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RELATIONSHIP BETWEEN RAINFALL AND ROAD TRAFFIC ACCIDENTS IN LOKOJA, KOGI STATE, NIGERIA

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Abstract
This study assessed the relationship between rainfall and traffic accidents in Lokoja, Nigeria from 2011 - 2020. Rainfall data was obtained from Nigerian Meteorological Agency, while data on traffic accidents and casualties were obtained from the Federal Road Safety Corps (FRSC), both for a period of ten years (2011-2020). Data obtained were summarised using simple percentages, charts, and frequency distribution tables; while Pearson Product Moment Correlation, One-Way Analysis of Variance (ANOVA), and Simple Linear Regression were used for testing of hypotheses. Results revealed that, the amount of rainfall recorded in the study area vary over months and years. The month of September has the highest rainfall amount with an average of 279.35mm, while the month of December is the driest month with an average of 0.78mm. A high positive correlation was found between the monthly traffic crashes and casualties during the period of analysis which was statistically significant ($r = .898$*,* $n = 12$*,* $P < .001$*). Analysis indicates that 5.4% of the variation in traffic accidents can be explained by rainfall. However, rainfall significantly predict traffic accidents,* $F(1, 119) = 6.763$*,* $P = .01$*. Analysis also revealed that for every 1mm increase in rainfall, traffic accident cases decrease by 0.018 in the study area. In order to consolidate the efforts of FRSC in effectively reducing the rates of road traffic accidents in the study area and in the country at large, there is need to also obtain data on weather elements of accident prone areas.*

Key Words: *Rainfall, Road Traffic Accidents, Road Safety, Causalities, Weather Elements*

Introduction

The principal objective of transportation is to bridge the gap created in space by the friction of distance. However, in its attempt to overcome distance through the delivery of goods, services and people from one location to another, there are associated problems resulting from transportation activities. The most important transport problems are often related to urban areas and take place when transport systems, for a variety of reasons, cannot satisfy the numerous requirements of urban mobility. Some of the common urban transport problems are; traffic congestion and delay, road traffic accidents, air and noise pollution, indiscriminate parking, among others

(Rodrigue *et al*., 2016). Notable among the urban transport problems is road traffic accidents. This is because, the majority of transportation casualties in both developed and developing countries of the world can be attributed to traffic accidents (Atubi, 2010).

According to World Health Organisation (WHO) (2013), road traffic injuries are the eighth leading cause of death globally. About 1.24 million people die in road traffic accidents and between 20 and 50 million people are injured (WHO, 2013). Road traffic accidents and their related deaths have become a major health problem and concerns worldwide. As noted by Andrey *et al*. (2013), while many crashes are primarily due to factors that the driver can control, such as impairment due to lack of sleep, consumption of alcohol, or other distractions, numerous studies have demonstrated that extreme weather conditions can lead to increased risks of automobile crash, injury, and fatality.

There are a number of weather elements such as: frost, temperature, wind speed and direction, and visibility-reducing hazards such as fog, smoke, and dust that have been examined in relation to road hazards, but most of these researches have focused on crashes during rain and snow (Bergel-Hayat *et al*., 2013; Brijs *et al*., 2008; Ashley *et al*., 2015; Abdel-Aty *et al*., 2011). According to Jaroszweski and McNamara (2014), out of the weather events, the rainfall has the most significant impact on the traffic flow. Therefore, rainfall is consistently cited as the weather element responsible for the greatest number of weather-related accidents (Jaroszweski and McNamara, 2014). As observed by Elvik (2006) and Jackson and Sharif (2016), rain causes accidents through a combination of several physical effects that degrade the driving environment, which include but not limited to loss of friction between the tyre and road, impaired visibility through rain on the windshield, and spray from other vehicles. It is this combination of negative factors and the resultant strain on cognitive that leads to increased accident rates capacity.

Number of studies have been carried out across the world to assess the influence of rainfall on road traffic accident. While most of the studies indicate a positive relationship between precipitation and frequency (severity) of road accidents, some have found negative or non-significant correlations between rainfall and accidents. For instance, Andrey *et al*. (2002) studied weather-related road accident risks in mid-sized Canadian cities and found that, extreme increases in road accidents and injuries are due to precipitation. On average, precipitation increases the number of accidents by 75% and the number of related injuries by 45%, with snowfall having a more substantial effect than rainfall. Similarly, Jackson and Sharif (2016) conducted a study on rainfall impacts on traffic safety: rain-related fatal crashes in Texas from 1982 to 2011. It was observed that increase in rainfall is often linked to high accident frequencies. Also, Eisenberg (2004) studied the risk of precipitation on traffic crashes across the United States of America and reported that one cm of rain can increase the fatal crash rate for a day by about 3% if exactly 2 days have passed since the last precipitation and about 9% if more than 20 days have passed.

Available studies on weather and road traffic accidents in Nigeria are recent and very few. Besides, most of these studies were conducted in the Southern part of the country. For example, Enete and Igu (2011) analysed weather and wet road crashes in Enugu Urban, Nigeria and found that the effect of rainfall on road accident count depends on the length of time since the last rainfall. Large dry spell days were discovered to record more accident counts. Similarly, Ayeni and Oni (2012) examined road accidents in Lagos State, Nigeria in relation to seasonal climatic variations for 6 years (2005 - 2010). The results revealed that on the average, 46.69% accidents occurred in dry season, with an increase of 6.62% in the rainy season. The higher cases of recorded accidents in the rainy season are attributed to the slippery condition of road surfaces and low visibility. The casualty is about 45.64% during the dry season which increased by 8.64% in the raining season. The highest and lowest casualties were recorded in the June and April respectively. Of the 4,375 death recorded, 50.22% occurred in dry season with the highest incidence of 431 in the month of December alone. In the same vein, Olawole (2016) in a study of the impact of weather on road traffic accidents in Ondo State, Nigeria (2005–2012) reported that correlations between road traffic accidents and elements of weather were generally low and never exceeding 0.41. Both rainfall and temperature were negatively and positively correlated on yearly bases. The study also showed that the variations in road traffic accidents accounted for by rainfall and temperature are equally low never exceeding 25.7%.

The growing interest in understanding the interrelationship between weather elements and road traffic accidents in Nigeria has necessitated this study. The geographical location of Lokoja in the middle belt of Nigeria makes it a gateway linking the Northern part with Southern part of the country (Ukoje, 2016). This research therefore builds on the existing works by providing insights into the relationship between rainfall and road traffic accidents in Lokoja metropolis, in North Central part of Nigeria, from the year 2011 to 2020. The study also highlights policy issues to improve safety for the movement of people and goods at local and national levels.

Study Area

Lokoja serves as the administrative capital of Kogi State and doubles as the Headquarters of Lokoja Local Government Area (Figure 1). With an area of about 3,180km^2, the city is positioned between latitudes 7°45′27.56″ N and 7°51′04.34″ N of the Equator, and longitudes 6°41′55.64″ E and 6°45′36.58″ E of the Greenwich Meridian (Atomode and Majekodunmi, 2016). Lokoja is a city with its unique combination of climatic and vegetative characteristics (Alabi, 2009). It is characterized by a tropical climate that comprises of wet and dry seasons and falls within the Guinea Savannah vegetation belt. It experiences annual rainfall and temperature of about 1150 mm and 27.7°C respectively (Animashaun *et al*., 2020). The wet season is from April to October while cessation is from November to March, with a short break in August (Olatunde and Ukoje, 2016; Olatunde and Adejoh, 2017). The relative humidity is about 30% in dryseason and 70% in wet season (Ifatimehin *et al*., 2010; Olatunde and Adejoh, 2017).

Lokoja is a nodal town which straddles strategic roads to five geopolitical zones out of the six zones in the country.

Consequently, through traffic constitute significant proportion of traffic flows in the town. The increase in vehicular traffic in Lokoja without proportionate provision of road infrastructure induces serious pressure on the available road networks and thereby exacerbating urban transport problems such as traffic congestion and accidents. Notable roads in Lokoja include; Okene/Lokoja-Abuja Road, Lokoja/Obajana-Kabba Road, and the Lokoja-Ajaokuta Road which connect the town to other settlements within and outside Kogi State Also important is the Murtala Mohammed Road, which is a township road connecting secondary and primary roads in the town (Adetunji, 2014; Atomode and Majekodunmi, 2016).

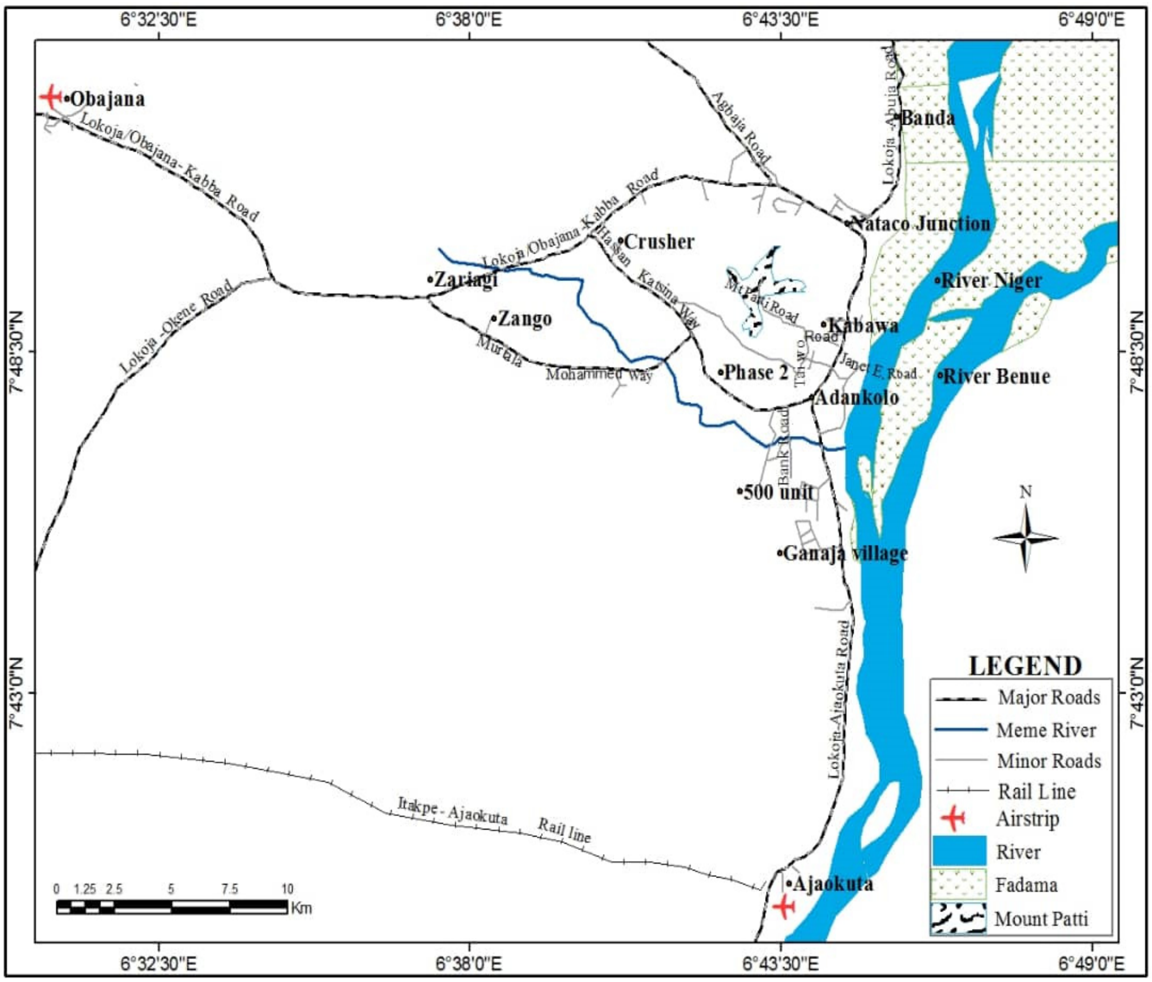

Fig. 1: The Study Area

Source: Adapted and Modified from Atomode and Abru, (2017)

Research Methods

This study made use of only data generated from secondary sources. Data on rainfall amount and reported cases of road traffic accidents were obtained from the Nigerian Meteorological Agency (NIMET), Lokoja and the Federal Road Safety Corps (FRSC) office, Lokoja, Nigeria respectively. Both data were obtained for a period of ten years (2011 to 2020). Data obtained were sorted and summarised into different time scales (monthly, seasonally, and yearly). This provides the opportunity for temporal analyses.

Descriptive statistical techniques such as frequency distribution table, simple percentages, mean and line graph were used to summarise the data on variation of the rainfall amount in the study area from the year 2011 to 2020. In addition to descriptive statistical technique, One-Way ANOVA was used to test the hypothesis that "there is no seasonal variation in the occurrences of road traffic accidents in the study area". The number of road traffic accidents represents the criterion or the dependent variable while the seasons (wet and dry) represent the factors or independent variable.

In addition, Pearson Product Moment Correlation was used to examine the association between road traffic crashes and casualties. The Product Moment Correlation was also used to examine the association between monthly rainfall and road traffic crashes. Moreover, Simple Linear Regression analysis was employed to assess the degree to which the variations in road traffic accidents were associated with rainfall. This was done by testing the hypothesis that "the occurrence of road traffic accidents in the study area is independent of rainfall". The number of road traffic accidents represent the dependent variable while rainfall amount represents the independent variable. The regression model is given by:

$Y = a + bX + e$ …………… Equation 1

Where;

Y= dependent variable (traffic accidents)

a = constant

b = the regression coefficients which determines the contribution of the independent variable.

X= independent variable (rainfall amount)

e= residual or stochastic error (which reveals the strength of bX)

Result and Discussion

Temporal Variation of Rainfall amount in the Study Area (2011-2020)

The average monthly rainfall in Lokoja from year 2011 to 2020 is presented in Figure 2. The analysis shows that the rainy season is from the month of April to October. The highest amount of rainfall is recorded in the month of September with an average of 279.35mm. This is followed by August, July, and June with an average of 201.99mm, 177.11mm, and 168.03mm respectively. The month of December is the driest month with an average of 0.78mm, followed by the month of January which recorded an average of 6.6mm of rainfall.

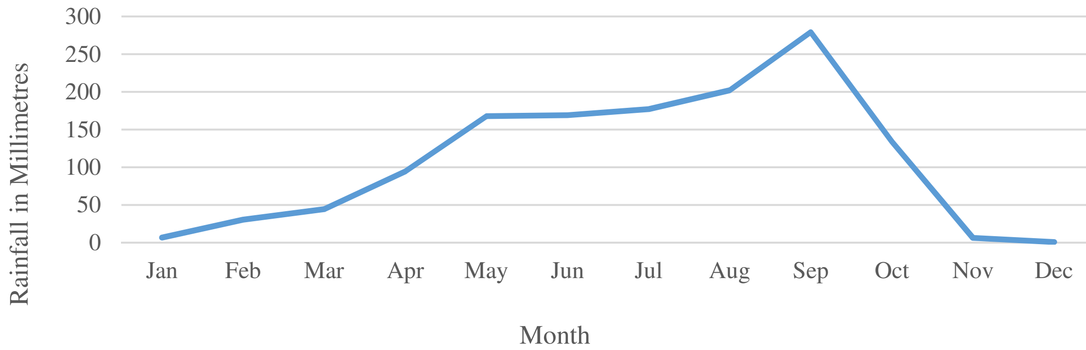

Fig. 2: Average Monthly Trend of Rainfall in Lokoja (2011-2020)
Source: NIMET, Lokoja

Similarly, variation occurred in the amount of rainfall from year to year. The analysis of the yearly variation in Figure 3 reveals that year 2011 experienced the highest average rainfall amount of 1,521.5mm. The year 2019 came second with an average of 1,494.6mm, while year 2013 came third and followed by year 2016 with average rainfall amount of 1,387mm and 1,349.5mm respectively. The lowest amount of rainfall was recorded in the year 2017 with an average of 1,166.2mm and year 2015 was only 30.5mm higher than the least year.

The result of this research agreed with the study by Olatunde and Adejoh (2017) who analyzed the intensity, duration, and frequency (IDF) of rainstorms in Lokoja. The study reported that rainfall onset take place in April while cessation commences in November. The finding also conforms with that of Olawole (2016) who observed that, generally the amount of rainfall increases gradually from no rainfall/little rainfall from the dry months (November to March) to substantial amount during the wet months (April to October).

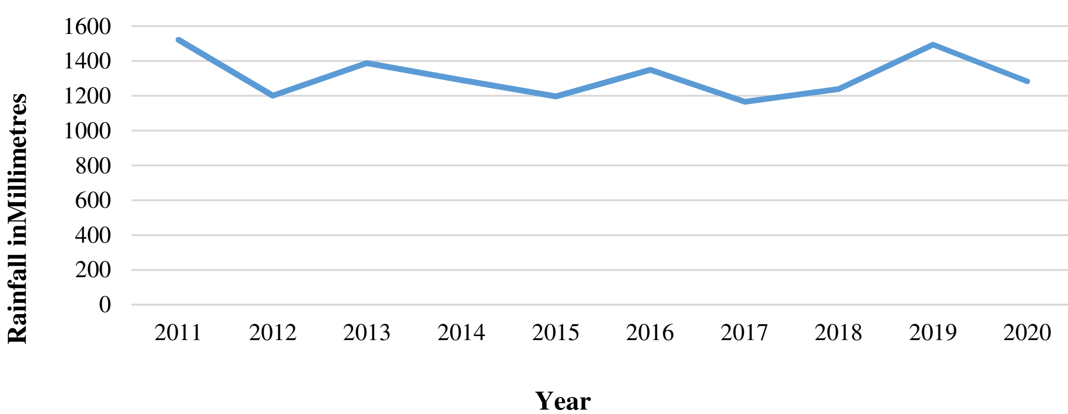

Fig. 3: Yearly Varaition in Rainfall Amount in Lokoja (2011-2020)
Source: NIMET, Lokoja

Temporal Variation of Road Traffic Accidents and Casualties in the Study Area (2011 -2020)

During the period of analysis (2011 to 2020), a total of 3,524 road traffic accidents were recorded; 25.11% were fatal, 53.43% classified as serious crashes, and 21.45% are minor crashes. The crashes resulted in 2,138 fatalities and 11,812 injuries, altogether totalling 13,950 road traffic casualties between 2011 and 2020.The injury to fatality ratio thus stood at about 5.5 to1, implying that for every person killed in road traffic crashes (from 2011-2020), about six other people were injured (Table 1).

Table1: Traffic Accidents and Casualties in Lokoja, 2011-2020

	Road Traffic Crashes				Casualties		
Year	**Fatal**	**Serious**	**Minor**	**Total**	**Injured**	**Killed**	**Total**
2011	94	192	108	394	1407	322	1729
2012	85	206	96	387	1338	205	1543
2013	96	174	90	360	1298	181	1479
2014	93	153	71	317	1084	199	1283
2015	102	179	71	352	1242	182	1424
2016	93	183	67	343	1021	229	1250
2017	90	162	72	324	1088	236	1324
2018	72	175	62	309	997	228	1225
2019	95	217	41	353	1227	190	1417
2020	65	242	78	385	1110	166	1276
Total	**885**	**1883**	**756**	**3524**	**11812**	**2138**	**13950**
Percentage	**25.11**	**53.43**	**21.45**	**100.00**	**84.67**	**15.33**	**100.00**

Source: FRSC, Kogi State Sector Command, 2021

Further analysis reveals that there is no significant yearly variation in road traffic crashes and casualties in Lokoja during the period of study. The result of the One Way Analysis of Variance in Table 2 shows that no significant yearly variation were found in road traffic crashes (F (9,119) = 1.221, P = .289) and casualties (F (9,119) = 1.233, P = .282), at .05 level of significance from 2011 to 2020.

Table 2: One Way ANOVA Results of Yearly Variation in Traffic Accidents and Casualties in Lokoja, 2011 -2020

ANOVA					
Crashes					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	673.367	9	74.819	1.221	.289
Within Groups	6738.500	110	61.259		
Total	7411.867	119			
Casualty					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	18626.000	9	2069.556	1.233	.282
Within Groups	184616.500	110	1678.332		
Total	203242.500	119			

In a similar vein, the average monthly variation in traffic accidents and casualties is presented in Figure 4. Analysis reveals that the highest average number of traffic crashes and casualties was recorded in December with an average of 43 crashes and 176 casualties. October recorded the least with an average of 22 crashes and 84 casualties.

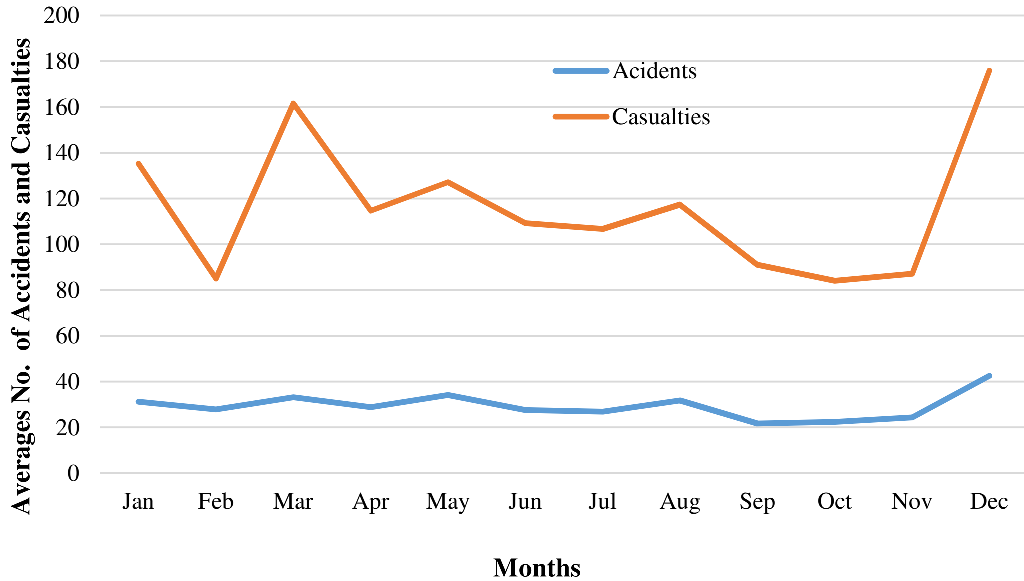

Fig. 4: Monthly Trend of Traffic Accidents and casualties in Lokoja
Source: FRSC, Kogi State Sector Command, 2021

Further analysis of the monthly trend reveals that significant relationship exist between road traffic crashes and casualties. The result of Pearson Product Moment Correlation shows that there is a high positive correlation between monthly traffic crashes and casualties during the period of analysis (2011-2020), which was statistically significant ($r = .898$, $n = 12$, $P < .001$) (Table 3).

Table 3: Pearson Product Moment Correlation of Average Monthly Traffic Accidents and Casualties

Correlations		
		Casualties
Accidents	Pearson Correlation	.898**
	Sig. (2-tailed)	.000
	N	12
**. Correlation is significant at the 0.01 level (2-tailed).		

In terms of seasonal variation in road accidents during the study period, Figure 5 reveals that the dry season recorded higher traffic crashes and casualties than the wet season despite having lesser number of months (5 against 7). About

54% and 55% of road traffic crashes and casualties occurred in the dry season compared to about 46% and 45% in dry season respectively. The analysis also shows that, the crashes to casualties' ratio in the dry season stood at about 4.06 to 1, compared to about 3.9 to 1 in the wet season. The finding of this research is similar to previous studies on temporal variations of road traffic crashes. For example, Olawole (2016) in a study of impact of weather on road traffic accidents in Ondo State, Nigeria, also reported that between 2008 and 2012, dry season months had more cases of road traffic accidents than the wet season months.

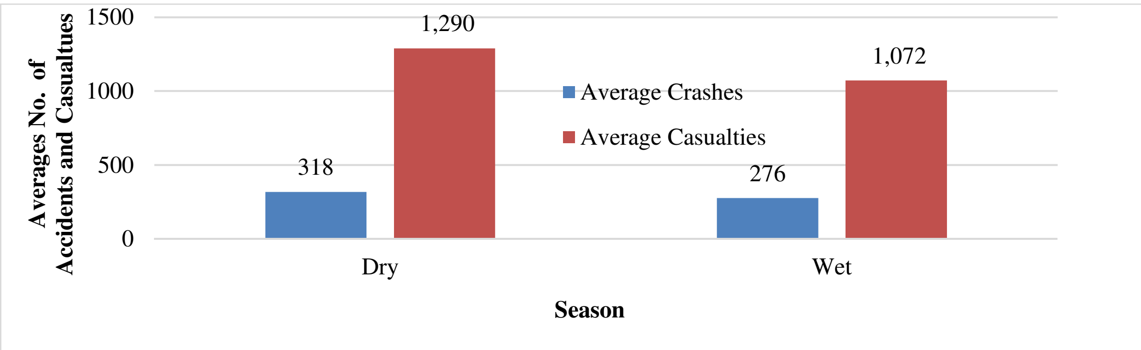

Fig. 5: Seasonal Variation of Road Traffic Crashes and Casualties in Lokoja (2011 – 2020)

A One-Way ANOVA statistical technique was used to examine the seasonal variation in the occurrence of road traffic accidents in Lokoja during the study period. There was a significant difference; F (1, 119) = 8.828, P=.004 – at 0.05 alpha level (Table 4). The Null hypothesis is hereby rejected, meaning that there is seasonal variation in the occurrences of road traffic accidents in the study area.

Table 4: One Way ANOVA Result for Seasonal Variation of Road Traffic Accidents in the Study Area

ANOVA					
Accidents					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	515.901	1	515.901	8.828	.004
Within Groups	6895.966	118	58.440		
Total	7411.867	119			

Relationship between Rainfall and Road Traffic Accidents

Figure 6 indicates a number of obvious differences between the average monthly rainfall and road traffic accidents in the study area. For instance, September with the highest average rainfall (279.35mm) has the same average cases of road traffic accidents (22) with October, even though the average rainfall amount of September is twice that of October. Also, December has the least average rainfall of 0.78mm (which is so small that it could barely be seen on the chart) but recorded the highest cases (43) of traffic accidents. This implies that a change in rainfall amount does not correspond with constant change in number of traffic crashes.

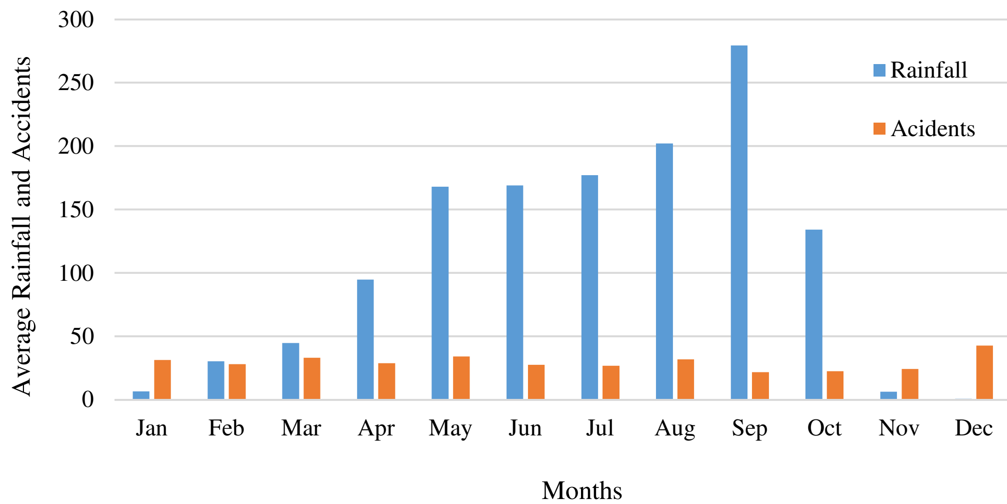

Fig. 6: Average Monthly Rainfall and Accidents in Lokoja, 2011-2020
Source: NIMET and FRSC, 2021

Similarly, Table 5 shows the correlation coefficient between average monthly rainfall and accidents for the study duration. Different degrees of positive and negative correlations are revealed. The correlations are not significant and the correlation coefficients are generally low with none exceeding 0.50 (Table 5).

Table 5: Correlation between Average Monthly Rainfall and Road Traffic Accidents in Lokoja, 2011 - 2020

Month	**r**	**sig**
January	.287	.421
February	-.359	.309
March	-.320	.367
April	.123	.734
May	.384	.273
June	.308	.387
July	-.325	.359
August	-.087	.811
September	.379	.281
October	.314	.377
November	.112	.758
December	-.244	.496

In addition, the analysis of seasonal average of rainfall amount and traffic accidents is presented in Figure 7. The result shows that dry season with an average of 177.46mm of rainfall had 42 more cases of road traffic accidents than the wet season which has about ten times higher rainfall amount (Figure 7).

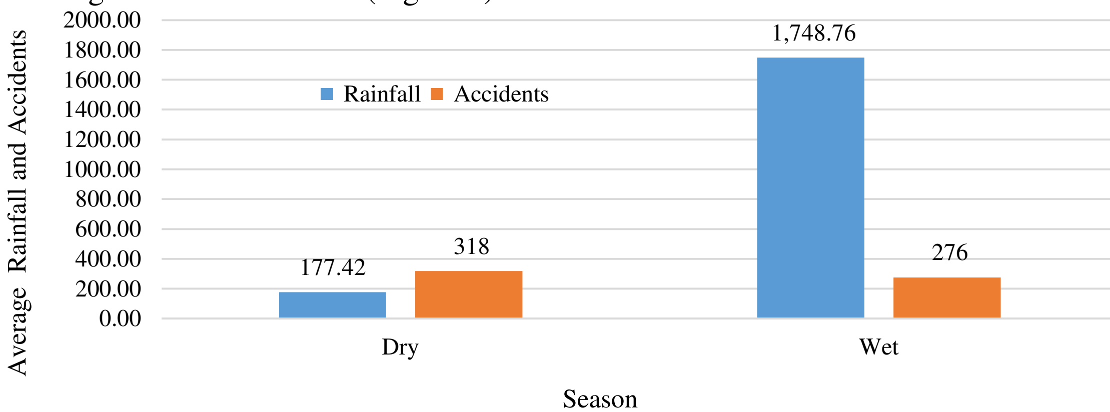

Fig. 7: Average Seasonal Rainfall and Accdents in Lokoja, 2011 - 2020
Source: NIMET and FRSC, 2021

Furthermore, the yearly distribution of rainfall and accidents shown in Figure 8 reveals that 2011 had the highest rainfall amount (1,521.5mm) as well as reported cases (394) of traffic accidents. Year 2019 came second in the annual rainfall amount (1,494.6mm) but fifth in reported cases of accidents (353), while year 2013 came third in rainfall (1,387.1mm) and fourth in accidents (360). Year 2017 had the least rainfall amount (1,166.2mm) while 2018 had the least reported cases of accidents (309) (Figure 8).

From the results of this study, there seems to be non-linear relationship between rainfall and traffic accidents. This is in agreement with previous studies that have found negative or non-significant correlations between rainfall amount and road traffic accidents. For instance, Enete and Igu (2011) in a study in Enugu city, Nigeria, found that the effects of rainfall on road accident count depends on the length of time since the last rainfall. Large dry spell days recorded more accident counts. Also, from the work of Aguero-Valverde and Jovanis (2006) who analyzed 5-year injury and fatal crashes in Pennsylvania, U.S.A, and concluded that, although total precipitation was found to have a positive linear relationship in the traditional negative binomial models, it was not statistically significant in the hierarchical Full Bayesian models.

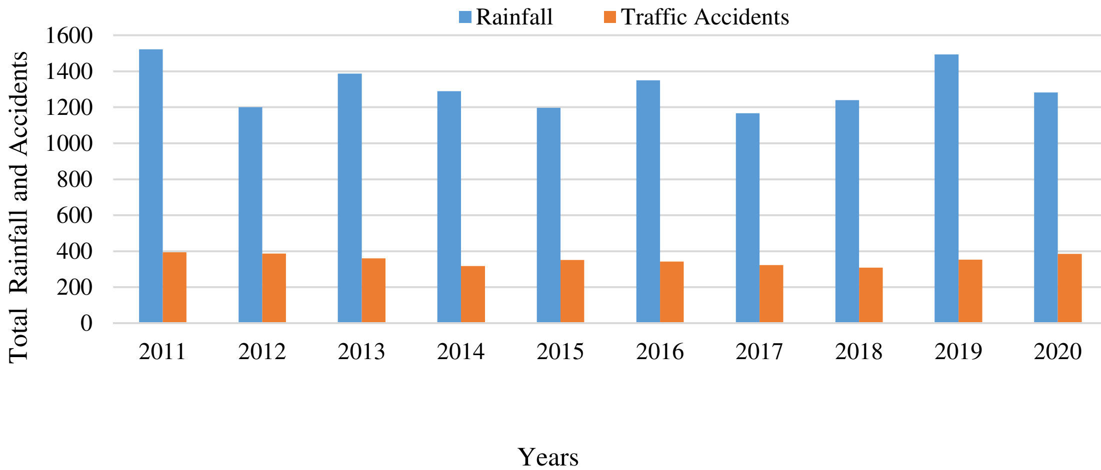

Fig. 8: Yearly Trend of Rainfall and Accidents in Lokoja, 2011-2020
Source: NIMET and FRSC, 2021

Moreover, Simple Linear Regression statistical technique was used to examine the effect of rainfall on the occurrence of road traffic accident in the study area. The summary statistics of the model is presented in Table 6. A low level of prediction of the dependent variable (traffic accidents) was indicated by the value of the correlation coefficient (R), 0.233. The coefficient of determination (R^2) value of 0.054 indicated the model only explained 5.4% of the total variation in the traffic accidents. It therefore means that 94.6% of the variation is still unexplained. In other words, the total road traffic accidents in the study area is a function of several other variables aside rainfall. Hence, adding other independent variables (such as human, mechanical, and other environmental factors, e.g. temperature, wind speed, etc.) could improve the fit of the model.

Table 6: Summary Statistics of Regression of Rainfall and Traffic Accidents

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.233[a]	.054	.046	7.708
a. Predictors: (Constant), Rainfall				

However, the F-ratio in the ANOVA table was used to test whether the overall regression model was good fit for the data (Table 7). The table reveals that the independent variable (rainfall) significantly predict the dependent variable (traffic accidents), F (1, 119) = 6.763, *P* =.01. Since the P-value is less than 0.05, the regression model is a good fit of the data. The null hypothesis that 'the occurrence of road traffic accidents in the study area is independent of rainfall' is hereby rejected. This implies that traffic accident is dependent on rainfall.

Table 7: ANOVA of Relationship between Rainfall and Traffic Accidents

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	401.783	1	401.783	6.763	.010[b]
	Residual	7010.084	118	59.407		
	Total	7411.867	119			
a. Dependent Variable: Traffic Accidents						
b. Predictors: (Constant), Rainfall						

The unstandardized coefficients in the coefficient table indicate how far rainfall varies with the occurrence of road traffic accidents when all other variables are held constant (Table 8). Therefore, for every 1mm increase in rainfall, traffic accident cases decrease by 0.018. A reduction in the traffic accident cases with increasing rainfall could be as a result of low traffic during heavy rainy periods, and light vehicle speed due to impaired visibility and runoff effect.
The equation to predict traffic accidents from rainfall therefore becomes:

Traffic Accidents = 31.307-0.018(rainfall) ………………Equation 2

The finding of this regression equation is consistent with other studies. For example, Karlaftis and Yannis (2010) used 21 years of daily count data for Athens, Greece, and found that high amount of rainfall may reduce the number of accidents. This effect according to Jaroszweski and McNamara (2014) may be attributed to driver risk compensation behaviour or to a simultaneous decrease of exposure.

Table 8: Regression Coefficients of Relationship between Rainfall and Road traffic Accidents

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	31.307	1.025		30.528	.000
	Rainfall	-.018	.007	-.233	-2.601	.010

Conclusion and Recommendations

This study examined the relationship between rainfall and road traffic accidents in Lokoja from 2011 to 2020. The study found that the highest amount of rainfall is recorded in the month of September with an average of 279.35mm, while the month of December is the driest month with an average of 0.78mm. In addition, it was revealed that year 2011 had the highest average rainfall amount of 1,521.5mm, while the lowest amount of rainfall was recorded in the year 2017 with an average of 1,166.2mm. The study also discovered that there is a high positive correlation between monthly traffic crashes and casualties during the period of analysis (2011-2020). However, no significant yearly variations were found in road traffic crashes and casualties. In addition, different low degrees of positive and negative correlations between rainfall and traffic accidents were revealed in the study area. Rainfall was found to explain only 5.4% of the variation in traffic accidents.

The findings of this study provide an insight for incorporating rainfall effects into traffic planning and management policies. This study demonstrates that exploring the relationship between rainfall and traffic accidents is critical in the implementation of road safety best-management practices. The study also advocates that analysis of rainfall related traffic accidents data will assist in the development of educational and prevention drives aimed at minimising traffic accidents. Further research into the effects of other weather elements (such as temperature, wind speed, and direction, as well as visibility-reducing hazards, e.g., harmattan dust) on traffic accidents would be valuable.

The study therefore recommends that the Federal Road Safety Corps need to also obtain data on weather elements of accident-prone areas to consolidate her efforts in effectively reducing the rates of road traffic accidents in the country. In addition, consistent road safety measures should be intensified during the months of December, May, March, August, and January. These are periods when the highest number of road accidents and casualties are recorded in the study area. Finally, in order to determine whether or not rainfall significantly influence traffic accidents, researches at extensive spatial and temporal coverage are needed to replicate this study in the country.

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