Journal of Econometrics and Statistics
Vol. 4, Issue 2, 2024, pp. 175-192

Weather Condition Relationship with Road Traffic Accidents in Nigeria: An Application of the Dynamic Autoregressive Distributed Lag Model

[a]Samuel Olorunfemi Adams, [a]Trust Okechekwu, [b]Medina Umar
[a]Department of Statistics, University of Abuja, Abuja, Nigeria.
[b]Department of Physics, University of Abuja, Abuja, Nigeria.
[a]Corresponding Author: Samuel Olorunfemi Adams, Department of Statistics, University of Abuja, Abuja, Nigeria. samuel.adams@uniabuja.edu.ng

Abstract
Comprehending the influence of weather conditions on vehicular traffic crashes might facilitate the formulation of focused measures and regulations intended to mitigate incidents and enhance traffic security. The purpose of this study is to investigate the short- and long-term effects of weather conditions on Nigerian traffic accidents. We used information from the Federal Road Safety Corps (FRSC), the National Bureau of Statistics (NBS), and the Nigerian Meteorological Agency (NIMET). To evaluate the spatial short and long time association between meteorological conditions and traffic crashes, an autoregressive distributed lag model is used. The findings indicate that there is a positive and significant long-term relationship between temperature, rainfall, and cloud cover and the number of road crashes in Nigeria. However, in the short term, only temperature and rainfall showed a positive and significant relationship; evaporation, relative humidity, and cloud cover showed a negative and insignificant relationship with road accidents in Nigeria. For everyone who uses the roads and travels, including government agencies, groups dedicated to road safety, insurance providers, and the general public, this study is extremely important. In the end, it can save lives and lessen the financial damages brought on by traffic accidents by teaching drivers safe behaviors to follow in inclement weather.

Keyword: Climate; Weather; Transportation, Road Accident; ARDL Model; Error Correction Mechanism (ECM)

HIGHLIGHTS

- We developed an appropriate autoregressive distributed lag model to test the relationship between the weather climate variables and number of road accidents.
- Temperature, rainfall, and cloud coverage has positive and significant long term relationship with road crashes occurrence in Nigeria
- Temperature and rainfall has a positive and significant short run relationship with road accidents in Nigeria
- Evaporation and relative humidity had a negative insignificant short and long term relationship with road accidents in Nigeria
- The study provides a policy recommendation for drivers, road users and Government

Article History
Received : 16 September 2024; Revised : 19 October 2024; Accepted : 26 October 2024; Published : 28 December 2024

To cite this paper

Samuel Olorunfemi Adams, Trust Okechekwu, Medina Umar (2024). Weather Condition Relationship with Road Trafic Accidents in Nigeria: An Application of the Dynamic Autoregressive Distributed Lag Model. *Journal of Econometrics and Statistics.* 4(2), 175-192.

1.0 Introduction

Road transportation is the most common mode of transportation in Nigeria, it is the backbone of the movement of people and goods, the transportation industry is essential to the economic success of any country like Nigeria with a varied topography. It serves as a vital conduit for social contact, economic activity, and overall national development (World Bank, 2020). Nigeria's extensive road network links both rural and urban areas, promoting trade, business, and access to basic services. As a result, it is a vital aspect of daily life for the people of Nigeria. Nonetheless, the nation faces an enduring and formidable obstacle in the form of traffic accidents. Numerous lives have been lost, injuries have been sustained, and significant financial losses have been caused by these crashes, which have had dire effects (FRSC, 2019). These mishaps have far-reaching effects on the country's infrastructure, productivity, and healthcare system in addition to the immediate death toll. Investigating the many variables causing traffic accidents is essential to solving this complex issue, and one important component to take into account is the state of the weather. The vast array of meteorological phenomena that make up weather conditions is a major factor in determining how safe driving is. Unfavorable weather conditions, like intense rain, fog, and low visibility, can have a major impact on road safety and frequently make driving extremely dangerous for drivers (Viner, 2016). Reduced road grip, shortened stopping distances, poor visibility, and a higher chance of hydroplaning on wet roads are some of these weather-related difficulties. Such circumstances may increase the probability of traffic accidents and make driving dangerous. The impact of weather on road safety is made more difficult in the Nigerian environment, where regional climate variations are notable. Different weather patterns and circumstances are experienced throughout the nation; for example, coastal districts in the south may be vulnerable to excessive rainfall and the risks that go along with it, while the northern regions may see dust storms and adverse weather conditions. It is critical to comprehend the complex relationships between weather and transportation accidents in these diverse climatic environments. It can offer information that is not only region-specific but can also help with the creation of customized road safety plans for various areas of the nation. Given these variables, it is clear that a thorough investigation into the connection between weather and traffic accidents in Nigeria is necessary. To develop evidence-based policies and treatments to lessen the impact of weather-related incidents, this kind of investigation is essential. This study project uses sophisticated statistical models, such the Autoregressive Distributed Lag (ARDL) model, to shed light on the intricate relationship between weather and road safety in Nigeria. Ultimately, the findings of this study can serve as a valuable resource for policymakers, transport authorities, and road safety organizations, enabling them to make informed decisions that enhance road safety and reduce the human and economic costs associated with road traffic crashes. The remaining part of the paper include; Section two review of related literature regarding the effect of weather on road crashed. Section three presents the materials and methods, while Section four provided the results, section five discussed the results and the paper concludes in section six.

1.1 Weather Conditions and Road Traffic Crashes: The Nexus

The literature suggests that weather can account for roughly 5% of the fluctuation in monthly accidents and fatalities (Fridstrom et al., 1995; Adams & Bamanga, 2019; Hermans et al., 2006). Because it provides a short-term trend that will make it easier to identify the effects of safety policy, taking into account the influence of weather conditions in the analysis of road accident trends at an aggregate level is especially appropriate for short-term analysis, whether for the past or the near future. It is not easy to measure and capture the climate factor. It brings up several questions, most important among them how to identify the meteorological phenomena that have a substantial impact on the degree of road risk, what variables to use in evaluating them, and when to measure the weather in order for it to be considered relevant on a monthly basis. Rain is now regarded as the primary meteorological explanatory factor for road accident risk due to the frequency of injury accidents that are reported during bad weather (Brodsky & Hakkert, (1988); Adams, Mustapha & Alumbugu (2019)). For example, over the years 1990–2000 in France, 14% of all injury accidents occurred during wet weather, while 1% occurred at most during fog, frost, snow, or hail (Aron et al., 2007). The next stage is to determine the weather conditions that increase or decrease mobility, since the total number of injury accidents is dependent on the aggregate exposure level. It seems reasonable to consider temperature as a suitable variable for representing the regular changes in mobility throughout the year (the general cycle, from January to December, that is repeated during every 12-month period) as well as the atypical changes in mobility that occur in the event of unusually hot or cold weather. Fair weather promotes mobility, while cold spells reduce it.

Models that take into consideration the impact of weather on mileage in France have been presented by Bergel (1992), Jaeger (1998), and Gaudry and Lassare (2000), who have done so more broadly internationally. Scott (1986) was the first to estimate the variations in the monthly number of injury accidents and casualties in the UK from 1970 to 1978 and examine the effects of temperature and rainfall on these totals. Since then, a great deal of work has been done to develop an explanatory model that uses these two variables, either separately or together, to account for the influence of climate. In this section, we review and summarize these efforts. However, the outcomes of these endeavors differ based on the analysis's time scale (day or month) and how the meteorological variables were constructed (mean values or extreme values for the time period under consideration). Furthermore, in situations where the meteorological factors are important, their effects may vary in terms of both size and occasionally even sign. Recent years have seen a significant investigation into the relationship between weather and traffic accidents; research findings that concentrate on extremely short-term ties (daily level) and short-term links (at a monthly level) have been reported in (Karlaftis & Yannis, 2010). With the assumption of a stochastic trend, the impact of weather on traffic accidents in Belgium has been shown on a monthly time scale (Hermans et al., 2006) and on a daily time scale once the serial temporal correlation was taken into consideration (Brijs et al., 2008). Although the use of the daily and monthly variability of the weather information was not taken into account in a single model, both these studies appear to show the importance of which time series model is chosen for the analysis. This is now accepted in the road safety research field at international level, as the use of appropriate techniques for analysing road safety trends has been recommended (Dupont & Martensen (Eds.), 2007).

2.0 Review of Related Literature

There has been a lot of research done on the relationship between weather and traffic accidents worldwide; some studies have tried to look at this problem in the context of traffic management and road safety more broadly. The majority of research on the global impact of extreme weather events on traffic accidents highlighted the role that temperature on whether hot or cold. (Basagaña et al. (2015); Liu et al. (2017); Wu et al. (2018); Park et al. (2021); Basagaña & de la Peña-Ramirez 2023), some of them on extreme precipitation (Liu et al. 2017; Jaroszweski & McNamara, 2014, Keay & Simmonds, 2005), snowfall (Eisenberg & Warner 2005; Abohassan et al. 2022), or seasonal variations in road injuries (Gill and Goldacre, 2009). In light of the delays brought on by a traffic accident, the high wind, poor visibility, and temperature were taken into account (Su et al., 2023). The effects of weather (barometric pressure, ambient temperature, relative humidity, and rainfall) on the incidence of trauma among patients being transported to hospitals were investigated by Abe et al. (2008**).** Pińskwar, Choryński, and Graczyk (2024) evaluated how extreme weather occurrences affected people's perception, mental state, and even physical health when driving, which may have resulted in an automobile accident. The study examined four indicators, including maximum daily temperature and maximum humidex value, as well as an examination of vehicle accidents that occurred in Wielkopolska, Poland, between 2010 and 2019. The association between these indicators and auto accidents was determined using a distributed lag nonlinear model (DLNM) technique. Additionally, evidence suggested that the "good weather for aride" conditions are actually making accidents more likely. According to Basagaña et al. (2015), there is a significant 2.9% increase in the probability of collisions during heat wave days in Catalonia. This risk can further grow to 7.7% when characteristics related to driver performance, such as distractions, driver error, weariness, or sleepiness, are considered. With each degree Celsius that the maximum temperature rose, the predicted risk of collisions including such factors increased dramatically by 1.1%. According to a study conducted in Spain by Basagaña & de la Peña-Ramirez (2023), there was a 23% rise in the likelihood of crashes with linked causes. In their global study, He et al. (2023) reported a decrease in two indices of road injury related to high temperatures: age-standardized mortality rates (ASMR) and age-standardized disability-adjusted life years rates (ASDR), but the absolute death and disability-adjusted life years (DALYs) are on the rise.

There are studies on the relationship between weather and traffic accidents in Nigeria, but none of them use statistical techniques like the bound test, co-integration, or ARDL model. Owolabi & Oni's (2012) study looked at how the weather affected traffic accidents in Lagos, Nigeria. According to the study, fog and rainfall, especially in metropolitan areas, there are major contributors to traffic accidents. One of the first studies to look into the relationship between weather and traffic crashes in Nigeria was this one. Olawole (2016) investigated how the weather affected Ondo State, Nigeria, traffic accidents from 2005 to 2012. The primary conclusion is that, aside from temperature and rainfall, a number of other factors also influence the overall number of traffic accidents. In particular, correlations between weather conditions and traffic accidents were often weak, never rising over 0.41. On an annual basis, there was a negative and positive correlation between temperature and rainfall. Similarly, on an annual basis, multiple linear regression models examining the relationship between weather factors and traffic accidents reveal that the changes in traffic accidents caused by temperature and rainfall are likewise negligible, never surpassing 25.7%. Further research with additional weather and without weather variables is required to duplicate this study across the nation in order to ascertain whether or not the effects of weather on traffic accidents are significant. Ohakwe, Iwueze, & Chikezie (2011) investigate the connection between Nigerian road traffic accidents. The study found that the rising number of traffic accidents in Imo state and the resulting injuries and fatalities made the case for routine investigation of these accidents more compelling. Traffic road accidents were found to have a substantial seasonal influence and an upward trend using the time series decomposition method. The different causes of accidents and accident cases (minor, fatal, and serious) were found to differ significantly from one another over time in terms of the types of cars involved, according to the results of the chi-square test of significance. Reckless driving, inexperience, mechanical issues, and road flaws accounted for 30.3, 21.5, and 21.1% of the 5921 accident instances, respectively. Out of the 855 recorded deaths during the study period, 38.9, 37.5, and 14.9% were caused by two motorbikes, motorcycle-vehicle and vehicle-vehicle crashes. Additionally, it was discovered that 94.7% of all accidents occurred in private automobiles, minibuses, and taxis. The impact of rainfall on the number of road accidents is dependent on the duration of time since the last rainfall, according to Enete & Igu's (2011) analysis of weather and wet road crashes in Enugu Urban, Nigeria. It was shown that days with long dry spells will yield higher accident counts. Folorunsho, Atomode, & Uwandu (2022) evaluated the correlation between rainfall and traffic accidents in Lokoja, Nigeria, for the period of 2011 to 2020 in a different study. To test hypotheses, statistical techniques such as One-Way Analysis of Variance (ANOVA), frequency distribution tables, charts, basic percentages, Pearson Product Moment Correlation, and simple linear regression were employed. Results revealed that, a high positive correlation was found between the monthly traffic crashes and casualties during the period of analysis. Analysis indicates that 5.4% of the variation in traffic accidents can be explained by rainfall. The analysis period's monthly traffic crashes and casualties showed a strong positive link, according to the results. Rainfall accounts for 5.4% of the fluctuation in road accidents, according to analysis. Rainfall, however, is a major predictor of traffic accidents. Additionally, analysis showed that the number of traffic accidents in the study area decreases by 0.018 for every 1 mm rise in rainfall. In a study analyzing road traffic crashes in Anambra, Nigeria, Ihueze & Onwuroh (2017) discovered that the ARIMAX model performed better than the ARIMA(1,1,1) model when performance was assessed using the Bayesian Information Criterion (BIC). The results of the study also showed that the influence of weather on traffic accidents in Anambra was not very great. Nigeria.

While some research has addressed the impact of weather conditions on road traffic crashes in Nigeria, there are notable gaps in the existing literature. The studies conducted so far have primarily focused on specific regions, and a comprehensive national analysis is lacking. Furthermore, there is a need for more detailed investigations into the role of individual weather parameters, such as rainfall, temperature, relative humidity, evaporation and cloud cover on road traffic crashes. Additionally, considering the dynamic nature of weather conditions, it is crucial to employ advanced econometric models, such as the bound test, cointegration test and ARDL model, to capture the long-run and short-run relationships between the weather condition variables and the number of road crashes witnessed in Nigeria.

3.0 Materials and Methods

3.1 Data

The dataset utilized in this study was sourced from the Nigerian Meteorological Agency (NIMET), the Federal Road Safety Corps (FRSC), and the National Bureau of Statistics (NBS). It comprised variables related to weather conditions, road traffic crashes, and other relevant factors. The dataset covers a time span of ten years and four months, (2013 – 2023) allowing us to capture the dynamic nature of weather patterns and road crashes in Nigeria.

3.2 Model Estimation

The ordinary least squares (OLS) method is used in the study to estimate the ARDL model. To estimate the model's coefficients and determine whether the variables are significant, the OLS technique is employed. The best lag duration for the model is ascertained by the study using the Schwartz Bayesian Criterion (SBC) and the Akaike Information Criterion (AIC). The ARDL model's validity and any potential problems with the model specification can be evaluated using the findings of these diagnostic tests. Reestimating the model with new specifications or utilizing alternative estimation methods like the Generalized Method of Moments (GMM) or Bayesian methodologies may be required if the model's assumptions are broken, (Adams, Bamanga & Mbusube (2019); Adams, Zubair & Aiyedun-Olatunde (2022)).

$$f_i = g_i X + h_i Y + \varepsilon_i \tag{1}$$

Where f_i is number of road accident (RACC) i over a given period, *Xi* represents a constant variables while Yi, in contrast, consists of variables chosen to capture weather conditions like temperature (TEMP), rainfall (RAIN), evaporation (EVAP), relative humidity (REHU) and cloud coverage (CCG). These variables were considered with an aim to considering the impact that on road crashes

$$RACC_t = TEMP_t + RAIN_t + EVAP_t + REHU_t + CCG_t + \mu_t \tag{2}$$

The autoregressive distributed lag (ARDL) model proposed by Pesaran et al. (2001) is concerned with single equation modelling, it is a co-integration technique for examining long-run and short-run relationships among variables under study simultaneously. Following Pesaran et al. (2001) the ARDL model presented in Equation (2), the model can be written specifically as;

$$\Delta RACC_i = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i} \Delta RACC_{i-1} + \sum_{i=0}^{n} \alpha_{2i} \Delta\, TEM_{t-1} + \sum_{i=0}^{n} \alpha_{3i} \Delta\, RAIN_{t-1} + \sum_{i=0}^{n} \alpha_{4i} \Delta\, EVAP_{t-1} + \sum_{i=0}^{n} \alpha_{5i} \Delta\, REHU_{t-1} + \sum_{i=0}^{n} \alpha_{6i} \Delta\, CCG_{t-1} + \beta_1 RACC_{t-1} + \beta_2 TEM_{t-1} + \beta_3 RAIN_{t-1} + \beta_4 EVAP_{t-1} + \beta_5 REHU_{t-1} + \beta_6 CCG_{t-1} + \varepsilon_t \tag{3}$$

Where;

RACC = Road Accident

TEMP = Temperature

RAIN = Rainfall

EVAP = Evaporation

REHU = Relative humidity

CCG = Cloud coverage

Δ is the first difference operator, α_0 is the drift component, and ε is the error term. The left-hand side is the number of road accidents (RACC). The expressions with the summation sign ($\alpha_1 - \alpha_6$) on the right-hand side represent the short-run dynamics of the model. The first until six expressions ($\beta_1 - \beta_6$) on the right-hand side correspond to the long-run relationship of the model.

4.0 Result

The graph presented in Figure 1 is the combine first differenced visuals of the dependent variable, road accident and the corresponding explanatory variables; temperature, rainfall, evaporation, road accident, relative humidity and cloud coverage. The plot show that the series displays a fairly stable variance in the six variables after taking the first differencing. The summary statistics of the log-transformed variables were also conducted. Table 1 below presents the descriptive analysis of the dependent variable, and the explanatory variables utilized in this study. The result presented in the table shows the mean, median, minimum, maximum, standard deviation, skewness, kurtosis, and Jarque-Bera probability of the variables. The mean of the variables shows their average values from 2013 to 2023. The standard deviation shows that there is some dispersion in all the variables. Lastly, skewness, kurtosis and Jarque-Bera statistics showed that all the variables are normally distributed at 5% level of significance. The descriptive analysis indicated that the variables have some variations and employing the variables in the models will require identifying their stationarity properties. The six plots presented in Figure 1 indicated that there is evidence of non stationarity or outliers in the variables, but the graphs of the series display a more stable variance than the changes at the level stage after taking the logarithmic of the original series as seen in Figure 2.

The Augmented Dickey-Fuller (ADF) unit root test results for the weather variables are presented in Table 2 below. The results indicated that the ADF test statistic for each of the variables are greater than the respective critical values. Thus, the hypothesis of unit roots in each of the time series variable is accepted. In the final evaluation of all the variables became stationary after first difference. Hence, they are integrated of order I (1). Once all the series are non-stationary in the level, one can estimate an econometric model only if they are co-integrated. Thus co-integration tests can be applied for all variables.

Table 3 presents the lag length criteria, which are used to determine the optimal number of lags to include in the autoregressive (AR) model. The table displays the values of different information criteria, such as the log-likelihood (LogL), likelihood ratio (LR), final prediction error (FPE), Akaike Information Criterion (AIC), Schwarz Criterion (SC), and Hannan-Quinn Criterion (HQ) for different lag lengths (0 to 4). The goal is to choose the lag length that minimizes the selected information criterion. The log-likelihood function evaluates the goodness of fit of the model, while the likelihood ratio test assesses the statistical significance of the added lags. The FPE estimates the variance of the forecast errors, while the AIC, SC, and HQ are used to trade-off between model complexity and goodness of fit. In summary, the optimal number of lags to include in the AR model depends on the selected information criterion. Based on the results of Table 3, the model with one lag appears to provide the best trade-off between goodness of fit and model complexity.

Having established that road traffic accidents and the weather conditions indices are integrated of order one, the existence of the long-run relationship and short-run are tested using Auto-regressive distributed lags (ARDL) model. The result of F-bounds tests is reported in Table 4 shows that the F-statistic of 12.96 is found to be higher than the critical value of 2.26, 2.62. 2.96 and 3.41 of the lower Bound I(0) and 3.35, 3.79, 4.18 and 4.68 of the upper Bound I(1) at the 10%, 5%, 2.5% and 1% significant levels. The null hypothesis is rejected, which implies that the variables under study are co-integrated. In other word there exist a long-run relationship among road traffic accidents and the weather conditions indices.

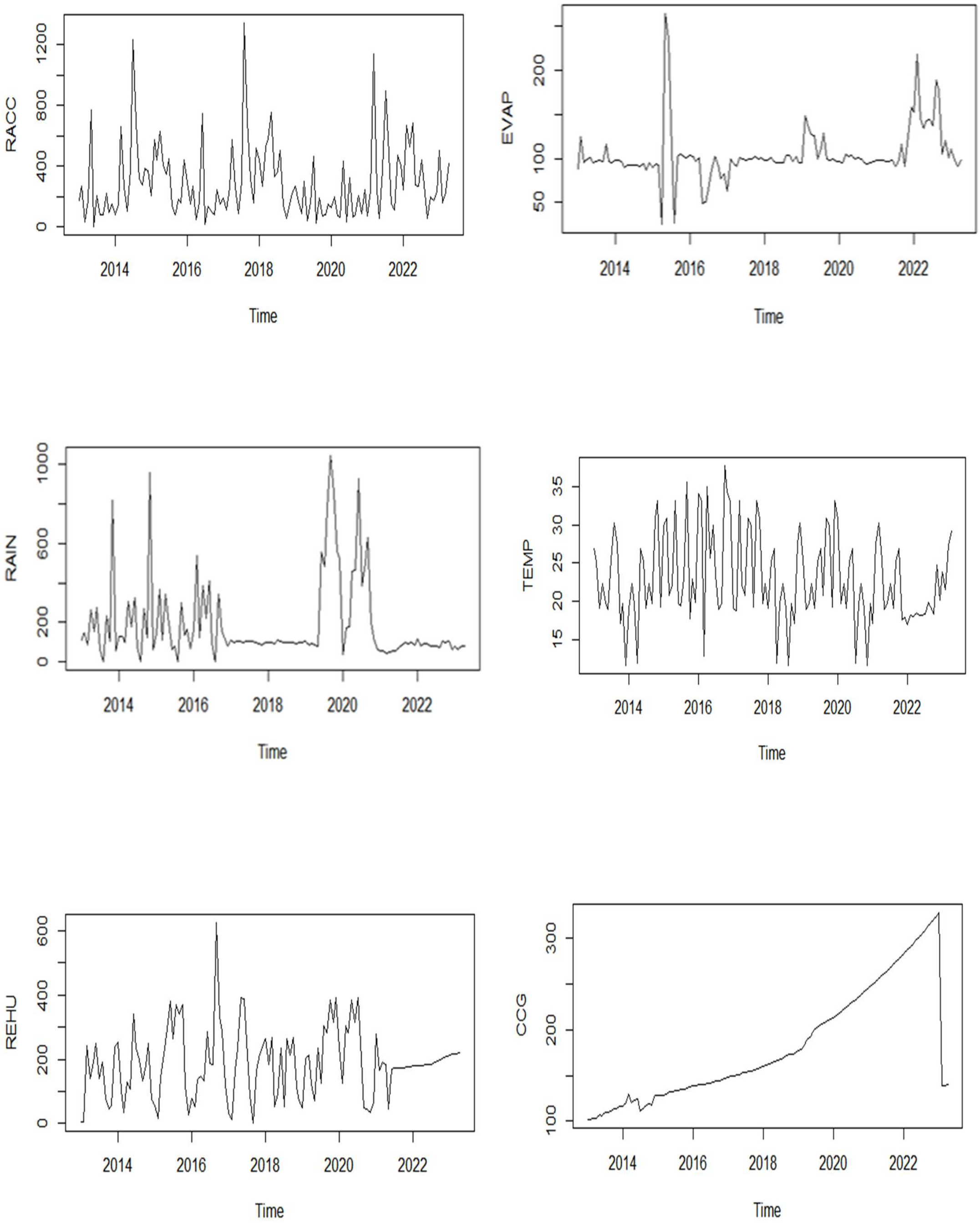

Figure 1: Plot of various weather component and Road Accident at level

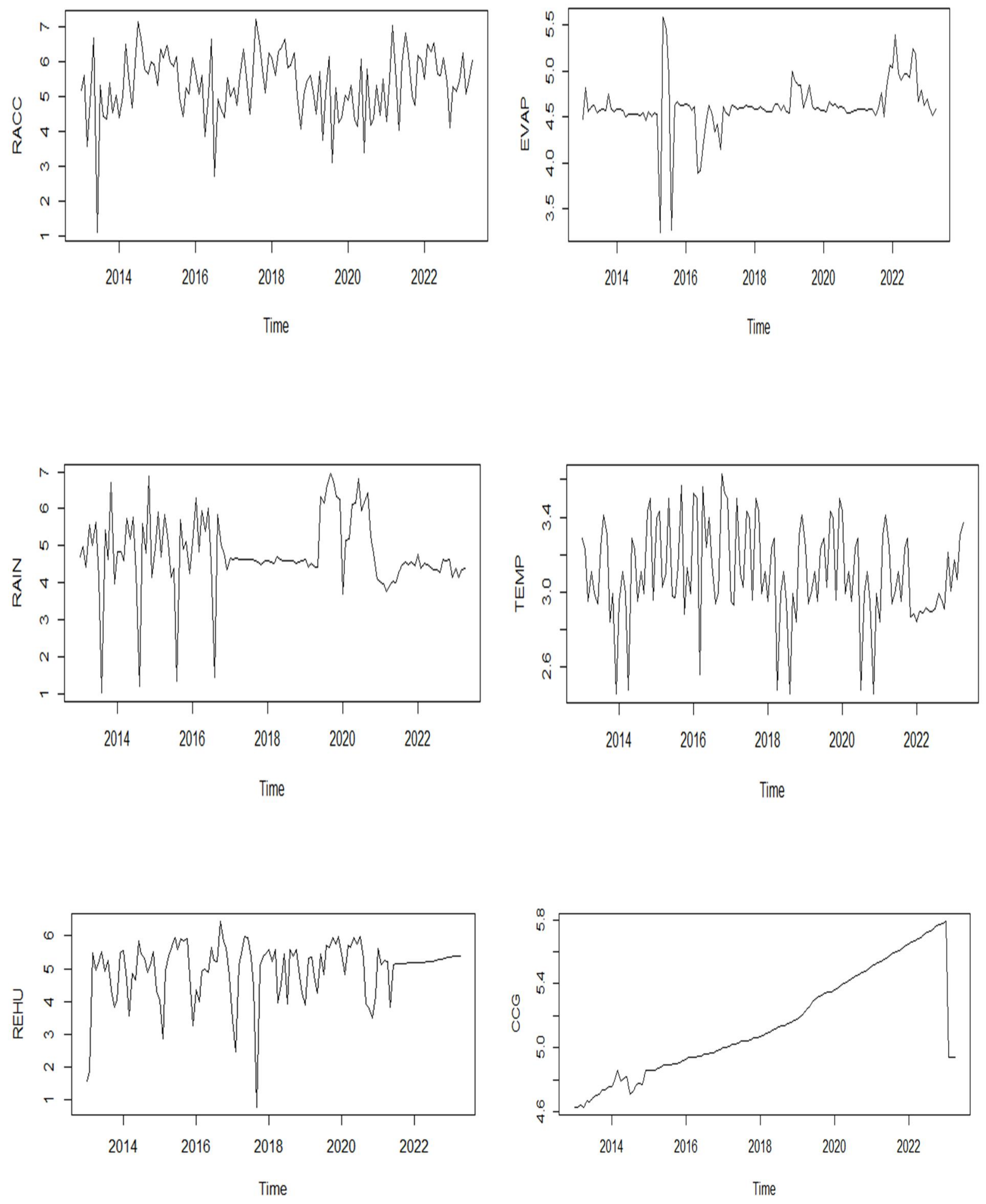

Figure 2: Plot of various weather components and Road Accident after first differencing

Table 1: Descriptive Statistics

	RACC	TEMP.	RAIN	REHU	EVAP	CCG
Mean	295.7984	23.06044	189.8941	188.2663	105.0347	181.5959
Median	229.000	21.83626	102.1193	183.2279	98.25337	157.8391
Maximum	1345.000	37.70000	1043.022	624.7000	264.0600	328.2400
Minimum	3.000000	11.70000	2.830000	2.200000	25.87000	102.1700
Std. Dev.	246.0271	5.842445	208.0512	106.6806	30.68092	63.05159
Skewness	1.726320	0.392232	2.277544	0.611643	2.200545	0.757026
Kurtosis	6.752622	2.549985	7.884690	4.145286	12.06538	2.368066
Jarque-Bera	134.3483	4.225809	230.4800	14.50856	524.6791	13.90710
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	36679.00	2859.49	2354.87	23345.02	13024.30	488986.8
Observations	124	124	124	124	124	124

Table 2: Unit root Test

Variables	ADF Test	Critical ADF Value		P-Value	Order of integration	Remark
RACC	-3.6677	1%	-3.4866	0.0000	*I* (1)	Stationary
		5%	-2.8861		*I* (1)	Stationary
		10%	-2.5799		*I* (1)	Stationary
RAIN	-4.5437	1%	-2.9437	0.0058	*I* (1)	Stationary
		5%	-2.7543		*I* (1)	Stationary
		10%	-2.5422		*I* (1)	Stationary
REHU	-6.5930	1%	-3.4856	0.000	*I* (1)	Stationary
		5%	-2.8855		*I* (1)	Stationary
		10%	-2.5797		*I* (1)	Stationary
EVAP	-6.7712	1%	-3.4842	0.000	*I* (1)	Stationary
		5%	-2.8851		*I* (1)	Stationary
		10%	-2.5794		*I* (1)	Stationary
TEM	-5.0609	1%	-3.4852	0.000	*I* (1)	Stationary
		5%	-2.8854		*I* (1)	Stationary
		10%	.2.5796		*I* (1)	Stationary
CCG	-4.4432	1%	-3.2426	0.0033	*I* (1)	Stationary
		5%	-2.7534		*I* (1)	Stationary
		10%	-2.6642		*I* (1)	Stationary

Table 3: Lag length criteria

Lag	LogL	LR	FPE	AIC	SIC	HQ
0	-835.0228	-	63793.53	13.90120	14.03984	13.95751
1	-835.3126	5.106673*	62018.53	13.87294	14.03468*	13.93863*
2	-835.2230	2.035206	61930.66	13.87145	14.05630	13.94653
3	-835.4924	3.203812	61192.27*	13.85938*	14.06733	13.94383

Table 4: F-Bound Test for Co-Integration

Test Statistics	Value	Significant Level	I(0)	I(1)
		Asymptotic n = 1000		
		10%	2.26	3.35
F-Statistic	12.96	5%	2.62	3.79
		2.5%	2.96	4.18
		1%	3.41	4.68
		Finite Sample n = 80		
Actual	123	10%	2.36	3.50
Sample Size		5%	2.79	4.02
		1%	3.73	5.16

Since weather conditions and its determinants are cointegrated, the long-run parameters of the ARDL(1,1,1,1,1) model are selected based on AIC and the results presented in the Table 5. The model was estimated using a lag of three given the annual nature and relatively short sample properties of the data. The result indicated that all the estimated variables except evaporation and relative humidity are statistically significant. Specifically, the result confirm a positive significant long term relationship of temperature, rainfall and cloud coverage with road accidents in Nigeria over the period 2013 – 2023. This implies that in the long-run increases in temperature, rainfall and cloud coverage has the potential of cause fatal accident in Nigeria. From the results, the coefficient of road accident is statistically significant at the1% and 5 % level, indicating that if the country witness an increase in the temperature, rainfall and cloud coverage by one percent, road traffic accident will increase by 2.87, 1.74 and 0.17 percent respectively. The result also indicated that, evaporation and relative humidity has a negative insignificant long run relationship with road traffic crashes. The implication of this result is that, in the long run, one percent increase in relative humidity and evaporations in the country will not lead to an increase in road traffic accident, instead, it will result in a .036 and 0.35 percentage decrease in road traffic accidents. The long run ARDL long run model is given as;

$$ECM = lnIp + .366019 * lnRACC + 2.869893 * lnTEM + 1.735082 * lnRAIN - 0.356865 * lnEVAP - 0.347909 * lnREHU + 0.167192 * lnCCG4 + 0.662716 * C \quad (4)$$

Table 6 provides the short-run dynamic parameters within the ARDL framework, it is the linear combination denoted by the error-correction term, $ECM_{t-1)}$ as retained by the ARDL model. The result of the estimated error-correction model of weather conditions for Nigeria as generated by the ARDL technique and selected through AIC criterion indicated that the short relationship was consistent with the long run. The result affirmed the existence of a positive and significant short term relationship of rainfall and temperature with road accidents in Nigeria over the period 2013 – 2023. The remaining climatic indicator exhibited a negative and insignificant short-term relationship with road accident. The implication of this findings is that; at the short run, an increases in temperature and rainfall will returns in increase road accidents in Nigeria. From the results, the coefficient of road accident is statistically significant at the1% and 5 % level, indicating that if the country witness an increase in the temperature and rainfall by one unit, road traffic accident will increase by 2.36 and 1.17 respectively. Conversely, a unit increase in climatic condition like evaporation, cloud and relative humidity will lead to 0.54, 0.32 and 0.27 reduction in road traffic accident. ARDL short run model is given as;

$$ECM_{t-1} = lnIp + .0.654322 * \Delta lnRACC + 2.360677 * \Delta lnTEM + 1.175854 * \Delta lnRAIN - 0.543426 * \Delta lnEVAP - 0.275078 * lnREHU - 0.302303 * lnCCG4 + 1.848383 * C \quad (5)$$

Table 5: ARDL Long Run Model

ARDL(1,1,1,1,1) selected based on AIC				
Variables	Coefficient	Std. Error	T-Statistic	P-value
Constant	0.662716	21.61260	0.0030663	0.9756
$LnRACC_t$	0.366019	0.114786	3.188706	0.0018**
$lnTEM_t$	2.869893	3.075783	3.933061	0.0035**
lnRAINt	1.735082	0.107997	3.680652	0.0049**
$lnEVAP_t$	-0.356865	0.681203	-0.523875	0.6014
$lnREHU_t$	-0.347909	0.199990	-1.739634	0.0846
$lnCCG_t$	0.167192	0.252820	0.413342	0.0008***
ECM	-1.117506	0.146654	-7.620002	0.0000***

* Significant at 0.05, ** Significant at 0.01, *** Significant at 0.001

Table 6: ARDL Short Run Model

ARDL(1,1,1,1,1) selected based on AIC				
Variables	Coefficient	Std. Error	T-Statistic	P-value
Constant	1.848383	27.73231	0.066651	0.4702
$\Delta LnRACC_t$	0.654322	0.75423	3.653421	0.0056
$\Delta lnTEM_t$	2.360677	3.925276	4.601404	0.0057
ΔlnRAINt	1.175854	0.137768	4.276445	0.0020
$\Delta lnEVAP_t$	-0.543426	0.872650	-0.622731	0.5347
$\Delta lnREHU_t$	-0.275078	0.256085	-1.074167	0.2850
$\Delta lnCCG_t$	-0.302303	0.872650	-0.622731	0.8503
ECM_{t-1}	-1.117506	0.146654	-7.620002	0.0000***

R-Square	0.424523	Mean dependent var.	1.229508
Adjusted R-Square	0.389186	S.D. dependent var.	305.3474
S.E. of Regression	238.6429	Akaike info criterion	13.85114
Sum Squared Resid	6492351	Schwarz criterion	14.03501
Log Likelihood	-836.9195	Hannan-Quinn criter.	13.92582
F-Statistic	12.01377	Durbin-Watson stat	1.874381
Prob(F-Statistic)	0.000000		

* Significant at 0.05, ** Significant at 0.01, *** Significant at 0.001

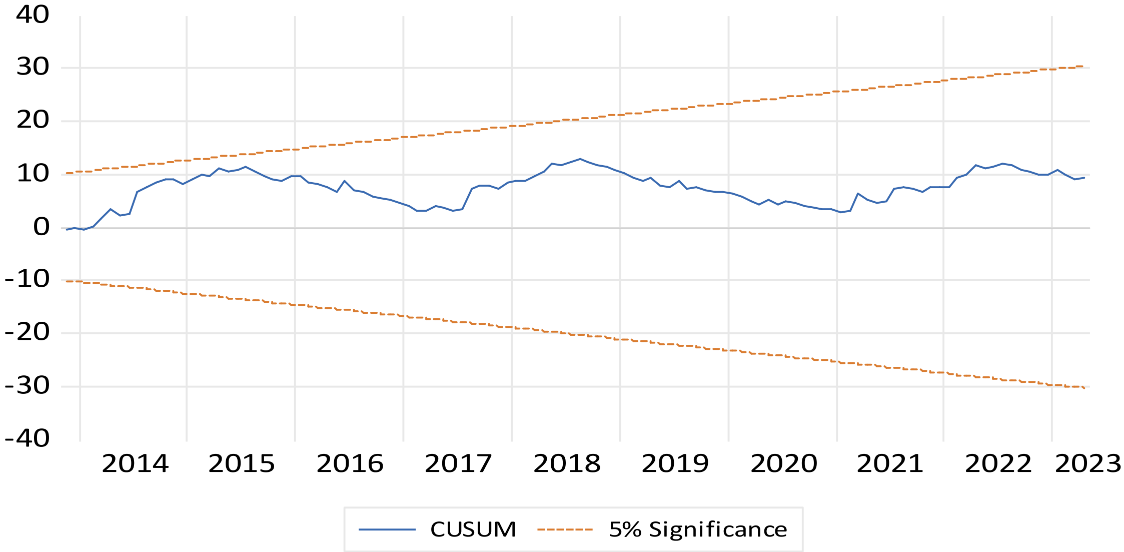

Figure 3. Cumulative sum (CUSUM) of recursive residuals plot

5.0 Discussion

The findings of this article indicates that temperature, rainfall, and cloud coverage has positive and substantial long run relationship with road collisions occurrence in Nigeria. The majority of investigations support this discovery. In particular, our findings are supported by research by Davies (2015), Olawole (2016), Pińskwar, Choryński & Graczyk, (2024), Folorunsho, Atomode & Uwandu (2022) Throughout the study period, a statistically significant strong positive correlation (r =.898, n = 12, P <.001) was discovered between the monthly traffic crashes and casualties. According to analysis, rainfall accounts for 5.4% of the variation in road accidents. Nonetheless, F (1, 119) = 6.763, P =.01 indicates that rainfall strongly predicts traffic accidents. Additionally, analysis showed that in the research area, the number of traffic accidents decreases by 0.018 for every 1 mm rise in rainfall. Data on the meteorological characteristics of accident-prone locations must also be gathered in order to coordinate the FRSC's efforts to successfully lower the rates of traffic accidents in the study area and throughout the nation. In addition, there was a significant positive correlation found between temperature and rainfall on an annual basis. The study also demonstrated that the variations in road traffic accidents explained by temperature and rainfall are equally small, never surpassing 25.7%. Liang et al. (2022), Basagana et al. (2015), Brijis, et al. (2008) found a significant correlation between high temperature and road traffic accident (RTA) and traffic accident injuries (TAIs). Motor vehicle crashes involving driver performance associated factors were elevated in correlation with heat waves and rising temperatures.

The results of this study are also supported by Bergel-Hayat et al. (2013), who conducted a study with the objective of highlighting the relationship between meteorological conditions and the likelihood of traffic accidents both monthly and overall. Significant monthly connections between meteorological factors and the total number of injury accidents were discovered, however the strength and even direction of these relationships differ depending on the kind of route (motorways, rural roads, or urban roads). Furthermore, it appears that the rainfall effect in the context of the French interurban network is mostly direct on motorways, where exposure remains constant, and partially indirect on main roads, where exposure varies. Additional daily results for the Athens region show that the consequences of extreme weather are highlighted when the within-month variability of the weather variables is captured and incorporated into a monthly model. However, the results of this study are in opposition to the majority of empirical findings, such as those of Karlaftis & Yannis (2010), who used 21 years of daily count data for Athens, Greece, and discovered that heavy rainfall may actually lower the number of accidents. According to Jaroszweski & McNamara (2014), this effect could be related to a concurrent reduction in exposure or driver risk compensatory behavior.

6.0 Conclusion

This study aimed to empirically examine the long- and short-term dynamic relationship between weather conditions such as rainfall, temperature, evaporation, relative humidity, and cloud cover on the increase in road crashes in Nigeria during the period of 2013–2023. Relevant statistical techniques were used in the investigation, including the Autoregressive distributed lag model, F-bound test, and co-integration test. Through the application of these methodologies, the project hopes to produce reliable and consistent models that can provide relevant prediction models for Nigerian stakeholders, drivers, and road users. The study identifies critical meteorological conditions that have had a major influence on Nigerian road traffic accidents over the study period. Long-term empirical research revealed that temperature, precipitation, and cloud cover are the primary meteorological determinants that might either cause or increase traffic accidents. The short-term, considerable beneficial effects of rainfall and temperature on traffic accidents suggest that unfavorable weather conditions have a significant confirmatory role in traffic accidents. When driving, it's best to maintain concentration and awareness, especially in challenging weather circumstances like fog or rain. To ensure they can drive safely in inclement weather, drivers should do regular maintenance on their vehicles. The tires of the vehicle should be correctly inflated, and the brakes should be verified to be smoothly and correctly operating. The weather can be unpredictable at times, and if cars are not adequately equipped to handle it, it can become dangerous. Wiper blades should be inspected for optimal performance and longevity. Lastly, it's critical to ensure that your brakes are functioning correctly by checking them. In inclement weather, it might be hazardous for you and other drivers to drive if there is a problem with the brakes.

Reference

Abe T, Tokuda Y, Ohde S, Ishimatsu S, Nakamura T, Birrer RB (2008). The Influence of Meteorological Factors on the Occurrence of Trauma and Motor Vehicle Collisions in Tokyo, *Emergency Medicine Journal*, 25(11):769–772. https://doi.org/10.1136/emj.2007.056960

Abohassan A, El-Basyouny K, Kwon TJ (2022). Effects of Inclement Weather Events on Road Surface Conditions and Traffic Safety: An Event-Based Empirical Analysis Framework, *Transportation Research Record: Journal of the Transportation Research Board*, 2676 (10):51–62. https://doi.org/10.1177/03611981221088588

Adams, SO, Bamanga, MA (2020). Modelling and Forecasting Seasonal Behavior of Rainfall in Abuja, Nigeria; A SARIMA Approach. *American Journal of Mathematics and Statistics* 10(01):10–19. https://doi.org/10.5923/J.Ajms.20201001.02.

Adams, SO, Bamanga, MA, Mbusube, A (2019). Principal Component Analysis of Nigerian Economy from 2006 – 2017. *Asian Journal of Advanced Research and Reports,* 5(4), 1 – 9. https://doi.org/10.9734/Ajarr/2019/V5i430139

Adams, SO, Mustapha, B, Alumbugu, AI (2019). Seasonal Autoregressive Integrated Moving Average (SARIMA) Model for the Analysis of Frequency of Monthly Rainfall in Osun State, Nigeria. *Physical Science International Journal*, 22(4), 1-14. https://doi.org/10.9734/Psij/2019/V22i430139.

Adams, SO, Zubair, MA, Aiyedun-Olatunde, TG (2022). The Role of Some Social Infrastructures Indicators on Economic Growth of Nigeria: A Causality Analysis Approach, *Economic Growth and Environment Sustainability (EGNES),* 1(2), 41-48. http://doi.org/10.26480/Egnes.02.2022.41.48

Aron, M, Bergel-Hayat, R, Saint Pierre, Guillaume, Violette, E (2007). Added Risk by Rainy Weather on the Roads of Normandie-Centre Region in France: Some Elements for the French IRCAD-SARI Traffic Monitoring and Information System for Drivers and Operators, 11th World Conference on Transport Research (WCTR), (hal-00371870)

Basagaña, X, De La Peña-Ramirez, C (2023) Ambient Temperature and Risk of Motor Vehicle Crashes: A Countrywide Analysis in Spain, Environmental Research, 216(2), 114599. https://doi.org/10.1016/j.envres.2022.114599

Basagaña, X, Escalera-Antezana JP, Dadvand, P, Llatje Ò, Barrera- Gómez, J, Cunillera J, Medina-Ramón M, Pérez K (2015) High Ambient Temperatures and Risk of Motor Vehicle Crashes in Catalonia, Spain (2000–2011): A Time-Series Analysis, *Environmental Health Perspectives*, 123(12), 1309–1316. https://doi.org/10.1289/ehp.1409223

Bergel Hayat, R, Debbarh, M, Antoniou, C & Yannis, G (2013). Explaining the Road Accident Risk: Weather Effects, *Accident Analysis & Prevention*, 60, 456-465. https://doi.org/10.1016/j.aap.2013.03.006

Bergel R (1992). Utilisation de modèles ARIMA avec variables externes dans le secteur des transports. *Proceedings of the 6th WCTR*, World Conference on Transport research Society (in French).

Brijs T, Karlis D,Wets G (2008). Studying the effect of weather conditions on daily crash counts using a discrete time series model. *Accident Analysis and Prevention 40(3)*, 1180-1190. https://doi.org/10.1016/j.aap.2008.02.001

Brodsky H, Hakkert S (1988). Risk of Road Accident in Rainy Weather, *Accident Analysis and Prevention*, 20(3), 161-176. https://doi.org/10.1016/0001-4575(88)90001-2

Davies, J (2015). Analysis of Weather Effects on Daily Road Accidents, *Reported Road Casualties Great Britain: annual report 2015,* 1-7.

Dupont E, Martensen H (Eds) (2007). Multilevel Modelling and Time Series Analysis in Traffic Safety Research – Manual, *Deliverables D7,* SafetyNet, http://www.erso.eu

Eisenberg, D, Warner, KE (2005). Effects of Snowfalls on Motor Vehicle Collisions, Injuries, and Fatalities, *American Journal of Public Health*, 95(1), 120–124. https://doi.org/10.2105/AJPH.2004.048926

Enete, IC, Igu, IN (2011). Analysis of Weather and Wet Road Crashes in Enugu Urban, *Pakistan Journal of Social Sciences*, 8(1), 289-293. https://doi.org/10.3923/pjssci.2011.289.293

Fridstrøm L, Ifver J, Ingebrigtsen S, Kulmala R, Thomsen LK (1995). Measuring the Contribution of Randomness, Exposure, Weather, and Daylight to the Variation in Road Accident Counts, *Accident Analysis & Prevention*, 27(1), 1-20. https://doi.org/10.1016/0001-4575(94)E0023-E

FRSC, (2019). Annual Report, Federal Road Safety Corps. https://frsc.org.ng/publications/

Folorunsho, JO, Atomode, TI, Uwandu, SC (2022). Relationship between Rainfall and Road Traffic Accidents in Lokoja, Kogi State, Nigeria, *Ethiopian Journal of Environmental Studies & Management,* 15(5), 557 – 572. https://ejesm.org/doi/v15i5.1

Gaudry M, Lassarre S (Eds.) (2000). *Structural Road Accident Models - The International DRAG Family*, Pergamon. Editors: Gaudry, M & Lassatte, S. https://doi.org/10.1108/9780080518015

He L, Liu C, Shan X, Zhang L, Zheng L, Yu Y, Tian X, Xue B, Zhang Y, Qin X, Wang C, Zhang K, Luo B (2023) Impact of High Temperature on Road Injury Mortality in a Changing Climate, 1990–2019: A Global Analysis, *Science of the Total Environment,* 857(1), 159369. https://doi.org/10.1016/j.scitotenv.2022.159369

Hermans, E, Wets, G, Van Den Bossche, F (2006). Frequency and Severity of Belgian Road Traffic Accidents Studied by State-Space Methods, *Journal of Transportation and Statistics*, 9(1), 63-76. https://www.bts.gov/publications/journal of transportation_and_statistics/

Ihueze, CC, Onwuroh,, UO (2017). Road Traffic Accidents Prediction Modelling: An Analysis of Anambra State, Nigeria, *Accident Analysis & Prevention*, 112(1), 20-29. https://doi.org/10.1016/j.aap.2017.12.016

Jaeger, L (1998). *L'évaluation du risque dans le système des transports routiers par le développement du modèle TAG*. Thèse de doctorat ès sciences économiques, Université Louis Pasteur, Strasbourg (in French).

Jaroszweski, D, Mcnamara, T (2014). The Influence of Rainfall on Road Accidents in Urban Areas: A Weather Radar Approach, *Travel Behaviour and Society*, 1(1), 15–21. https://doi.org/10.1016/j.tbs.2013.10.005

Karlaftis M, Yannis G (2010). Weather Effects on Daily Traffic Accidents and Fatalities: A Time Series Count Data Approach, *Transportation Research Board 89th Annual Meeting*, Washington DC, United State.

Keay, K, Simmonds, I (2005). The Association of Rainfall and other Weather Variables with Road Traffic Volume in Melbourne, Australia, Accident Analysis & Prevention, 37(1), 109–124. https://doi.org/10.1016/j.aap.2004.07.005

Liang, M, Min, M, Guo, X, (2022). The relationship between Ambient Temperatures and Road Traffic Injuries: A Systematic Review and Meta-Analysis, *Environmental Science Pollution Research*, 29, 50647 – 50660. https://doi.org/10.1007/s11356-022-19437-y

Liu, A, Soneja, SI, Jiang, C, Huang, C, Kerns, T, Beck, K (2017). Frequency of Extreme Weather Events and Increased Risk of Motor Vehicle Collision in Maryland, *Science of Total Environment*, 580, 550–555. https://doi.org/10.1016/j.scitotenv.2016.11.211

Olawole, MO (2006). Impact of Weather on Road Traffic Accidents in Ondo State, Nigeria: 2005 – 2012, *Analele Universitatil Din Oradea*, 26(1), 44-53.

Ohakwe, J, Iwueze, IS, Chikezie, D.C. (2011). Analysis of Road Traffic Accidents in Nigeria: A Case Study of Obinze/Nekede/Iheagwa Road in Imo State, Southeastern Nigeria. Asian Journal of Applied Sciences, 4(2), 166-175. https://doi.org/10.3923/ajaps.2011.166.175

Owolabi, AA, Oni, SI (2012). Seasonal Climatic Variations and Road Accidents in Lagos, Nigeria. Proceedings of the 2012 Annual Conference on Climatic Change and Variability, Saving our tomorrow today, edited by Odjugo, P.A.O, Asikhia, M.O. and Ikelegbe, O.O., 120 – 124. https://ir.unilag.edu.ng/handle/123456789/9641

Park, J, Choi, Y, Chae, Y (2021) Heatwave Impacts on Traffic Accidents by Time-Of-Day and Age of Casualties in Five Urban Areas in South Korea, *Urban Climate*, 39, 100917. https://doi.org/10.1016/j.uclim.2021.100917

Pesaran, MH, Smith, RJ, Shin, Y (2001). Bounds Testing Approaches to the Analysis of Level Relationships, *Journal of Applied Econometrics,* 16, 289-326. https://doi.org/10.1002/jae.616

Pińskwar, I, Choryński, A, Graczyk, D (2024). Good Weather for a Ride (Or Not?): How Weather Conditions Impact Road Accidents: A Case Study from Wielkopolska (Poland), International Journal Of Biometeorology, 68, 317-331. https://Doi.Org/10.1007/S00484-023-02592-3

Scott, PP (1986). Modelling Time-Series of British Road Accident Data, *Accident Analysis & Prevention*, 18(2), 109-117. https://doi.org/10.1016/001-4575(86)90055-2

Su, X, Zhi, D, Song, D, Tian L, Yang Y (2023) Exploring Weather-Related Factors Affecting the Delay Caused by Traffic Incidents: Mitigating the Negative Effect Of Traffic Incidents, Science of the Total Environment, 877,162938. https://doi.org/10.1016/j.scitotenv.2023.162938

Viner, K (2016). Long Read: How Technology Disrupted the Truth, The Guardian, Published on 12/07/2016. Available at https://www.theguardian.com/media/2016/jul/12/how-technology-disrupted-the-truth

World Bank, (2020). World Development Report 2020 Chapters and Data. https:////www.worldbank.org/en/publication/wdr2020/brief/world-development-report-2020-data

Wu, CY, Zaitchik, BF, Gohlke, JM (2018). Heat Waves and Fatal Traffic Crashes in the Continental United States, *Accident Analysis & Prevention,* 119:195–201. https://doi.org/10.1016/j.aap.2018.07.025

Data availability: The data and materials that support the findings of this study are available on request.

Declarations
Ethical approval: This research did not contain any studies involving animal or human participants, nor did it take place in any private or protected areas.

Consent to participate: Not applicable.

Consent for publication: Not applicable.

Author contribution: Research design, methodology and data collection, data analysis and interpretation: S. O. Adams and M. Umar; writing original draft preparation; T. Okechekwu; writing review: M. Umar and T. Okechekwu; supervision: S. O. Adams. All authors have read and agreed to the published version of the manuscript.

Funding: Authors received no funding for this article

Competing interests: The authors declare no competing interests