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Influence of Land use and Traffic on Road Safety Along Jimeta Bypass

Hadi A. Abba[1], Mahmoud H. Abubakar[2*] , Zaynab A. Belel[2] and Adejoh Benjamin Ochola[1]

[1] Department of Civil Engineering, Kaduna Polytechnic, Nigeria.
[2] Department of Civil Engineering, Modibbo Adama University Yola, Nigeria.

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ABSTRACT

Many roads in some urban areas in developing countries, such as Nigeria, are characterized by a high level of traffic and, because of limited resources, receive inadequate forms of protection and inappropriate maintenance strategies. Some of the roads have become part of landfill dump embankments, which cause defects that contribute to road accidents. The study sought to investigate the effect of Land use and traffic on road safety along the Jimeta Bypass Road. Vehicle enumeration was carried out by manual counting. Road traffic accident data for the analysis was obtained from the Federal Road Safety Commission in Yola. Physical inspection of the pavement section revealed that it was in an unsuitable condition for riding and safety. The findings also revealed that the road pavement had an annual average daily traffic volume of about 1470 vehicles per day, with tricycles having the highest traffic volume and luxurious buses having the lowest traffic volume. Analysis of variance showed that there was no significant variation in traffic volume between periods (morning, afternoon, and evening); traffic only differs between vehicle types. Accident data collected was found to highly correlate with traffic volume, an indicator that the high traffic volume along the Jimeta Bypass Road could be responsible for the occurrence of road traffic crashes along the road. The study findings also indicate there is need to adopt the maintenance culture by Road Authorities and relevant stakeholders so as to address the failure condition at the onset.

* Corresponding author E-mail address hijabmahmoud@mau.edu.ng
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1. Introduction

The importance of road transportation to every society and nation cannot be overstated. It determines the rate of a country's socioeconomic development. It is important to note that without a good road, no economy can flourish [1, 2]. However, roads contribute significantly to the growth of a nation's gross domestic product. Pavement is an engineered structure installed on natural soils and designed to withstand the effects of traffic and weather with minimal deterioration and in the most cost-effective manner. The relative performance of various pavements is their relative ability to serve traffic over a period of time [3–5].

As roads are being used over time, functionality declines. Numerous vehicles have a cumulative effect that causes permanent deformation over time [6, 7]. Thus, high traffic volume is one of the most important factors that reduces the road's usability. In Nigeria, for instance, the available pavement road networks are insufficient for the population of active road users, resulting in a high traffic volume and, in some cases, traffic congestion. This traffic congestion has not only reduced the serviceability of roads but also culminated in a public movement frenzy [8]. In Lagos state, for instance, traffic congestion is now the new normal; people wake up early only to arrive at work late, and leave work early only to arrive home late. Other implications that could result from such high traffic congestions are road traffic accidents. Usage of road networks creates pavement distresses which overtime turns good roads into bad roads due to high numbers of pavement distresses on the road network. Combined with other factors such as drunk driving or failed brakes, accidents would eventual result leading to loss of lives and properties [9, 10].

However, when accidents happen in traffic congested road networks, it is often devastating, as emergency services such as ambulances might not be able to navigate through traffic to provide the needed medical attention [11, 12]. Traffic surveys are a means of obtaining information about traffic. This is a method of collecting data that can be used for a variety of traffic engineering purposes. Traffic data is required during the research, planning, designing, and regulation phases of traffic engineering, as well as when establishing priorities and schedules for traffic improvements. To measure and comprehend the magnitude, composition, time, and route distribution of volume for each area falling under his jurisdiction, the traffic engineer must gain a general understanding of traffic volume characteristics [13–15].

The existing road pavement in Jimeta Bypass has shown signs of premature distress because of the unexpected demands of growing traffic volume and heavier axle loads. The road has started to fall short of its structural capacity and hence it is greatly overstrained. In Nigeria, the funds allocated for road development programs have been decreasing constantly over the years as a percentage of the gross domestic product (GDP) [8, 16]. Almost all of the allocated funds are utilized for a new construction with little or no funds for maintaining the existing pavements such as Jimeta Bypass thus making it less functional to road users. The current level of performance offered by Jimeta Bypass Road to road users i.e. motorists, cyclists, and pedestrians formed the basis of this study. It is against this background that researcher sought to investigate the traffic volume as it impacts on road pavement failure along the Road.

2. Materials and Method

2.1. Location of the Research Area

Figure 1 depicts the location of the study area along the A13 highway in the Yola North local government area of Adamawa State, extending from the River Benue bridge at point "B" (9°17'14.1"N 12°27'02.7"E) to point "A" (9°17'06.4"N 12°25'51.1"E), while Figure 2 depicts a digital map of the study area. The road traverses commercial areas (Kasuwan Gwarri) which contributes to erratic traffic flow and congestion. It is 186m above sea level and has a tropical climate with annual precipitation between 900mm and 1200mm [17]. The damaged stretch of road was the

subject of a field investigation. The surface of the pavement was visually inspected, and the identified pavement damage was photographed and documented.

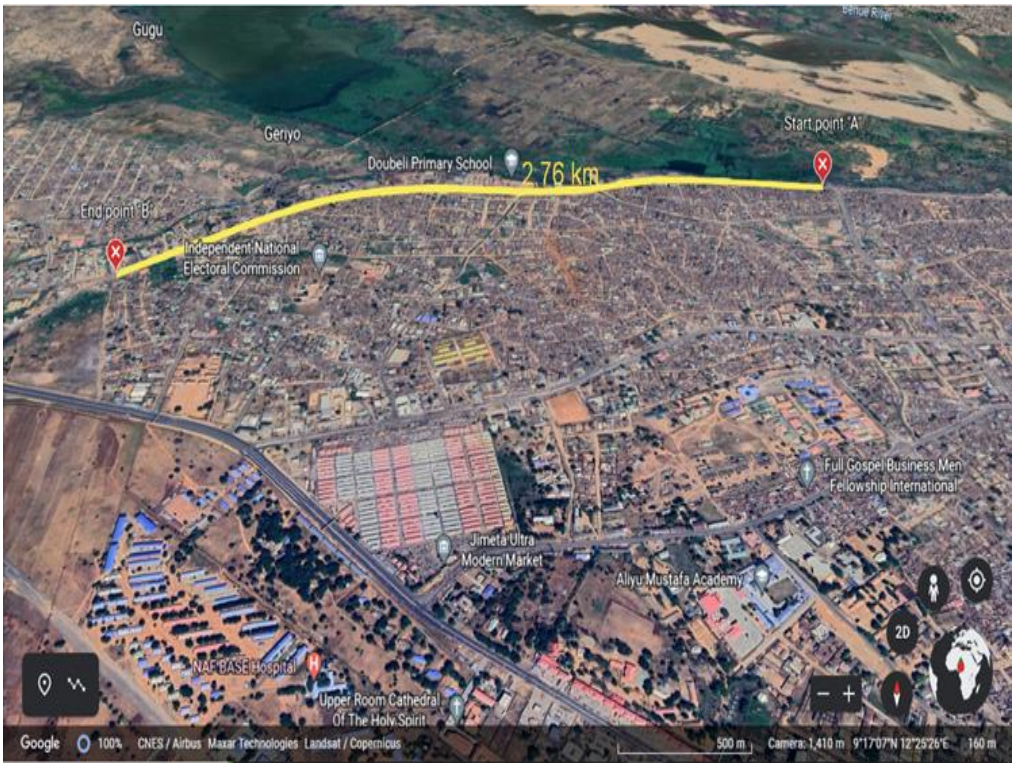

Figure 1. Study area on the google earth street map of Yola-North

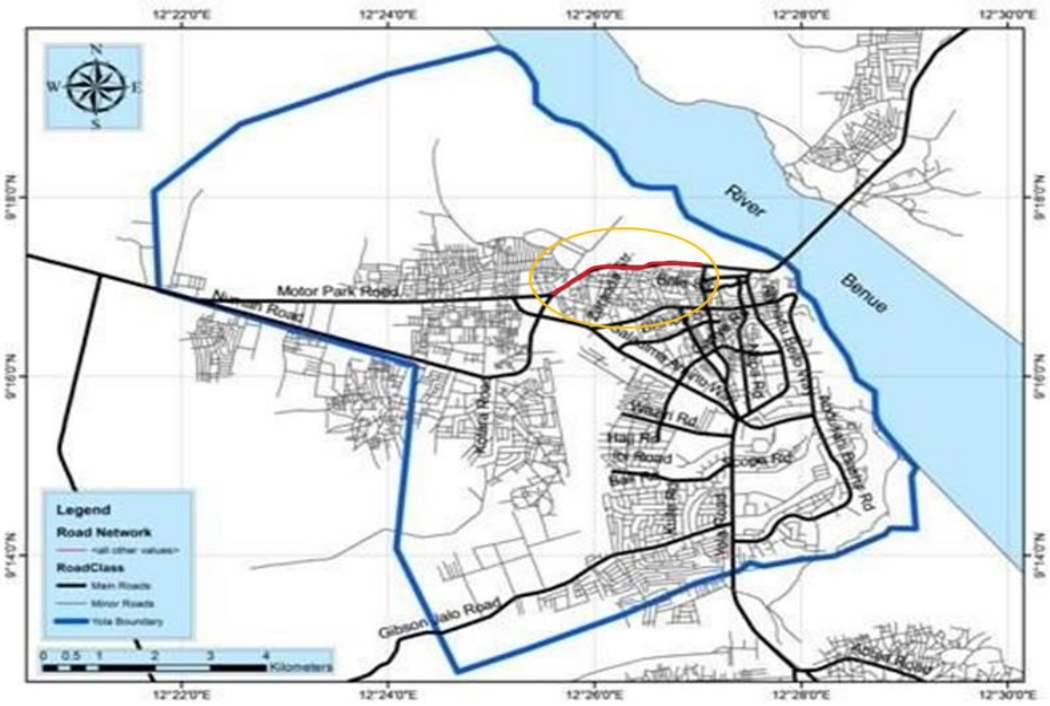

Figure 2. A digital map of the area of study [18]

2.3. Determination of Traffic Volume

Traffic volume was determined manually in this study. Manual counting of the number of vehicles passing through the specified location on the Jimeta Bypass road during 1-hour time intervals. This was carried out 3 times each day mainly in the morning (6-7 am), afternoon (12-1 pm) and evening hours (6-7 pm). Since the road has double carriage way, two observers, taking traffic count for each carriage way was employed with the help of traffic volume recording sheet. This was done seven days in a row (Monday through Sunday) in April 2023. The information recorded included type of vehicles and the numbers of each vehicle type passing by the hour as well as the direction of the vehicle. The data collected was used to determine the annual average daily traffic (AADT) [19] according to equation 1:

$$AADT = \frac{TADT}{365} \quad \ldots. \quad (1)$$

Where TADT is the total average daily traffic which is sum total of the average daily traffic for each day of the traffic volume. TADT is determined according to equation 2:

$$TADT = \sum_{i=1}^{30} ADT_i \quad \ldots.. \quad (2)$$

Where ADT_i is the average daily traffic which the average of the morning, afternoon and evening traffic volume on a particular day *i*. Equation 3 was used to determine the results:

$$\mathrm{ADT_i} = \frac{\mathrm{TV_i^{morning}} + \mathrm{TV_i^{afternoon}} + \mathrm{TV_i^{evening}}}{3} \ldots.. (3)$$

Where $TV_i^{morning}$ is the traffic volume in the morning of day *i*, $TV_i^{afternoon}$ is the traffic volume in the afternoon of day *i*, and $TV_i^{evening}$ is the traffic volume in the evening of day *i*. The data were analysed using descriptive statistics and analysis of variance (ANOVA).

3. Results and discussion

3.1 Physical evaluation of Surface Deformation

Physical inspection revealed significant failures in the road segment, and the investigated road was characterized by failures of various types and magnitudes. Due to the lack of proper drainage along the road segment, the shoulders were eroded for a distance of approximately 3 kilometers (see Figure 3a-d). In some areas, fatigue cracks and potholes comprise a second mode of failure on the road. The lengths of the potholes ranged between 0.5 and 5 meters. Additionally, the depths of the potholes range from 5 to 25 cm. Similarly, the waste disposal practiced in the area is through an open dump for solid waste. The majority of municipal solid waste is dumped along the flood plains of the Benue River, which runs alongside the Yola-Mubi bye-pass. The growth in population has affected the land use pattern, which has subsequently resulted in the area generating more waste than is more or less manageable. Along this stretch of road, the roadway had become an embankment of the solid waste pile. Consequently, the useful lane width was diminished, and the potential for accidents increased (see Figure 3d). This may lead to further environmental hazards, as emissions from the deposits will be inadvertently inhaled by the commuters as well as the communities close by.

3.2 Traffic Volume Data

The volume of traffic on the flexible pavement was investigated for Monday using morning, afternoon, and evening event time the summary of It can be observed from Table 1a that a total of 3,785 vehicles were counted, indicating a total traffic volume in both directions. Cars (C), buses (B), trucks (Tk), trailers (TL), luxury buses (LB), and tricycles (TC) constitute 518 (13.7%), 81 (2.1%), 71 (1.9%), 105 (2.8%), 43 (1.1%), and 2967 (78.4%) of the total traffic volume, respectively. The average daily traffic (ADT) for C, B, Tk, TL, LB, and TC were estimated to be 173, 27, 24, 35, 14, and 989, respectively. The distribution of traffic along the road revealed that the road on that day was mostly trafficked by tricycles, followed by cars and trailer vehicles.

Figure 3. Physical condition survey indicating the degree of pavement section deterioration.

Table 1a: Jimeta Bypass Road Traffic Volume Data for Monday

Period	Vehicle Type					
	Car	**Bus**	**Truck**	**Trailer**	**Luxury Bus**	**Tricycle**
Morning	174	35	25	41	16	1008
Afternoon	140	19	17	30	9	892
Evening	204	27	29	34	18	1067
Total	518	81	71	105	43	2967
mean	173	27	24	35	14	989
Standard Dev.	26.1	6.5	5.0	4.5	3.9	72.6957

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Table 1b, shows the results of the ANOVA. For Monday traffic data, there are no significant variations in traffic data due to differences in time period since the p-value obtained is greater than 0.05, however there are significant variations in traffic volume due to vehicle type since p-value obtained is less than 0.05. Hence one vehicle type tends to have more traffic volume than another vehicle type on Monday.

Table 1b: Analysis of Variance for Monday Traffic Volume Data

Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Periods	6513.778	2	3256.889	2.783613	0.109382	4.102821
Between Vehicle Types	2236062	5	447212.3	382.2255	4.45E-11	3.325835
Error	11700.22	10	1170.022			
Total	2254276	17				

Tuesday's morning, afternoon, and evening traffic volumes on the flexible pavement were analyzed; the summary can be observed from Table 2a that a total of 2,951 vehicles were

counted, indicating a total traffic volume in both directions. Cars (C), buses (B), trucks (Tk), trailers (TL), luxury buses (LB), and tricycles (TC) account for 530 (18.0%), 73 (2.5%), 77 (2.6%), 97 (3.3%), 19 (0.6%), and 2155 (73.0%) of the overall traffic volume, respectively. The average daily traffic (ADT) for C, B, Tk, TL, LB, and TC were estimated to be 177, 24, 26, 32, 6, and 718, respectively. The distribution of traffic along the road revealed that tricycles, followed by cars, trailers, and trucks, were the most common vehicles on the road that day.

Table 2a: Jimeta Bypass Road Traffic Volume Data for Tuesday

Period	Vehicle Type					
	Car	**Bus**	**Truck**	**Trailer**	**Luxury Bus**	**Tricycle**
Morning	184	40	36	37	14	1032
Afternoon	149	13	16	29	0	1001
Evening	197	20	25	31	5	122
Total	530	73	77	97	19	2155
mean	177	24	26	32	6	718.3
Morning	184	40	36	37	14	1032

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A two-way analysis of variance without replication was conducted to see if there were variations in traffic between vehicle types and travelling period at 5% level of significance using Excel software. Table 2b shows the results of the ANOVA.

Table 2b: Analysis of Variance for Tuesday Traffic Volume Data

Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Periods	86685.4	2	43342.7	0.96494	0.41383	4.10282
Between Vehicle Types	1164851	5	232970	5.18661	0.01319	3.32583
Error	449177	10	44917.7			
Total	1700713	17				

For Tuesday traffic data, there was no significant variations in traffic data due to differences in time period since the p-value obtained is greater than 0.05, however there are significant variations in traffic volume due to vehicle type since p-value obtained is less than 0.05.

The volume of traffic on the flexible pavement was investigated for Wednesday using morning, afternoon, and evening hours; Table 3a's summary shows that a total of 2,900 vehicles were counted, representing the overall volume of traffic in both directions. Cars (C), buses (B), trucks (Tk), trailers (TL), luxury buses (LB), and tricycles (TC) constitute 453 (15.6%), 71 (2.4%), 70 (2.4%), 21 (0.7%), and 2214 (76.3%) of the total traffic volume, respectively. The average daily traffic (ADT) for C, B, Tk, TL, LB, and TC were estimated to be 151, 24, 24, 23, 7, and 738, respectively. The distribution of traffic along the route revealed that tricycles were the most common mode of transportation that day, followed by vehicles, buses, and trucks.

Table 3a: Jimeta Bypass Road Traffic Volume Data for Wednesday

Period	Vehicle Type					
	Car	**Bus**	**Truck**	**Trailer**	**Luxury Bus**	**Tricycle**
Morning	193	41	9	45	13	1047
Afternoon	107	5	25	13	5	1027
Evening	153	25	37	12	3	140
Total	453	71	71	70	21	2214
mean	151	24	24	23	7	738
Standard Dev.	35.1	14.7	11.5	15.3	4.3	422.9

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A two-way analysis of variance without replication was conducted to see if there were variations in traffic between vehicle types and travelling period at 5% level of significance. Table 3b shows the results of the ANOVA.

Table 3b: Analysis of Variance for Wednesday Traffic Volume Data

Source of Variation	SS	df	MS	F	P-value	F crit
Between Periods	91299.1	2	45649.6	1.0126	0.39769	4.10282
Between Vehicle Types	1240254	5	248051	5.50225	0.01084	3.32583
Error	450817	10	45081.7			
Total	1782370	17				

For Wednesday traffic data, there was no significant variations in traffic data due to differences in time period since the p-value obtained is greater than 0.05, however there are significant variations in traffic volume due to vehicle type since p-value obtained is less than 0.05.

The volume of traffic on the flexible pavement was investigated for Thursday using morning, afternoon, and evening times; Table 4a reveals that a total of 4,979 vehicles were counted, demonstrating the total volume of traffic in both directions. Cars (C), buses (B), trucks (Tk), trailers (TL), luxury buses (LB), and tricycles (TC) constitute 440 (8.8%), 107 (2.1%), 99 (2.0%), 90 (1.8%), 12 (0.2%), and 4231 (85.0%) of the total traffic volume, respectively. The average daily traffic (ADT) for C, B, Tk, TL, LB, and TC were estimated to be 147, 36, 33, 30, 4, and 1410, respectively. The distribution of traffic along the road revealed that tricycles dominated the road that day, followed by cars, buses, and trucks.

Table 4a: Jimeta Bypass Road Traffic Volume Data for Thursday

Period	Vehicle Type					
	Car	**Bus**	**Truck**	**Trailer**	**Luxury Bus**	**Tricycle**
Morning	99	28	50	39	4	1075
Afternoon	109	36	14	19	6	1176
Evening	232	43	35	32	2	1980
Total	440	107	99	90	12	4231
mean	147	36	33	30	4	1410
Standard Dev.	60.5	6.1	14.8	8.3	1.6	404.9

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A two-way analysis of variance without replication was conducted to see if there were variations in traffic between vehicle types and travelling period at 5% level of significance. Table 4b shows the results of the ANOVA.

Table 4b: Analysis of Variance for Thursday Traffic Volume Data

Source of Variation	SS	df	MS	F	P-value	F crit
Between Periods	110687	2	55343.4	1.4077	0.28929	4.10282
Between Vehicle Types	4664238	5	932848	23.7277	3E-05	3.32583
Error	393147	10	39314.7			
Total	5168072	17				

For Thursday traffic data, there was no significant variations in traffic data due to differences in time period since the p-value obtained is greater than 0.05, however there are significant variations in traffic volume due to vehicle type since p-value obtained is less than 0.05.

Table 5a shows that a total of 6,030 vehicles were counted on Friday, representing the overall volume of traffic in both directions. Cars (C), buses (B), trucks (Tk), trailers (TL), luxury buses (LB), and tricycles (TC) account for 448 (7.4%), 117 (1.9%), 111 (1.8%), 114 (1.9%), 38 (0.6%), and 5202 (86.3%) of the total volume of traffic, respectively. The observed average daily traffic (ADT) for C, B, Tk, TL, LB, and TC was 149, 39, 37, 38, 13, and 1734, respectively. The distribution of traffic along the road revealed that tricycles dominated the road that day, followed by cars, buses, and trailers.

Table 5a: Jimeta Bypass Road Traffic Volume Data for Friday

Period	Vehicle Type					
	Car	Bus	Truck	Trailer	Luxury Bus	Tricycle
Morning	123	43	34	45	14	2002
Afternoon	127	38	32	27	13	1440
Evening	198	36	45	42	11	1760
Total	448	117	111	114	38	5202
Mean	149	39	37	38	13	1734
Standard Dev.	34.5	2.9	5.7	7.9	1.2	230.2

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A two-way analysis of variance without replication was conducted to see if there were variations in traffic between vehicle types and travelling period at 5% level of significance. Table 5b shows the results of the ANOVA.

Table 5b: Analysis of Variance for Friday Traffic Volume Data

Source of Variation	SS	df	MS	F	P-value	F crit
Between Periods	30102.3	2	15051.2	1.13415	0.35981	4.10282
Between Vehicle Types	7080603	5	1416121	106.709	2.4E-08	3.32583
Error	132709	10	13270.9			
Total	7243414	17				

For Friday traffic data, there was no significant variations in traffic data due to differences in time period since the p-value obtained is greater than 0.05, however there are significant variations in traffic volume due to vehicle type since p-value obtained is less than 0.05.

During the morning, afternoon, and evening hours on Saturday, the traffic volume on the flexible pavement was analyzed; Table 6a shows that a total of 4,949 vehicles were counted, representing a total traffic volume in both directions. Cars (C), buses (B), trucks (Tk), trailers (TL), luxury buses (LB), and tricycles (TC) make up 9.9 percent, 2.2 percent, 1.9 percent, 2.3 percent, 0.9 percent, and 82.9 percent, respectively, of the overall traffic volume. The average daily traffic (ADT) for C, B, Tk, TL, LB, and TC were estimated

to be 149, 39, 37, 38, 13, and 1734, respectively. The distribution of traffic along the road revealed that tricycles dominated the road that day, followed by cars, buses, and trailers.

Table 6a: Jimeta Bypass Road Traffic Volume Data for Saturday

Period	Vehicle Type					
	Car	**Bus**	**Truck**	**Trailer**	**Luxury Bus**	**Tricycle**
Morning	171	36	23	44	13	1220
Afternoon	142	39	32	19	19	1102
Evening	175	34	37	50	13	1780
Total	488	109	92	113	45	4102
Mean	163	36	31	38	15	1367
Standard Dev.	14.7	2.1	5.8	13.4	2.8	295.7

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A two-way analysis of variance without replication was conducted to see if there were variations in traffic between vehicle types and travelling period at 5% level of significance. Table 6b shows the results of the ANOVA.

Table 6b: Analysis of Variance for Saturday Traffic Volume Data

Source of Variation	SS	df	MS	F	P-value	F crit
Between Periods	50229.8	2	25114.9	1.17634	0.34769	4.10282
Between Vehicle Types	4339196	5	867839	40.6483	2.5E-06	3.32583
Error	213500	10	21350			
Total	4602925	17				

For Saturday traffic data, there was no significant variations in traffic data due to differences in time period since the p-value obtained is greater than 0.05, however there are significant variations in traffic volume due to vehicle type since p-value obtained is less than 0.05.

Sunday morning, afternoon, and evening were used to evaluate the volume of traffic on the flexible pavement; Table 7a's summary reveals that a total of 5,293 vehicles were counted, representing a total traffic flow in both directions. Cars (C), buses (B), trucks (Tk), trailers (TL), luxury buses (LB), and tricycles (TC) constitute 454 (8.6%), 79 (1.5%), 100 (1.9%), 123 (2.3%), 38 (0.7%), and 4499 (85.0%) of the total traffic volume, respectively. The average daily traffic (ADT) for C, B, Tk, TL, LB, and TC were estimated to be 149, 39, 37, 38, 13, and 1734, respectively. The distribution of traffic along the road revealed that tricycles, followed by cars, buses, and trailers, were the most prevalent vehicles that day.

Table 7a: Jimeta Bypass Road Traffic Volume Data for Sunday

Period	Vehicle Type					
	Car	**Bus**	**Truck**	**Trailer**	**Luxury Bus**	**Tricycle**
Morning	157	22	23	49	20	1432
Afternoon	111	14	44	23	0	1080
Evening	186	43	33	51	18	1987
Total	454	79	100	123	38	4499
Mean	151	26	33	41	13	1500
Standard Dev.	30.9	12.2	8.6	12.8	9.0	373.4

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A two-way analysis of variance without replication was conducted to see if there were variations in traffic between vehicle types and travelling period at 5% level of significance.

Table 7b: Analysis of Variance for Sunday Traffic Volume Data

Source of Variation	SS	df	MS	F	P-value	F crit
Between Periods	92116.78	2	46058.39	1.394287	0.292341	4.102821
Between Vehicle Types	5270208	5	1054042	31.90811	7.76E-06	3.325835
Error	330336.6	10	33033.66			
Total	5692661	17				

For Sunday traffic data, there was no significant variations in traffic data due to differences in time period since the p-value obtained is greater than 0.05, however there are significant variations in traffic volume due to vehicle type since p-value obtained is less than 0.05.

3.3 Determination of the Annual Average Daily Traffic

Table 8 gives the breakdown of the analysis of total average daily traffic (TADT) volume along Jimeta Bypass Road

Table 8: Determination of the Total Average Daily Traffic Volume

Day	Morni	Afterno	Eveni	Average Daily Traffic Volume
Monday	1299	1107	1379	1261.67
Tuesday	1343	1208	400	983.67
Wednesda	1348	1182	370	966.67
Thursday	1295	1360	2324	1659.67
Friday	2261	1677	2092	2010.00
Saturday	1507	1353	2089	1649.67
Sunday	1703	1272	2318	1764.33
Total Average Daily Traffic				10295.67

Hence the average annual daily traffic volume based on the data was;

$AADT = \frac{TADT}{7} = \frac{10295.67}{7} = 1470.81$ vehicle per annum

The data for road traffic accident for Jimeta Bypass Road was collected from the Federal Road Safety Commission (FRSC) for the months of January to May 2023 and presented in Table 9. The data collected made no attribution to the causes of road traffic crashes.

3.4 Road Traffic Accidents investigation

Table 9: Road Traffic Accident Data for Jimeta Bypass Road

Month	Fatal	Serious	Minor	Total Crashes	Number Injured	Number Killed	Total Casualty	People Involved
January	27	85	53	165	11	9	20	95 (18%)
February	33	83	54	170	13	9	22	67 (13%)
March	24	56	13	92	31	22	53	158 (30%)
April	25	86	23	134	10	9	19	81 (15%)
May	24	75	43	142	38	23	61	124 (24%)
Total	133	385	186	703	103	72	175	525 (100%)
Percent	19%	55%	26%	100%	59%	41%	100%	

Table 9 depicts the monthly distribution of road traffic accidents during the study period in the first quarter of 2021. which reveals a total of 703 road traffic crashes, 19% of which were fatal, 55% of which were serious, and 26% of which were minor. The crashes impacted the lives of 175 people, 59% of whom were injured and 41% were killed. and involving a total of 525 people This could be attributed to poor pavement conditions as well as the presence of complex land use in close proximity to the roadway such as commercial, educational, residential, and transportation facilities, which attract high traffic and inadvertently lead to traffic accidents

Table 10: Pearson's Correlation Between Total Crashes and Road Traffic Volume

	Total Crashes	**Average Daily Traffic Volume**
Total Crashes	1	
Average Daily Traffic Volume	0.815653021	1

Table 10 showed that correlation between the total number of crashes and the average daily traffic volume is 0.816 which is high. Hence it is highly likely that the large traffic volume of Jimeta Bypass is the cause for road traffic accidents occurring on the road.

4. Conclusions

The study examined the significance and necessity of a rebalancing traffic volume survey in Nigerian urban areas, with a particular emphasis on a prominent bypass route in Yola (Adamawa state) that is essentially a critical connection for national and regional accessibility and connectivity. According to the study's key findings, tricycles accounted for the greatest volume of traffic on the selected roadway, followed by Cars/SUVs and then trailers. This boost for tricycles can be attributed to the aftermath of the insurgency problem in the region and a regulation that barred motorbikes as a method of transportation in urban areas. This study also revealed that there was no statistically significant variation in traffic volume between periods of traffic flow, confirming that the observed variation results from poor physical condition as well as traffic congestion along the road corridor, which also contributes to traffic accidents. Moreover, due to the obvious neglect of a traffic volume survey and the total decline in the provision and maintenance of basic infrastructural facilities, which have contributed to difficulties in road transport and traffic throughout the region, the nature of road transport planning and highway maintenance by governments have remained significant challenges. The study's findings provide the basis for recommending a total redress of traffic volume survey and road transport planning along road corridors; There is need to conduct an extended survey on the traffic volume as well as accident information especially in Ember months (September - December); the installation of automated traffic count devices, including permanent count devices and videotaping devices along the roadway; periodic maintenance of road networks with quality facilities; prompt road improvement and expansion with telecommunications infrastructure; and the periodic maintenance of road networks with quality service.

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