By applying this method, a key insight into vehicle speed, traffic density and flow rate at the intersection segments was obtained which are essential for understanding traffic patterns and for informing transportation planning and policy decisions.

C) Detailed procedure to compute time headway along the intersections

A specific measuring point was established along the selected intersection for the purpose of quantifying vehicles spacing and recording time intervals. A measuring tape was employed to accurately determine the distance between successive vehicles within the traffic flow. The measurement process involved assessing the distance from the front bumper of one vehicle to the front bumper of the following vehicle travelling in the same direction. To facilitate the recording of time intervals, a stopwatch was utilized. The stopwatch was activated as the front bumper of the lead vehicle crossed the designated measuring point and collection of data was done to captured the traffic scenario. It was subsequently stopped when the front bumper of the subsequent vehicle reached the same point. This systematic approach to measuring vehicle spacing and timing enables an accurate evaluation of traffic dynamics at the intersection, facilitating a deeper understanding of vehicle interactions and congestion patterns and camera was used to captured the traffic conditions at the intersections.

D) Use of levels of service (LOS) approaches to assess congestion at the selected intersections

The Highway Capacity Manual (HCM), 2010 used the LOS method because it is easy to understand, and it is typically rated at a scale from A to F. The Level of Service was determined using Theoretical Maximum Capacity (TMC) procedures and compared with the Technical Standard Method (TSM). Levels of Service (LOS) Based On the Corresponding Volume to Capacity Operating Conditions with A represent free flow ranges from 0.00-0.60, B represent Stable flow with unaffected speed ranges from 0.61-0.70, C represent Stable flow but speed is affected and ranges from 0.71 -0.80, D represent High density but the stable flow and ranges from 0.81 -0.90, E represent Traffic volume with low speed and ranges from 0.91 - 1.00 and F represent forced or breakdown flow which is greater than 1.00 (Roess et al., 2011).

Method for estimating the capacity of Sango – Polytechnic Ibadan road intersection

As shows in Equation 2 and 3 the study adopted the Highway Capacity Manual (HCM), 2010 measure called the volume to capacity ratio to evaluate how well the intersection is operating.

$$\mathrm{V:C} = \frac{\mathrm{V_m}}{\mathrm{C}} \tag{2}$$

Where V:C is Volume to Capacity ratio and V_m is Maximum hourly volume (pcu/hr)

$$\mathrm{V_m} = \frac{\mathrm{V_p}}{\mathrm{PHF}} \tag{3}$$

Where V_p is passenger equivalent volume for peak period and $PHF$is Peak hour factor which is usually (0.92).

The kind of intersection determine the type of traffic it can handle. It’s determined by the number of intersections and lanes on main roads and smaller roads. As used by Manual of Guidelines for road construction (1997) the intersection code is 322 with 3 number of intersections Arm, 2 numbers of Minor road lanes and 2 number of main road lanes and the basic capacity for all the legs is 2700 Pcu/hr.

Method of estimating the capacity of Iwo Road intersection

The Kimber model is an empirical analysis method used to analyze the Iwo Road intersection. It shows the capacity of entering, $Q_{e,}$ as a straight – line relationship with the flow of circulation using a method that looks at real experiences. This study employed a systematic methodology to evaluate the traffic capacity of the Iwo Road Intersection. It analyzed various data factors, including the geometric design of the roundabout, the volume of traffic and to ascertain the intersection’s traffic handling capacity, a comprehensive traffic count was conducted at each approach leading to the intersection. This involved measuring the volume of vehicles in all directions. The number of vehicles was changed into a measure called Passenger Car Equivalent (PCE), which is shown as Passenger Car Units per hour (Pcu/hr) to analyzed traffic operations.

Iwo road intersection capacity analysis procedure

In the study conducted by the Transportation Research board (2007), the concept of demand volume movement was revised to reflect flow rates with a peak hour of 0.94. flow rates for heavy vehicles were adjusted to account for a demand proportion of 20% for heavy vehicles, with a conversion rate of 1.0 passenger car equivalent for standard vehicles and 2.0 passenger car equivalents for heavy vehicles. The circulating flow rate was analyzed across all approach legs, and entry volumes were measured in terms of passenger cars. Additionally, the exiting volume was evaluated based on passenger car equivalents, leading to the calculation of the volume- to-capacity ratio.

Using of statistical model to predict the factors that contribute significantly to the performance of the selected intersections

A) Research design

The research plan for this study used a qualitative method because it helps meet the study's goals. This involves a detailed questionnaire for road users, including drivers and passengers. It also includes analyzing the survey data using statistical and descriptive information. The survey data include:

- Identification of factors affecting the road users along the intersection
- Identification of factors contributing to the performance of the intersection.
- Preparation of the questionnaire
- Identify the targeted response group
- Distribute the questionnaire to the targeted response group
- Data collection and analysis
- Statistical analysis and modelling

B) Questionnaire development

A questionnaire, as explained by Sreejesh (2014), is a set of organized questions given to people during an interview. It comes with clear instructions on how to ask the questions and chose who will answer them. The study used a qualitative method with a carefully designed questionnaire to gather information from drivers and commuters at the intersections. These questionnaires were administered by the researcher physically. The survey for this study was made using the multiple choice questions format wherein Section A contained the Respondents' Background information, Section B, the factors that contribute significantly to the performance of the selected intersection and Section C, the effect of Traffic congestion that contribute significantly to enhancing the performance of the selected intersections. The equation for estimating the sample size of respondents developed by Cochran (1953) is presented in equation 4. This equation was used to estimate the sample size required for this research.

$$n = (Z^2 \times p \times (1 - p)\varepsilon^2 \tag{4}$$

where n is the sample size, Z is the desired confidence level which is 1.96 for a 95% confidence level, p is the estimated proportion of the population which is 0.5 which gives the most conservative, largest sample size and ε is the desired margin of error also called the confidence interval, which is 5%.

Sample size $= 1.96^2 \times 0.5 \times (1 - 0.5))/\ 0.05^2$
Sample size = 384
And Response Rate of 65% was used
Sample size = 384 × 0.65
Sample size = 250 Respondent

C) Relative importance index analysis

The Relative Importance Index (RII) is a quantitative technique employed primarily in fields such as social sciences, and engineering to evaluate the significance of various factors, attributes or variables in relation to a specific outcome or goal. The methods provide a way to rank the congestion variables based on their perceived importance, as determined by the perspectives of stakeholders or subject matter experts. RII is used in project management to prioritize project risks or determine the most critical success factors (Saleh et al.,2013). The respondent's opinions about the different rankings in the questionnaire survey were measured using the Relative importance index (R.I.I) method. The relative index (R.I.I) was found using the formula shown in the equation 5.

$$\text{RII} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{A \times N} \tag{5}$$

For (0 ≤ R.I.I ≤ 1)

Where; n_5 is for how many respondents strongly agree, n_4 is for how many respondents agree, n_3 is for how many respondents neither agree or disagree, n_2 is for how many respondents disagree, n_1 is for how many respondents strongly disagree, N is total number of respondents, A is highest weight.

The RII values can be interpreted as follows:
$\text{RII} < 0.60$, items is assessed to have low rating,
0.60 ≤ RII < 0.80, item assessed to have high rating,
RII ≥ 0.80, item assessed to have very high rating.

Likert scale showing ranking and weights of the responses of the road users and the drivers is shown in Table 1.

Table 1. Likert scale: Ranking and weights Assigned by respondents

Item	Strong Agreement	Little Agreement	May or May not Agree	No Agreement	Virtually No Agreement
Description	Strongly Agree	Agree	Neither Agree or Disagree	Disagree	Strongly Disagree
Weights	5	4	3	2	1

Binary logistic regression model analysis

Binary regression analysis is a statistical method used to model the relationship between a binary dependent variable; a variable that can take only two values which is (congestion status) often coded as 0 and 1 and one or more independent variables: predictors which are (Road side market, No parking lot, increased population, Peak congestion and poor driving. It's a form of regression analysis, but specifically designed for situations where the outcome is a choice between two possibilities. A key strength of binary regression analysis is its ability to determine how different variables influence the probability of a binary outcome. This makes it particularly useful for understanding situations where the result for understanding situations is a "yes" or "no" response.

Model prediction

Factors with RII $\geq$ 0.80, have very high rating, they are said to significantly contribute to the congestion at the selected intersection. The model's details are shown in equation 6:

$$Y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 \qquad (6)$$

Where Y is the level of effectiveness of the selected Intersections, $X_1$is Road side market factor, X_2 is No parking lot factor, X_3 is increased population factor, X_4 is Peak congestion hour factor and X_5 is the poor driving factor influencing the congestion at the selected intersections and β_0 is the constant and β_1 to β_5 is the estimates of the independent variables. i.e. the coefficients of the independent variables. The explanatory variables X_1, X_2, X_3, X_4 and X_5 determine the factors influencing the congestion at the selected intersections in Ibadan, represented by the variable Y.

The statistical Package for Social Sciences (SPSS), version 25, was used.

Assumptions for binary logistic regression analysis

Binary regression analysis has a few key assumptions which are:

- The dependent variables (response) is binary which means this can take one of two possible outcomes such as 0 and 1.
- Independence of Errors: This means that the predicted probability for one observation does not affect the predicted probability for another observation.
- Linearity of the Logit: This illustrate that the relationship between the independent variables and the Log odds of the independent variables should be linear. If the relationship is non-linear, logistic regression may not fit well and transformation or non-linear terms may need to be included.
- No multicollinearity: Independent variables should not be too highly correlated with each other. High multicollinearity makes it difficult to determine the individual effect of each predictor variable on the response variable.
- Model fit Assessment: The goodness of fit of the model should be assessed after fitting the model. Common methods include the Hosmer-Lemeshow test.

Model evaluation

it is crucial to evaluate how well the model fits the data and this method were used.

- Likelihood Ratio Test: This is used to assess the overall fit of the model.
- Pseudo R-square value: To estimate the proportion of variance explained by the model.
- Classification Table: This is used to assess the model ability to correctly predict the data outcome
- Hosmer-Lemeshow Test: This is used to check the goodness of fit of the model.

RESULT AND DISCUSSION

Traffic flow variation for the selected intersections

Figure 3 depicts the variations in traffic volume at the Iwo road intersection each day with a graph illustrating a varying pattern. This implies there is a stable level of traffic on the roads that lead to the intersection for the duration of the day. From Figure 3 the graph of Lagos approach leg, the volume of vehicles begins to rise steadily from 8 am, hitting its maximum between 4 pm and 6 pm. In Ife approach leg, the heaviest traffic occurs from 4 pm to 6 pm, while there tends to be lighter congestion between 9 am and 1 pm due to its status as a heavily traveled route. The busiest hours of Gate approach leg occur from 4pm to 6pm, while the leg experiences lighter traffic from 10 am to 4 pm, largely due to the influx of workers commuting between 8 am to 6 pm. The Ojoo approach leg experiences similar traffic patterns as that of Gate approach leg with peak congestion occurring between 5pm and 6pm, and reduced traffic levels observed from 11 am to 3 pm. The Iwo approach leg experiences its highest traffic between 5 pm and 6 pm, while off – peak periods occur from 10 am to 3 pm. As a result, numerous trips are attracted to the intersection, resulting in the Lagos approach leg and Ife approach leg of the Iwo road intersection being the most congested.

Figure 4 shows the graph of traffic patterns of the approach legs of Sango – Polytechnic Ibadan road intersection. The Sango – Ojoo road approach had heavy traffic from 8 am to 10 am and 2 pm to 6 pm, but less traffic from 10 am to 2 pm. The Sango – Mokola road approach had its busy time from 12 pm to 6 pm, and very little traffic from 9 am to 12 am and this is because of the presence of an old railway track in the vicinity causes vehicles to move at a slower pace. From 12 am to 4 pm, the Eleyele – Polytechnic Ibadan road approach experienced consistent traffic, while it was particularly a slow movement of vehicles around between 8 am and 12 am due to student environment and also had heavy traffic from 4 pm to 6 pm. The way traffic moves are greatly affected by the role of the road features Ginting and Widyaningsih (2022). This implication means by understanding the relationship between road features and traffic flow, transportation planner can identify areas where road design improvements or other interventions (like traffic management strategies) are needed to mitigate congestion and improve safety at this selected intersections.

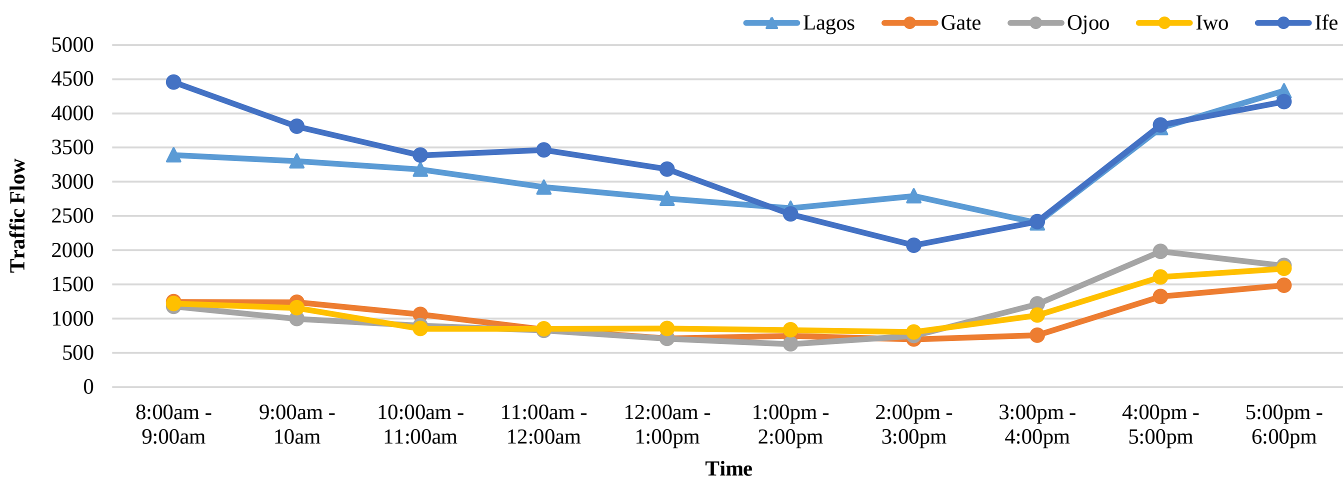

Figure 3. Traffic variation chart for iwo road intersection

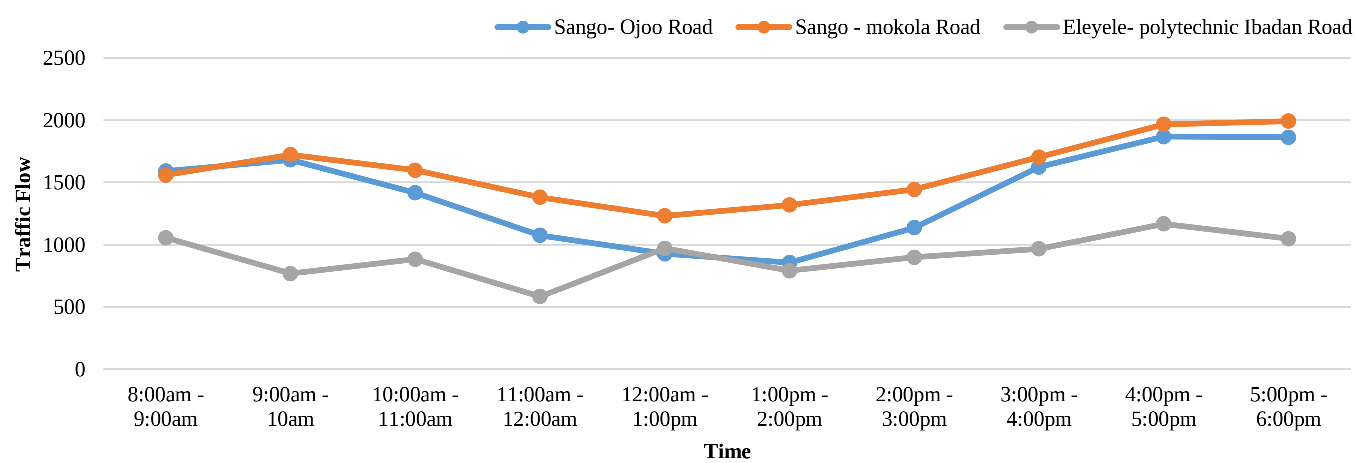

Figure 4. Traffic variation chart for Sango- Polytechnic Ibadan road intersection

Flow – density diagram illustration of the Selected Intersections in Ibadan

The analysis presented in Figure 5 through 12 illustrates that an increase in vehicle density correlates with a more efficient traffic flow. This relationship indicates that a higher number of vehicles within a specified area contributes to improved traffic movements at the selected intersections, a concept commonly referred to as fundamental diagram of traffic flow.

The Sango-Ojoo approach has a maximium flow of 1950veh/hr with a critical density of 110.3 veh/km (Figure 5), while Sango –Mokola reaches 1999 veh/hr and 189.35 veh/km (Figure 6). The Eleyele – Polytechnic Ibadan achieves 1929 veh/hr at 123.34 veh/km (Figure 7). At the Iwo road intersection, the Lagos leg shows a maximum flow of 4328 veh/hr (Figure 8) and a critical density of 124.52 veh/km, whereas the Gate leg has 1485 veh/hr at 59.4 veh/km (Figure 9), and the Ojoo leg achieves 1773 veh/hr at 70.92veh/km (Figure 10). The Iwo leg has 1731 veh/hr at 69.24 veh/km (Figure 11), and the Ife leg reaches 4169 veh/hr at 98.45 veh/km (Figure 12). At Optimal density at the selectd intersections the roads operate efficiently but beyond this point, vehicle movement slows as congestipn increases.

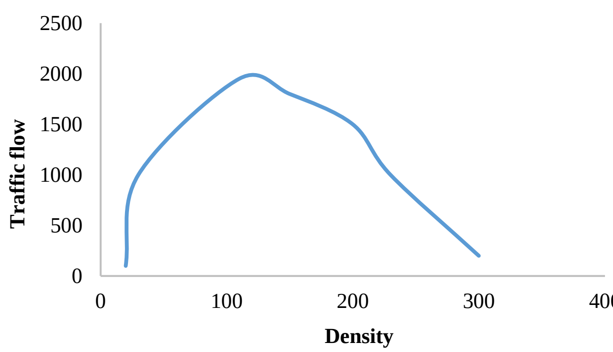

Figure 5. Flow – density relationship of Sango –Ojoo leg approach

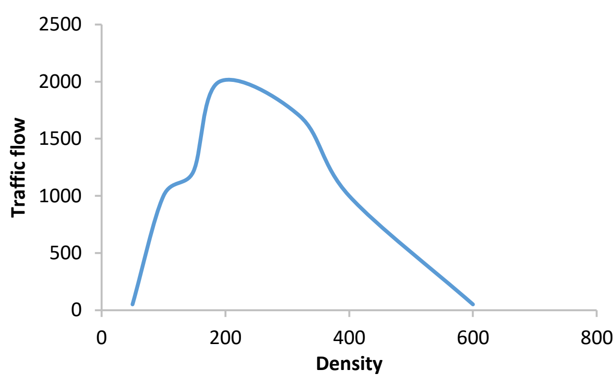

Figure 6. Flow – density relationship of Sango – Mokola Leg approach

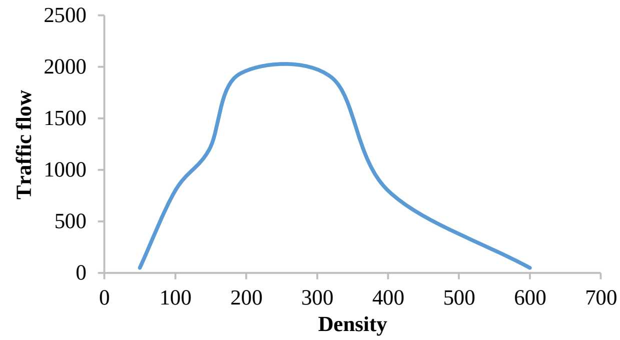

Figure 7. Flow – density relationship of Eleyele Polytechnic Ibadan Leg approach

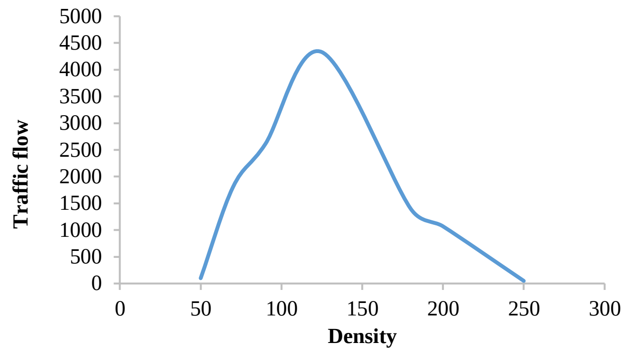

Figure 8. Flow – density relationship of lagos leg approach of Iwo Road Intersection

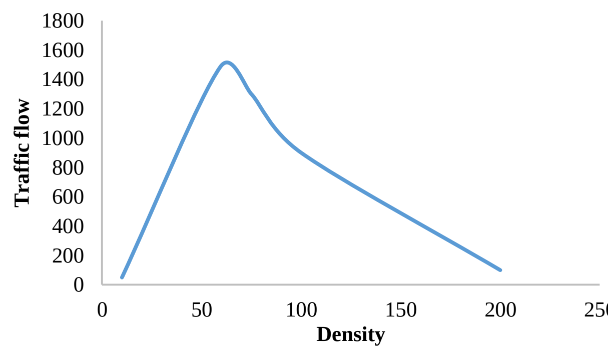

Figure 9. Flow – density relationship of Gate Leg approach of Iwo road intersection

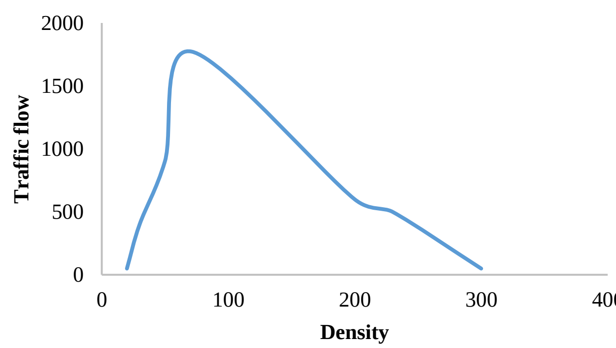

Figure 10: Flow- density relationship of Ojoo Leg Approach Of Iwo road intersection

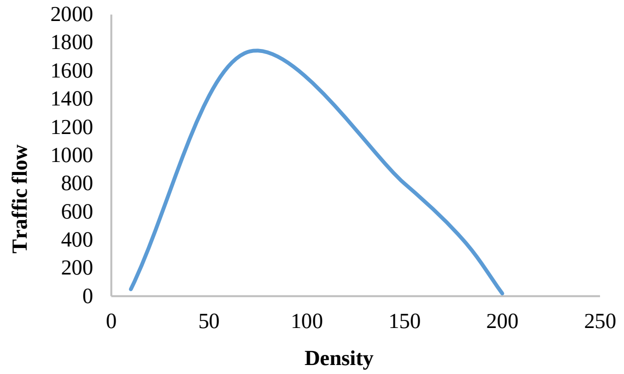

Figure 11: Flow- density relationship of Iwo Leg Approach of Iwo road intersection

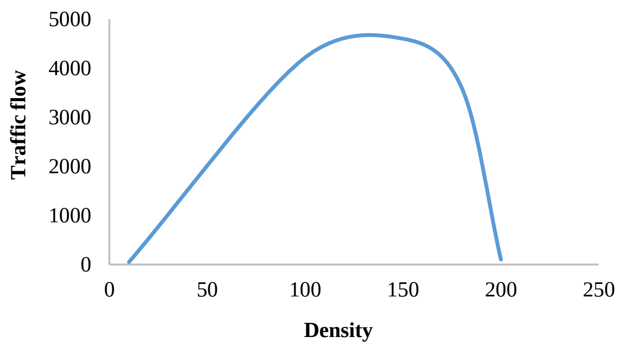

Figure 12: Flow- density relationship of Ife Leg approach of Iwo road intersection

Peak hour and off peak hour of The Headway in the selected intersections

The time of the day strongly influences the headway between vehicles. During peak hours, drivers typically behave differently than they do during off-peak. The vehicle headways at the Iwo Road Intersection in Lagos as depicted in Figure 13 exhibit significant variaions between peak and off-peak hours. On peak day 5, the Lagos approach recorded a headway of 45.23 seconds, in contrast to 163.6 seconds during off-peak hours on day 1 which implies operational inefficiency. The Gate approach as depict in Figure 14 reached a peak of 67.34 seconds on day 5 and off peak hour with a headway of 138.5 seconds on day 1 and day 2 of observation, a limited variety of vehicles was noted during peak hours, and this pattern continued on day 4 even during off peak hour and this was due to the effect of incursion from the Sango Market and development of shopping stalls on both sides of this legs. Figure 15 depicts the peak and off peak hours of Ojoo leg approach of Iwo road intersection with the peak hour of 45.9 seconds on day 2 and the off peak hour of 156.36 seconds which falls on day 5. During the highest traffic period on day 2, the vehicles did not operate as they did on another route and on day 5, there was a slight increase in vehicle numbers during peak hours as drivers sought to reach their destinations more quickly.

Figure 16 depicts the peak and off peak hour of Iwo leg approach of Iwo road intersection with a peak hour requires roughly 44.23 seconds and off peak hour of 157.38 seconds in day 5. While there are more significant variations in the spacing between vehicles during off peak hour compared to peak hours. And also Figure 17 illustrates the peak and off peak hour of Ife leg approach of Iwo road intersection, the peak activity occurred on day 5 with peak hour of 55.23 seconds and the off peak period of 156.45 seconds which falls in day 4, and indiscriminate stops of Taxis to pick/ discharge passengers on the main road, reducing the gap between vehicles.

The Sango – Polytechnic Ibadan road Intersection is depicted in Figure 18– 20, the time of day had a considerable impact on the spacing between vehicles. Figure 18 depicts the off peak and peak hour of Sango – Ojoo leg approach of the intersection with an highest peak hour of 60.86 seconds which falls in day 5 and an highest off peak hour of 120.23 seconds which falls in day2. Day 2 and day 5 differ greatly since there is an excessive volume of traffic during peak hour, which is more than the capacity of the road and old railway tracks are currently unused, leading to delays in service. Also, Figure 19 illustrate the peak and off peak hour of Sango – Mokola leg approach of the intersection with an highest peak hour of 54.38 seconds which falls on day 3 and highest off peak hour of 112.37 seconds which falls on day 3 and there were similar numbers of vehicles observed during peak hours on both day 2 and day 5 and the vehicles moved ineffectively due to abandoned railway track and presence of potholes which reduced efficiency as traffic moved more slowly.

Also, Figure 20 illustrates the peak and off peak traffic patterns on Eleyele – Polytechnic Ibadan leg approach of the intersection. The peak period occurs at 47.98 seconds and takes place on day 5 and an highest off peak hour of 124.23 seconds which falls in day 1 and day 3. During peak hours on day 2, day3 and day 5, numerous vehicles were packed closely together and this arose due to drivers' desire for quicker travel, causing them to closely follow the car in front and decrease the space between vehicles. Vehicles tends to arrive more often during peak hours and less frequently during off peak hour. When headways decrease across all the approach legs, services become more frequent, which enhances accessibility and lowers time spent in traffic.

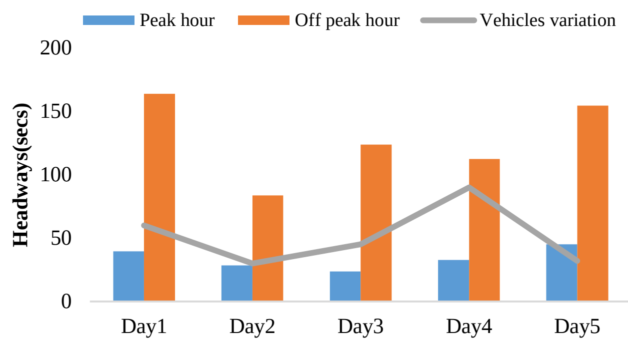

Figure 13. Peak hour and off peak hour headway of Lagos Leg of Iwo Road intersection

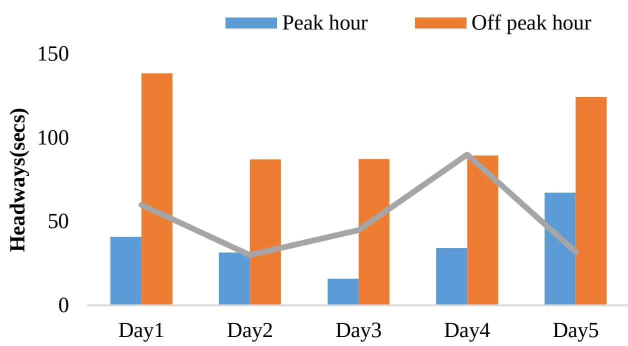

Figure 14. Peak hour and off peak hour headway of Gate Leg of Iwo Road intersection

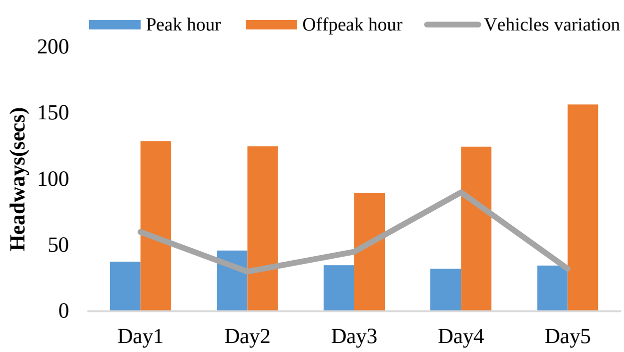

Figure 15. Peak hour and off peak hour headway of Ojoo Leg of Iwo road intersection

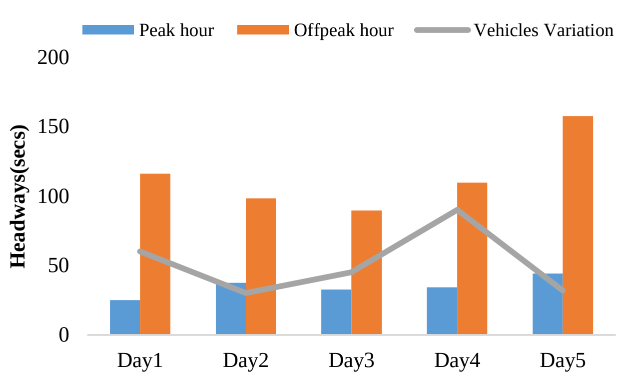

Figure 16. Peak hour and off peak hour headway of Iwo Leg of Iwo Road intersection

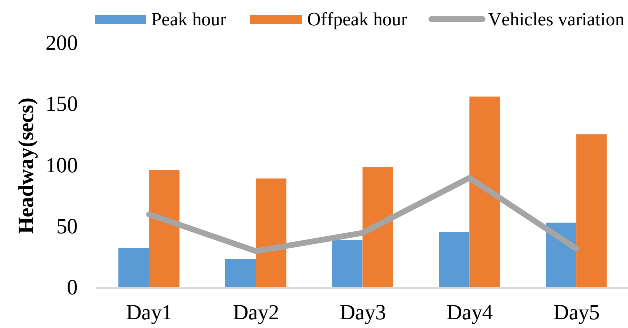

Figure 17. Peak hour and off peak hour headway of Ife Leg of Iwo Road intersection

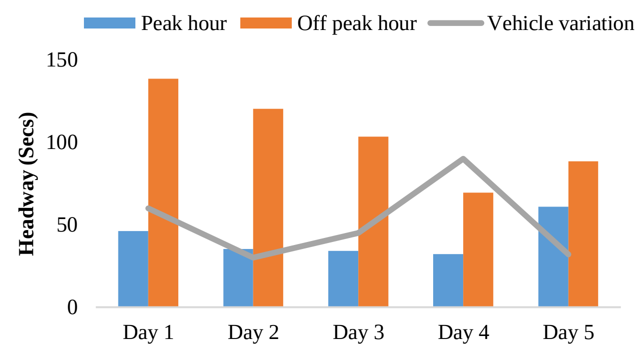

Figure 18. Peak hour and off peak hour headway of Sango-Ojoo Leg In Sango intersection

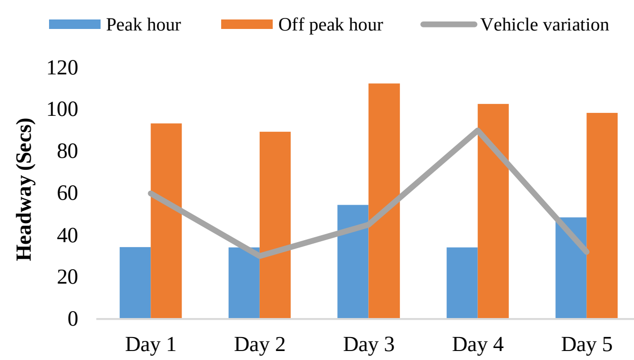

Figure 19. Peak hour and off peak hour headway of Sango-Mokola Leg In Sango intersection

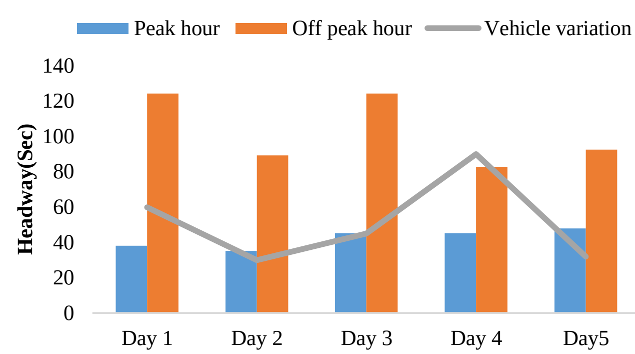

Figure 20. Peak hour and off peak hour headway of Eleyele – Polytechnic Ibadan Leg In Sango intersection

Volume to capacity ratio to assess the congestion level of Sango – Polytechnic Ibadan road intersection

Table 2 depicts the levels of service of Sango – Polytechnic Ibadan Road Intersection. This table illustrates the peak traffic levels on the various intersections leg approach during peak hours with Sango – Ojoo leg approach records 1950 Pcu/hr and Sango-mokola leg approach records 1999 Pcu/hr and Eleyele – polytechnic Ibadan leg approach records 1929 Pcu/hr. The capacity for all the traffic stream is 2700 Pcu/hr. In addition, the estimation of the volume to capacity ratio is performed for the three legs sections of the intersection and the ratios ranges from 0.71, 0.72 to 0.74. This intersection is rated at a Class C service level, with a volume to capacity of 0.71 – 0.80 according to Roses et al. (2011). This indicate stable flow but speed is affected and the implication is that vehicles are generally travel at similar speeds, but motorists may encounter delays in heavy traffic during peak hours and there is enhanced connectivity between vehicles and the various services they engage with. According to the LOS C evaluation for the intersection, all the roads are utilized at nearly 70 – 80% of their available capacity. The road remains functional and is in decent shape, although it's becoming increasing congested and motorists do experience minor delays and face increased difficulty in navigating their routes. Increased traffic at this intersection leads to unpredictable travel times and negatively impacts the economy.

To enhance the effectiveness of the intersection, the transportation planners have to overlook the effect of Bus-stops for Taxis / buses on the axis of Elewure – Sango – U.I road, the effect of incursion from the Sango market and development of Shopping stalls on both sides of this leg, indiscriminate stops of Taxis to pick/ discharge passengers on the main road and introduction of gap - separated structures will require more right of way which is not visible at this location. These modifications will alleviate congestion on the intersection and aid transportation planners in assessing the traffic volume at the intersection.

Table 2. Level of service of Sango – Polytechnic road intersection

Traffic stream	Maximium peak hour volume (V) (pcu/hr)	Capacity	V/C ratio	LOS
Sango Ojoo road	1950	2700	0.72	C
Sango - Mokola road	1999	2700	0.74	C
Eleyele - Polytechnic Ibadan road	1929	2700	0.71	C

Volume to capacity ratio to assess the congestion level of Iwo road intersection

An assessment was conducted regarding the traffic capacity at the Iwo Road Intersection employing Kimber's empirical regression analysis. This evaluation focused on several critical metrics, including a lane width of 7.3 meters, a flare length of 25 meters. The flow capacity coefficient was established at 0.79, accompanied by an entry flow factor of 8.11, with heavy vehicles accounting for 2% of the overall demand. The analysis of traffic flow as illustrated in Table 3 which reflect the count of passenger cars by employing a metric referred to as Passenger Car Equivalent(PCE), indicated the presence of congestion during peak hours. The volume to capacity ratios,in accordance with the Highway capacity manual (HCM) as illustrated in Table 4, are as follows: Lagos (0.96, Level of Service E), Gate(0.73, Level of Service C), Ojoo (0.77, Level of Service C), Iwo (Level of Service C), and Ife (0.90, Level of Service D). The capacity utilization of the Gate,Ojoo, and Iwo leg approaches is about 80%, indicating a Level of service C with frequest congestion during peak hours. In contrast, the Lagos leg is at LOS E, signifying dense vehicle accumulation, while the Ife leg is classified as LOSD, where minor traffic increase can cause delays. To enhance traffic flow at the Iwo road Intersection, strategies could include promoting construction in less congested areas, adding bus stops, and enforcing stricter traffic regulations. Irunokhai et al. (2020) found that transitioning from LOS D To E leaves 68% of the roadway at LOS D, meaning minor traffic increases can lead to delays and reduced speeds.

Table 3. Volume of traffic conversion to passenger car equivalent for Iwo road intersection

Raw turning volume (Vph)					PCE	Adjusted turning volumes(pcu/hr)				Roundabouts volume (Pcu/hr)		
Legs	U-turn	Left	Through	Right		U-turn	Left	Through	Right	Circ.	Entry	Existing
Lagos	128	395	1589	520	1.085	139	429	1724	564	2584	1776	3204
Gate	105	355	786	98	1.085	114	385	853	106	2377	1701	1725
Ojoo	156	432	945	102	1.085	169	469	1025	111	2055	1338	1808
Iwo	142	384	748	95	1.085	154	417	812	103	2073	1521	1645
Ife	125	364	1432	348	1.085	136	395	1554	378	2664	2501	2480

Table 4: V/C Ratio of Iwo road Intersection

S/N	Legs	Entry	Exit	Average	LOS
1	Lagos	0.68	1.24	0.96	E
2	Gate	0.72	0.73	0.73	C
3	Ojoo	0.65	0.88	0.77	C
4	Iwo	0.73	0.79	0.76	C
5	Ife	0.94	0.86	0.9	D

Demographic information of the respondents

The key determinants of a study's credibility include the accuracy of the analytical methods employed and the reliability of the sources from which the data is drawn. To enhance reliability and foster trust in the results, questions regarding the respondents' backgrounds were included in the survey. The determination of the sample size was done which involve definition of the population which involve a survey of the respondents plying the intersections and we consider a margin Error of 10% which is less precise to get away with a smaller sample and a confidence level of 95% was used to gives a very high certainty and a population proportion of 50% was used because it is the most conservative estimate to give a largest size. The response rate of 65% was used as the percentage of the respondents for the two intersections. Table 5 provides detailed information of respondents.

Analysis of factors that contribute significantly to the performance of the selected intersections

Sixteen different factors were identified based on how the respondents' ply the intersections and their experience during congestion, the identified factors were measured on a Likert rating scale and computed relative importance Index. Table 6 shows the relative important index values and the ranking of these factors. When an excessive number of vehicles congregate in one area, it leads to traffic congestion, which hampers vehicle movement and extends travel durations.

As illustrated in Table 6, the primary contributor to traffic congestion at the selected intersections is the presence of roadside market, with an (RII of 0.888). Additional factors include the lack of parking facilities resulting to on street parking (RII of 0.878), increased population (RII of 0.820), peak hour congestion (RII of 0.810) and poor driving behaviours(RII of 0.807) and this is corroborated by Tanzina and Nita (2020) who maintained that congestion arises when there is rapid growth of motorization with less than corresponding improvement in the road network, traffic management techniques and related transport facilities.

To improve the situation of congestion at the selected intersections, transport authorities in Ibadan need to focus on resolving the underlying causes of traffic congestion to improve mobility.

Effects of traffic congestion that contribute significantly to affecting the performance of the selected intersections

A total of seven effects of traffic congestion that contribute significanttly to affecting the performance of the selected intersections were identified. The identified effects were rated using likert scale and the relative importance index value of each effects were calculated for ranking. The computation of the relative important index values and ranking of these effects are presented in Table 7. It is shown from the result of the analysis presented in Table 7 that congestion causes delay (RII of 0.827) and slow down transportation (RII of 0.807) which indicate traffic flow is hindered, leading to slower speeds and reduced efficiency in the movement of vehicles which are the major effect of traffic congestion along the selected intersection and this agrees with Mobereola (2008) who disclosed and use relative importance index in assessing that commuters in Lagos spend on average 40% of their income on transportation. Also, congestion on this road network also induces stress on the road users. This is because of the long duration spent commuting and thus human productivity is reduced. 20.3% of the respondents' which are civil servant indicated that being stuck in traffic caused them to arrive late to work and took up their time unnecessarily.

Table 5. Respondents' profile

Description	Frequency	Percentage (%)
Gender		
Female	31	52.5%
Male	28	47.5%
Total	59	100.0%
Age		
Under 18	1	1.7%
19 – 25	17	28.8%
25 – 50	41	69.5%
Total	59	100%
Level of education		
Adult education	6	10.2%
No formal education	8	13.6%
Primary education	15	25.4%
Secondary education	18	30.5%
Tertiary education	12	20.3%
Total	59	100%
Occupation		
Civil servant	12	20.3%
Driver	9	15.3%
Self employed	13	22.0%
Student	12	20.3%
Trader	13	22.0%
Total	59	100.0%
How ferquently do you ply through the intersection		
Daily	26	44.1%
Monthly	11	18.6%
Rarely	6	10.2%
Weekly	16	27.1%
Total	59	100.0%
How often do you encounter congestion at intersections during your daily commute		
Daily	35	59.3%
Frequently	24	40.7%
Total	59	100%

Table 6. RII Values and Ranking of Causes of Traffic Congestion along the Selected Intersection

S/N	Causes of traffic congestion	RII	Ranking
1	Poor intersections design	0.620	1
2	Accidents	0.678	2
3	Ongoing road maintainance	0.698	3
4	Inadequate public transport services	0.725	4
5	Poor land use	0.732	5
6	Religious worship Activities	0.740	6
7	Increased private car ownership	0.746	7
8	Inadequate road capacity	0.766	8
9	Non compliance to road rules	0.769	9.5
10	Poor incident management on the roads	0.769	9.5
11	Bad roads	0.786	11
12	Poor driving behaviours	0.807	12
13	Peak hour congestion	0.810	13
14	Increased population	0.820	14
15	Lack of parking facilities resulting to on street parking	0.878	15
16	Presence of road side market	0.888	16

Table 7. RII values and ranking of effect of traffic congestion along the selected intersections

S/N	Effect of Traffic Congestion	RII	Ranking
1	Overloads Infrastructure	0.647	1
2	Encourage mass transit	0.722	2
3	Fosters road rage	0.739	3
4	Poses security risks	0.780	4
5	Causes accidents involving vehicles	0.783	5
6	Slow down transportation	0.807	6
7	Causes delay	0.827	7

Binary logistic regression model analysis

Binary logistic regression model excels by analyzing how various independent variables influence a binary outcome. This technique simultaneously examines all the independent variables (poor driving behaviour, peak hour congestion,increased population, absent of parking lots resulting to on street parking and presence of road side market) in a single analysis. Absent of parking lots resulting to on street parking has the highest ranking of 0.878 and highest tolerance value of 0.979 and this make the factor to have the highest influence on congestion at the intersection. This analysis result informs the transportation planner in Ibadan to provide a parking space for vehicles at the intersections to provide a safe environment.

Model prediction

Since factors with RII ≥ 0.80, have very high rating, they are said to significantly contribute to the congestion at the selected intersections in Ibadan. These factors include the following: Poor driving behavior, Peak hour congestion, Increased Population, absent of parking lots resulting to on street parking and Presence of road side market. This factors are the predictors variables to model the congestion status at the intersections in Ibadan. This factors are caused when there is rapid growth of motorization with less than corresponding improvement in the road network, traffic management techniques and related traffic facilities.

Table 8 shows the binary logistic regression analysis because our categorical has 2 categories: sometimes and daily. Where the dependent variable is the congestion status and the predictors (constant), Roadside market, no parking lot, increased population, peak congestion hour and poor driving has a significant level of 0.1 of congestion at the intersections.

Prior to conducting the regression analysis, it was essential to assess whether, the selected model adequately fit the data (see Table 9). The fit of the model was assessed by performing an omnibus test of the model coefficients, which provided an overall evaluation of the model's performance, commonly referred to as a goodness of fit (Pallant,2010). The omnibus test was based on the null hypothesis that the model did not fit the data well. The results from the regression analysis revealed a Chi-square statistic of 26.439 with 13 degrees of freedom and a P-value of 0.034. This indicates the rejection of the null hypothesis at the 5% significance level, suggesting a good fit of the model to the data. The AUC classification is equal to 1, which means the model has perfect classification accuracy for the factors of congestion and the model identifies all positive instances correctly and the model does not incorrectly classify any negative instances as positive.

Table 8. Variables definition

Variable	Measurement scale	Remark
Factors (Y)	Categorical scale	Daily
Road side market (X1)	Numeric	Sometimes
No parking lot (X2)	Numeric	Sometimes
Increased population (X3)	Numeric	Sometimes
Peak congestion hour (X4)	Numeric	Sometimes
Poor driving (X5)	Numeric	Sometimes

A further test was carried out to assess the model fit, specifically the Hosmer and Lemeshow test. This test is based on the null hypothesis that the model provides a good fit to the data, which differs from the omnibus test that seeks to identify a significant value surpassing the previously mentioned threshold (Pallant, 2010). The findings presented in Table 9 indicate a Chi-square of 1.582, accompanied by a significance value of 0.956. This result suggests that we failed to reject the null hypothesis, which indicates a good fit. In light of the findings, it can be concluded that the model demonstrates an adequate fit at the 5% significant level. And a model summary of the Logistic model is presented in Table 9 the model demonstrates a relatively high pseudo R^2 value of 0.95 for the Nagelkerke R^2 and 0.132 for the Cox and Snell R^2, indicating that it can account for 95% of the variation in the dependent variable. This suggests that the model is a good fit for the data. The variables in the models were checked for multicollinearity. The variance inflation factor (VIF) results indicated no significant concerns regarding multicollinearity among the variables in the model, with VIF values at less than 2 and tolerance values exceeding 0.1. No parking lot has the highest tolerance value of 0.979 which leads to on-street parking which majorly caused congestion at the selected intersections and this give an insight to the transportation planner and authorities in Ibadan to proffer solutions to this major problem.

Table 9: Diagnostic tests and summary results for the binary logistic regression model

Omnibus test of model coefficients		**Hosmer and Lemeshow test**
Chi-square= 26.439 P-value=0.034		Chi-square= 1.582 P-value = 0.956
-2Log Likelihood=620.317	Cox and Snell R-squared =0.132	Negelkerke R-square =0.95
	Test for multicollinearity	
Constant	**Tolerance**	**VIF**
Road side market	0.584	1.876
No parking lot	0.979	1.092
Increased population	0.589	1.748
Peak congestion hour	0.954	1.069
Poor driving	0.879	1.289

Table 10 presents the results of the binary logistics regression model. In this analysis, the congestion status is coded as “over congested” represented by 1 and “not congested” by 0. A significance level of 10% (α=0.1) was selected, as many of the variables in the study demonstrate significance at this level. According to Gujarati and Porter (2010), significance levels of 1%, 5% and 10% are commonly employed. This particular level was chosen primarily due to the study’s small sample size. As noted by Labovitz (1968), “Small error rates (0.01 or 0.001) should generally accompany large sizes, while larger error rates (0.10 or 0.05) are more appropriate for smaller sample sizes. The estimation of parameters of the logistic regression by using maximum Likelihood method (MLE) on wald statistics for the final model is shown in Table 10 which gives the result of fitting the logistic regression model to the factors that influenced congestion and showing coefficients, which are used in the equation for making the classification in Binary logistic regression gathering with the sum of products of the coefficients with the observations gives the discrimination scores.

Equation 7 shows the model equation from the Table 10 Where, X_1 is presence of roadside market, X_2 is absence of parking lot, X_3 is increased population, X_4 is peak congestion hour, X_5 is poor driving.

$$Y = \beta_o + \beta_1 X1 + \beta 2\, X2 + \beta 3\, X3 + \beta 4\, X4 + \beta 5\, X5 \quad (7)$$

$$Y = 6.024 - 0.617\, X1 - 0.902\, X2 + 0.663\, X3 - 0.179\, X4 - 0.220\, X5$$

The equation presented above explained the magnitude of the factors influencing congestion, with each variables, playing a significant role in the binary logistic regression model. If the presence of roadside markets increases by one unit, the odds will multiply by a factor of $e^{-0.617}$ assuming other variables remain constant. This indicates that an increase of one unit in the presence of roadside markets corresponds to a rise in congestion factors. Similarly, if the absence of parking lot facilities increases by one unit, the odds will multiply by a factor of $e^{-0.902}$, again with other variables held constant and absent of parking lots resulting to on street parking has the highest ranking of 0.878 and highest tolerance value of 0.979 and this make the factor to have the highest influence on congestion at the intersection. This analysis result informs the transportation planner in Ibadan to provide a parking space for vehicles at the intersections to provide a safe environment. This finding correlates with the research conducted by Popoola et al. (2013), which discusses the causes, effects and potential solutions to traffic congestion along the Lagos-Ibadan corridor, identifying the creation of parking spaces as a viable remedy and making others factors variables constant. Additionally, if the variable related to the absence of parking facilities increases by one unit, congestion will significantly influence the selected intersections by a factor of 0.406. if the population density increases by one unit while other variables remain constant, congestion is likely to influence the selected intersections significantly at a factor of 0.836. This aligns with the findings of Takyi et al. (2013) who investigated the impact of traffic congestion on productivity in Ghana. Their analysis determined that limited mobility in the Kumasi metropolis is a direct result of congestion, which adversely affects productivity by prolonging travel times, particularly during peak hours. If peak congestion hours increase by one unit, while other variables are constant, congestion will significantly influence the selected intersections by a factor of 0.803 and if the variable related to poor driving increases by one unit with other variables held constant, congestion will have a substantial impact on the selected intersections, amplified by a factor of 413,127.

Table 10: Binary logistic regressions results

	Factors	B	S.E	Wald	Df	Sig.	Exp(B)
Step1[a]	Roadside market	-0.617	0.525	1.381	1	0.240	0.539
	No parking lot	-0.902	0.628	2.058	1	0.151	0.406
	Increased population	0.663	0.518	1.639	1	0.200	1.941
	Peak congestion hour	-0.179	0.415	0.186	1	0.667	0.836
	Poor driving	-0.220	0.580	0.143	1	0.705	0.803
	Constant	6.024	3.816	2.492	1	0.114	413.127

Despite its robust methodology, the study acknowledged certain limitation. Self reported data may introduce biases as respondents' perceptions may not always align with objective realities. Xiaofeng and Zhenshun (2020) note that cross-sectional designs capture conditions at a single point in time, limiting the ability to assess seasonal variations. The small sample size utilized in the regression analysis may elevate the margin of errors and reduce the statistical power of the findings. This limitation could obstruct the identification of significant relationship between variables, such as traffic volume and congestion levels, potentially leading to incomplete or misleading conclusions. Therefore, future studies should aim to employ larger sample sizes to improve the accuracy of predictions. Another limitation is the potential for observer bias in manual traffic counts. This bias can result in inaccurate data collection, as different observers may count vehicles differently or place greater emphasis on certain types of vehicles, such as larger ones over smaller ones. The subjectivity introduced in this process can distort results and lead to misinterpretations of traffic patterns. Future research should clarify how confounding factors, such as weather conditions, time of the day, special events, accidents and seasonal variations may influence interpretations related to the causes and consequences of traffic congestion at selected intersections in Ibadan.

CONCLUSION

The research findings indicate that the capacity utilization of the intersections is around 80% levels of service which implies that during high traffic times, congestion occurs and influences the overall experience and this underscores the need for a sustained investment in road maintenance and the introduction of smart technologies to optimize traffic flow at the selected intersections in Ibadan. The binary logistic regression model reveals that a 95% model fit is remarkably effective in predicting traffic related outcomes. The results offer significant policy recommendations and provide actionable insights that promote data-driven decision making all aimed at improving traffic flow across the city.

Contribution to knowledge

This research contributes to the ongoing conversation about sustainable urban transportation in developing countries. By analyzing traffic patterns, levels of service of congestion, identifying the fundamental causes and effects of congestion, and assessing possible solution, it establishes a foundation for addressing comparable issues in different urban setting. Future studies should aim to incorporate smart technologies into traffic management, utilizing the knowledge acquired from this research.

DECLARATIONS

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Data availability

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Authors' contributions

Both authors contributed equally to this work. Conceptualization, resources, review and editing: OLADIPO MOSES ARIYO. Both authors read and approved the final manuscript.

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Acknowledgement

The authors appreciate the civil engineering department of the federal university of technology Akure for providing a suitable research environment for this work. Appreciation is extended to Bolaji Reuben for his valuable contribution to this research.

Funding

No funding was received for this study.

Competing interests

The authors declare that they have no competing interests

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