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Assessing the Impact of Rainfall on Road Traffic Accidents in Yola Metropolitan Area: A Statistical Analysis

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ABSTRACT

This study investigates the relationship between rainfall and road traffic accidents (RTAs) in Yola Metropolitan Area, Nigeria, from 2010 to 2020, using monthly data from the Federal Road Safety Commission (FRSC), Nigeria Police Force (NPF), and Nigerian Meteorological Agency (NIMET). Descriptive analysis revealed that leading causes of accidents were speed violation (38.7%), dangerous driving (21.5%), and mechanical failure (14.2%). Most accidents occurred in the evening (37.1%) and afternoon (31.5%), with the least occurring at night and early morning. Statistical analyses involved the use of linear regression. The regression model revealed a non-significant inverse relationship between rainfall and RTAs (coefficient = –0.001, p = 0.435), and ANOVA supported this with a p-value of 0.435, indicating rainfall does not significantly predict accident occurrences. The study concludes that rainfall is not a major determinant of RTAs in Yola and recommends that future research incorporate factors such as road condition, driver behavior, and traffic enforcement for a more comprehensive understanding and effective policy formulation.

Keywords: *Traffic Safety, Average Rainfall, Temporal Analysis, Spatial Variation, Road Safety*

1.0. Introduction

Road traffic accidents (RTAs) are unforeseen collisions involving two or more road users, typically arising from poor traffic management, human error, mechanical failure, or adverse environmental conditions. These incidents frequently result in injuries, fatalities, and substantial property damage (Kual et al., 2005; Schwela, 2008; Agbeboh & Osarumwense, 2013; Lawal et al., 2018). Beyond their immediate physical toll, RTAs impose long-term psychological, social, and economic burdens on victims, families, and healthcare systems, making them a pressing public health concern rather than a purely transportation-related issue. Globally, RTAs constitute a significant public health and socio-economic threat, particularly in low- and middle-income countries (LMICs), where they remain a leading cause of death, disability, and economic loss (Yordphol et al., 2011; Kuo, 2011; Sumaila, 2013; Onyikwu, 2016; Jude et al., 2019; Mwatelah, 2001). Currently, RTAs rank as the eighth leading cause of death worldwide, accounting for approximately 1.35 million deaths annually, with about 90% of these fatalities occurring in LMICs (WHO, 2013; 2023; Odusola et al., 2023). On average, an estimated 3,287 people die daily from road crashes (ASIRT, 2013), and LMICs remain disproportionately affected due to inadequate infrastructure, risky driving behaviors, weak law enforcement, and limited emergency response capacity (Oginni, 2008; Richard et al., 2020). Notably, the road traffic death rate in LMICs is three times higher than that recorded in high-income countries (WHO, 2019), underscoring a persistent global inequality in road safety outcomes that continues to widen despite international road safety initiatives.

In Nigeria, this pattern mirrors global trends, reflecting the broader challenges faced by many LMICs in managing road safety. Annually, approximately 20,000 of the 11 million registered vehicles in the country are involved in RTAs (NBS, 2018). In a single year, 8,437 Nigerians sustained injuries from road crashes94% of them adults while 1,331 lives were lost, with adult males constituting the majority of both injuries and fatalities. This demographic skew has significant implications for household income, labor productivity, and dependency ratios, given that adult males often represent primary breadwinners in many Nigerian households. Urban centers, in particular, experience disproportionately higher RTA rates due to dense populations, mixed transport modes, and the resulting complexity of traffic interactions (Nantulya & Reich, 2002; Baloye & Palamuleni, 2015). Common contributing factors include poor road conditions, lack of effective traffic enforcement, and institutional corruption (Sumaila, 2013), all of which weaken the deterrent effect of existing road safety regulations. More broadly, RTAs arise from general factors such as increased vehicular activity and rapid road network expansion, as well as specific and often preventable factors including driver error, speeding, and noncompliance with road signage (Ansari et al., 2000). Additional determinantsvehicle type, road design, traffic flow, and prevailing weather conditionsfurther compound accident risk and severity (Li, Zhu & Sui, 2007; Pepple & Adio, 2014; Baloye & Palamuleni, 2015). Taken together, these factors suggest that RTA occurrence is not randomly distributed but is instead shaped by identifiable spatial, infrastructural, and behavioral patternsan insight that has motivated a shift toward spatially explicit approaches to road safety analysis.

In response to this need for spatial understanding, recent advances in Geographic Information Systems (GIS) have significantly improved the ability to identify and predict RTA hotspots, offering a data-driven foundation for more informed road safety planning and traffic management decisions (Al-Omari et al., 2020; Odusola et al., 2020; Prasannakumar et al., 2011; Mohammad et al., 2017). GIS-based spatial analysis techniques including kernel density estimation, spatial autocorrelation, and hotspot mappingallow researchers and policymakers to move beyond aggregate national or regional accident statistics toward a more granular understanding of where and under what conditions accidents cluster. Such approaches have proven valuable for prioritizing intervention sites, allocating limited road safety resources efficiently, and evaluating the effectiveness of engineering and enforcement interventions over time. However, despite this growing body of GIS-based road safety literature, most existing studies in the Nigerian context have tended to focus on descriptive spatial mapping of accident occurrence, with comparatively limited attention paid to integrating temporal accident dynamics, road environment characteristics, and socio-demographic risk factors within a single, unified spatial analytical framework. This gap limits the practical utility of existing findings for targeted, context-specific interventions, particularly in rapidly urbanizing settings where traffic patterns and accident risk factors are continuously evolving.

It is against this backdrop that the present study is situated. Unlike previous studies that have largely treated RTA hotspot identification as a static, descriptive exercise, this study advances the field by integrating multi-temporal GIS-based spatial clustering with road-environment and socio-demographic variables to model RTA risk within a rapidly urbanizing corridor, an approach that has not previously been applied to this study area. By doing so, the study provides a more robust and actionable evidence base for road safety planning, offering policymakers and transport authorities a replicable framework for prioritizing intervention along high-risk corridors rather than relying solely on historical accident tallies.

2.0. Methodolog

The study was carried out in Yola Metropolis, comprising Yola North and Yola South Local Government Areas in Adamawa State, Nigeria. Jimeta, one of the twin cities forming the state capital with Yola town (about 7 km south), serves as the administrative center of Yola North LGA. Located in the Benue Trough, Yola covers 109 km² making it the state's smallest LGA by land area and lies between latitudes 9°13′30″N to 9°18′30″N and longitudes 12°24′E to 12°29′E, along the southern bank of River Benue. Designated a first-order settlement (Illesanmi, 1999), Yola has seen significant growth in social and economic infrastructure, with a mixed urban land use pattern comprising residential, commercial, administrative, industrial, and agricultural zones. Figure 1 shows the study area map.

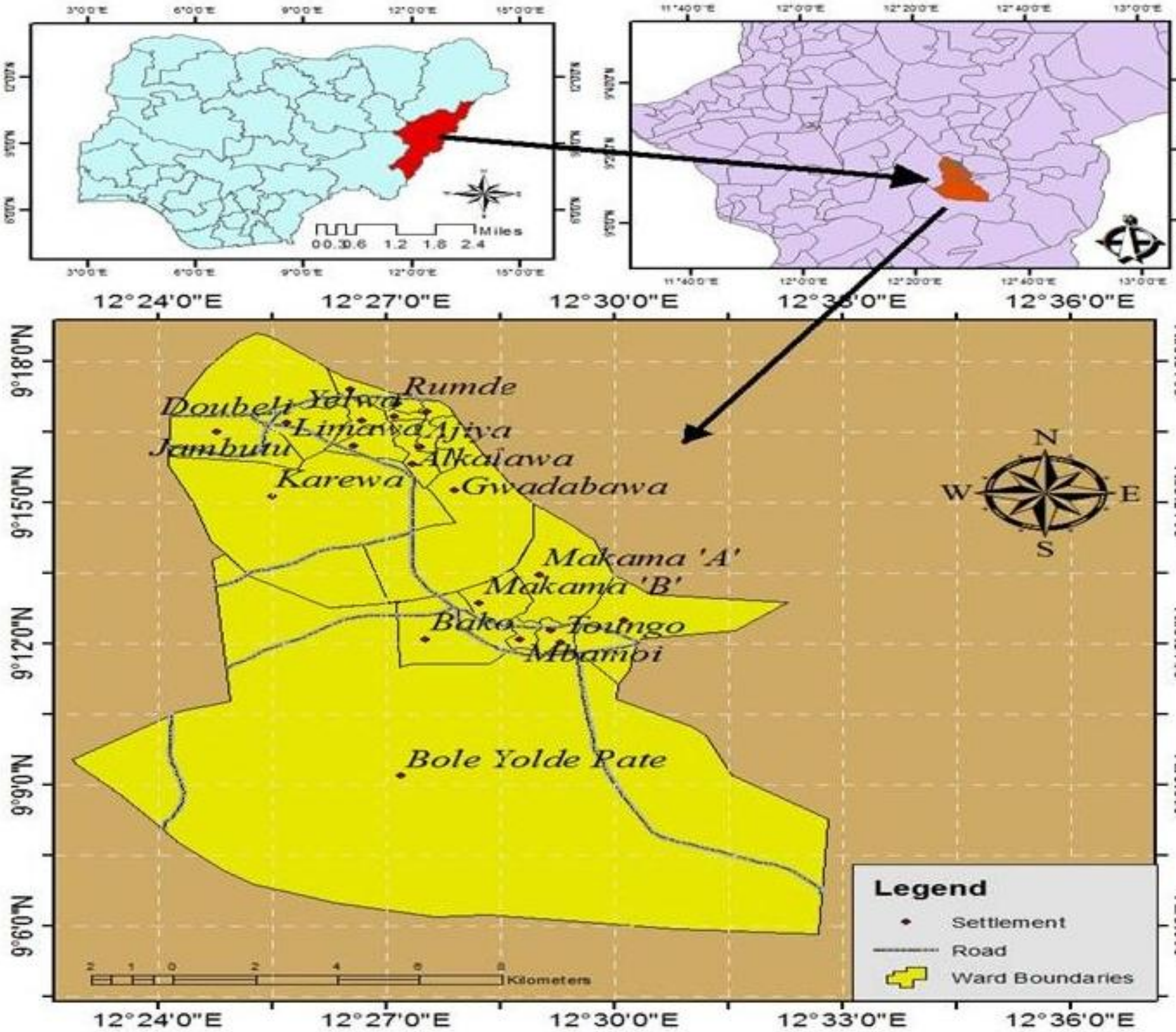

Figure 1: Map of the study area

As per the 2006 Census (NPC), the population was 198,247 (107,646 males and 90,601 females), with high urban density. Transport in the metropolis is dominated by buses (50%), while taxis (5%) operate mainly in Jimeta and Yola. After the 2009 state of emergency, motorcycles (kekenapep) rose to 35% of usage, and private vehicles accounted for 25% (Purokayo et al., 2014).

Yola experiences a tropical wet and dry climate, with a dry season from late September to early May (~215 days), and a rainy season from May to September (~150 days). Peak rainfall occurs in August and September, contributing over 20% of the annual average of 960 mm (Zemba, 2002). The terrain is generally low-lying, between 152.4 m and 213.4 m above sea level. Geologically, the area consists of Cretaceous sedimentary formations overlain by alluvial deposits within the Yola Arm of the Benue Rift, which divides Adamawa into two parts. Jimeta is underlain by the Albian-Aptian Bima Sandstone in its northeastern, southeastern, and southwestern zones (Opeloye & Dio, 1999).

2.2 Accident Data

This study employed secondary data to examine the relationship between rainfall and road traffic accidents (RTAs) in Yola Metropolitan Area from 2010 to 2020. Accident data were obtained from the Federal Road Safety Commission (FRSC) and Nigeria Police Force (NPF), including accident types, causes, number of people injured, killed, and involved. The data were aggregated monthly and reclassified into broader cause categories to facilitate temporal analysis. Monthly average rainfall data for the same period were sourced from the Nigerian Meteorological Agency (NIMET). Descriptive statistics were used to summarize trends in both RTAs and rainfall. To assess the relationship between rainfall and accident frequency, Pearson's correlation coefficient was applied to measure the strength and direction of association between rainfall and RTA. Furthermore, linear regression model was applied to evaluate the extent to which rainfall could predict the frequency of road traffic accidents. The correlation equation is expressed as shown in Equation 1:

$$r = \frac{n\sum_{i=1}^{n} XY - (\sum_{i=1}^{n} X)(\sum_{i=1}^{n} Y)}{\sqrt{(n\sum X^2 - (\sum X)^2)((n\sum Y^2 - (\sum Y)^2))}} \quad (1)$$

Where: r is the Pearson correlation coefficient, X is the monthly rainfall, Y refers to the number of accident cases, and n shows the number of observations
A positive r value indicates a direct relationship, while a negative r value indicates an inverse relationship.

The regression equation (2) is expressed as:

$$Y=\beta_0+\beta_1X+\epsilon \quad (2)$$

Where: Y is the number of road traffic accidents (dependent variable), X is the rainfall (independent variable), β_0 is the regression intercept, β is the regression coefficient and ϵ shows the random error term.

The model's statistical significance was tested using Analysis of Variance (ANOVA), with a significance level set at α=0.05\alpha = 0.05α=0.05. A p-value less than 0.05 indicates a statistically significant predictive relationship between rainfall and RTAs.

3.0. Results and Discussions

3.1 Causes of RTA in Yola Metropolitan Area

Table 1 shows human factors responsible for accident occurrences in the study area indicated that, Diverted attention attributed to (28%), Fatigue accounted for (17%), Inexperience Drivers stood at (22%), Recklessness at (23%). While Helen (2018) found reckless driving to account for (22.37%); while over speeding only accounted for (10%). Okongbota (2011), as cited in Abdurrahman (2014) found that the prevalence of road traffic accident among young drivers is as a result of over-speeding.

Table 1: Causes of RTA in Yola Metropolitan Area

S/N	Causes of RTA	Frequency	Percent
1	Diverted attention	28	28.0
2	Fatigue	17	17.0
3	Inexperienced drivers	22	22.0
4	Reckless Driving	23	23.0
5	Over speeding	10	10.0
	Total	**100**	**100.0**

3.2 RTA Across Various Roads in Yola Metropolitan Area

Table 2 shows that Numan road has the highest number of fatal accident with 27.8% followed by Yola road with 17.7%, this is due to over speeding along the routes. Majority of the serious accidents occurs within the main town as they are caused majorly due to wrong parking, High volume of Traffic, Diverted Attention, Inexperience Driver, Sometime Tight Junctions, Unnecessary U-Turn or Mechanical Fault. Galadima Aminu and ModibboAdama Roads have 13.8% and 18.6% respectively. Mubi road also has 14.2%. Yola and Mubi road both has low occurrences of Minor accidents with 7.7% and 5.1%. Numan Road has high number of accidents Fatal, Serious and Minor.

Table 2: RTA Across Various Roads in Yola Metropolitan Area

	Accident type						Total
Road of the accident	**Fatal**	**%**	**Serious**	**%**	**Minor**	**%**	
Muhammad Mustapha Way	13	9.2	46	9.7	22	23.5	81
Galadima Aminu Way	13	9.2	65	13.8	43	21.9	121
Ahmadu Bello Way	0	0.0	0	0 .0	2	1.0	2
Yola Road	25	17.7	33	7.0	15	7.7	73
Jimeta Bye pass	10	6.9	26	5.5	3	1.5	39
Lamido Sanda Road	0	0.0	6	1.2	4	2.0	10
Yola Bye Pass	12	8.3	66	14.0	25	12.8	103
ModibboAdama Road	8	5.6	88	18.6	24	12.2	120
Numan Road	40	27.8	61	12.9	422	4.1	143
Mubi Road	13	9.2	67	14.2	10	5.1	90
Hospital Road	7	4.9	10	2.2	6	3.1	23
Kashim Ibrahim Way	3	2.1	3	0.6	0	0	6
Total	**144**	**100%**	**471**	**100%**	**196**	**100%**	**811**

3.3 Time of the Accident Occurrences in Yola Metropolitan Area

Table 3 shows that, (46.5%) of the accident occurred in the morning for the period of 11 years (2010-2020) is fatal, (35.2%) is Serious with (37.7%) minor. The total percentage of accident occurred in the morning accounted to (37.9%). Accident occurrences in the afternoon showed that, (18.0%) is fatal, (21.1%) is serious and (23.4%) is minor making the total percentage of accidents occurred during the afternoon time to stand at (21.3%). Evening time accounted for (29.1%) fatalaccident and (37.4%) and minor stood at (30.1%). The total percentage of accident that occurred in the evening is (34.2%). Accident occurrence during night time is low with both fatal, serious and minor standing at (6.2%), (5.9%) and (8.6%) respectively. The total of accident that occurred during the night time for the period of 11 years (2010-2020) stood at (6.7%).

The analysis from the table above shows that, morning time and evening time are the rush hours. They have the highest number of road traffic accident; these is due to the fact that, in the morning, people are rushing to the work, school, businesses, farm and in the evening people have closed from work, markets, coming back from farms.

Table 3: Time of the Accident Occurrences

	Accident type								
S/N	**Time of RTA**	**Fatal**		**Serious**		**Minor**		**Total**	
		Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
1	Morning	67	46.5	166	35.2	74	37.7	307	37.9
2	Afternoon	26	18.0	101	21.1	46	23.4	173	21.3
3	Evening	42	29.1	176	37.4	59	30.1	277	34.2
4	Night	9	6.2	28	5.9	17	8.6	54	6.7
Total		**144**	**100%**	**471**	**100%**	**196**	**100%**	**811**	**100%**

3.4 Seasons of RTA Yola Metropolitan Area

Figure 2 shows that accident on a seasonal basis, rainy season recorded high number of accident with (53.02%) while Dry season accounted for (46.98%). This is because, in the rainy season, there are lots of environmental factors that may cause accidents and they are, heavy downpour leading to break failure and poor visibility. This agreed with the findings of Jude et al, (2019) where they found (59.43%) that is, 249 out of 419 occurred during the rainy season. They also attributed the causes t be slippery of the road surfaces and low visibility as a result of consistent rainfall.

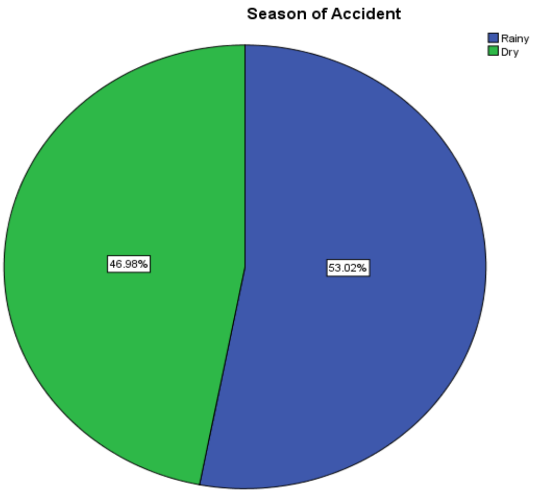

Figure 2: Seasons of RTA Yola Metropolitan Area

3.5 Mode of Vehicle involved in RTA in Yola Metropolitan Area

Figure 3 shows that, commercial tricycles has the highest percentage of road traffic accident with (38.96%) because tricycles are high in number compared to other means of transportation within the study area. More so, most of tricycle operators are young and inexperienced drivers and associated with use of substances. Followed by private vehicles with (38.35%) and commercial cars standing at (17.26%) with motorcycles having the least with (5.43%) due to their stoppage from operation within the study area since 2012.

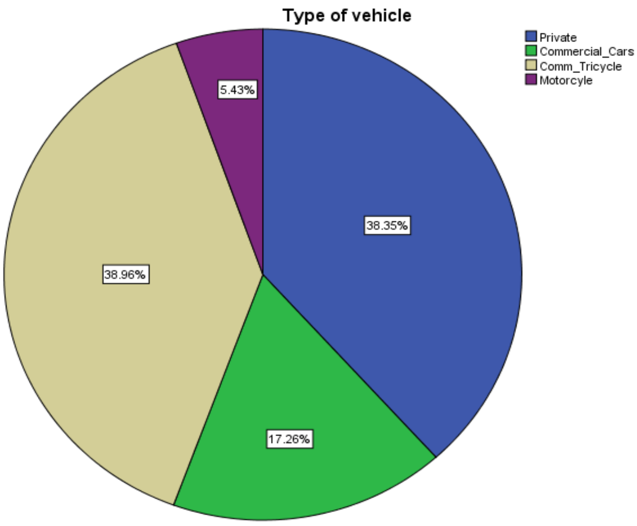

Figure 3: Mode of Vehicle Involved in Road Traffic Accident

3.6 Monthly Road Traffic Accidents and Average Rainfall in Yola Metropolitan Area (2010–2020)

Table 4 shows the monthly data from April to October over the 11-year period (2010–2020). The findings reveal a fluctuating pattern in both road traffic accidents (RTAs) and average monthly rainfall (AMR) in Yola Metropolitan Area. The peak rainfall months June, July, August, and September typically recorded higher rainfall values (often exceeding 200 mm), especially in August and September. However, the corresponding RTA figures during these months did not consistently increase with rainfall. For instance, August 2011 recorded the highest rainfall (411 mm) with only 6 RTAs, while June 2020 had a similarly high rainfall (256.1 mm) but only 4 RTAs.

Conversely, some months with lower rainfall, such as October and May, still reported relatively high numbers of accidents (e.g., 8 RTAs in October 2018 with only 75.9 mm of rain). This inconsistent relationship between rainfall and RTAs suggests that rainfall alone does not have a strong or direct influence on accident occurrence in the area. Other underlying factors such as road condition, driver behaviour, visibility, or traffic volume may have a greater impact on accident frequency than rainfall levels.

Table 4: Monthly Road Traffic Accidents and Average Rainfall in Yola Metropolitan Area (2010–2020)

2010		2011		2012		2013		2014		0215		2016		2017		2018		2019		2020	
RTA	MAR	RTA	MAR	RTA	MAR	RTA	MAR	RTA	MAR	RTA	MAR	RTA	MAR	RTA	MAR	RTA	MAR	RTA	MAR	RTA	MAR
4	41.5	4	67	8	2.5	6	12	3	86.8	6	53	5	71.5	5	48.2	4	57.2	5	19.5	4	46.2
6	57.3	6	69.3	6	58.8	7	108	6	61	6	100.8	3	76.4	6	115.5	5	66.5	4	28.2	5	226.3
6	147.8	6	203	8	29.9	8	213.4	6	142.4	4	69.2	5	175.4	5	211.3	3	134.3	5	50.9	4	256.1
4	158.2	3	252	6	75.7	4	157.1	5	93.8	4	135.7	2	57.4	5	102.7	5	148.1	4	156.7	6	113.8
5	341.7	6	411	6	134.1	5	162.8	7	120	5	185.2	5	211.5	5	284.7	5	162.4	5	203.2	8	208.6
7	253.4	5	389.3	7	210	7	189.5	7	178.7	6	205.3	7	287.8	5	197	7	156.9	4	216.4	8	198.7
7	68.6	7	67.9	7	55.9	7	67.2	5	40.9	7	56.5	7	48.3	7	52	8	75.9	5	57.4	8	30.2

Sources: FRSC/NPF, 2020 and NIMET, 2020

3.7 Correlation between Rainfall and Road Traffic Accident

Table 4 shows that the coefficient for rainfall is -0.001 with a p-value of 0.435. Since the p-value is greater than the significance level ($\alpha = 0.05$), we fail to reject the null hypothesis. This suggests that while a one-unit increase in rainfall is associated with a slight decrease of 0.001 in accident cases, the relationship is not statistically significant. In other words, the variation in accident cases may be due to natural fluctuations or other unexamined factors such as temperature, humidity, or other environmental variables not included in this study.

A recent study by Atomode et al. (2022) assessed the relationship between rainfall and road traffic accidents in Lokoja, Nigeria, from 2011 to 2020. The study found a statistically significant positive correlation between monthly rainfall and traffic accidents ($r = 0.898$, $p < 0.001$), indicating that increased rainfall was associated with higher accident rates. However, the study also noted that rainfall accounted for only 5.4% of the variation in traffic accidents, suggesting that other factors contribute to the occurrence of accidents. The authors concluded that while rainfall significantly predicts traffic accidents, it is not the sole determinant, and other variables should be considered in road safety assessments.

This finding aligns with this study results, where a slight reduction in accident cases was observed with increased rainfall, but the relationship was not statistically significant. Both studies suggest that while weather conditions like rainfall may influence traffic accidents, they are not the sole factors, and other variables should be considered in understanding accident patterns.

Table 5: Estimation of Regression Coefficient

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5.809	.285		20.397	.000
	RAINFALL CASES	-.001	.002	-.090	-.785	.435
Rsquared= 0.008, Adjusted Rsquared= -0.05						

Based on the results obtained, the regression model can be expressed mathematically as follows:
Accident Occurrences = 5.809 – 0.001 × Rainfall Cases
This relation suggests that for each additional unit increase in rainfall, the number of accident occurrences is expected to decrease by 0.001.

3.8 Analysis of variance (ANOVA)
Table 6 presents the results of the analysis of variance (ANOVA), showing an overall p-value of 0.435. This indicates that the predictor variable (rainfall) does not significantly contribute to the model in explaining variations in the response variable (accident occurrences).

Table 6: Test of Significant

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.190	1	1.190	.616	.435^b
	Residual	144.888	75	1.932		
	Total	146.078	76			

3.9 Area for further study

Based on the finding f this study which clearly shows weak negative relationship (-0.09) between accident cases and rainfall which means that as the rainfall increases the accident case reduces based on the data used. Thus, more data, other factors may be needed to investigate the causes of the accident occurrences.

4.0 Conclusion

This study examined the influence of rainfall on the occurrence of road traffic accidents (RTAs) in Yola Metropolitan Area over 11-year period (2010–2020). Through descriptive statistics, correlation analysis, and linear regression, the findings revealed that although a weak negative relationship exists between rainfall and RTAs, the relationship is statistically insignificant. This indicates that variations in rainfall do not significantly predict the frequency of road traffic accidents in the area. While some seasonal trends were noted such as a slight reduction in accident cases during months of peak rainfall these fluctuations were not strong enough to establish a causal link. Furthermore, the analysis of accident causes, timing, and vehicle types showed that human-related factors, such as speed violations and dangerous driving, as well as the dominance of commercial vehicles, play a more prominent role in accident occurrences.

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