

# Impacts of rainfall on road crashes in Onitsha metropolis of Anambra State, Nigeria

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**ABSTRACT:** The World Health Organization, in particular, is concerned about road traffic accidents that occur during rainfall. However, this has resulted in global deaths, injuries, and property losses. The effects of rainfall on road crashes in the Onitsha metropolis were investigated in this study. The Nigerian Meteorological Agency (NiMET) provided rainfall data from 2009 to 2018, while the Federal Road Safety Commission (FRSC), Awka provided road accident data from 2009 to 2018. Pearson's Product Moment Correlation (PPMC) and Analysis of Variance (ANOVA) were the statistical approaches used to achieve the research goal. The significance level for all inferential analyses was set at 95 percent (0.05). Yearly road crashes and annual rainfall amount have a negative relationship, according to the findings. Rainfall patterns are negatively and insignificantly linked with annual road crashes ( $p=0.153>0.05$ ), showing that rainfall patterns are not the cause of road crashes in Onitsha. The correlation between monthly road crashes and rainfall received during wet season months is not significant, as demonstrated by the p-value (0.577). The relationship between monthly road crashes and rainfall recorded during dry season is not significant, as indicated by the p-value (0.797). The findings further reveal that, there are non-linear correlations between the rate of road crashes and the two seasons of the year because drivers were more careful when driving under rainfall. Therefore, slower driving during rainfall and parking of cars during torrential downpours are recommended by the study to further reduce the probability of road accidents.

**Keywords:** Onitsha metropolis, rainfall effects, road accidents, seasons, weather.

## INTRODUCTION

Advances in transportation have enabled changes in people's lifestyles and how societies are organized, both of which have a significant impact on development and civilization (Rodrigue et al., 2013). When compared to other modes of transportation in Nigeria, such as air, rail, and water, road transportation is by far the most frequently used (Onokala and Olajide, 2020). The term "road transport" refers to land-based transportation (Ladan, 2007). Road transportation is one of the best modes of transport for providing optimum service to everyone (Rodrigue, 2020). This mode of transportation offers the most flexibility in terms of route, direction, duration, and speed of travel, among other factors (Rodrigue, 2020). Passengers and cargo must first be transported by road before being transferred to a train station or airport for further travel (Rodrigue and Slack, 2020). As a result,

according to Rodrigue (2020), the road is the mode of transportation that is closest to man.

However, road transportation is associated with road crashes and accidents causing injuries and deaths (Afolabi and Gbadamosi, 2017). Road traffic injuries are a severe public health and development concern that is expected to worsen if member states do not sufficiently address road safety (World Health Organization, 2004). Accidents on the road are a global tragedy with an ever-increasing trend (Kareem, 2003). Every year, over 1.5 million people die in car accidents around the world (Nieuwenhuijsen and Khreis, 2019).

Weather is commonly acknowledged as having a substantial impact on the performance of surface transportation systems (Onwuadiochi et al., 2021; Rodrigue et al., 2013). Rainfall events are viewed as a

source of uncertainty by all road users and management, and they can have impacts on traffic safety and operations. In addition, rain is one important meteorological factor that leads to many deaths or injuries in terms of safety (Xu et al., 2013). Rain-related crashes occur when it is raining (Jackson and Sharif, 2014; Federal Highway Administration (FHWA), 2012). The FHWA further stated that, 75 percent of weather-related automobile crashes occur on wet pavement, with 47 percent occurring during rain. Andrey et al. (2003) reported that a 50 percent to 100 percent increase in collision probability during precipitation. Rain can raise the crash rate by 71 percent and the injury rate by 49 percent, according to Lin and Nixon (2008).

In addition, Sangkharat et al. (2021) reported that rain can impair driving in a variety of ways. Rain can diminish the performance of headlamps, tail lights, braking lights, and other indicator lights from an optical standpoint, as well as reduce the driver's ability to see clearly and lower the contrast between objects and the road, making driving more difficult. From a mechanical perspective, wet roads can weaken the traction of a vehicle's tires on the road, making driving conditions more perilous.

In Lagos, Nigeria, the rise in accidents is in tandem with rainfall increase, meaning that more accidents are likely to occur during the rainy season's subsequent peak (Ayeeni and Oni, 2012). Precipitation and moisture, according to Enete and Igu (2011), also contribute to the deterioration of road infrastructure. In the Warri metropolis, Ojeh and Ojoh (2011) found a substantial link between transportation costs and climate (rainfall, temperature, and humidity). Increases in heavy precipitation would certainly lead to more weather-related accidents, delays, and traffic disruptions in a network that is already overburdened (Markolf et al., 2019). However, all these studies were carried out elsewhere, as a result, the goal of this research is to evaluate the impacts of rainfall on road transportation, with a focus on road crashes in Onitsha metropolis.

## Hypotheses

**H<sub>01</sub>:** There is no significant relationship between annual rainfall occurrence and annual road crashes in Onitsha metropolis.

**H<sub>02</sub>:** There is no significant relationship between the rate of road crashes and rainy season months.

**H<sub>03</sub>:** There is no significant relationship between the rate of road crashes and dry season months.

## MATERIALS AND METHODS

### Study area

The study area is Onitsha metropolis, which includes Onitsha South and Onitsha North Local Government

Areas (Figures 1 and 2). Onitsha is one of Anambra State's metropolitan cities, situated on the eastern bank of the River Niger and covering an area of approximately 49,000 km<sup>2</sup>. The area is located between latitudes of 06° 04.58"N and 06° 10.00"N, and longitudes of 06° 44.59" and 06° 48.52"E (Ofomata, 1987). Nsugbe and Nkwele-Ezunaka border Onitsha on the northeast, Asaba, Delta State, and the River Niger on the southwest, and Obosi and Nkpor on the southeast. Onitsha North Local Government Area (Onitsha in-land town or Enu-Onitsha and Odoakpu) and Onitsha South Local Government Area (Fegge and Woliwo) make up this area. The River Niger and its various tributaries, especially the Anambra River (which gives the State its name), the Nkisi, and the Idemili Rivers, which drain into the River Niger, pass and drain the planning area of Onitsha (UN-Habitat, 2012).

### Method of data collection

The data was obtained from the Nigerian Meteorological Agency (NiMET), Awka were annual and monthly rainfall data from 2009 to 2018. While data on number of monthly road crashes recorded, crashed vehicles, number of persons involved in the crashes, number of persons that were injured and persons that died from 2009 to 2018 were obtained from Federal Road Safety Commission (FRSC).

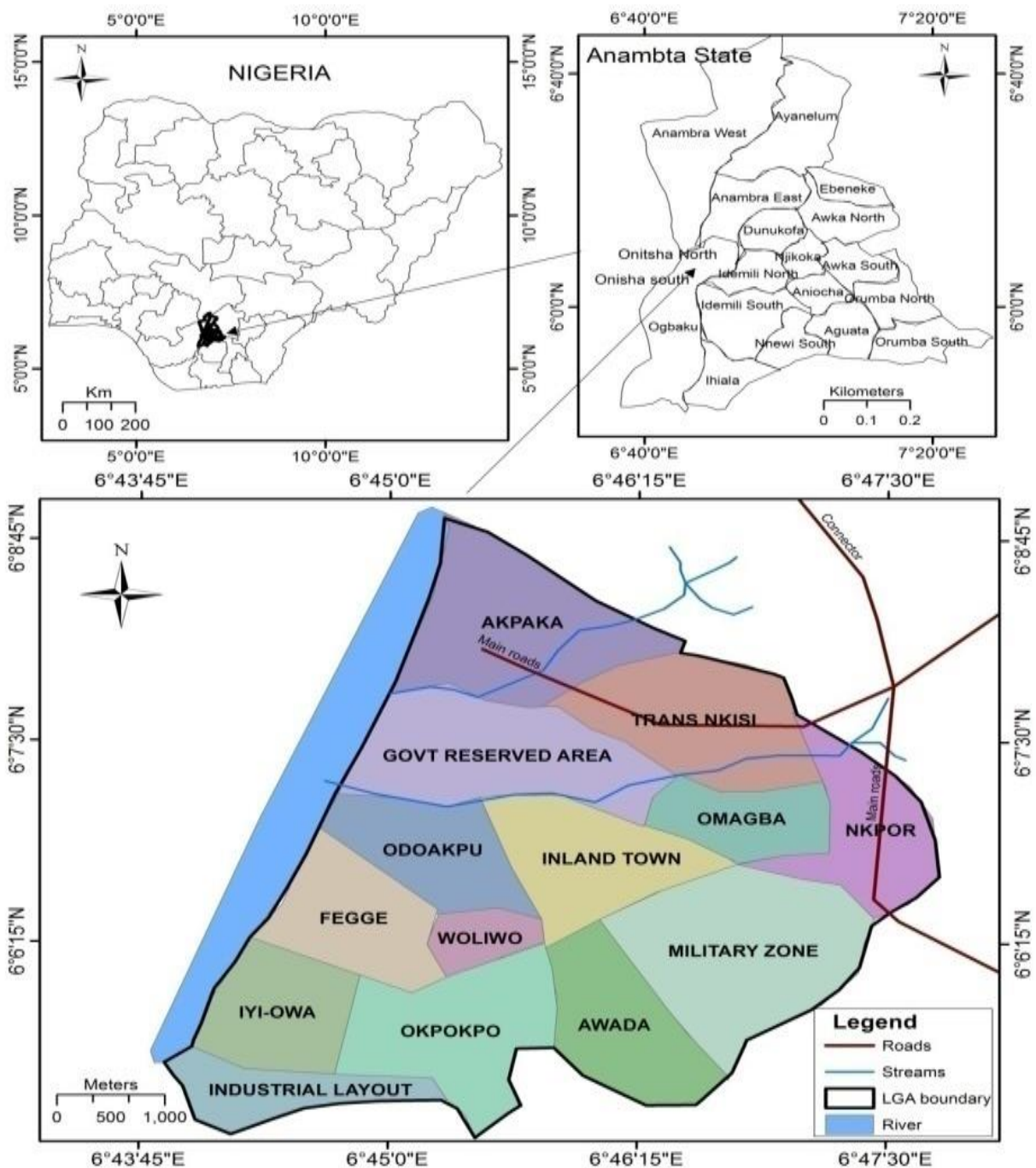
### Method of data analysis

The statistical techniques employed in achieving the research target are Pearson's Product Moment Correlation (PPMC) and Analysis of Variance (ANOVA). All inferential analyses were judged at 95% (0.05) level of significance.

### Pearson's Correlation

The Pearson's correlation technique was employed in validating the extent and relationship among the study variables without suppressing the other. Pearson's product moment correlation was used to evaluate the relationship between rainfall occurrence and road crashes in the study area at 0.05 level of significance. This statistical tool was chosen because it measures the strength of the linear correlation between variables that are continuous in nature. This same correlation was used to determine the relationship between the rate of automobile collision and seasonality. It helped to assess the degree to which rainfall was associated with road crashes. The Pearson's Correlation Coefficient is generally computed as:

$$r = \frac{Cov(M,N)}{\sqrt{(Var(M))(Var(N))}} = \frac{\sum_{i=1}^T [(M-\bar{M})(N-\bar{N})]}{\sqrt{[\sum_{i=1}^T (M-\bar{M})^2][\sum_{i=1}^T (N-\bar{N})^2]}} \quad (2)$$

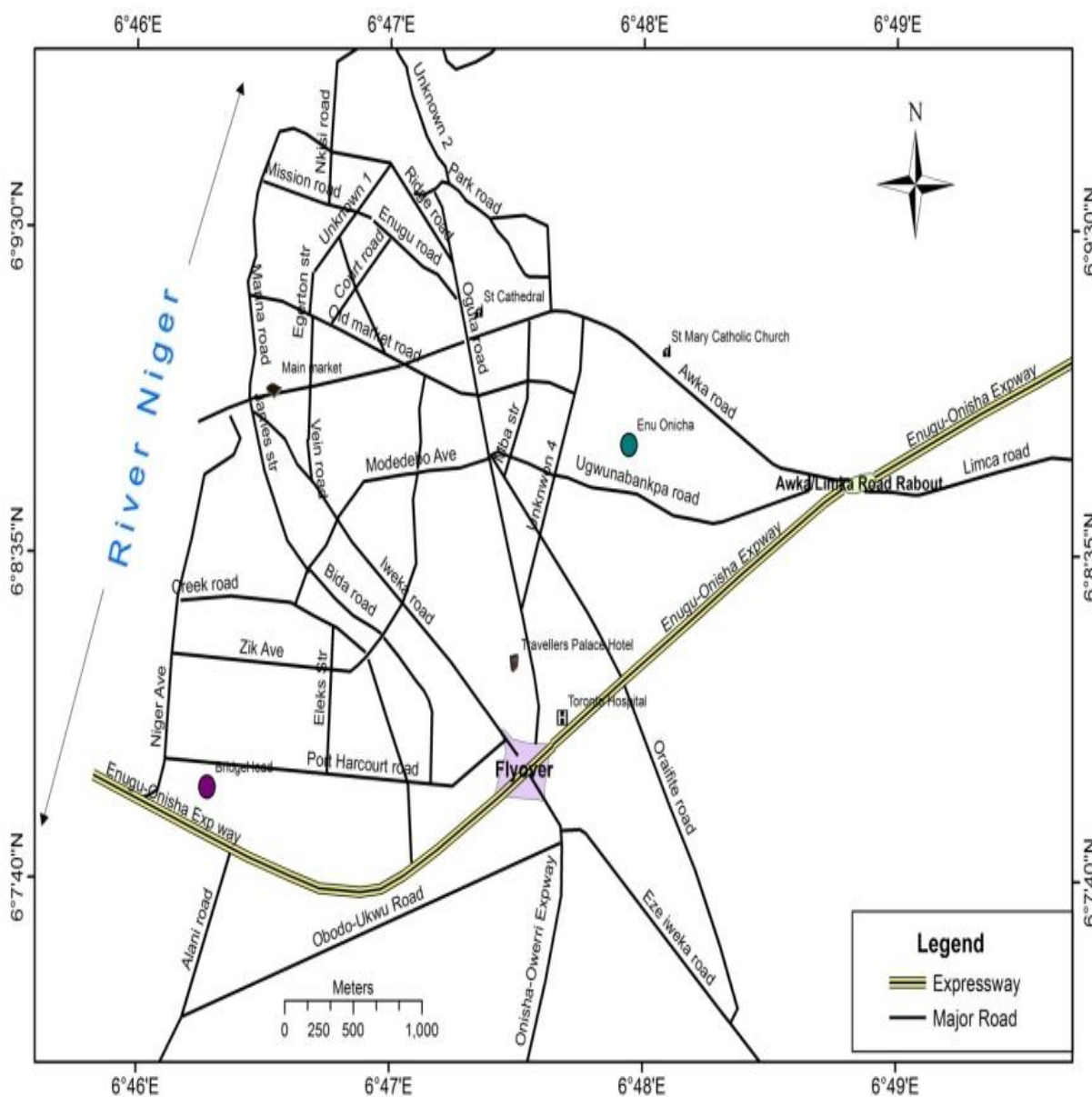


**Figure 1.** Map of Onitsha metropolis (Source: Department of Geography and Regional Planning, Delta State University, 2018).

Where:  $r$  = correlation coefficient,  $Cov(M, N) = \sum_{i=1}^T [(M - \bar{M})(N - \bar{N})]$  is the covariance of M and N series,  $Var(M) = \sum_{i=1}^T (M - \bar{M})^2$  is the variance of M series,  $Var(N) = \sum_{i=1}^T (N - \bar{N})^2$  is the variance of N series,  $T$  = Total number of observations,  $\bar{M}$  and  $\bar{N}$  = mean values of series of M and N values, M and N = variables of interest.

### Analysis of Variance (ANOVA)

The Analysis of Variance compares the means of two or more groups. It is an extension of the t-test which is limited to only two groups. In this study, the Analysis of Variance technique was used to determine and compare whether a



**Figure 2.** Map of roads in Onitsha metropolis (Source: Department of Geography and Regional Planning, Delta State University, 2018).

significant variation exist in the data series among road crashes and month(s) with the highest automobile collision and casualties. ANOVA test the significant difference among more than two independent means. The Fisher's statistics for the ANOVA test is generally estimated thus:

$$F - \text{Ratio} = \text{Ms}_b / \text{Ms}_w \tag{2}$$

Where:  $\text{Ms}_b$  is the between Mean Square and  $\text{Ms}_w$  is the within Mean Square

The within groups means square therefore will be:

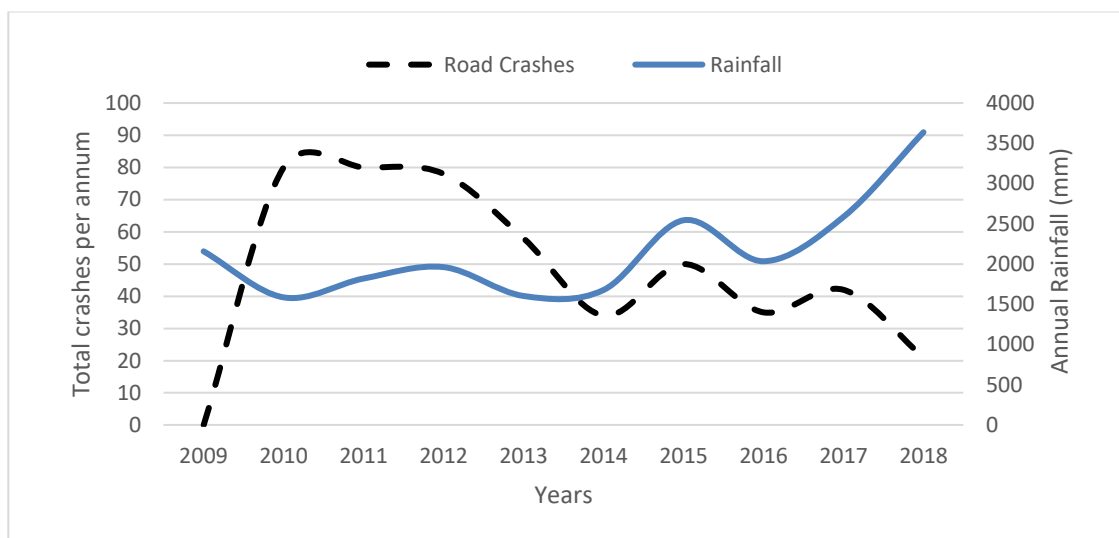
$$\text{MSW} = \text{SSW} / n - m \tag{3}$$

Where:  $n$  = no. of observations and  $M$  = no. of groups

Similarly, the mean squares between is expressed as:

$$\text{Msb} = \text{SSb} / m - 1 \tag{4}$$

The decision to reject or accept a significant difference was based on probability value less than 0.05 (i.e.,  $p < 0.05$ ). All the data obtained were analyzed using SPSS (version 20.0) and Microsoft excel.



**Figure 3.** Annual rainfall pattern and annual road crashes (2009-2018). Source: Researchers' work.

## RESULT AND DISCUSSION

### Relationship between rainfall pattern and road crashes in Onitsha (2009-2018) using Pearson's Correlation

The nature of the relationship between rainfall and road crashes was sought to examine the significance of such relationship and to test the null hypothesis stated herein:

*H<sub>01</sub>: "There is no significant relationship between annual rainfall occurrence and annual road crashes in Onitsha Metropolis".*

During the study period, Figure 3 depicts the link between yearly rainfall patterns and total annual road crashes. When the full period is taken into account, it shows erratic swings. On the other hand, it revealed that, while there was little clarity about the variations of both parameters when viewed in isolation between 2009 and 2018, their patterns began to resemble each other as they experienced similar fluctuations. For example, between 2014 and 2016, road crashes grew and dropped in lockstep with the rainfall pattern for the three years, but from 2017 to 2018, they diverged significantly.

The null hypothesis is accepted based on the negative association established between annual traffic crashes and annual rainfall amount (Table 1 and Figure 4). This study's findings are in line with the majority of similar investigations. It agrees with the findings of Yannis and Karlaftis (2010) research conducted in Greece. Increased rainfall was observed to reduce the total number of accidents, which was linked to the safety offset hypothesis, which states that more careful and slower conduct results

in fewer accidents.

Similarly, Nzoiwu et al. (2017) reported a negative but not statistically significant link between the wet period and road crashes in Awka. The study concluded that an increase in the wet period resulted in a small reduction in road traffic crashes during a three-year (36-month) period under investigation. Rainfall's effect on accidents appears to be non-linearly connected to accident rates, despite some research implying a linear relationship with the number of accidents (Sangkharat et al., 2021).

Annual road crashes are negatively and insignificantly associated with rainfall patterns, according to the Pearson's correlation estimate in Table 1 ( $p=0.153>0.05$ ). This suggests that the relationship between rainfall patterns and road crashes is statistically insignificant, and the null hypothesis is accepted, implying that rainfall patterns are not the cause of Onitsha road crashes.

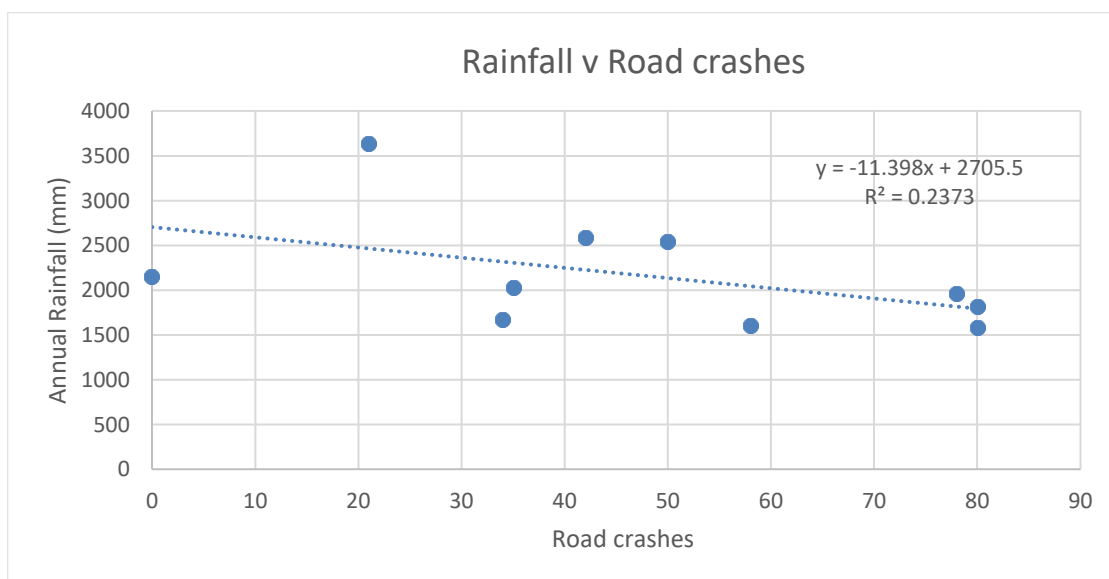
According to Jaroszweski and Mcnamara (2014), the effect of this outcome in Table 1 could be attributed to driver risk compensatory behavior or a simultaneous decrease in exposure. This, however, corroborated Enete and Igu (2011) and Mondal (2011)'s hypothesis that a negative rain crash effect (RCEi) during rainy months might be attributable to increased driver caution and the fact that negative RCEi accounted for fewer crashes per unit wet day in a month.

The yearly rainfall pattern was plotted alongside road crashes for improved clarity in their associations, yielding a trend that exhibited an inverse link. According to the results indicated in Figure 4, increased rainfall correlates to a reduction in road crashes. According to the coefficient of determination,  $r^2$ , which is 0.2373, around 23.73 percent of variations in the number of road crashes in Onitsha can be related to rainfall. It was also clear that the relationship

**Table 1.** Correlation analysis for road crashes and rainfall pattern.

		Road Crashes	Rainfall
<b>Road Crashes</b>	Pearson Correlation	1	-0.487
	Sig. (2-tailed)		0.153
	N	10	10
<b>Rainfall</b>	Pearson Correlation	-0.487	1
	Sig. (2-tailed)	0.153	
	N	10	10

Source: Author’s computation.



**Figure 4.** Relationship between rainfall pattern and road crashes (2009-2018).

is not statistically significant, as the simple correlation analysis yielded a correlation coefficient of -0.487 with a coefficient of determination of 0.2372 at a 0.05 level of confidence. In addition, it is equally clear that the number of road crashes decreases as rainfall increases, as the slope of the regression coefficient ( $b = -11.398$ ) shows.

**Pearson’s Correlation analysis of the relationship between the rate of road crashes and seasonality**

Monthly rainfall and crash data are shown in Tables 2 and 3 for the study period. The amount of rainfall grew progressively from little rainfall in the dry season months (November, December, January, February, and March) to high rainfall during the wet season months (February, March, and April) (April to October). The distribution of rainfall varied from year to year in general. There are few correlations between monthly rainfall and road crashes. For example, the maximum rainfall (887.80 mm) in

September 2018 is connected with a relatively low (1) event of road crash. Similarly, the number of crashes was the same in March 2013 and July 2015, but the rainfall was significantly different, 93.30 and 550.9 mm respectively. As a result, a combined analysis of Tables 2 and 3 reveals that, between 2013 and 2018, dry season months and wet season months had similar rates of road crashes. These data were used to investigate the hypothesis that was put to the test herein:

$H_{02}$ : “There is no significant relationship between the rate of road crashes and rainy season months”

$H_{03}$ : “There is no significant relationship between the rate of road crashes and dry season months”

As seen in Table 4, when monthly road crashes are compared to rainfall received during rainy months, the Pearson’s correlation revealed a correlation value of 0.258, clearly indicating a positive although extremely weak relationship. The association is certainly not

**Table 2.** Data on monthly road crashes and dry season (monthly rainfall) recorded.

Months	2013		2014		2015		2016		2017		2018	
	MRC	MR	MRC	MR	MRC	MR	MRC	MR	MRC	MR	MRC	MR
January	5.00	20.20	4.00	61.40	3.00	0.00	3.00	0.00	5.00	3.40	6.00	0.00
February	3.00	0.00	2.00	2.60	3.00	161.60	2.00	26.00	3.00	0.00	2.00	17.40
March	11.00	93.30	1.00	107.2	5.00	107.60	4.00	122.60	5.00	33.40	5.00	39.60
Nov	5.00	1.90	4.00	93.50	.00	64.50	4.00	42.70	4.00	93.50	0.00	141.20
Dec	8.00	6.30	2.00	19.00	2.00	0.00	0.00	4.00	4.00	19.00	0.00	0.00

**Key:** MRC = Monthly road crashes; MR = Monthly rainfall in millimeters (mm) (Source: FRSC, 2019; NIMET, 2019).

**Table 3.** Data on Monthly road crashes and rainy season (monthly rainfall) recorded.

Months	2013		2014		2015		2016		2017		2018	
	MRC	MR	MRC	MR	MRC	MR	MRC	MR	MRC	MR	MRC	MR
April	4.00	164.00	4.00	130.20	4.00	54.90	2.00	187.00	6.00	519.80	1.00	322.90
May	2.00	254.10	0.00	187.50	2.00	289.10	6.00	229.20	2.00	299.50	4.00	240.00
June	2.00	348.70	4.00	140.30	4.00	264.60	0.00	282.20	2.00	680.80	0.00	438.70
July	6.00	127.70	3.00	290.40	11.00	550.90	5.00	239.60	3.00	290.40	1.00	689.20
August	6.00	128.20	4.00	173.30	3.00	261.70	1.00	419.00	3.00	173.30	1.00	447.70
September	3.00	261.70	2.00	329.70	7.00	586.70	2.00	221.60	3.00	329.70	1.00	887.80
October	3.00	197.30	4.00	142.60	0.00	202.10	2.00	264.80	2.00	142.60	0.00	412.00

**Key:** MRC = Monthly road crashes; MR = Monthly rainfall in millimeters (mm) (**Source:** FRSC, 2019; NIMET, 2019).

**Table 4.** Correlation between road crashes and rainy season months.

		MRC	MR
<b>MRC Rainy season</b>	Pearson Correlation	1	0.258
	Sig. (2-tailed)		0.577
	N	7	7
<b>MR Rainy Season</b>	Pearson Correlation	0.258	1
	Sig. (2-tailed)	0.577	
	N	7	7

**Source:** Author's computation.

significant, as evidenced by the p-value (0.577) at the 0.05 level of significance, and hence the null hypothesis is accepted. This suggests that the relationship is not significant.

The results of the dry season hypothesis correlation are provided in Table 5. When monthly road crashes are compared to rainfall recorded during dry season months, the Pearson's correlation revealed a correlation value of -0.160 and a p-value of 0.797, indicating a slight negative relationship. The null hypothesis is accepted based on the p-value and correlation coefficient results, and the correlation result shows that road crashes decrease when rainfall increases in dry months. The association is not significant, as evidenced by the p-value (0.797), and

hence the null hypothesis is accepted. This suggests that the relationship is not significant.

Table 6 shows different degrees of positive and negative correlations for the two seasons on an annual basis. Any correlation with a p-value of less than 0.05 is significant, while any correlation with a p-value greater than 0.05 is not significant. Except in the wet season of 2013 (0.009), the correlations in this table are not significant because the computed r-value is greater than the critical value. The rate of road crashes seems to have a non-linear relationship with the two seasons of the year.

The findings in this study are consistent with those of other researches. Yannis and Karlaftis (2010) looked at 21 years of daily rainfall data for Athens and discovered that

**Table 5.** Correlation between road crashes and dry season months

		MRC dry season	MR dry season months
<b>MRC Dry season months</b>	Sig. (2-tailed)		0.797
	N	5	5
<b>MR Dry season months</b>	Pearson Correlation	-0.160	1
	Sig. (2-tailed)	0.797	
	N	5	5

Source: Author's computation.

**Table 6.** Correlation result between the rate of road crashes and yearly dry and wet seasons.

Year	Dry season		Wet season	
	R	P-value	R	P-value
2013	0.829	0.083	-0.878	0.009
2014	0.133	0.832	-0.422	0.346
2015	0.305	0.617	0.737	0.059
2016	0.616	0.268	-0.414	0.356
2017	0.055	0.931	0.269	0.559
2018	-0.428	0.472	-0.345	0.448

Source: Author's computation.

**Table 7.** ANOVA result between total monthly crashes from 2013 to 2018.

	Sum of squares	df	Mean square	F	Sig.
Between groups	61.667	11	5.606	1.127	0.357
Within groups	298.333	60	4.972		
Total	360.000	71			

Source: Author's computation.

a lot of rain can help minimize the number of accidents. In their investigation of potential interactions between rainfall features and road crashes in Awka, Anambra State, Nzoiwu et al. (2017) discovered that a rise in the wet period led to a modest reduction in road traffic crashes over a three-year period (36 months).

#### Variance analysis of the difference in the number of road crashes per month

Furthermore, One-way ANOVA was also deployed to test the significance of road crashes across the months. This was conducted using SPSS statistics (version 20). This was used to test the null hypothesis given thus:

*Ho: "There is no significant difference in the number of road crashes per month".*

As can be seen in Table 7, the p-value is 0.357, which is greater than 0.05. This means that there is no discernible

difference in the number of road crashes per month. This suggests that the number of road crashes per month is insignificant.

#### Conclusion

The results obtained from study show a negative relationship between the annual road crashes and annual rainfall amount. It apparently shown that road crashes in Onitsha are not the result of rainfall patterns. In addition, there is no discernible association between monthly road crashes and rainfall recorded during wet and dry season months. To further reduce the risk of road accidents, the study therefore recommends slower driving during rainfall and entirely parking of cars during torrential downpours.

#### CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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