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Application of Spot Speed Study and Delay Analysis on Some Selected Roads in Asaba, Delta State, Nigeria

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ABSTRACT: Studies show that speeding reduces reaction time during emergencies and increases accident risk. Deviations from the mean speed affect road capacity and user safety. The aim of this study was to evaluate the speeds and travel times for various classes of vehicles on selected roads in Asaba, Delta State, Nigeria, using manual traffic studies and spot speed analyses to define speed parameters and Speed Spread Ratio (SSR) on the roads. The study shows Class 2 and Class 5 roads have high heavy vehicle usage. Asaba-Agbor Road's design, safe, and minimum speeds are 78.81 km/h, 58.65 km/h, and 29.00 km/h, respectively. Other roads range from 60.44 km/h to 68.9 km/h, with median speeds of 34-40 km/h. Summit Road's wide speed variation raises safety concerns. Nnebisi Road experiences increasing delays and congestion towards the week's end, while Summit Road maintains stable travel times and speeds, indicating predictable traffic patterns.

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The economic progress of a country hinges on efficient goods and service transportation. Roadways, railways, airways, and waterways constitute the four major transportation modes, with roadways being the most widely used. However, road transportation faces significant challenge in high-speed-related accidents. The World Health Organisation (WHO) estimates approximately 1.17 million annual deaths due to traffic accidents, with around 70 percent occurring in developing nations. The surge in accidents is attributed to population growth and increased motorized vehicle usage, particularly in urban areas, known as the automotive revolution (Atubi, 2012).

Since driving at a higher speed than that permitted results in a reduction in the reaction time during an emergency for controlling vehicular movement, the avoidance of traffic accidents is inversely related to the increase in speed. When vehicles move at a speed different from the mean speed, the capacity of the facility is affected, as is the safety of the users. And driving at a higher speed than that allotted may lead to serious road crashes, deaths, and injuries (Tanishita and Wee, 2017; Singh and Singh, 2010). Speed stands as a fundamental parameter in understanding traffic flow, holding significance in safety, travel time, travel quality (congestion), and traffic control (Hashim, 2011). Spot speed studies yield crucial data for evaluating average, median, modal, and percentile speeds, along with speed distribution characteristics. These findings inform various traffic engineering analyses, influencing decisions on speed zones, limits, and passing restrictions. They aid in assessing traffic control device efficacy, monitoring speed enforcement

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programs, and evaluating highway geometric elements. Additionally, the data help understand speed's impact on safety, determine speed trends, validate speeding complaints, and support simulation programs (Garber and Hoel, 2009; Hashim, 2011).

The establishment of safe speed limits within a road traffic corridor should be based on the application of engineering studies rather than speculative studies, as incorrectly posted speed limits on the road may affect the compliance of drivers, and roads without spelled-out speed limits will result in the occurrence of accidents (Shrestha and Shrestha, 2016). Speed Spread Ratio (SSR) is a metric used to quantify the variability or dispersion in vehicle speeds within a given traffic stream. It is calculated as the ratio of the standard deviation of speeds to the mean speed. A higher SSR indicates greater speed variation among vehicles. SSR is valuable in assessing traffic homogeneity, identifying potential safety concerns, and aiding in the design of efficient traffic management strategies (Salter and Hounsell, 1996). As most roads in Asaba and its environs in Delta State are newly constructed and the general speed limits are not specified by the road planning agency in the state, there have been some serious accidents on most of the roads in the state as a result of over speeding by many drivers, which may not be too overwhelming if there had been some limits placed on the roads as a result of a careful and thoroughly carried out study on the speeds within the state. In addition, the determination of the speed trend of vehicles that flow on the road is important for the planning of an estate road. Of which this study is also important. Traffic engineers utilize speed studies to evaluate the efficiency of speed limits and enforcement measures, establish suitable speed limits, assess speed trends nationally, and analyze speed-related factors in design applications. These studies also aid in determining appropriate sight distances, understanding the relationship between speed and highway alignment, and evaluating speed performance concerning grades. Additionally, speed studies are essential for specific control applications, such as timing intervals for traffic signals and proper sign placement. Investigation of high-accident locations where speed may contribute to accidents is also a crucial aspect (Roess *et al*. 2011; Roshandeh *et al*. (2009). Spot speed data plays a vital role in determining signage placement, signal design, road safety, and speed zone establishment. In modern traffic engineering, areas such as accident analysis, road maintenance, and congestion management heavily rely on spot speed data as a fundamental input. These studies evaluate vehicle movement rates within specific road segments during traffic surges. The research aims to gauge speed characteristics considering the prevailing traffic and environmental conditions at the study time and location (Naser, 2021). Spot speeds are influenced by various factors like road geometry, pavement conditions, intersections, and environmental elements, affecting travel choices. Measurement methods include the use of either the enoscopic or manual approach (Singh and Singh, 2010; Gupta and Gupta, 2010). Singh and Singh (2010) distinguish two types of speed studies: Operational and Design. Operational studies focus on real-time traffic speeds, statistically analyzing a sample to assess the 85th percentile speed, a key determinant for posted speed limits. Conversely, design studies scrutinize plans and profiles, extracting the 'effective' speed based on design features. Design speed assessments can be conducted pre-construction, allowing adjustments to the effective speed at the planning stage. Consequently, a design speed study is advocated over an operational one due to its proactive nature in aligning the road's design with desired speed outcomes. Rahim *et al*. (2020) conducted a study on Federal Road 5 (FR5) in Kapar Town, investigating the safety implications of vehicles exceeding operating speeds at different access points. The spot speed survey covered three locations, analyzing data on traffic volume and spot speed for 200 vehicles. Results revealed higher speeds on straight road stretches compared to curved ones. The multiple regression model suggested an inverse relationship between the number of accesses and 85th percentile speed, while traffic volume positively correlated with V85 operating speed. Statistical analysis indicated a significant difference in speed between straight and curved road stretches. Hashim (2011) conducted a comprehensive analysis of speed characteristics on rural two-lane highways using empirical data from intercity rural roads in Minoufiya Governorate, Egypt. The study explored the relationship between 85th percentile speed and headway, assessed the suitability of posted speed limits, and examined the normal distribution of spot speed data. Results indicated a constant 85th percentile speed at a headway of 5 seconds or more, suggesting a possible threshold for free-moving vehicles. Additionally, a significant proportion of drivers exceeded posted speed limits, questioning their appropriateness, and spot speed data exhibited a normal distribution. Azwari and Hamsa (2021) conducted an evaluation of vehicle speeds on the Duta-Ulu Kelang Motorway during free-flow traffic conditions. Using road geometrical surveys and spot speed surveys, around 400 vehicles were measured over a 4-hour period during off-peak hours. Descriptive statistics and t-tests were employed to analyze speed trends. Results revealed that, on average, 66% of vehicles exceeded the allowable speed limit of 90 km/h, highlighting a significant

difference between the actual average speed and the permissible speed limit. Adeke *et al*. (2018) conducted a study on spot speeds of vehicular traffic along highways in Makurdi town. Manual traffic counts and speed measurements were carried out on Otukpo, Gboko, Lafia, and Iorchia-Ayu highways. Statistical analysis revealed average speeds of 51 km/h, 53 km/h, 63 km/h, and 50 km/h, respectively. The study proposed a speed limit of 50-55 km/h for Makurdi town highways for safe travel, emphasizing that existing speeds were below design specifications. Factors impacting speeds included speed calming devices, high traffic volume, and geometric layout. Road rehabilitation and speed limit warning signs were recommended for improved safety. Vijayvargiya and Joshi (2016) emphasize the significance of spot speed studies in determining the speed distribution and percentiles of a traffic stream at a specific location.

The study conducted along the Civil Lines route in Vidisha, NH-86, Madhya Pradesh, aimed to gather traffic characteristics, including spot speed and flow. Results indicated a maximum speed of 80 km/h, with drivers rarely exceeding this limit. Their analysis revealed that vehicles predominantly operated within the speed range of 30 to 70 km/h, providing valuable insights into the prevailing traffic conditions on the studied roadway. The aim of this study focuses on the application of spot speeds and speed spread ratio of heterogeneous vehicles on some roads in Asaba, Delta state.

MATERIALS AND METHOD

Description of the Study Area: Asaba the capital of Delta state, is geographically located between longitudes 6°38′44″ and 6°44′00″ east of the Greenwich Meridian and latitude 6°08′00″ and 6°16‟00" North (Ojiako *et al*., 2018). It is situated at Oshimili South LGA and the boundary include, Oshimili North LGA, Ndokwa East LGA, River Niger and Aniocha South and North LGA respectively (Ochilli *et al*., 2020). The estimated land mass of the city is 268km^2 and the population estimate of 407, 196, makes this city to be ranked the 40th largest city in Nigeria (Ojiako *et al*., 2018). Illah – Anwai Road serves as a local access route within Asaba, connecting residential areas with educational and healthcare facilities like the Olisadebe University Anwai, the Delta State film village. This road also connects to Anambra State linking up to Kogi state. The Asaba – Igbuzor Road connects Asaba to the town of Ibusa and serves as an essential link for both residents and businesses. This road links up to the southern part of Delta State, which includes Kwale, Ozoro, Ughelli and Warri. This road also serves as an alternative road that links up the eastern part of the country to the other southern part of Nigeria. Nnebisi Road is a significant urban road in Asaba, often experiencing high traffic volume due to its proximity to key government offices, markets, and recreational areas..

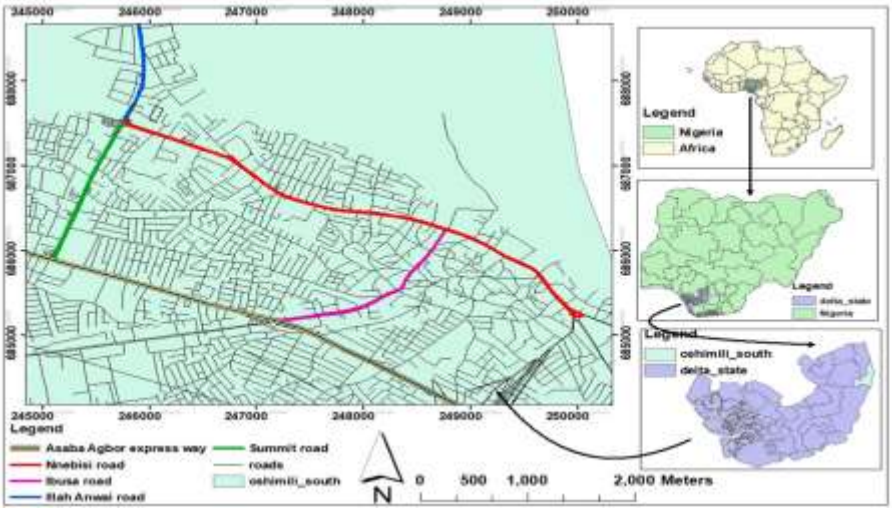

Fig. 1: Road Network of Asaba Showing the area of Study

The geometrical features that were considered in the study are as summarized in Table 1 and this include the road width, number of lanes present, the width of each lane, presence of medians and side walk. These are used to define each road section as applied in this study. These roads are all dual carriage way. Based on ownership these roads are state owned roads that connect to major towns in Delta state, Nigeria. This study was conducted by collecting data for a period of 6days from Monday to Saturday, and between 8:00am

to 5:00pm. The days were chosen as Mondays to Fridays are working days in the week as well as ascertaining the speed study for each working day of the week, while Saturday was chosen in order to select a day of the weekend when the usage of the road is also high. The results of field studies had shown that the distribution of spot speed data closely approximates the normal curve. To verify a normal distribution in the data used for this investigation, the following statistical tests were applied: chi-square test, moment test, percentile method for testing normality (2), and normality test using probability paper. All these statistical techniques indicated that the spot speed data significantly conformed to a normal distribution. The Berry and Belmont analysis is a simple and widely used method for determining the sample size in a spot speed study. However, it assumes that the speed distribution is normal, which may not always be the case. The method is based on the 85th percentile speed, which is the speed at or below which 85% of the vehicles are travelling. The sample size is given by the expression as shown in equation 1

$$Sample\ size = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1 + \left(\frac{z^2 \times p(1-p)}{e^2 N}\right)} \quad (1)$$

Where z is the Z score, e is the margin of error, p is the standard of deviation and N is the population size. With the Z score value of 1.96 and a 95% confidence interval the minimum number of sample size needed for this study is 384. Therefore, for the spot speed study a total of 1000 vehicles were used in this study to determine the spot speed study of the flow of vehicles on these road sections.

RESULTS AND DISCUSSION

Table 2, shows the result of the traffic count conducted on Illah – Anwai road, the total vehicles recorded amounted to 13,969. Predominantly, Class 2 vehicles constituted the majority, comprising 30.93% of the total, followed by Class 5 at 24.96%, Class 4 at 21.82%, Class 3 at 16.04%, and Class 1 at 6.25%. Notably, traffic patterns varied across the days of the week, with Wednesday observing the highest traffic and Saturday the lowest. The road section displayed a prevalence of heavy vehicles, particularly Class 4 and Class 5, suggesting potential challenges in maintenance and safety. Table 3 showed the traffic count conducted on Nnebisi road with the total vehicles utilizing this road facility amounted to 18,507 during the study. The prevalent vehicle category was Class 5, constituting 29.72% of the total, followed by Class 2 at 25.01%, Class 4 at 20.68%, Class 3 at 16.10%, and Class 1 at 8.48%. Notably, traffic volume varied across days, with Monday witnessing the highest count and Saturday the lowest. The road section exhibited a predominance of heavy vehicles, specifically Class 4 and Class 5, suggesting potential challenges in maintenance and safety considerations. Table 4 also showed the traffic count conducted on Asaba – Igbuzor road. The total numbers of vehicles that make use of this road facility was 15,523 during the course of carrying out this study. With the majority of vehicles being Class 2 with a percentage of 28.90%, Class 5 vehicles accounted for 28.71%, while Class 4 accounted for 17.54%, Class 3 accounted for 16.72% and Class 1 accounted for 8.13%. And the traffic composition on this road section was dominated by heavy vehicles, which are made up of Class 4 and Class 5 vehicles.

Table 1: Description of Road Section

Road Section	Road Width	No of lanes	Lane width	Median	Walk way
Illah – Anwai Road	17.4m	2	3.6m	Yes	Yes
Nnebisi Road	17.4m	2	3.6m	Yes	Yes
Asaba – Ibusa Road	26m	3	4m	Yes	Yes

Table 2: Vehicular Count (PCU) along Illah – Anwai Road Section

Days of Week	Vehicular Class					Total
	Class 1	Class 2	Class 3	Class 4	Class 5	
Monday	243	680	418	494	389	2224
Tuesday	156	784	471	558	791	2760
Wednesday	131	805	417	638	777	2768
Thursday	135	739	360	490	508	2232
Friday	106	687	353	464	630	2240
Saturday	102	625	222	404	392	1745
Total	873	4320	2241	3048	3487	13969

Table 3: Vehicular Count (PCU) along Nnebisi Road Section

Days of Week	Vehicular Class					Total
	Class 1	Class 2	Class 3	Class 4	Class 5	
Monday	340	854	541	722	1022	3479
Tuesday	300	753	479	642	1008	3182
Wednesday	275	749	544	646	1033	3247
Thursday	231	796	513	506	893	2939
Friday	201	742	496	642	805	2886
Saturday	223	735	407	670	739	2774
Total	1570	4629	2980	3828	5500	18507

Table 4: Vehicular Count along Asaba - Igbuzor Road Section

Days of Week	Vehicular Class					Total
	Class 1	Class 2	Class 3	Class 4	Class 5	
Monday	204	741	436	404	538	2323
Tuesday	219	783	471	535	824	2832
Wednesday	198	751	391	497	805	2642
Thursday	248	788	488	433	883	2840
Friday	206	742	459	458	759	2624
Saturday	187	681	351	396	647	2262
Total	1262	4486	2596	2723	4456	15523

Table 5 and Figure 2; show the summary of the spot speed study and the speed frequency distribution curve carried out on Illah – Anwai road. From which it was found that the weighted average speed ranged from 36.01 km/h to 36.83 km/h, with the highest speed observed on Monday. The modal speed ranged from 27 km/h to 34.36 km/h, with the highest speed observed on Friday. The design speed ranged from 62.67 km/h to 67.4 km/h, while the safe speed ranged from 47.54 km/h to 48.33 km/h. The median speed ranged from 33.75 km/h to 35.33 km/h, while the lowest speed limit ranged from 26.67 km/h to 29.02 km/h. The speed limit upper ranged from 27.20 km/h to 67.71 km/h. The standard deviation of the speed ranged from 10.26 km/h to 11.06 km/h. Also, since the speed spread ratio is between 0.2924 and 0.3076, there is a moderate variation in speed, and the traffic flow on this road section is uniform, the traffic volume on this road is low as proposed by Shah and Gupta (2016).

Table 5: Volume/Capacity Ratio along Ibusa – Ilukwu Junction

	Mon	Tues	Wed	Thurs	Fri	Sat
Weighted Average speed (km/h)	36.83	36.64	36.43	36.01	36.56	35.95
Modal Speed (km/h)	27	28	28	27	34.36	28
Design Speed (98th Percentile) (km/h)	66.71	66.5	67.18	62.67	63.25	67.4
Safe Speed (85th Percentile) (km/h)	48.33	48.18	47.91	47.54	47.8	47.62
Median Speed (50th Percentile) (km/h)	35.33	35.14	35.05	35.07	36.22	33.75
Lowest Speed Limit (15th Percentile) (km/h)	27.2	27.06	26.88	26.8	26.67	29.02
	27.20	27.06	26.88	26.8	26.67	29.02
Speed limit upper (15th to 85th percentile)	-	-	-	-	-	-
(km/h)	66.71	66.50	67.18	62.67	63.25	67.40
Standard Deviation (km/h)	10.77	10.86	10.82	10.26	10.44	11.06
SSR	0.2924	0.2964	0.2970	0.2849	0.2856	0.3076

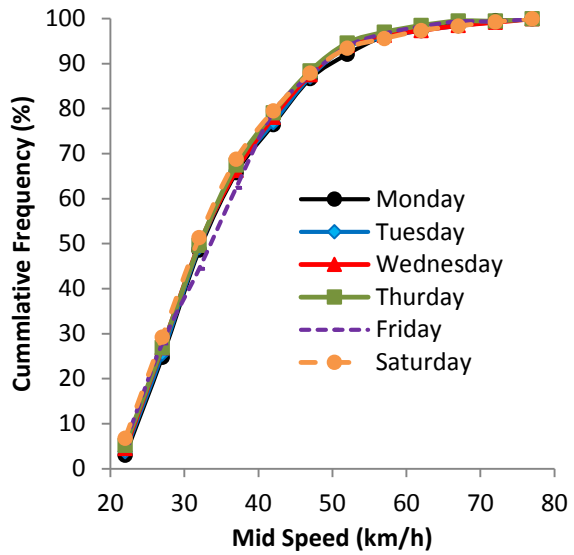

Fig. 2: Ogive of the Speed of Vehicles along Illah – Anwai Road

Table 6 and Figure 3 show the summary of the speed study and the frequency distribution curve conducted along Nnebisi road. It was observed that the average speed of vehicles ranged from 36.11km/h to 39.87km/h with the highest being on Monday, the modal speed varies from 36 km/h on Friday to 53.05 km/h on Monday, indicating significant daily fluctuations in the most prevalent speed. The design speed ranged from 58.71km/h to 65.12km/h, while the safe speed ranges from 45.34km/h to 51.92km/h. the median speed range from 35.95km/h to 38.23km/h, while the lowest speed limit ranged from 26.83km/h to 30.06km/h. the standard deviation of the speed ranged from 9.03km/h to 10.92km/h. The speed spread ratio (SSR) in this road section lies between 0.2501 and 0.2751, as such there is a moderate variation in speed, therefore the traffic flow on this road section is uniform as proposed by Shah and Gupta (2016).

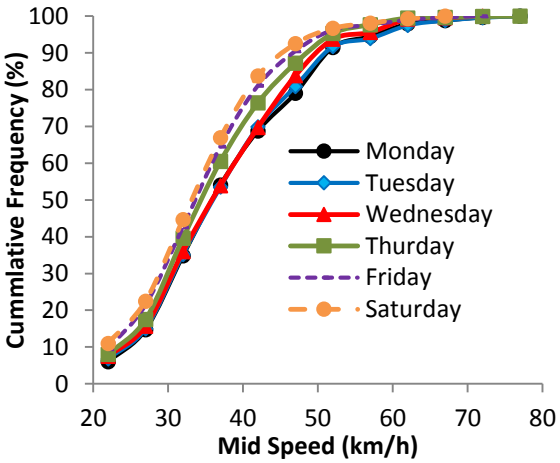

Fig. 3: Ogive of the Speed of Vehicles along Nnebisi Road

Table 7 and Figure 4 show the summary of the speed study and the frequency distribution curve along Asaba – Igbuzor road. It was observed that the average speed ranges from 34.24 km/h to 36.97 km/h. The modal speed ranges from 33.51 km/h on Tuesday, Wednesday, and Thursday to 42.26 km/h on Monday. The design speed ranges from 55.89 km/h to 65.12 km/h, while the safe speed ranges from 43.87 km/h to 51.92 km/h. The median speed ranges from 33.14 km/h to 38.37 km/h. And the lowest speed limit (15th percentile) ranges from 25.89 km/h to 30.06 km/h. The 98th percentile and 85th percentile speeds represent

upper limits for most vehicles, while the modal speed is relatively consistent. The standard deviation indicates the degree of speed variability on the road. Since, the speed spread ratio lies between 0.2543 and 0.2718, which indicates a moderate variation in speeds of vehicular speed along this road section, and all the vehicles travel at almost same speed but not at an extreme variation. Hence, the traffic flow on this road section is uniform as explained by Shah and Gupta (2016).

Table 6: Summary of Spot Speed Study along Nnebisi Road

	Mon	Tues	Wed	Thurs	Fri	Sat
Weighted Average speed (km/h)	39.87	39.69	39.08	37.75	36.76	36.11
Modal Speed (km/h)	53.05	38.77	45.82	43.83	36	37.33
Design Speed (98th Percentile) (km/h)	65.12	65.3	62.67	60.5	61.14	58.71
Safe Speed (85th Percentile) (km/h)	51.92	51.52	45.34	48.19	46.66	45.31
Median Speed (50th Percentile) (km/h)	38.15	38.23	38.13	36.99	36.33	35.95
Lowest Speed Limit (15th Percentile) (km/h)	30.06	29	28.66	27.95	26.83	26.39
	30.06	29.00	28.66	27.95	26.83	26.39
Speed limit upper (15th to 85th percentile)	-	-	-	-	-	-
(km/h)	65.12	65.30	62.67	60.50	61.14	58.71
Standard Deviation (km/h)	10.85	10.92	10.16	9.56	9.41	9.03
SSR	0.2721	0.2751	0.2600	0.2532	0.2560	0.2501

Table 7: Summary of Spot Speed Study along Asaba – Igbuzor Road

	Mon	Tues	Wed	Thurs	Fri	Sat
Weighted Average speed (km/h)	36.97	35.51	35.64	34.92	34.24	34.3
Modal Speed (km/h)	42.26	36	36	33.51	33.51	33.51
Design Speed (98th Percentile) (km/h)	60.44	55.89	56.82	57.22	56.14	57.86
Safe Speed (85th Percentile) (km/h)	47.23	46.27	46.71	45.98	43.92	43.87
Median Speed (50th Percentile) (km/h)	36.37	35.37	35.05	33.44	33.17	33.14
Lowest Speed Limit (15th Percentile) (km/h)	26.04	26.63	26.65	26	25.9	25.89
	26.04	26.63	26.65	26.00	25.90	25.89
Speed limit upper (15th to 85th percentile)	-	-	-	-	-	-
(km/h)	60.44	55.89	56.82	55.22	56.14	57.86
Standard Deviation (km/h)	9.41	9.03	9.38	9.49	8.81	9.1
SSR	0.2545	0.2543	0.2632	0.2718	0.2573	0.2653

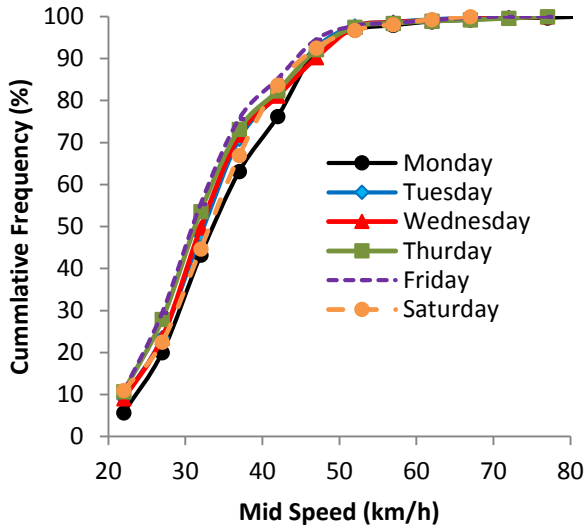

Fig. 4: Ogive of the Speed of Vehicles along Asaba – Igbuzor Road

Conclusion: This study concluded that traffic counts by day of the week provide insights into the road's utilization patterns. With relation to the speed spread ratio (SSR), it was observed that all the road sections have a low SSR and the vehicular flow is uniform on the roads. It was recommended that a study on the relationship between speed and accident, helps in identifying the factors contributing to the high variation in speed and develop strategies to improve safety for road users and pedestrians and a study on the impact of heavy vehicles on road infrastructure and pavement design. This study can help identify the effects of heavy vehicles on road deterioration and develop strategies to improve road durability and safety.

Declaration of Conflict of Interest: The authors declare no conflict of interest in carrying out this study.

Data Availability Statement: Data are available upon request from the corresponding author of this study

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