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Spot Speed Study of Vehicular Traffic on Major Highways in Makurdi Town

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Abstract

Spot speeds of vehicular traffic along Otukpo, Gboko, Lafia and Iorchia-Ayu highways in Makurdi town where examined. Manual traffic count was carried out to ascertain traffic volume per hour per lane on each lane of the sampled road segments, and spot speeds of vehicles travelling in both directions of the highways where randomly measured using a Brushel speed gun at different spots for a period of 12 hours (6: 00 am – 6:00 pm) daily. Data analysis using statistical techniques revealed that vehicles travelled at average speed of 51 km/h, 53 km/h, 63 km/h and 50 km/h on the Otukpo, Gboko, Lafia, and Iorchia-Ayo highways respectively. Also, the range of travel pace and corresponding percentages of traffic (in brackets) on highways in Makurdi town were; 46-56 km/h (57%), (47-57km/h (50%), 55-65(32%) and 46-56(49%) for the Otukpo, Gboko, Lafia and Iorchia-Ayu roads respectively. Therefore speed limit ranging between 50-55km/h was proposed for highways in Makurdi town to guarantee safe travel. The study also revealed that highways in Makurdi town operated at a design speed below design specifications of 80–100 km/h required by the Nigeria Highway Design Manual except the Lafia road that has design speed of 80km/h. Speed calming devices, high traffic volume, geometrical layout or highway capacity and possibly pavement condition were identified as factors affecting vehicles speeds on highways in Makurdi town. Road rehabilitation for improved capacity and traffic volume to satisfy design speed, and use of speed limit warning signs to guarantee travel safety were recommended.

Keywords: Highways in Makurdi town, spot speed, speed limit, design speed, travel pace.

1.0 Introduction

Despite the huge benefits of highway transportation, it is not without some negative externalities, some of which include congestion, noise and air pollution, delay, crashes, etc. Traffic engineers and transport planners need information about road traffic to be able to develop solutions for these problems and propose operational framework for efficient and sustainable transport systems development, hence the need for traffic studies which is a systematic way of collecting data and analysis to be used for the various traffic engineering activities. Among the various traffic studies that are conducted by traffic engineers to evaluate current road traffic conditions and develop solutions is the spot speed study, the purpose of which is to estimate the distribution of speeds of vehicles in a stream of traffic at a particular location on a highway (Garber and Hoel, 2009; Roshandeh et al., 2009). The presentation of a visualized outcome of such analysis simplifies or makes the analysis more meaningful since key parameters of the data can easily be deduced from the visualized plots. Speed is one of the basic parameters used for describing the characteristics of traffic flow and it is an important transportation parameter because it relates to safety, travel time, quality of travel (in terms of traffic density on a road segment - congestion), and the regulation and control of traffic operations (Hashim, 2011; Federal Republic of Nigeria, 2013). Data obtained from spot speed studies are used for evaluating important speed characteristics such as; average speed, median speed, modal speed, percentile speeds, the standard deviation of speeds, etc. These speed characteristics are used in many traffic engineering analyses including to: establish parameters for traffic operation and control (such as speed zones, speed limits, passing restrictions, etc); evaluate the effectiveness of traffic control devices; monitor the effectiveness of speed enforcement programs, evaluate and or determine the adequacy of highway geometric elements; evaluate the effect of speed on highway safety; determine speed trends, to determine the validity of complaints about speeding and to carryout simulation programs (Derry, 2007; Garber and Hoel, 2009; Hashim, 2011). Generally, speed studies have significant impact on the Level of service (LOS) of highway facility in terms of travel speed and time (HCM, 2010). To achieve an efficient transport system in a city partly depends on the performance of highway facilities where vehicles spot speeds is a key indicators (Marler et al., 1993; Homburger et al., 1996; Currin, 2001; ODOT, 2014;). Information derived from

spot speed studies could also be used for measuring the compliance of drivers with the posted speed limits; check the conformity of speed data with normal distribution, and for development of simulation programs (Hashim, 2011). Other uses of spot speed data include to determine traffic signal timing, evaluate roadway capacity and the effectiveness of road improvements strategies (Manual on Uniform Traffic Studies, 2014). Thus, a boost in administrative, commercial and recreation activities in a city requires the understanding of vehicular speed characteristics for the development of efficient, sustainable and enhanced performance of transport systems for sustainable development of cities (Sheehan, 2010).

Considering these numerous applications of spot speed data and the fact that they are essential for the design and operation of highways, the need for speed studies cannot be over-emphasized. Where speed data are not readily available at the town or local government council, or private transport management organisations, as is the case for roadways in many Nigerian cities, speed-related decisions cannot be reasonably made. This paper presents the findings of a study that was conducted to examine vehicular traffic spot speeds on major highways in Makurdi town. The objectives of the study were to: measure and record the spot speed of vehicles on major highways in Makurdi town; determine the speed characteristics of vehicles in Makurdi town based on its present vehicular traffic volume and composition and check the conformity of speed data with normal distribution; and to propose a reasonable and safe range of speed limits that could be applicable to most road segments in Makurdi town.

2.0 Materials and Methods

2.1 Description of the Study Area

Makurdi is the capital city of Benue State in Nigeria. It falls within Nigeria's North-central geopolitical zone. The town is located in the Benue trough. It is the center of administration and commerce in Benue State and hosts two major universities and other tertiary institutions. Just like any other urban centre in Nigeria, Makurdi has recorded a huge growth in traffic volume over the years following rapid increase in population and corresponding car ownership. Traffic streams within Makurdi town are best described as being homogeneous in nature, as they basically consist of private cars, motorcycle (Okada), tricycles, minibuses, taxicabs and trucks travelling on the same roadways at the same time. Minibuses which are the dominant modes of public transportation in the town cruise mainly the major streets, picking up and dropping off passengers anywhere along the routes. Okada in addition to competing with the minibuses on the major streets, serve low density routes and the outlying neighbourhoods which are not served by the minibuses. The mixed or homogeneous traffic streams in Makurdi town are characterized by significant variations in speeds of various means of travel. This study considered four major highways in Makurdi town which included the Otukpo Road, Gboko Road, Iorchia Ayu Road and Lafia Road all of which intersect at the Wurukum roundabout, a major and centrally located rotary intersection in the town. The Otukpo Road serves neighbourhoods south of the town, and is also a major route for inter-city travel to the southern parts of Nigeria. Gboko Road is the only corridor connecting the town with cities in the North-eastern part of the country, and is also a major arterial that serves neighbourhoods east of Makurdi town. Lafia Road is an inter-city link for vehicles travelling to and from the northern parts of the country; it also serves neighbourhoods at the northern part of the town. Iorchia Ayu Road is also an arterial that serves the western parts of the town. Figure 1 is an aerial view of Makurdi town showing its major highways.

Figure 1: Aerial view of Makurdi town showing its Major Highways (Google Map, 2017)

2.2 Data Collection

Spot speeds of randomly selected vehicles were measured at different road segments using a Brushel speed gun (radar meter). The fieldwork exercise lasted between 08:00 am to 05:00pm daily. Study sites were located at mid-blocks of the highways, ensuring that they were free from the effects of intersections, packed vehicles, influence of curvature and grades, pedestrian movement, and other obstacles to free flow of vehicular traffic. The instrument was held and positioned such that its angle of inclination with the travel path or angle of deflection was significantly minimal to ensure high degree of accuracy of measurements. Care was taken to conceal the instrument from drivers, and to ensure that the study personnel remained inconspicuous throughout the study. Spot speeds were measured for vehicles travelling in both directions. Vehicular traffic volume counts were carried out simultaneously at the speed study sites using the manual traffic count method. The traffic enumerators carried out classified manual traffic count to establish volume and compositions of traffic of the highways.

3.0 Results and Discussion

Table 1 presents the geometric features and traffic volume characteristics of highways in Makurdi town that were considered by this study.

Table 1: Characteristics of Major Highway in Makurdi Town

Description	Highways			
	Otukpo Road	Gboko Road	Lafia Road	Iorchia-Ayo Road
Lane width (m)	3.6	3.9	4.6	3.7
No. of Lanes in one direction	1	2	1	2
Avg. Traffic Volume in one direction (Veh/h).	1,127	1,939	1,014	1,484
Traffic Compositions (%)				
Motorcycles	66.91	66.65	62.04	61.22
Cars/Mini Buses	31.45	31.83	35.02	38.23
Trucks	1.01	0.90	1.71	0.25
Trailers	0.63	0.61	1.23	0.21

Table 1 revealed that Otukpo and Lafia roads are two-lane single carriageway roads, while Gboko and Iorchia-Ayu roads are four-lane divided highways. Results of traffic volume counts reveal that the average hourly traffic volume on all the highways was above 1000 veh/h. Each highway recorded high proportion of motorcycles volume in the traffic stream which is due to the fact that motorcycles are also a major source of public transport system in Makurdi town.

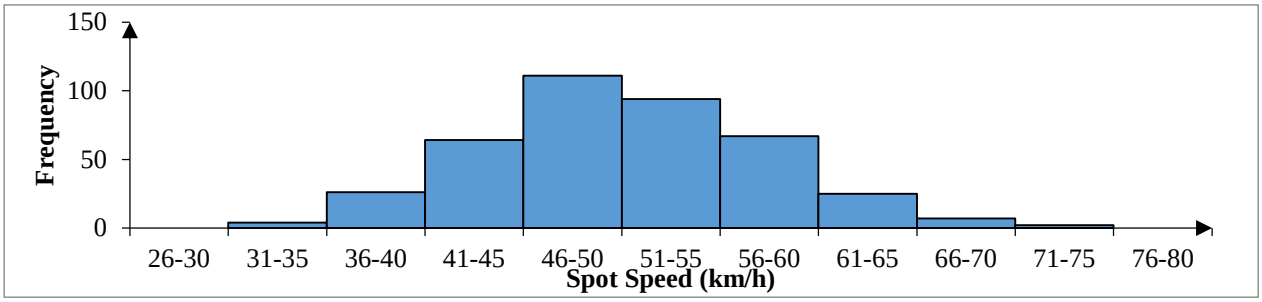
3.1 Analysis of Spot Speeds

The descriptive statistics of data obtained from spot speed survey of vehicular traffic travelling on the sampled highways in Makurdi town is as shown in Table 2.

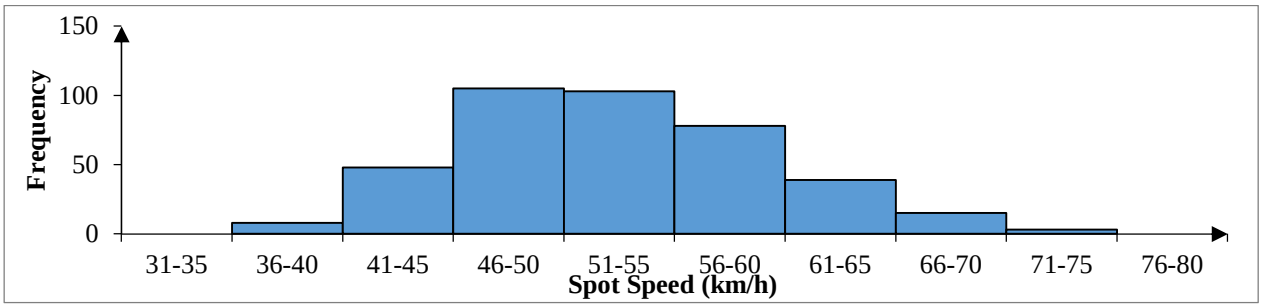
Table 2: Descriptive Statistics of Vehicular Spot Speeds on Highways in Makurdi

Statistical Parameters	Highways			
	Otukpo Road	Gboko Road	Lafia Road	Iorchia-Ayu Road
Sample Size	407	400	413	400
Min. speed (km/h)	34	38	31	25
Max. speed (km/h)	74	75	98	81
Range (km/h)	40	37	67	60
Mean (km/h)	50.678	52.883	63.648	49.893
Variance (km/h)	48.259	47.001	237.3	64.894
Std. Deviation (km/h)	6.9469	6.8557	15.405	8.0557
Coef. of Variation (km/h)	0.13708	0.12964	0.24203	0.16177
Std. Error (km/h)	0.34734	0.34279	0.77023	0.40278
Skewness (km/h)	0.26118	0.44055	0.31257	0.05882
Excess Kurtosis (km/h)	-0.10603	-0.0134	-0.67165	0.6795

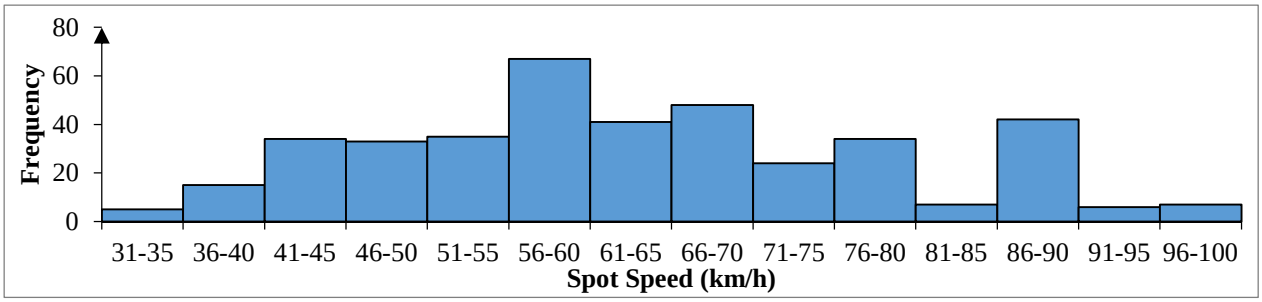
Table 2 reveals that Lafia road has the highest average spot speed of 63.64 km/h, followed by Gboko, Otukpo and Iorchia Ayu roads having 52.88 km/h, 50.68 km/h and 49.89 km/h respectively. The high average vehicular traffic spot speed on Lafia road is attributed to its relatively low traffic volume and possibly better pavement condition as observed during the fieldwork. The route has relatively high standard deviation of 15 km/h which indicates significant spread of data points over the range of data obtained. This could also be attributed to the fact that the Lafia highway serves both township shuttle and interstate travelling vehicles. Its relatively high percentage composition of heavy trucks also has significant impact on travel speed characteristics on the highway. The spread of data points on the other highways is within a relatively closer range (about 6 – 8 km/h) with average spot speed measuring between 50 – 53 km/h, these highways majorly serve township travels. In addition, the Gboko road is characterised by traffic calming bumps sited at intervals of approximately 200 meters apart covering total length of 3 km which reduces vehicles travel speed significantly for safety reasons. Otukpo and Iorchia-Ayo roads recorded relatively low and approximately equal vehicle spot speeds, these highways equally serve as collectors connecting major streets, hence traffic flow on them is significantly interrupted more than the Lafia and Gboko roads. Also, because the Iorchia-Ayu road is an intercity highway which serves several distributor roads, it has several junctions and contains insignificant number of heavy vehicles. This analysis shows the representative values of spot speeds of vehicles travelling on the highways. Figure 2(a), 2(b), 2(c) and 2(d) show histogram plots of vehicular traffic spot speeds for the Otukpo, Gboko Lafia and Iorchia-Ayu roads in Makurdi town respectively.



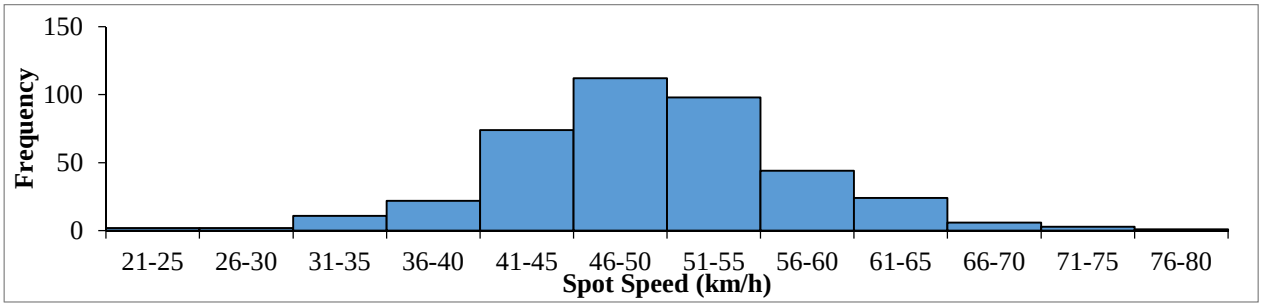
(a) Otukpo Road



(b) Gboko Road



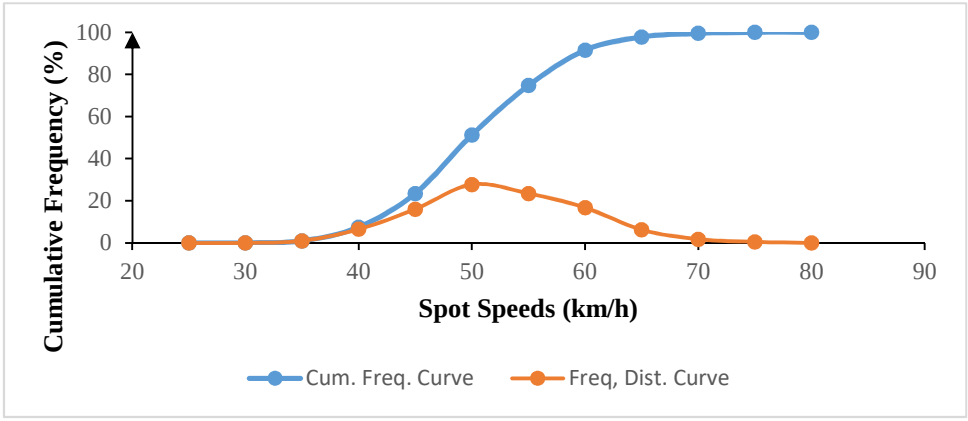
(c) LafiaRoad



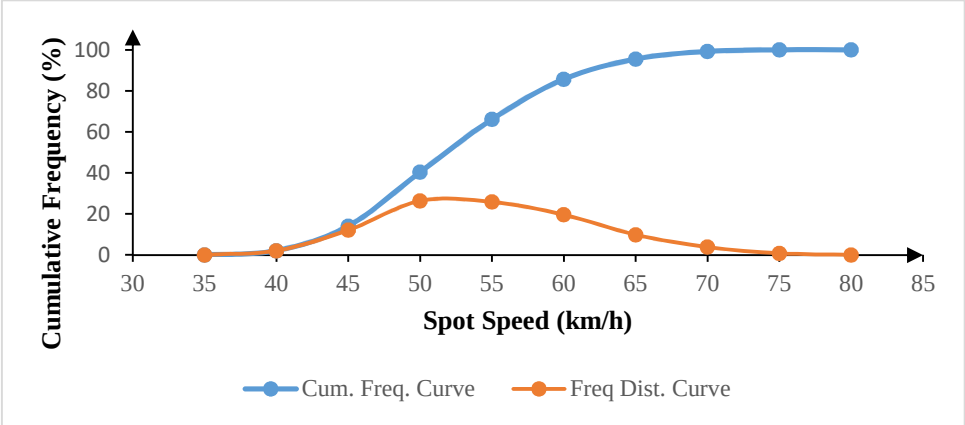
(d) Iorchia-Ayu Road

Figure 2: Histograms of Observed Spot speeds on Highways in Makurdi.

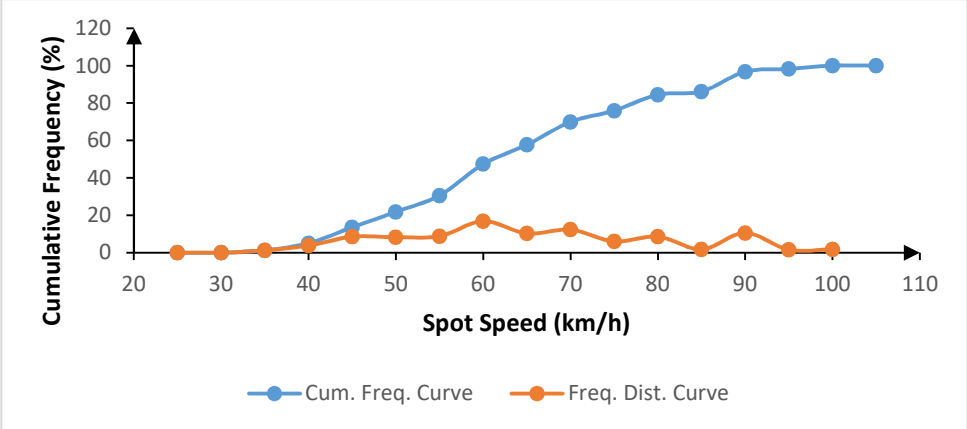
The modal spot speeds are deduced from histogram plots as the longest bar for each highway. Figure 2 revealed that, the Otukpo, Gboko and Iorchia-Ayu roads have modal spot speed within the range of 46 – 50 km/h. Lafia road has a relatively high modal spot speed within the range of 56 – 60 km/h, this is attributed to its relatively low volume since traffic speed is inversely proportional to density which is a function of traffic volume (Findley et al., 2016). On the other hand, most vehicles travelled at speeds ranging between 41 – 60 km/h on Otukpo road, 46 – 60 km/h on Gboko road and 41 – 55 km/h on Iorchia-Ayu road as shown in Figures 2(a), 2(b) and 2(d) respectively. Unlike Lafia road which had a multimodal spot speed distribution pattern, most vehicles traveled at 56 – 70 km/h and 86 – 90 km/h, traffic stream on the Lafia road was characterized by series of shockwave flow pattern. Corresponding statistical measures of dispersion of vehicular traffic spot speeds on highways in Makurdi town were further examined using superimposed spot speed distribution plots as shown in Figure 3.



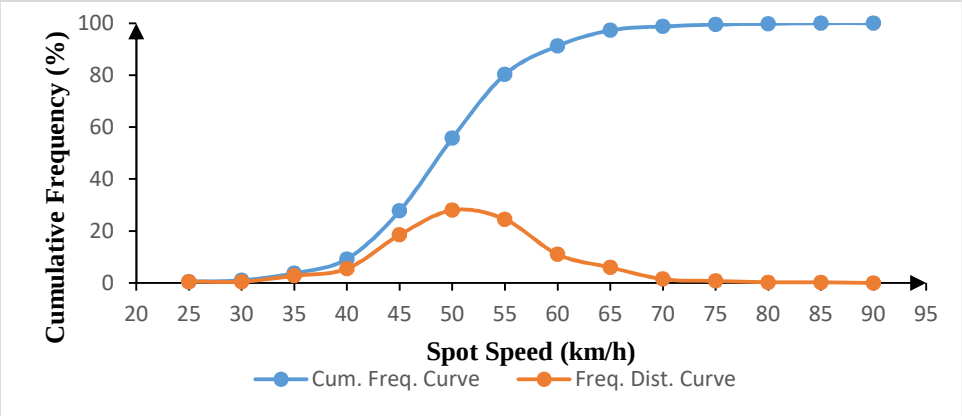
(a) Otukpo Road



(b) Gboko Road



(c) Lafia Road



(d) Iorchia-Ayu Road

Figure 3: Spot Speed Distribution Curves of Vehicular Traffic on Highways in Makurdi

Figure 3 is a superimposed plots of frequency distribution and cumulative frequency distribution curves of spot speeds of vehicles travelling on highways in Makurdi town. The shape of frequency distribution curves for Otukpo, Gboko and Iorchia-Ayu roads shown in Figures 3(a), 3(b) and 3(d) respectively indicated that, spot speed data on these highways conform to a perfect normal distribution as established by other researchers (Roshandeh et al., 2009), where the median speed is approximately equal to the mean speed value; except spot speed data for Lafia road which gave a multi-modal distribution curve as shown in Figure 3 (c). This indicated that the speed data is not normally distributed. This lack of conformity to normal distribution was attributed to the significant presence of slow-moving trucks on the road alongside fast moving cars thereby giving rise to the wide variation in the speed distribution caused by series of shockwaves in the traffic stream. Though the Federal Road Safety Commission of Nigeria (2008) stipulates a speed limit of 50 km/h for towns and cities in Nigeria. The cumulative distribution curve of vehicles spot speeds on highways in Makurdi town indicate that the speed limit of 50km/h is below the operating speeds of vehicles traveling on highways in Makurdi town. Consequently, posting a speed limit that is below the 85th percentile spot speed which constitutes the mostly used travel speed by drivers may lead to driver non-compliance and speed differential on the highway, which may result to road crashes as reported by previous studies (Hashim, 2011). Using the cumulative distribution curve, the minimum speed of vehicular traffic on the highways was deduced as the 15th percentile, while the median speeds were estimated as the 50th percentile. The 85th percentile gave the operating speed of vehicular traffic on the highways since it represent the most convenient speed limit for most motorist, while the 98th percentile represented the design speed. The normal distribution curves were used to estimate the pace of vehicular travel on the highways and then projections made to ascertain the percentage of traffic traveling at the specified pace. The summary of key parameters as deduced from the analysis are as shown in Table 3.

Table 3: Summary of Key Speed Parameters on Highways in Makurdi Town

Parameters	Highways			
	Otukpo Road	Gboko Road	Lafia Road	Iorchia Ayu Road
Minimum Speed (km/h) (15%)	43	45	47	42
Median Speed (km/h) (50%)	50	52	61	49
Modal Speed (km/h)	46 - 50	46 - 50	56 - 60	46 - 50
Speed Limit (km/h) (85%)	58	60	80	57
Design speed (km/h) (98%)	65	65	90	65
Travel Pace (km/h)	46 – 56 (57%)*	47 – 57 (50%)*	55 – 65 (32%)*	46 – 56 (49%)*

** Percentage of vehicles travelling at the given pace*

Table 3 revealed that the minimum travel speed of vehicular traffic on highways in Makurdi town ranges between 42 - 47 km. The maximum also known as the operational travel speed of vehicles rages between 57 – 80

km/h which is greater than the standard speed limit of 50 km/h as specified by traffic safety enforcement agency in Nigeria. This study also revealed that, the design speed of 80 - 100 km/h specified by the Nigerian highway design manual does not depict reality or is not applicable to Makurdi town highways, hence calls for a review. This study also revealed that approximately 50% of vehicles in Makurdi town travel at a pace ranging between 46 – 57 km/h, except the Lafia road where 32% of the vehicles travel within the aforementioned range of travel pace. This variation is attributed to the fact that, speed characteristics of vehicles travelling on Lafia road is described by a multimodal pattern caused by homogenous traffic stream having different travel speeds or shockwave flow trend, since it serves both intercity travel demand and interstate traffic flow which consists majorly trucks conveying agricultural produce (such as timber, oranges, yams), cement and crude petroleum produce to the northern part of Nigeria.

4.0 Conclusions and Recommendations

4.1 Conclusions

Based on the findings of this study, the following conclusions were made:

(a) The average speed of vehicular traffic on highways in Makurdi town ranged between 50 – 53 km/h except for the Lafia road which recorded an average spot speed of 64 km/h approximately. This discrepancy was attributed to its homogenous traffic composition with higher percentage composition of heavy vehicles and very fast moving vehicles.

(b) The modal speed of vehicular traffic on Makurdi highways falls within the range of 46 – 50 km/h except the Lafia road which recoded a modal speed ranging between 56 – 60 km/h due to its peculiar characteristics.

(c) Though the national speed limit of 50 km/h as stipulated by the Federal Road Safety Commission for Nigeria towns and cities was below the 85th percentile vehicular speed on highways in Makurdi town. A general speed limit within the range of 50 - 55 km/h is reasonable and guarantees safety of motorist and pedestrians travelling on highways in Makurdi town.

4.2 Recommendations

The following recommendations were made;

i. Road rehabilitation by installing roadway facilities such as hard shoulders, pavement markings, standard minimum lane width, etc so as to improve highway capacity to accommodate increased traffic volume and satisfy design speed are essential strategies for improved traffic flow and guarantee safety of road users.

ii. The erection of speed limit warning signs in line with findings of this study along each highway at selected spots in Makurdi town shall guarantee vehicular travel safety to a reasonable extent.

iii. The findings of this study should be employed by local council and state government authorities for planning and development of transportation facilities in Makurdi town to improve liveability and guarantee safe, efficient and sustainable transportation system in the town.

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