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Traffic Congestion Analysis of Asaba Road Using Volume to Capacity Ratio and Speed Performance Index

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ABSTRACT: With Nnebisi Road acting as a case study, this study focuses on the investigation of traffic congestion on Asaba Road. The study aims to examine the relationship between vehicle volume and road capacity, enabling transportation authorities to assess congestion levels and make informed decisions to alleviate traffic issues. Peak traffic counts were conducted, revealing the highest traffic flow on specific road sections on different days. The Ibusa – Stadium junction saw the highest volume on Monday, reaching 3,056 vehicles, while Ibusa – Ofili-Ilukwu junction peaked at 3,128 vehicles, also on Monday, and Ibusa – Ogbeogonogo junction hit 3,151 vehicles on Tuesday. Speed performance index varied across junctions and days, generally exceeding 60%. For instance, Ibusa – Stadium Junction ranged from 69.57% to 71.82% from Monday to Friday, Ibusa – Ofili-Ilukwu junction showed values between 63.59% and 68.95%, and Ibusa – Ogbeogonogo Junction ranged from 61.57% to 70.11%. These findings suggest a better road traffic state with higher average speeds. Moreover, the volume to capacity ratio, indicates the level of congestion and delays experienced. The ratio values along the studied road sections ranged from 0.61 to 0.70. These ratios, along with the speed performance index, classify the level of service as class B, indicating moderate congestion and delays with slightly longer travel times, yet still acceptable to users.

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A fundamental aspect of a nation's social and economic progress lies in its transportation infrastructure. As we transition to the era of intelligent transport systems, focus has predominantly been on developed cities, neglecting rapidly developing rural areas assimilated into metropolitan regions. The urbanization of these areas, termed semi-urban cities, escalates traffic volume, stressing the existing transportation system and highlighting the necessity for comprehensive solutions (Singh and Saraswat, 2019). Urbanization leads to heightened vehicular traffic on roadways, causing deteriorating road conditions, particularly during peak hours, with consequential economic, social, and environmental impacts. These include time wastage, elevated accident rates, and increased fuel consumption, as population growth often outpaces infrastructure expansion, diminishing service quality. This underscores the relationship between infrastructure capacity, dictated by traffic volume, and service level (Slimani *et al.*, 2019; Akhtar and Moridpour, 2021). According to Garber and Hoel (2009), traffic flows

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smoothly below a roadway's designed capacity, but congestion and delays arise near or beyond this limit. This is pivotal in highway planning, aiming to design facilities operating efficiently below their maximum capacities. Capacity analysis assesses a road segment's ability to accommodate traffic quantitatively, determining its maximum volume under prevailing conditions. According to Roess *et al*. (2011), capacity is the maximum vehicle passage rate within a specific timeframe. "Level of service" (LoS) aids in transportation and urban planning, crucial for trip duration estimation and infrastructure performance assessment. LoS categorizes traffic flow based on speed, density, and delay (Habib *et al*., 2018). The degree of saturation, defined as the volume to capacity ratio, determines infrastructure LoS (Koringa *et al*., 2017). Roads are classified by ownership and functionality, forming a hierarchical structure. Ownership-wise, they encompass freeways, arteries, collector/distributor roads, and local roads (US Department of Transportation, 2013).

Freeways, prioritized for high-speed travel, feature limited access and grade separation. Arteries, positioned below freeways, maintain some access control while serving both movement and access functions. Collector/distributor roads facilitate access and connect local roads to the broader network. Local roads, designed for lower speeds and minimal traffic, complete the hierarchy (AASHTO, 2018). In Nigeria, roads are categorized into Trunk A, B, C, and D, representing Federal, state, and local connections (Federal Ministry of Works and Housing, 2013). The road's serviceability concerns its function regarding traffic flow, encompassing speed and delays (TRB, 2016), vital for transportation planning. Capacity denotes a facility's ability to accommodate people or vehicles under current conditions, influencing road serviceability (Findley *et al*., 2016).

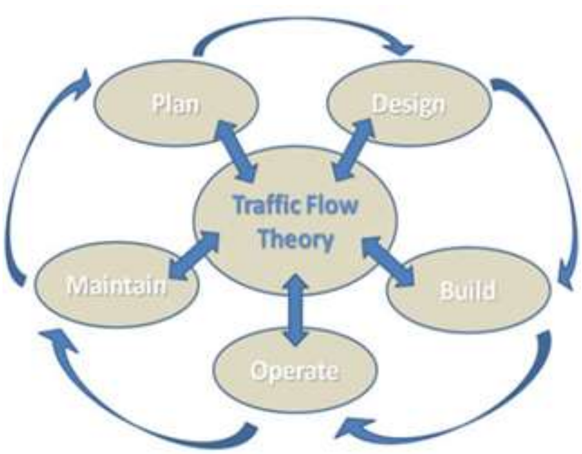

Fig 1: Traffic flow theory and its relationship to transportation infrastructure (Source: Elefteriadou, 2014)

Traffic flow theory, addressing infrastructure capacity and quality (Ni, 2016), informs planning by analyzing operations in various scenarios. Design incorporates geometric elements for desired traffic quality, while construction manages traffic around work zones and network congestion. In operations, it maximizes network efficiency, linking traffic control to the environment. Maintenance adapts to traffic patterns and infrastructure decay, initiating a new cycle (Ni, 2016; Elefteriadou, 2014). Monitoring flow, speed, and density are crucial in the dynamic and location-dependent study of traffic flow (Teodorović and Janić, 2017; Roess *et al*., 2011). It involves assessing macroscopic metrics like volume, speed, and density, alongside microscopic factors such as individual vehicle behavior (Teodorović and Janić, 2017).

On a highway, flow or volume, measured in vehicles per hour (veh/h), indicates the number of vehicles passing a specific point within an hour (Garber and Hoel, 2009; Garber *et al*., 2011). Equation 1 defines hourly flow rate using N as total cars and T as time.

$$q = \frac{N \times 3600}{T} \quad (1)$$

Daily traffic volumes vary significantly, especially during peak morning and evening commutes, making them unsuitable for design or operational analysis. Traffic engineers prioritize the peak hour, which records the highest traffic volume, using the highest 15-minute flow within that hour for analysis (Roess *et al*., 2011; Mannering and Washburn, 2013). Traffic capacity can be assessed using traffic volumes, but service quality for road users relies heavily on speed (HCM, 2016). Speed represents the distance a vehicle travels within a set time, usually measured in kilometres per hour (km/h) or meters per second (m/s). Speed can be calculated as either the time mean speed (u_t), determined by averaging speeds as vehicles pass a point, or the space mean speed (u_s), calculated by averaging speeds over a specific highway stretch at a given moment (Garber *et al*., 2011). Time mean speed, denoted as u_t, is the simple average of spot speeds measured for all vehicles passing a location over a specific time period, and is given by equation 2.

$$u_t = \frac{1}{n}\sum_{i=1}^{n} u_i \quad (2)$$

Where *v* is the spot speed of *i*th vehicle, and *n* is the number of observations. The time mean speed can be summarized to be the arithmetic mean of the vehicle speeds observed at some designated point along the roadway (Mannering and Washburn, 2013). Spot speed refers to a vehicle's speed at a specific point on a road. It's calculated based on the time taken to cover a particular distance.

Space mean speed, on the other hand, is an average of spot speeds but considers spatial weighting rather than time weighting. Space mean speed is often used for traffic modelling, assuming that all vehicles are measured over the same road length (Murthy and Mohle, 2001; Garber *et al.,* 2011; Mannering and Washburn, 2013). The space mean speed is as expressed in equation 3.

$$v_s = \frac{1}{\frac{1}{n}\sum_{i=1}^{n}\left[\frac{1}{\left(l/t_i\right)}\right]} \quad (3)$$

Traffic density, a macroscopic traffic flow parameter, is crucial for both drivers and system operators in assessing traffic performance. It's determined by the proximity of vehicles, affecting drivers' freedom and psychological comfort (Al – Sobky and Mousa, 2016). This density, often referred to as concentration, it is the number of vehicles per unit length of highway at a specific moment (measured in veh/km). Its significance lies in characterizing traffic operation quality, making it vital for uninterrupted-flow infrastructures and overall traffic assessment (HCM, 2016; Papacostas and Prevedouros, 2009). The traffic density is given expressed by equation 4.

$$k = \frac{n}{l} \quad (4)$$

Evaluating density directly is challenging as it requires an elevated viewpoint to observe the studied road section. Nevertheless, it stands out as the most crucial of the three fundamental traffic stream factors because it directly relates to traffic demand. Traffic demand is not a rate of flow; rather, it results from diverse land uses contributing to a high vehicle density. The observed flow rate is determined by the interplay of speed and density, as used by traffic engineers to gauge demand (Roess *et al*., 2011; Walsen and Saleh, 2017). The three basic macroscopic parameters of a traffic stream (i.e., flow, speed, and density) are related by the expression as seen in equation 5.

$$q = vk \quad (5)$$

The foundation for assessing traffic stream parameters lies in the provided definitions and relationships. To comprehensively analyze the operational performance of the traffic stream, it's essential to understand how these macroscopic metrics interact. Speed-flow and speed-density curves are computed once the relationship between speed and density is established (Roess *et al*., 2011; Mannering and Washburn, 2013). At very low densities, there's minimal interaction among drivers due to the scarcity of vehicles. In this scenario, vehicle performance and posted speed limits are the primary factors influencing speed, referred to as "free flow speed." However, as traffic density gradually increases, especially during the morning rush, congestion may develop in certain situations. In the early hours of the day, traffic density is minimal when the road is nearly empty, and vehicles travel at their maximum speed, known as free flow speed. However, as more vehicles join the roadway, traffic density gradually increases, causing a decline in the average speed. When traffic volume becomes substantial, it can lead to congestion, where vehicles come to a standstill with a speed of zero (Asaithambi *et al*., 2016). Figure 2 illustrates a standard speed-density relationship, including free-flow speed and jam density, characterized by a linear pattern. This relationship depicts how traffic density affects vehicle speed (Jain *et al*., 2016).

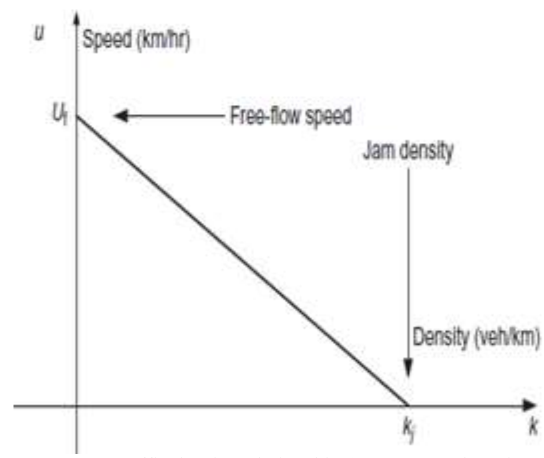

Fig 2 Speed-traffic density relationship (Source: Teodorović and Janić, 2017)

A linear speed-density relationship is approximation of the reality and is known as the Greenshields model as expressed in equation 6. By multiplying the density k by speed v from equation 6, the rate of flow can be defined by the equation 7 derived from equation 5 as

$$v = v_f\left(1 - \frac{k}{k_j}\right) \quad (6)$$

$$q = v_f\left(1 - \frac{k}{k_j}\right)k \quad (7)$$

From the above equation it was observed that the flow q is a quadratic function of the density *k*.

The graph shown in Figure 3 takes on a parabolic shape. As traffic density increases, the flow rate grows from zero to its maximum value q_{max}, which signifies the road's capacity. q_{max} is often termed traffic flow at capacity, while k_{max} represents the density associated with highway capacity. The corresponding speed is u_{max}. With a further rise in density, the flow rate begins to decline. Eventually, at jam density, the flow reaches zero, indicating that all vehicles are at a standstill. Studying density at capacity, k_{max}, is crucial as it distinguishes between stable (densities from zero to k_{max}) and unstable (densities higher than k_{max}) traffic conditions. Additional vehicles entering the highway, resulting in densities surpassing k_{max}, reduce highway flow (Teodorović and Janić, 2017; Roess *et al*., 2011; Garber and Hoel; 2009: HCM, 2016).

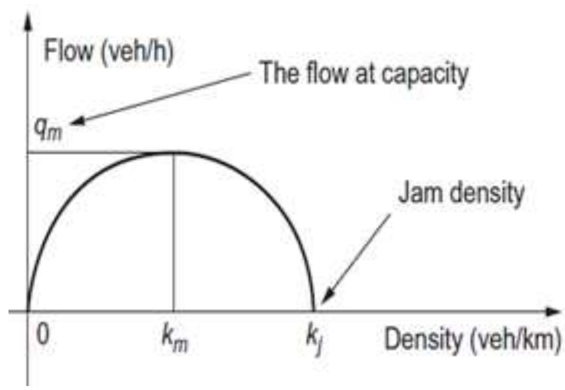

Fig 3 Flow q as a quadratic function of the density k (Source: Roess et al., 2011)

The maximum density is seen in equation 8 and the corresponding maximum velocity that defines this maximum flow is seen in equation 9.

$$k_{max} = \frac{k_j}{2} \quad (8)$$

$$v_f = \frac{u_f}{2} \quad (9)$$

The flow at capacity q_{max} is as shown in equation 10

$$q_{max} = \frac{u_f k_j}{4} \quad (10)$$

The capacity of a system element represents the maximum hourly flow rate under current constraints (HCM, 2016). In traffic, it signifies the highest possible vehicle flow through a specific point within a timeframe, reflecting a highway's traffic-carrying capability (Elefteriadou, 2014). Freeway capacity is defined as the maximum sustained 15-minute flow rate, usually in passenger cars per hour per lane (pc/h/ln), accommodating a uniform freeway segment's traffic in one direction (Garber and Hoel, 2009). Capacity levels include basic, possible, and practical, ensuring reasonable traffic flow and safety (HCM, 2016; Elefteriadou, 2014).

The capacity of the highway as given by Pawar *et al*., (2015) and Habib *et al*., (2018) is given by the equation 11

$$C = {}^{3600}/_{H_t} \quad (11)$$

Where H_t is the time headway.

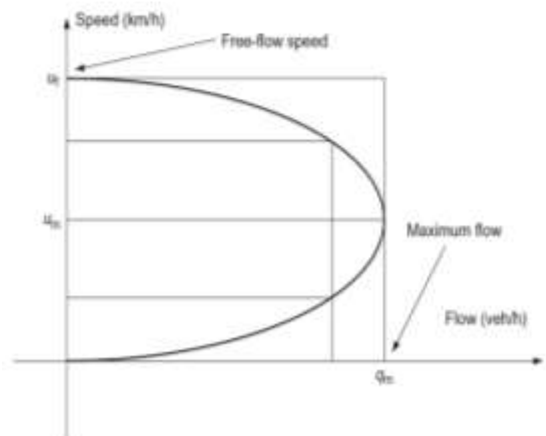

Fig 4: Speed-flow relationship (Source: Teodorović and Janić, 2017)

But an alternate formula for the determination of the capacity is as given by the equation 12, as given by Bhavsar *et al*., (2018) and Teodorović and Janić, (2017).

$$C = \frac{u_f k_j}{4} \quad (12)$$

The Level of Service (LOS) evaluates traffic operational conditions for road users under defined highway and traffic management conditions, indicating roadway performance below capacity (Garber and Hoel, 2009; HCM, 2016). LOS offers a qualitative overview of traffic, considering travel time, speed, and congestion (Mannering and Washburn, 2013). Selecting a performance measure reflecting motorists' perception, encompassing speed, travel time, delays, comfort, and convenience, is crucial for LOS analysis (Roess *et al*., 2011; Rogers, 2003; HCM, 2016; Yerawar *et al*., 2016). In the United States, the Highway Capacity Manual outlines six LOS levels, from A (best) to F (worst) (TRB, 1985), aiding in evaluating service quality based on speed, delays, and other factors (Pandey and Biswas, 2022). Visualizing traffic conditions is facilitated by the speed-flow relationship (Garber and Hoel, 2009). Level A reflects near-maximum speed, constrained by design, with low flows, while Level D optimizes flows with moderate speeds. Level F denotes breakdown conditions, indicating severe congestion (TRB, 1985).

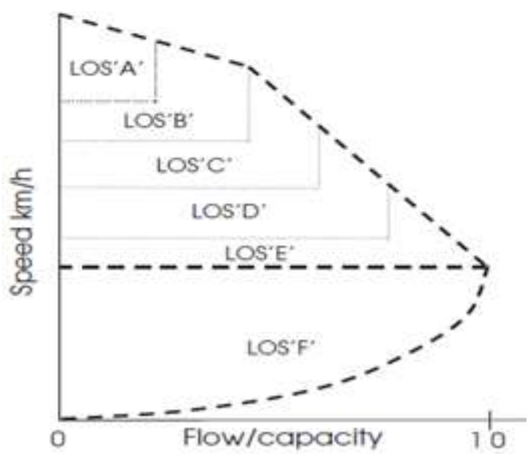

Fig 5: Linkage between level of service (LOS), speed and flow/capacity (Source: Rogers, 2003)

The volume-to-capacity ratio, referred to as the degree of saturation (DS), is the ratio of traffic flow (Q) to road capacity (C) in passenger car units per hour (PCU/hr). It is a critical metric for evaluating traffic performance, with higher saturation values indicating poorer performance (Susilo and Imanuel, 2018). This is as given by equation 13.

$$VCR = \frac{Traffic\ Volume\ (q)}{Road\ capacity\ (C)} \quad (13)$$

Where VCR = volume to capacity ratio.

This value is less than one and the traffic volume is less than the capacity of the road structure, hence the relationship between the volume to capacity ratio and the level of service is as seen in the Table 1

Table 1 Level of Service (LOS) and Q/C ratio (Source: Ajayi *et al*., 2016)

Level Of Service (LOS)	Q/C Ratio
A	< 0.6
B	0.61 – 0.70
C	0.71 – 0.80
D	0.81 – 0.90
E	0.91 – 1.00
F	> 1.00

The traffic congestion index objectively assesses road traffic conditions, aiding in management and planning (Wang *et al*., 2018), quantifying congestion potential perceived by road users. Vehicle speed, alone or combined with other factors, is crucial for evaluation. The index reflects the ratio of vehicle speed to the maximum allowable speed, typically ranging from 0 to 100. The Beijing Traffic Management Bureau (BTMB) categorizes urban road traffic using values of 25 and 50 (He *et al*., 2016), employing a speed performance index with threshold values of 25, 50, and 75 to categorize urban traffic conditions. The road segment and road network congestion indices are defined based on this assessment to study traffic congestion on urban road networks. Table 2 displays the speed performance index for a highway section

Table 2 Evaluation Criterion of Speed Performance Index on Expressway (Source: He *et al*., 2016)

Speed Performance Index	Traffic State Level	Description of Traffic State
0 – 25	Heavy Congestion	The average speed is low, road traffic state poor.
25 – 50	Mild Congestion	The average speed is lower, road traffic state bit weak.
50 – 75	Smooth	The average speed is higher, road traffic state better.
75 – 100	Very Smooth	The average speed is high, road traffic state good.

The speed performance index is as given by equation 14.

$$R_u = \frac{u}{u_{max}} \times 100 \quad (14)$$

Where, R_u = speed performance index, u = the average travel speed, km/h; u_{max} = maximum permissible road speed, km/h.

To establish speed-flow relationships for six-lane divided carriageways across different vehicle types, Jain *et al*. (2016) derived fundamental traffic flow parameters. The outermost lane experiences slow-moving vehicles in a free-flow state, as per the speed-flow relationship based solely on traffic speeds and flow. Traffic flow dynamics involve interactions among road infrastructure, vehicles, and user characteristics. Raji and Jagannathan (2019) illustrated the stochastic nature of traffic stream flow, resulting in random variations in vehicle movement and interactions. Modal speeds across the road network ranged from 36 to 45 kmph. Generally, the road facility's service level in the study area was designated as LOS A, except for Modal School Road and School Line Road, which exhibited LOS B. Phoenix Bay Road and Delanipur Road, with v-c ratios of 0.6 and 0.7 respectively, showed Level of Service C. However, other roads with v-c ratios ranging from 0.8 to 1.09 indicated LOS D or E. The study concluded that varying v-c ratios and speeds determine the level of service for the same road network in the study area. Pawar *et al*., (2015) presented an assessment of the level of service at highway midblock sections. Three highways (MSH-248, MSH-255, MSH-260) were selected for the assessment of level of service. Level of service of each highway section was assessed by using HCS-2000 Software. The results obtained using HCS-2000 clearly reflects that the deterioration in LOS is due to the increase in traffic volume and decrease in average spot speed. The aim of this study is to analyse traffic congestion at Ibusa junction in Asaba, Delta State by the use of volume to capacity ratio and congestion index. With the objectives of involving the determination of the flow rate and the capacity of traffic, speeds, speed performance index (SPI) of the road section under study, and the volume to capacity ratio, and comparing the speed performance index with the volume of capacity of the roads sections.

MATERIALS AND METHOD

Description of the Study Area: The city of Asaba lies between longitudes 6°38′44″ and 6°44′00″ east of the Greenwich Meridian and between latitude 6°08′00″ and 6°16‟00” North of equator (Ojiako *et al*., 2018). It is the capital of Delta State and located at the Niger Delta Area of the country. It is located at Oshimili South LGA and is bounded to the North by Oshimili North LGA, to the south by Ndokwa East LGA, to the East by the River Niger and to the West by Aniocha South and North LGA respectively (Ochilli *et al*., 2020). Being the centre of Delta state and the various ministries that are present. With an estimated population of 407, 196, this city is the 40th largest city in Nigeria. Therefore, the number of road networks in the city has increased as a result of the area's expansion (Ojiako *et al*., 2018). Figure 6 shows the road network in Asaba, Delta State and the study locations.

For this study, traffic counts and speed assessments were conducted at Ibusa junction, focusing on three road sections: Ibusa junction to Stadium junction, Ibusa junction to Ilukwu – Ofili Nwanne junction, and Ibusa junction to Ogbeogonogo market junction. These dual carriageways lack medians, each with two lanes and a width of 16.4m, except for the single carriageway along Ibusa – Ofili-Nwanne Junction. The Ibusa junction to Stadium junction, part of Nnebisi Road, experiences heavy traffic during peak periods from 8:00am to 10:00am and 4:00pm to 7:00pm. Similarly, the Ibusa junction – Ofili Nwanne junction, a section of Ibusa Road, faces high traffic during peak hours. The road connecting Ibusa junction to Ogbeogonogo market junction, also part of Nnebisi Road, experiences similar traffic flow, especially due to the market presence. The study procedures entail a reconnaissance survey of the road network, manual field data collection, and traffic flow modelling using volume-to-capacity ratio and speed parameters. This involves assessing flow concentration, conducting spot speed studies, and estimating congestion indices, including volume-to-capacity ratio and congestion index (CI).

Fig 6 Road Network of Asaba Showing the area of Study

Reconnaissance Survey of the roads Networks: Reliable traffic information is imperative for effective road network planning and decision-making. The reconnaissance study involves defining the roads under study, including their classification, width, lane count, and the types of vehicles utilizing them.

According to the FMWH manual (2013), Nigerian roads are categorized based on ownership into Federal, State, Local, and Rural Roads. Federal roads are further classified into four classes: A, connecting major urban areas; B, linking cities within a state and to Class A roads; C, connecting local centres; and D, serving minor centres like local markets. Vehicle classification includes passenger cars, trucks, and buses, encompassing various subcategories to aid in road infrastructure planning and management.

Volume of Traffic Determination: To ascertain the traffic volume on a road segment, conducting a traffic count is essential, involving the measurement of vehicles passing through the area during a specific timeframe. Traffic counts yield critical data used in road design, influencing factors like lane lengths and gradients. Neglecting traffic volumes in road design, akin to designing bridges without considering planned vehicle weights, would be futile (Findley *et al*., 2016). Manual traffic counts which involve observers manually tallying and classifying vehicles over shorter durations was used. This approach was used because it is cost-effective for single-day or shorter-duration data collection, making it a suitable choice for this study due to its affordability and classification capabilities, unlike automatic equipment, which can be expensive and lack classification features.

Traffic Speed Determination: To obtain the speed, the stopwatch method was applied and the length of the road section was determined by using the coordinates at the respective starts points and end points of the roadway under study, the observation was then recorded by the use of stopwatch spot speed data, from which the vehicular speeds were calculated and the time means speed which is the average speed of the vehicles were then determined.

Determination of Congestion Indices: The determination of the congestion was then measured based on data from the traffic volume. The measures used in this study include determination of the Speed Performance Index SPI, and Volume to Capacity ratio, which defines the Level of Service of the study.

RESULTS AND DISCUSSION

Summary of Road Characteristics: Nnebisi Road in Asaba, Delta State, connects Summit Road Flyover to the Federal Road Junction. This state-owned dual carriageway comprises two lanes separated by a 3.6m-wide median. Each lane has a covered drainage serving as a 1m-wide sidewalk. In total, the road section is 16.9m wide. The prominent Ibusa Junction is a key intersection along this road, linking Ibuso community and the bustling Ogbeogonogo Market in Asaba. Table 3 in the study provides a summary of this intersection and the road's alignment characteristics.

Traffic Volume and Road Capacity: Table 4 revealed the dominance of low-capacity vehicle i.e. 3 wheelers, passenger cars and small buses. At every section of the road, passenger cars have the highest counts follow by 3 wheelers, small buses, medium buses, light goods vehicles and heavy goods vehicles respectively.

Figure 7 summarizes the data as gotten from Table 4.5. It can be seen that the numbers of passenger cars for Friday was the highest, followed by Wednesday, with Thursday, Tuesday and Monday being least. These are also seen with other vehicular class.

Computation of Volume to Capacity Ratio: Tables 5 to 7 present the passenger car unit equivalent of the traffic volume. Using the British standard, the PCU factor for each class of vehicle are; 3 wheelers 0.8; passenger car 1.00; small buses, medium buses 2.00; light goods vehicles 1.5 and heavy goods vehicles 3.50 (Kadiyali, 2013).

For a dual carriage road of 2-lanes (7.3m/lanes) under the prevailing condition of been an all-purpose street with high-capacity junctions and with a no waiting restriction, the capacity is put at 1200 PCU/hour for both direction of flow (Ajala, 2019).

Table 3 Summary of Road Section

Section	length	Types of Carriageway	Width of Road
Ibusa – Stadium	728.57m	Dual	16.4m
Ibusa – Ilukwu	525.79m	Single	9.2m
Ibusa – Ogbeogonogo	509.40m	Dual	16.4m

Table 4 Average daily traffic characteristics along Ibusa – Stadium Junction

Vehicles	Monday	Tuesday	Wednesday	Thursday	Friday
3 Wheelers	823	806	824	818	899
Passenger cars	859	897	921	900	925
Small buses	373	348	325	320	310
Medium Buses	344	342	278	261	258
LGV	336	292	278	268	295
HGV	321	287	265	267	240
Total	3056	2972	2891	2834	2927

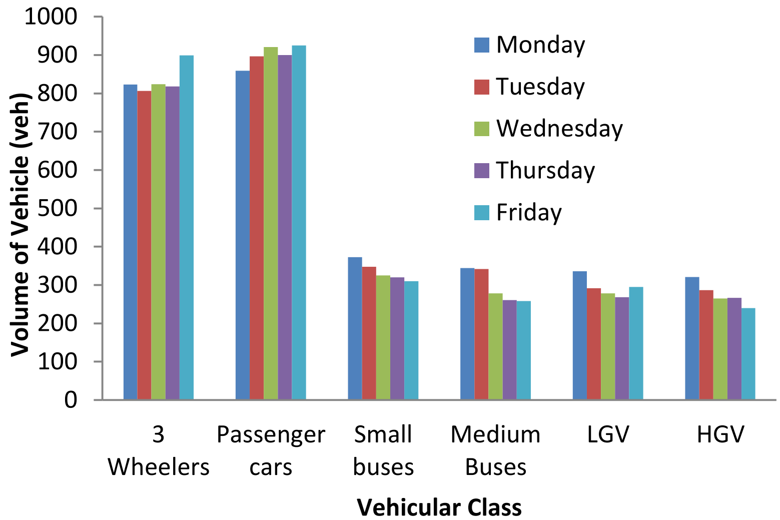

Figure 7 Traffic Characteristics along Ibusa – Stadium Junction

Table 5 Volume/Capacity Ratio along Ibusa – Stadium Junction

Vehicle class	PCU	Mon	PCUM	Tue	PCUT	Wed	PCUW	Thur	PCUTh	Fri	PCUF
3 wheelers	0.8	823	658.4	806	644.8	824	659.2	818	654.4	899	719.2
Passenger cars	1	859	859	897	897	921	921	900	900	925	925
Small buses	1	373	373	348	348	325	325	320	320	310	310
Medium Buses	2	344	688	342	684	278	556	261	522	258	516
LGV	1.5	336	504	292	438	278	417	268	402	295	442.5
HGV	3.5	321	1123.5	287	1004.5	265	927.5	267	934.5	240	840
Total		3056	4205.9		4016.3	2891	3805.7	2834	3732.9	2927	3752.7
Average capacity/hour			841.18		803.26		761.14		746.58		750.54
Road capacity			1200		1200		1200		1200		1200
V/C Ratio			0.70		0.67		0.63		0.62		0.63

Table 5 presents the daily PCU (Passenger Car Unit) capacity for the Ibusa – Stadium junction section. The capacity varies across the weekdays, with Monday having 4205.9 PCU/day, Tuesday 4016.3 PCU/day, Wednesday 3805.7 PCU/day, Thursday 3732.9 PCU/day, and Friday 3752.7 PCU/day. For each day, during a 5-hour survey, the average hourly capacity is calculated. These values are 841.18 PCU/hr (Monday), 803.26 PCU/hr (Tuesday), 761.14 PCU/hr (Wednesday), 746.58 PCU/hr (Thursday), and 750.54 PCU/hr (Friday). Additionally, the volume to capacity ratio (v/c ratio) is determined for each day. The ratios range from 0.70 (Monday) to 0.62 (Thursday). Overall, the level of service for this road section falls within class B, with a v/c ratio of 0.61 – 0.70 according to Roess et al. (2011). This indicates that there are constrains to traffic flow below speed limits, requiring drivers to pay extra attention for safe operations, resulting in reduced driver comfort and convenience.

Table 6 Volume/Capacity Ratio along Ibusa – Ilukwu Junction

Vehicle class	PCU	Mon	PCUM	Tue	PCUT	Wed	PCUW	Thurs	PCUTh	Fri	PCUF
3 wheelers	0.8	932	745.6	950	760	948	758.4	958	766.4	878	702.4
Passenger cars	1	952	952	953	953	952	952	962	962	878	878
Small buses	1	342	342	337	337	358	358	328	328	307	307
Medium Buses	2	302	604	331	662	321	642	293	586	286	572
LGV	1.5	322	483	284	426	291	436.5	283	424.5	275	412.5
HGV	3.5	254	889	265	927.5	258	903	244	854	246	861
Total		3104	4016		4065.5	3128	4049.9	3068	3920.9	2870	3732.9
Average capacity/hour			803.1		813.1		809.98		784.18		746.58
Road capacity			1200		1200		1200		1200		1200
V/C Ratio			0.67		0.68		0.67		0.65		0.62

Table 6 provides insights into the daily PCU (Passenger Car Unit) capacity for the Ibusa – Ofili-Ilukwu junction section. The capacity varies throughout the weekdays, with values of 4016

PCU/day (Monday), 4065.5 PCU/day (Tuesday), 4049.9 PCU/day (Wednesday), 3920.9 PCU/day (Thursday), and 3732.9 PCU/day (Friday). During a 5-hour survey, the average hourly capacity for each day is calculated, resulting in values of 803.1 PCU/hr (Monday), 813.1 PCU/hr (Tuesday), 809.98 PCU/hr (Wednesday), 784.18 PCU/hr (Thursday), and 746.58 PCU/hr (Friday). Furthermore, the volume to capacity ratio (v/c ratio) is determined for each day.

These ratios range from 0.67 (Monday) to 0.62 (Friday). The level of service for this road section falls within class B, with a v/c ratio of 0.61 – 0.70 (Roess et al. 2011). The drivers along this road section may experience a decrease in comfort due to the impression of being surrounded by other vehicles.

Table 7 Volume/Capacity Ratio along Ibusa – Ogbeogonogo Junction

Vehicle class	PCU	Mon	PCUM	Tue	PCUT	Wed	PCUW	Thurs	PCUTh	Fri	PCUF
3 wheelers	0.8	937	749.6	941	752.8	934	747.2	949	759.2	901	720.8
Passenger cars	1	865	865	927	927	850	850	874	874	877	877
Small buses	1	356	356	330	330	304	304	287	287	284	284
Medium Buses	2	335	670	338	676	313	626	271	542	279	558
LGV	1.5	306	459	327	490.5	265	397.5	266	399	259	388.5
HGV	3.5	280	980	288	1008	246	861	233	815.5	236	826
Total		3079	4079.6	3151	4184.3	2912	3785.7	2880	3676.7	2836	3654.3
Average capacity/hour			815.92		836.86		757.14		735.34		730.86
Road capacity			1200		1200		1200		1200		1200
V/C Ratio			0.68		0.70		0.63		0.61		0.61

Table 7 presents data related to the PCU (Passenger Car Unit) capacity for the Ibusa – Ogbeogonogo junction section. The capacity fluctuates for each weekday, with values of 4079.6 PCU/day (Monday), 4184.3 PCU/day (Tuesday), 3785.7 PCU/day (Wednesday), 3676.7 PCU/day (Thursday), and 3654.3 PCU/day (Friday).

The average hourly capacity is calculated based on a 5-hour survey, resulting in values of 815.92 PCU/hr (Monday), 836.86 PCU/hr (Tuesday), 757.14 PCU/hr (Wednesday), 735.34 PCU/hr (Thursday), and 730.86 PCU/hr (Friday).

The volume to capacity ratio (v/c ratio) is determined for each day, varying from 0.68 (Monday) to 0.61 (Thursday and Friday).

The level of service for this road section falls within class B, with a v/c ratio of 0.61 – 0.70 (Roess et al. 2011). The drivers may experience a decrease in comfort due to the impression of being surrounded by other vehicles.

Table 8 Speed Performance Index along Ibusa – Stadium Junction

Parameters	*Monday*	*Tuesday*	*Wednesday*	*Thursday*	*Friday*
Mean	55.29	54.63	54.63	52.85	54.23
Median	53.14	52.59	53.15	51.48	52.20
Mode	66.15	59.41	42.41	65.98	64.36
Minimum	41.12	40.18	39.90	39.06	38.71
Maximum	75.43	74.20	74.83	74.62	74.41
50th Percentile	53.14	52.59	53.15	51.48	52.20
98th Percentile	75.00	74.00	74.00	74.00	74.00
SPI (%)	70.85	71.07	71.82	69.57	70.54

Speed Performance Index Results: Tables 8 to 10 show the results of the summary of the speed study from which the average speed and the 98-percentile speed were derived.

Table 8 shows the summary of the spot speed study of the heterogeneous traffic along the Ibusa – Stadium junction and the speed performance index for the different days of traffic on the road section.

It was observed that for each of the day, the median speed which is also the 50th percentile speed was between the ranges of 51.48km/h to 53.15km/h.

Also, the Speed Performance Index (SPI) has the lowest which is on Thursday with a value of 69.57%, Friday with 70.54%, Monday 70.85%, Tuesday 71.07% and Wednesday 71.82%.

Since the range of 50 to 75% as given by He *et al*. (2016), suggested that the traffic flow is smooth and no congestion is experienced on this section of the road during the study.

Table 9 Speed Performance Index along Ibusa – Ilukwu Junction

Parameters	Monday	Tuesday	Wednesday	Thursday	Friday
Mean	50.56	50.09	50.57	50.48	52.72
Median	47.06	47.71	48.85	48.09	51.02
Mode	61.36	39.64	37.67	41.46	43.13
Minimum	35.02	34.32	33.21	33.28	34.37
Maximum	73.74	75.56	74.96	74.82	74.96
50th Percentile	47.06	47.71	48.85	48.09	51.02
98th Percentile	74.00	75.00	74.00	74.00	74.00
SPI (%)	63.59	63.61	66.01	64.99	68.95

Also, Table 9 shows the summary of the spot speed study of the heterogeneous traffic along the Ibusa – Ofili Ilukwu junction and the speed performance index of the traffic. It was observed that for each of the day the median speed which is also the 50th percentile speed was 47.06km/h on Monday, 47.71km/h on Tuesday, 48.85km/h on Wednesday, 48.09km/h on Thursday and 51.02km/h on Friday. Also, the Speed Performance Index (SPI) 70.11%, 64.43%, 61.57%, 64.51% and 61.69% for Monday to Friday respectively. In addition, the range of speed performance index was between 50 to 75% in accordance to the study by He *et al*. (2016), the traffic flow is smooth and no congestion is experienced on this section of the road during the study.

Table 10 Speed Performance Index along Ogbeogonogo Junction

Parameters	Monday	Tuesday	Wednesday	Thursday	Friday
Mean	52.88	49.35	48.94	48.97	48.59
Median	51.88	47.68	45.56	47.74	45.65
Mode	45.06	70.67	52.43	60.82	59.19
Minimum	39.25	34.21	33.54	33.17	33.49
Maximum	70.53	70.67	71.77	71.41	71.97
50th Percentile	51.88	47.68	45.56	47.74	45.65
98th Percentile	74.00	74.00	74.00	74.00	74.00
SPI (%)	70.11	64.43	61.57	64.51	61.69

And Table 10 shows the summary of the spot speed study of the heterogeneous traffic along the Ibusa – Ogbeogonogo junction and the speed performance index of the traffic. It was observed that for each of the day, the median speed which is also the 50th percentile speed was 51.88km/h on Monday, 47.68km/h on Tuesday, 45.56km/h on Wednesday, 47.74km/h on Thursday and 45.65km/h on Friday. Also, the Speed Performance Index (SPI) 63.59%, 63.61%, 66.01%, 64.99% and 68.95% for Monday to Friday respectively. In addition, the range of speed performance index was between 50 to 75% in accordance to the study by He *et al*. (2016), the traffic flow is smooth and no congestion is experienced on this section of the road during the study.

Comparison of Results from V/C ratio and Speed Performance Index: In the study, employing both methods to analyze road traffic congestion, it was noted that the maximum volume-to-capacity ratio occurred along the Ibusa – Ogbeogonogo section of the road, registering a value of 0.70. This indicates that the road section remained unsaturated during the study period. Furthermore, regarding the speed performance index, the highest index recorded was 71.82%, suggesting smooth traffic flow and levels below congestion thresholds on the road sections.

Conclusion: Analyzing traffic congestion on Asaba road using the volume-to-capacity ratio and speed performance index offers valuable insights for traffic management. By gauging the relationship between vehicle volume and road capacity, authorities can effectively assess congestion levels and make informed decisions to alleviate traffic issues. Nnebisi Road, a major artery connecting the summit area to the Federal Road leading to Onitsha, experiences primarily three-wheelers, passenger cars, small and medium buses, light goods vehicles, and heavy goods vehicles. Notably, three-wheelers and passenger cars dominate the road. Traffic counts during peak periods reveal Monday recorded the highest flow at Ibusa–Stadium junction with 3056 vehicles, Wednesday at Ibusa–Ofili-Ilukwu junction with 3128 vehicles, and Tuesday at Ibusa–Ogbeogonogo junction with 3151 vehicles. The study indicates a Level of Service B, signifying moderate congestion and delays, resulting in slightly extended travel times but still acceptable to users. The study's recommendations propose leveraging advanced analytics and predictive modelling to anticipate future traffic demand. Implementing signal timings and prioritizing infrastructure upgrades in high volume-to-capacity ratio areas are suggested strategies to address traffic challenges.

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