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EVALUATION OF CAPACITY AND LEVEL OF SERVICE FOR URBAN ARTERIAL ROAD UNDER MIXED TRAFFIC CONDITIONS - A CASE STUDY OF OBA ADESIDA ROAD AKURE, NIGERIA

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Abstract — The research focused on evaluating the capacity and level of service of an urban arterial road under mixed traffic conditions and subsequently proposed traffic improvement measures. Oba Adesida Road in Akure was selected as a case study using purposive sampling. The field traffic characteristics survey employed both video-graphic technology and manual techniques, conducted from 7:00 am to 7:00 pm for seven days (Monday to Sunday). The passenger car unit equivalent (PCU) technique, utilizing the British standard method and PCU factors for each vehicle class, was applied to determine the actual volume of vehicles on the study road. Statistical calculations, including mean, median, range, and skewness, were performed using various formulas for each element. The level of service (LOS) for the study road was determined using the volume/capacity ratio through both theoretical capacity and the technical standard method. The results revealed high congestion on the study road, with traffic volumes ranging from 1080 to 2221 PCU/hr and 13,908 to 25,788 PCU/day. Throughout the week, incoming flow exceeded outbound traffic, and the road exhibited poor operating conditions during peak hours. LOS varied from C to F (LOS-C to F) when using the ratio of theoretical maximum capacity to actual volume technique. However, LOS-F was consistently observed during peak hours throughout the week when employing the technical standard method. To address these challenges, the study suggests implementing traffic management strategies, including the construction and installation of efficient traffic signals. Strict enforcement of proper use of existing bus shelters at designated stops is recommended, and the introduction of alternative urban transportation modes, such as metros and trains, supporting mass movement, should be considered, drawing inspiration from major urban cities worldwide.

Keywords: level of service (LOS), capacity, volume/capacity ratio, vehicle characteristic, passenger car unit (PCU)

1.0 INTRODUCTION

The road infrastructure in both urban and rural areas serves as a vital lifeline. Assessing its efficiency is crucial for future transportation planning, design, operation, and maintenance. Despite the rising population and fuel costs in the country, there is a pressing need for a well-designed transport network that accommodates road users effectively [1, 2]. The smooth and timely movement of people and goods hinges on traffic flow, a factor intricately linked to traffic characteristics [3]. It is crucial to recognize that capacity and level of service are two interconnected concepts. While capacity seeks to provide insight into the amount of traffic a specific transportation infrastructure can handle, the level of service endeavours to assess the current quality of traffic on that infrastructure [4]. Consequently, they offer both quantitative and qualitative perspectives on traffic examination. The capacity and level of service for road infrastructure are contingent on factors such as the type of road, its intended purpose, current conditions, and typical traffic patterns. Over the years, the city of Akure has witnessed a significant surge in the number of vehicles on its roads, primarily driven by escalating socioeconomic activities [5, 6]. Despite the escalating costs associated with fuel consumption, Oba Adesida Road, one of the city's oldest thoroughfares, has not seen a reduction in vehicular traffic. Positioned strategically in the capital city, this road serves as a crucial link connecting other vital routes throughout the urban area. Surrounded by diverse economic and industrial activities, it has become a focal point for migration, leading to substantial pressures on existing transportation infrastructure and resulting in various traffic challenges. The city's developmental pattern follows a linear trajectory, particularly along its main arteries like Oba Adesida Road. Within this urban area, uncontrolled intersections are prevalent, typically overseen by government traffic wardens or officers. The traffic makeup in the metropolis is diverse, encompassing motorcycles, tricycles, taxis, buses, lorries, and trucks (trailers). However, the predominant components of traffic in Akure are taxis, motorcycles (Okadas), and buses. [7]. This project aims to assess the capacity and level of service on Oba Adesida Road in Akure, Ondo State, Nigeria.

An urban arterial road functions as a significant transportation route within a city or urban locality. It is specifically engineered to handle substantial traffic volumes, typically distinguished by its ability to support fast-moving vehicles across considerable distances [8, 9]. These roads play a vital role in facilitating the smooth and efficient movement of people and goods within urban environments. Oba Adesida Road exemplifies such a typical urban arterial road, as evidenced by its physical measurements, showcasing its capacity to cater for the transportation needs of the city's residents and businesses. Figure 1 depicts Oba Adesida Road during off-peak hours, featuring various commercial activities along both directions.

Figure 1 Oba Adesida Road, Akure during off-peak hour

Several researchers have explored the evaluation of capacity and level of service for urban arterial roads under mixed traffic conditions in the literature. These studies offer valuable insights into diverse facets of traffic congestion, road capacity, and potential solutions. Ajala [2] conducted a comprehensive study on the Analysis of Traffic Congestion on Major Urban Roads in Nigeria, focusing on Ota town roads within Ado-Odo/Ota local government area of Ogun state, South-Western Nigeria. The primary objective was to assess the operating capacity of the existing road facility, identify the causes and effects of traffic congestion, and propose measures to alleviate congestion on urban roads. To gather data, traffic counts were conducted on three days of the week (Monday, Wednesday, and Saturday) between 7 am and 7 pm. Roadside interviews were also conducted using structured questionnaires, involving 68 randomly selected vehicles and 240 road users at four major locations along the corridor. The British standard of Passenger Car Unit (PCU) was employed for the computation and analysis of road capacity. The findings revealed common congestion along the corridor, peaking during the morning hours of 7 a.m. to 12 noon. Causes identified includes poor road infrastructure, street trading, on-street parking, and uncontrolled high-capacity junctions. The assessment of road capacity indicated that it currently operates above the design capacity of 1200 PCU/hour. The study concluded by recommending junction improvements at Sango, Oju-Ore, and Winners, along with total road upgrading and expansion, provision of adequate public transport facilities, and land use control. Hamid et al. [10] explored the estimation of highway capacity under environmental constraints versus conventional traffic flow criteria in Tehran. The study introduced the concept of environmental capacity, determining the maximum traffic volume permissible without compromising residents' quality of life. Environmental capacity was calculated based on acceptable levels of air and noise pollutants, with notable differences observed compared to functional traffic capacity as per the highway capacity manual (HCM). Rojas et al. [11] focused on the diagnosis of road capacity and service level using the highway capacity manual in Santander, Colombia. The study assessed the capacity and level of service of Norte de Santander's main avenue using the Highway Capacity Manual 2000 and vehicle count data. The study concluded that the system operated at a level of service D and E.

Ariyo et al. [12] conducted a traffic congestion assessment of Akure's Central Business District using Geographic Information Systems (GIS). Their study revealed increased traffic levels leading to congestion in Akure, Ondo

State, Nigeria. GIS software, including ArcGIS 10.7 and QGIS 3.18, was employed to generate spatial and non-spatial data. The study proposed traffic restrictions, improved land use planning, road user education, and technology adoption as strategies to mitigate traffic congestion. Aderinola and Owolabi [5] investigated traffic congestion at critical intersections, focusing on the Odole intersection in Akure, Ondo State, Nigeria. Their study identified traffic congestion on major roads caused by bottlenecks at intersections within Akure. The researchers recommended signalization as a traffic control measure to improve conditions at the Odole intersection.

Laoye et al. [13] quantified traffic congestion indices on major roads in Akure, Nigeria. The study analysed traffic volume, headway, spot speed, density, and delay at intersections on major routes in Akure. The results indicated congestion on specific segments, with projections suggesting severe congestion on some routes by 2025. Recommendations included provision of adequate parking facilities, lane marking, prohibition of on-street trading and parking, effective traffic management, and efficient road maintenance. Jacob et al. [14] analyzed the extent of overloading on Nigerian Highways, focusing on the Lokoja-Abuja road. The study used weigh-in-motion data to reveal overloading among different truck types, emphasizing the impact on pavement structures. Woldemichael [15] assessed road capacity and level of service in Ambo Town, Oromia Regional State, Ethiopia, focusing on congestion and delay as major problems. The study employed both quantitative and qualitative approaches, highlighting the need for well-designed roadways and sufficient lanes to improve capacity. Cheng et al. [16] investigated spacing and geometric design indexes of auxiliary lanes on two-lane highways in China. The study established a calculation model for the minimum spacing of auxiliary lanes and suggested values based on highway classes, design speeds, and terrains.

Fadairo [17] investigated the issue of traffic congestion in Akure, Ondo State, Nigeria, utilizing Federal University of Technology Akure Road as a case study. The research identified contributing factors to congestion, including poor driving habits, adverse weather conditions, the absence of traffic lights, and roadside parking. The recommendations strongly advocated for the implementation of urban mass transit systems, such as metros and trains. A distinct gap in intellectual exploration emerged, particularly concerning research centred on the specific location of the project – Oba Adesida Road in Akure. While several studies delved into traffic congestion in different areas of Akure, the examination of road capacity and level of service under mixed traffic conditions on Oba Adesida Road remained limited. Laoye et al. [13] conducted a study on the indices of traffic congestion along major roads in Akure, Nigeria. The researchers gathered data on traffic volume, spot speed, density, delay, and headway at selected sections of the roads and intersections. Parameters such as volume-capacity ratio, minimum allowable speed, jam density, and critical delay were determined from the data analysis. These parameters served as indices for evaluating traffic congestion. The study concluded that based on these indices, some routes were moderately congested while others were heavily congested. In a study conducted by Woldemichael [15], the capacity and performance of selected road segments in Ambo town were assessed, focusing on their level of service. The research employed both quantitative and qualitative methodologies. Quantitative data, including volume counts, speed, and travel time surveys, were collected through primary sources and direct field measurements, complemented by secondary data. Three representative sections classified as sub-urban streets with interrupted flow, according to the Highway Capacity Manual 2000, were analyzed. The findings indicated that the segments generally performed well in terms of level of service, with ratings ranging from LOS D to LOS C. However, the capacity analysis revealed deficiencies, suggesting that the current infrastructure is inadequate. To enhance the capacity of these road segments, recommendations include the construction of well-designed roadways with sufficient lanes and lane width, along with the proper development of parking areas. In a separate study, Dukiya and Ajiboye [18] examined delay factors, time wastage, and traffic conflicts at urban intersections in Lagos, Nigeria. They utilized delay analytical tools, vehicle spot speed, and traffic volume to assess traffic congestion. The findings revealed that the intersections had Level of Service (LOS) ranging from B to E. The worst LOS was observed during the evening peak hour, particularly for traffic warden-controlled intersections. Osuolale et al. [19] investigated the level of service at selected major road intersections in Ibadan. They conducted traffic volume assessments for each intersection approach from 7 am to 7 pm on Mondays, Wednesdays, and Saturdays. Delay studies were performed during morning, afternoon, and evening peak hours, with the level of service determined for each approach based on the average delay per vehicle. Analysis of traffic volume indicated that passenger cars were the predominant vehicles at all approaches, with morning and afternoon peak hours observed between 8 to 9 am and 2 to 3 pm, respectively. The level of service for all approaches was graded as B, indicating a slight reduction in the capacity of the intersections. The study by Ajayi and Busari [20] aimed to assess traffic delays and Level of Service (LOS) at unsignalized intersections in the Akure metropolis. A cine camera was strategically placed at intersections to capture peak-hour traffic, and subsequent playback indoors facilitated data retrieval on traffic delay. Utilizing the Simple Linear Regression model (SLR), they established a strong correlation ($p<0.05$) between average delay and queue length. The identified LOS for Arisoyin Intersection, Oke-Ijebu Roundabout, Oba-Osupa Roundabout, NEPA roundabout, and State Hospital Roundabout were "E", "E", "A", "F", "C", respectively. Their findings underscored that average control delay is contingent upon queue length and entry flow. Thus, the LOS approach stands as a reliable method for transportation professionals to assess intersection conditions and propose appropriate measures for reducing traffic delays, not only in Akure but also in similar capital cities across Nigeria. The existing literature contributes valuable insights into traffic congestion, road capacity, and level of service across diverse urban environments. However, the absence of a focused study on Oba Adesida Road in Akure under mixed traffic conditions represents a significant intellectual gap in the present body of knowledge.

2.0 MATERIALS AND METHODS

Akure, situated in southwestern Nigeria, serves as the capital of Ondo State. Positioned between latitudes 7°15' and 7°17' north of the Equator and longitudes 5°14' and 5°15' east of the Greenwich Meridian, Akure spans an area of approximately 15,500 km² and stands at an elevation of around 370 metres above sea level [13]. The urban core, representing the oldest residential sector undergoing recent transformation, is enclosed by Oba Adesida Road to the North, Oke Aro Road to the West, and Hospital Road to the East [21]. Akure is divided into two local government areas: Akure South and Akure North LGA. Notably, Oba Adesida Road falls within the jurisdiction of Akure South Local Government Area. Figure 2 depicts a map outlining the boundaries of the two local governments within Akure city, highlighting the road as an arterial road.

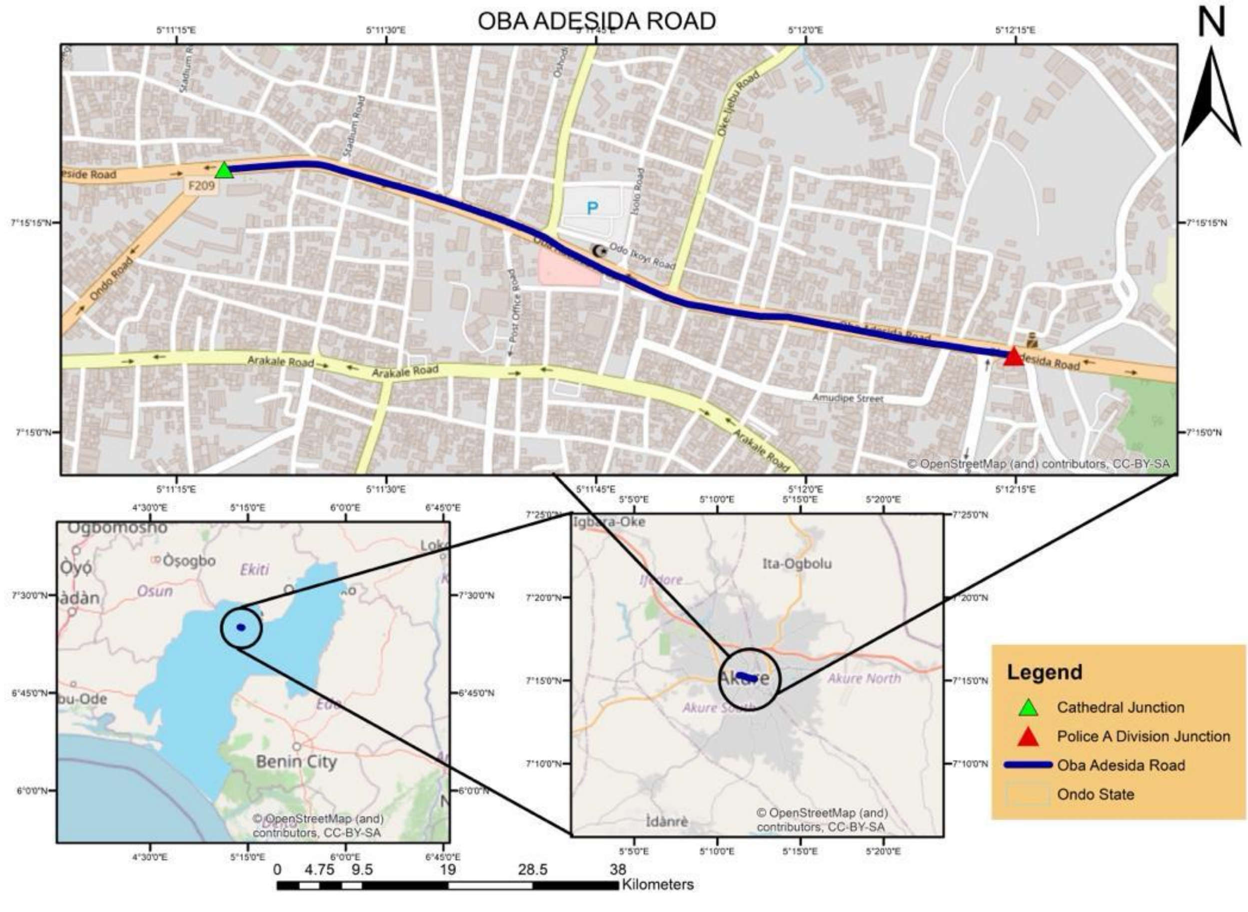

Figure 2 The Oba Adesida road network

2.1. Methods of Data Collection

The selection of Oba Adesida Road in Akure as a case study was made through purposive sampling. This dual-carriageway road is the oldest in the city and serves as a crucial link connecting key areas. It was chosen for its prominence in traffic activities and the substantial daily inflow and outflow of vehicles. Data collection relied primarily on direct field information gathering, including traffic counts, measurements, and observations. Road parameters were measured using wheel tape, with the recorded measurements presented in Table 1. Traffic characteristics were surveyed using a combination of video-graphic technology and manual techniques. A seven-day traffic count was conducted from 7:00 am to 7:00 pm daily in both directions, utilizing computer technology for data extraction. The passenger car unit (PCU) equivalent technique, based on the British standard method, was applied to each vehicle class to determine the actual volume of vehicles on the studied road, as shown in Table 2. Statistical analyses, including mean, median, range, and skewness, were performed to assess the traffic volume characteristics of Oba Adesida Road. The Level of Service (LOS) for the road was determined using Theoretical Maximum Capacity (TMC) procedures and compared with the Technical Standard Method (TSM) [15], as indicated in Table 3. According to the Highway Capacity Manual [8, 10], the scale, meaning, and volume-to-capacity values for the Level of Service (LOS) adopted are summarized in Table 3.

3.0 RESULTS AND DISCUSSION

The carriageway width of Oba Adesida Road, as indicated in Table 1, incorporates measurements for shoulder and clearance. With a total width of 14.6 metres, including shoulder and clearance on the right of way, the road adheres to the standards outlined in the Code of Practice, as compared to the [22]. It is recognized that narrow lanes may lead to collisions or difficulty in manoeuvring, while excessively wide lanes might encourage speeding and reduce driver alertness. In addition, insufficient shoulder width can constrain emergency stopping areas, elevating the risk of accidents. Oba Adesida Road unquestionably aligns with these practices. The lane width, encompassing shoulder and clearance as presented in Table 1, falls within a balanced range—not excessively narrow nor too wide. The median measurement, walkway, and drainage are all in compliance, meeting the safety conditions for the road.

Table 1 Physical Measurements of Study Road

Road Parameters	**Length Of Road**	**Width of Carriage way**	**Median**	**Walkway**	**Drainage**
Measurement (M)	1800	14.6	1.2	2.4	0.6

Source: Field Survey, 2023

The traffic composition of Oba Adesida Road is characterized by a diverse mix of vehicles, including motorcycles, tricycles, taxis, buses, and trucks. The trucks are subcategorized based on the number of axles, namely 2-axle, 3-axle, 4-axle, and 5-axle trucks. Table 2 outlines the vehicle classifications corresponding to their respective Passenger Car Unit (PCU) factors. However, upon evaluation, the traffic composition of this road predominantly consists of taxis, motorcycles (Okadas), and buses [12, 23].

Table 2 Composition of Vehicular Traffic Volume with its Equivalent PCU Factors

S/N	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Vehicle Classifications	Tricycle/ Motorcycle	Car	Bus	2-Axle Truck	3-Axle Truck	4-Axle Truck	5-Axle Truck
PCU Factors	0.75	1.0	2.0	2.0	3.0	4.0	4.0

Source: [24]

Table 3 presents the volume-to-capacity ratio for different levels of service (LOS) and their corresponding interpretations. A road assigned LOS-F indicates persistent congestion, signifying that the road is consistently operating beyond its vehicle capacity. On the other hand, a road designated LOS-A implies unrestricted and steady traffic flow without any delays or congestion. The weekly summary of traffic capacity for each day was calculated and recorded in Table 4. This table encompasses both field measurements and approximate Passenger Car Unit (PCU) values for traffic characteristics throughout the entire week, spanning from Monday to Sunday.

Table 3 Volume to Capacity Ratio for Various Level of Service (LOS)

Scale	Meaning	Volume to Capacity ratio (v/c)
A	Free flow (traffic flows at or above speed limit and motorists have complete mobility between lanes)	0 - 0.6
B	Stable traffic flow, speed is unaffected. Reasonably free flow (slightly more congested, with some impingement of manoeuvrability)	0.61 – 0.70
C	Stable traffic flow, speed is affected. (More congested than B, ability to pass or change lanes is not always assures, posted speed is maintained	0.71 – 0.80
D	Approaching unstable flow with high vehicle density (speeds somewhat reduces, motorists hemmed in by other vehicles)	0.81 – 0.90
E	Unstable flow. Low speed (flow becomes irregular, speed varies widely and rarely reaches speed limit, consistent with over capacity)	0.91 – 1.00
F	Breakdown flow. Forced or broken flow (constant traffic jam)	>1.00

It can be observed from Table 4 that Thursday traffic capacity characteristics have the highest traffic with average PCU value of 24047pcu/day when compared with the rest of the days. Sunday has the lowest average flow of vehicles (13863pcu/day). Inbound traffic is more than outbound traffic throughout the days of the week. While the outbound traffic ranges between 13818pcu/day and 20894pcu/day; the incoming is between 13908pcu/day and 22393pcu/day. The study shows that the selected road is highly congested with traffic volume between 1080–2221 pcu/hr. and 13818 – 25788pcu/day with the consideration of both directions. Figure 3 presents traffic characteristics capacity for the whole week. Each day comprises of incoming and outbound traffic. The blue colour denotes inbound traffic while the orange colour represents outbound traffic.

Table 4 Summary of Traffic Characteristics Capacity for the Whole Week

DAYS	IN-COMING VEHICLES Field Values	Approx. PCU Values	OUT-GOING VEHICLES Field Values	Approx. PCU Values	Average PCU Values
Monday	25050	22393	23053	20894	21644
Tuesday	25277	22633	23117	19945	21290
Wednesday	24237	21894	23076	20899	21397
Thursday	27090	25788	23539	22304	24047
Friday	24031	22124	23387	21390	21757
Saturday	17425	16065	16346	15289	15677
Sunday	15090	13908	14970	13818	13863

Source: Traffic Survey, 2023

From Figure 3, it is evident that Thursday (Day 4) recorded the highest PCU values for inbound traffic at 25,788 PCU/day. In comparison, the other weekdays showed relatively similar values: Monday at 22,393 PCU/day, Tuesday at 22,633 PCU/day, Wednesday at 21,894 PCU/day, and Friday at 22,124 PCU/day. However, Saturday and Sunday witnessed lower incoming vehicle numbers at 16,065 PCU/day and 13,908 PCU/day, respectively. Outbound traffic displayed a range between 13,818 PCU/day and 20,894 PCU/day. Thursday again exhibited the highest PCU values for outbound traffic, registering 22,304 PCU/day. The remaining weekdays demonstrated varied daily values. Notably, Saturday and Sunday had the lowest PCU values for both incoming and outbound traffic, as depicted in Figure 3. This indicates congestion during peak hours from Monday to Friday, with Thursday experiencing the highest congestion rate. On the weekends, specifically Saturday and Sunday, there was a relatively lower volume of vehicles, possibly due to reduced activities in the road's vicinity.

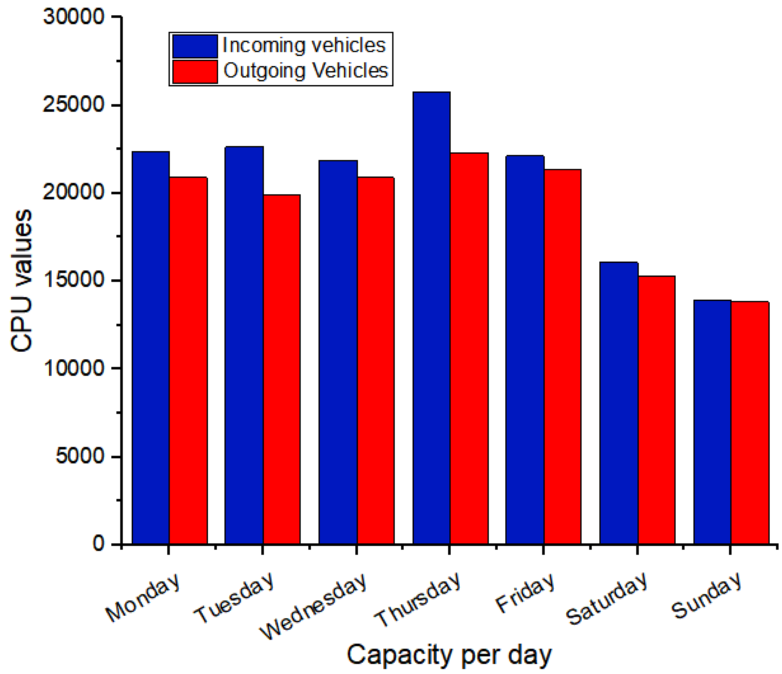

Figure 3 Graphical representation of PCU traffic characteristics capacity for the week

3.1. Statistical Calculations of Traffic Volume of OBA ADESIDA Road

The statistical analysis of the daily vehicular characteristics of both incoming and outgoing traffic on Oba Adesida Road involved a comprehensive examination of raw field values (RFV) and passenger car unit equivalents (PCU). Various statistical parameters were calculated, including mean, mode (maximum), median, range, and skewness, aiming to provide a detailed understanding of the dataset. In terms of inbound traffic, the range, representing the difference between the highest and lowest values, was found to be 12,000. The mean, calculated as the average of the given numbers, yielded a value of 22,600. The median, representing the middle number when arranged in ascending order, was determined to be 24,237. Skewness, a measure of distribution asymmetry, was calculated as -1.093, indicating a slight leftward skewness in the data. This skewness value was determined through the comparison of the mean, median, and standard deviation, providing insights into the shape of the distribution. Table 5 presents the statistical representation of inbound traffic per day, detailing the field values, mean, and differences between PCU values and the mean. Notably, Saturday and Sunday recorded traffic volumes lower than the mean for the entire week, resulting in negative differences when deducted from the mean. The standard deviation, calculated to assess the variability or dispersion of the data, was determined to be 4.495. This further complemented the skewness calculation in understanding the distribution characteristics of inbound traffic on Oba Adesida Road. The negative skewness and the lower traffic volumes on weekends suggest a distinctive pattern in the traffic flow on Oba Adesida Road. The statistical analyses offer valuable insights for traffic management and planning, highlighting specific days with higher congestion rates and variations in traffic patterns throughout the week. These findings contribute to a more nuanced understanding of the vehicular dynamics on Oba Adesida Road, aiding in the development of effective traffic management strategies.

3.1.1 PCU for inbound traffic

The meticulous statistical analysis of inbound traffic on the specified road delved into key parameters such as range, mean, and median to unravel the intricacies of traffic patterns. The calculated range of 11,880 highlighted the variability in daily traffic volumes, while the mean of 20,686 provided a central tendency measure for the dataset. The median, found to be 22,124, offered additional insights into the distribution of traffic volumes. Detailed statistical calculations, as presented in Table 5, focused on the passenger car unit equivalent (PCU), emphasizing differences between PCU values and the mean, along with their corresponding exponential values for each day. Notably, Thursday stood out with a significantly higher traffic volume, contributing markedly to the overall variance in the dataset. Conversely, negative differences observed on Saturday and Sunday indicated lower traffic volumes compared to the weekly mean, aligning with the typical trend of reduced vehicular activity during weekends. The cumulative total of 205,617,295 in the (X1 - X̄) ² column underscored the overall variability in incoming traffic, emphasizing the need for a nuanced understanding of daily fluctuations. Further scrutinizing the statistical analysis, additional measures such as standard deviation and skewness were computed to provide a more comprehensive understanding of the dataset. The calculated standard deviation of 4,154 quantified the spread of values around the mean, indicating the degree of variability in daily traffic volumes. The skewness of -1.039 suggested a slight leftward shift in the distribution, indicating that the dataset leaned towards lower traffic volumes on certain days.

Table 5 Statistical Representation of Inbound Traffic Per Day (PCU Values)

DAYS	PCU VALUES (X_1)pcu/day	MEAN (X^1)	(X_1 - X^1)	(X_1 - X^1)^2
MONDAY	22393	20686	1707	2913849
TUESDAY	22633	20686	1947	3790809
WEDNESDAY	21894	20686	1208	1459264
THURSDAY	25788	20686	5102	26030404
FRIDAY	22124	20686	1438	2067844
SATURDAY	16065	20686	-4621	21353641
SUNDAY	13908	20686	-6778	45941284
			TOTAL	**103557095**

Table 6 provides a summary of descriptive statistics for the incoming traffic volume on Oba Adesida Road. The mean values for traffic ranged from 20,686 PCU/day to 22,600 vehicles/day. In contrast, the median exhibited higher traffic values, ranging from 22,124 PCU/day to 24,237 vehicles/day, when compared to the mean.

Table 6 Descriptive Statistics of Traffic Volume at Oba Adesida Road (Incoming Direction)

Data Type	Maximum	Minimum	Range	Mean	Median	Skewness
Peak Traffic Volume (Veh/Day)	27090	15090	12000	22600	24237	- 1.09
Peak Traffic Volume (Pcu/Day)	25788	13908	11880	20686	22124	- 1.04

3.1.2. For field outbound traffic

Table 7 shows the statistical breakdown of outbound traffic, focusing on raw field values for each day. The differences between Passenger Car Unit Equivalent (PCU) values and the mean, along with their corresponding exponential values, were meticulously computed, providing a detailed understanding of daily fluctuations. The analysis of outbound traffic on the specified road encompasses various statistical parameters, shedding light on the traffic dynamics. The calculated range, indicating the difference between the highest and lowest values, was determined to be 8,569. Meanwhile, the mean, serving as the average of the given numbers, stood at 21,070, providing a central tendency measure for the dataset. Notably, the median, representing the middle number when arranged in ascending order, was found to be 23,076, surpassing the mean and suggesting potential variations in the dataset. Moving beyond central tendency measures, the standard deviation, calculated at 3,722, quantifies the spread of values around the mean, highlighting the variability in daily traffic volumes. Additionally, skewness, computed as -1.62, indicates a leftward shift in the distribution, suggesting a tendency towards lower traffic volumes on specific days. In summary, the comprehensive statistical analysis of outbound traffic on the specified road offers valuable insights into the variability, central tendency, and distribution asymmetry of the dataset. These findings are essential for traffic management and planning, providing a nuanced perspective to formulate strategies addressing the observed variations in daily traffic volumes.

Table 7 Statistical Representation of Outbound Traffic per Day (Field Values)

DAYS	FIELD VALUES (X_1)Veh/day	MEAN (X^1)	(X_1 - X^1)	(X_1 - X^1)^2
MONDAY	23053	21070	1983	3932289
TUESDAY	23117	21070	2047	4190209
WEDNESDAY	23076	21070	2006	4024036
THURSDAY	23539	21070	2469	6095961
FRIDAY	23387	21070	2317	5368489
SATURDAY	16346	21070	-4724	22316176
SUNDAY	14970	21070	-6100	37210000
			TOTAL	**83137160**

3.1.3. PCU for outbound traffic

Table 8 presents a comprehensive analysis of the difference between the mean values and passenger car unit equivalent per day, revealing a range between 725 and 5402 when compared with data from Tables 5, 6, and 8. This disparity highlights the variations in daily traffic volumes and emphasizes the dynamic nature of vehicular flow on the specified road. The subsequent calculation of standard deviation yields a value of 3291. Furthermore, the skewness is determined as -1.53. This negative skewness suggests a leftward shift in the distribution, signifying that the dataset leans towards lower traffic volumes on certain days. The skewness, coupled with the mean and standard deviation, provides a more nuanced perspective on the shape and characteristics of the incoming traffic dataset.

Table 8 Statistical Representation of Outbound Traffic per Day (PCU Values)

DAYS	PCU VALUES (X_1)Pcu/day	MEAN (X^1)	(X_1 - X^1)	(X_1 - X^1)^2
MONDAY	20894	19220	1674	2802276
TUESDAY	19945	19220	725	525625
WEDNESDAY	20899	19220	1679	2819041
THURSDAY	22304	19220	3084	9511056
FRIDAY	21390	19220	2170	4708900
SATURDAY	15289	19220	3931	15452761
SUNDAY	13818	19220	5402	29181604
			TOTAL	**65001263**

Table 9 presents statistical summary results of the traffic Volume of Oba Adesida Road on the outgoing direction. Both raw field values and its correspondent passenger car unit equivalent values were considered. The results show that the highest volume of vehicles in this direction per day was not more 23539veh/day and 22304pcu/day. The negatively skewed data in Table 9 show that the distribution of vehicles has more concentrated congestions on the right side than the left. Practically, there are more vehicles on the incoming direction than the outgoing on the other side of the road when place on the average per day. Definitely the congestion on the right direction was more than the left direction

Table 9 Descriptive Statistics of Traffic Volume at Oba Adesida Road (Outgoing Direction)

Data Type	Maximum	Minimum	Range	Mean	Median	Skewness
Peak Traffic Volume (Veh/Day)	23539	14970	8569	21070	23076	- 1.62
Peak Traffic Volume (Pcu/Day)	22304	13818	8486	19220	20894	- 1.53

3.1.4. Determination of theoretical maximum capacity

According to Manzoor and Mudasir (2020), theoretical maximum capacity was obtained using this relation:

$$C = \frac{1000 \times V}{S} \quad (1)$$

Where C = Capacity of a single lane in vehicle per hour.
V = Design Speed in Km/h
S = Average censer to canter spacing of vehicles, when they follow one behind the other as a queue or space headway in m.

$$S = Sg + L \quad (2)$$

$$Sg = 0.278 \text{ V x t} \quad (3)$$

Where L = the average length of the vehicle.
T = reaction time of the driver (0.75sec)
S = 0.278 x 0.75 x 60 + 6.9
S = 19.41m

Therefore:

$$C = \frac{1000 \times 60}{19.41}$$

C = 3091 per hr

The total volume of traffic during the peak hour session in each day for one week was determined as tabulated in Table 10. The design service volume per hour value was used to divide actual volume capacity of the road. It can be deduced from Table 10 that the level of service of Oba Adesida Road was between LOS-C to F while the predominant is LOS-F indicating poor performance. This means that the road was consistent with over capacity during the peak hour of the working days of the week. The flow becomes irregular and breakdown with constant traffic congestions. Figure 4 is the graphical representation of Level of Service (LOS) of Oba Adesida Road with theoretical maximum capacity method. In each day, the blue denotes level of service in the morning and orange stands for level of service in the evening. From Figure 4, it was observed that the only day that had a relatively stable traffic flow with level of service C was Sunday. It had LOS-C between 0.76 and .077. The evening and morning periods of Wednesday and Saturday had the volume capacity ratio 0.84 corresponding to LOS-D. Saturday evening had unstable flow with varied low speed when the flow became irregular. It had LOS-E with V/C of 0.92 which can be interpreted as having over capacity volume of vehicles. Monday to Friday experienced breakdown of flow at peak hours except evening of Wednesday. These days had LOS-F with V/C ratio ranges between 1.25 and 1.50 indicating poor performance because of the consistent over capacity. There were constant traffic congestions at peak hour of each working day of the week.

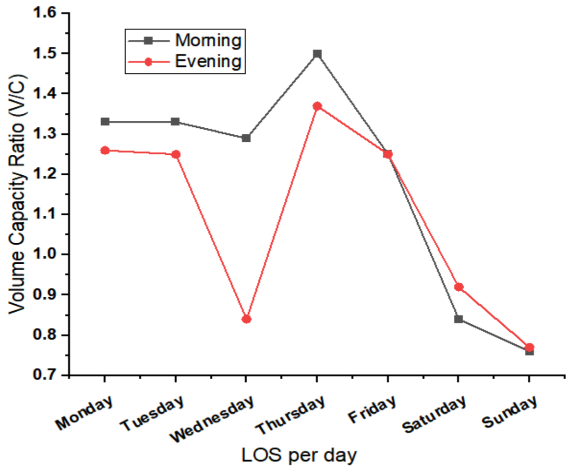

Figure 4 Graphical representation of Level of Service (LOS) of Oba Adesida road with theoretical maximum capacity

Table 10 Level of Service of Oba Adesida Road at Peak Hour of the Day

Days of the Week	Peak Period	Passenger Car Unit (PCU)/hr (Volume)	Design Service Volume (DSV)/hr (Capacity)	Volume Capacity (V/C) Ratio	Level of Service (LOS)
Monday	Morning	4112	3091	1.33	F
	Evening	3894	3091	1.26	F
Tuesday	Morning	4106	3091	1.33	F
	Evening	3864	3091	1.25	F
Wednesday	Morning	4000	3091	1.29	F
	Evening	2594	3091	0.84	D
Thursday	Morning	4648	3091	1.50	F
	Evening	4250	3091	1.37	F
Friday	Morning	3860	3091	1.25	F
	Evening	3858	3091	1.25	F
Saturday	Morning	2594	3091	0.84	D
	Evening	2852	3091	0.92	E
Sunday	Morning	2358	3091	0.76	C
	Evening	2374	3091	0.77	C

3.1.5. Using Technical Standard Method

Based on road classifications by technical standards of highways according to [11, 15], Oba Adesida road is classified as a Class II road with a design speed of 60 km/hr and capacity of 900 veh/hr. Table 11 presents the Level of Service of the road with average PCU values. From Table 11, it can be observed that the Level of Service of Oba Adesida was LOS-F indicating poor performance throughout the days of the week. This means that at every peak hour of the day, there were traffic congestions.

Table 11 Level of Service of Oba Adesida Road at Peak Hour of the Day

Days of the Week	Peak Period	Average Passenger Car Unit (PCU)/hr (Volume)	Design Service Volume (DSV)/hr (Capacity)	Volume Capacity (V/C) Ratio	Level of Service (LOS)
Monday	Morning	2056	900	2.28	F
	Evening	1947	900	2.16	F
Tuesday	Morning	2053	900	2.28	F
	Evening	1932	900	2.15	F
Wednesday	Morning	2000	900	2.22	F
	Evening	1297	900	1.44	F
Thursday	Morning	2324	900	2.58	F
	Evening	2125	900	2.36	F
Friday	Morning	1930	900	2.14	F
	Evening	1929	900	2.14	F
Saturday	Morning	1297	900	1.44	F
	Evening	1426	900	1.58	F
Sunday	Morning	1179	900	1.31	F
	Evening	1187	900	1.32	F

Figure 5 illustrates consistent LOS-F conditions throughout the entire week, with Volume Capacity Ratio ranging from 1.31 to 2.58. This indicates persistent congestion during peak hours on a daily basis; no day experienced relief from traffic congestion. The road consistently operated beyond its technical capacity throughout the week. This recurrent congestion can be attributed to the substantial commercial activities surrounding the road in both directions. The area serves as a hub for industrial, commercial, and residential purposes, contributing significantly to the high traffic volume. The presence of a substantial number of hawkers, vendors, roadside traders, stores, and shops along the road creates an environment conducive to traffic congestion. Notably, commercial vehicles, especially taxis, motorcycles, and tricycles, dominate the vehicular and human traffic along this route due to the prevalent commercial activities. Some designated areas along this road lacked adequate functioning traffic signals, with the existing few being in a state of disrepair and no longer operational. The prevalence of traffic rule violations was notable, primarily due to the hurried and frustrated demeanour of public transport drivers. The control of traffic by government traffic warden/officers was minimal, proving insufficient to alleviate peak-hour traffic congestions on this road. Additionally, careless parking of vehicles was observed along the roadside of this route. Commercial shop owners along the road often utilized road corridors, forcing customers to park along the road and consequently contributing to traffic congestion.

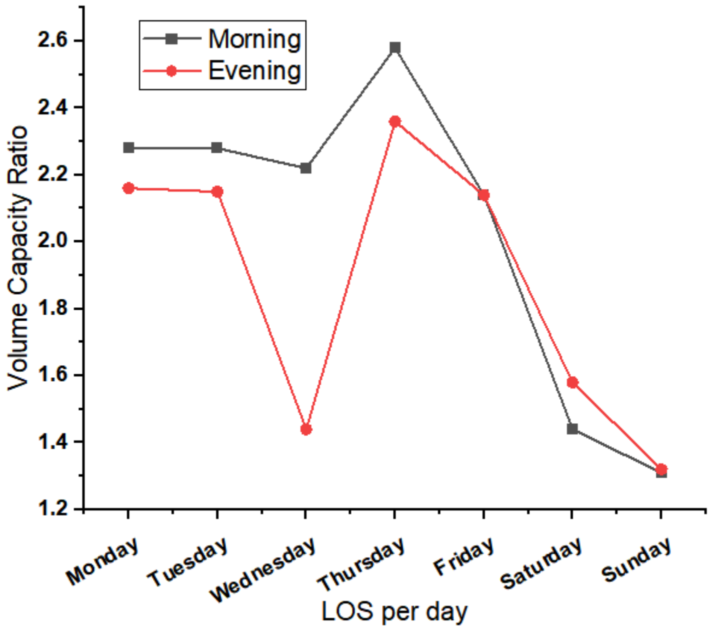

Figure 5 Graphical representation of Level of Service using Technical Standard Method

4.0 CONCLUSION AND RECOMMENDATIONS

The evaluation of the capacity and level of service (LOS) for Oba Adesida Road under mixed traffic conditions has provided crucial insights into the traffic dynamics and challenges faced by urban arterial roads in Akure, Nigeria. Our findings highlight significant congestion issues, particularly during peak hours, with LOS ranging from C to F. The consistent observation of LOS-F during peak hours underscores the urgency for effective traffic management strategies.

4.1. Implications for Theory, Practice, and Policy

Theoretically, this study contributes to the existing body of knowledge on urban traffic management by applying the passenger car unit (PCU) equivalent technique and evaluating LOS under mixed traffic conditions specific to developing countries like Nigeria. Practically, the insights gained from this study can inform the design and implementation of traffic management strategies tailored to similar urban settings. Policymakers can leverage these findings to prioritize investments in traffic infrastructure and enforcement measures to alleviate congestion and improve road safety.

4.1.1. Limitations of the study

Despite the valuable contributions, this study has several limitations. The reliance on purposive sampling and the focus on a single urban arterial road limit the generalizability of the findings. Additionally, the use of manual data collection methods may introduce human error, and the study’s temporal scope (7:00 am to 7:00 pm) excludes night-time traffic patterns, which may also affect LOS.

4.2. Recommendations for Future Research

To address the identified gaps and build on the findings of this study, future research should consider the following avenues:

a) Expanded Geographic Scope: Conduct similar studies on multiple urban arterial roads in different cities to enhance the generalizability of the findings and identify broader traffic patterns and challenges.
b) Advanced Data Collection Methods: Utilize advanced data collection technologies such as automated traffic counters and GPS-based tracking to improve data accuracy and reduce human error.
c) Comprehensive Temporal Analysis: Extend the study period to include night-time traffic patterns, providing a more holistic view of traffic dynamics and LOS over a 24-hour cycle.

By pursuing these research directions, future studies can provide deeper insights into urban traffic management and contribute to the development of more effective strategies for enhancing the capacity and level of service of urban arterial roads under mixed traffic conditions.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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