Statistical Modeling of Weather Impact on Road Accidents: A Nonlinear Distributed Lag Analysis in Tirana, Albania

ENDRI RAÇO, ETLEVA BELIU, KLEIDA HAXHI, ORIANA ZAÇAJ
Department of Mathematical Engineering
Polytechnic University of Tirane
Mother Tereza Sq, Nr. 4, Tirana
ALBANIA

Abstract: - This research aims to explore the impact of weather conditions on road accidents in Tirana through an in-depth analysis of meteorological data alongside accident records. This study employs a distributed lag non-linear model (DLNM) for its analysis of whether temperature, rainfall, and cloud coverality affect road safety both immediately after exposure but also at later time points. The results point to a U -shaped correlation between temperature levels and the risk of accidents, with both lower and higher temperatures contributing to increased accident risk. Rainfall, on the contrary, may be associated with a lower likelihood of an accident, although the effect is only very weakly significant: it makes sense that people might drive slightly more carefully during bad weather. The cloud cover analysis shows that the presence of medium-height clouds increases the danger to aircrafts, while high-altitude air masses help reduce it. In various countries around the world, studies have shown similar results, further demonstrating the impact that weather has on road safety as a whole. In light of these findings, the study recommends local-specific efforts to focus on public awareness campaigns and improvements in infrastructure that could help address hazards during extreme weather situations. The study has also discussed its limitations and recommendations for extending the present research such as employing real-time weather information, incorporating more variables.

Key-Words: - Meteorological Impact - Weather factors - Distributed Lag Nonlinear Model - Traffic Accidents

Received: July 9, 2024. Revised: January 11, 2025. Accepted: February 26, 2025. Published: March 26, 2025.

1 Introduction

The steady increase in global mean temperatures, an unmistakable sign of climate change, has been a catalyst for increasingly severe and unpredictable weather events. These shifts continue to significantly impact agriculture, energy supply, and industrial processes, with substantial consequences for both human health and productivity, as highlighted in studies, [1], [2], [3], [4]. The observed impacts in Albania mirror trends seen in other regions, underscoring the global relevance of studying the effects of climate on health and safety.

When it comes to the results of heat waves or flooding, there is a series of research studies that study the impacts of these disastrous phenomena on both ecosystems and human health , [1], [3]. It is understandable that these dramatic events have the headlines of media attention, but it seems that the whole picture is missing some not less critical components with arguably less immediate, but still very often enduring effects, such as the effects of climate change on mental health and social interactions.

Referring to these studies, there is a notable and very concerning link between climate changes and their impact on health aspects such as stress, anxiety, and depression, which can result fatal for target groups such as older adults, prone to chronic diseases or compromised immunity [5], [6], [7]. Since weather events are becoming less and less predictable, this can be very challenging for both urban and rural populations, requiring immediate response initiatives from public health organizations and governments.

In addition to the pressure on human health caused by heat, several studies point to an increased number of mental health issues that, if not treated, can lead to suicides, with an increasing number each year, [8], [9], [10]. In different studies, a strong link is observed between allergic diseases and global climate change, which means a very heavy weight for fragile health systems, [11], [12], [13].

Last but not least, extreme weather conditions affect road safety. Although this aspect often does not receive the necessary importance, statistics show that the phenomenon is turning into a large-scale problem for both government and insurance companies. Extreme heat weather results in less attention when driving, equal to a lower perception of risk in drivers. However, extreme cold results in icy roads, which can induce stress combined with fatigue for drivers equal to decreased driving capacity. In other words, there are many studies that correlate the higher incidence of traffic accidents with extreme weather conditions, [14], [15], [16]. In some of these studies, in addition to climate factors, accidents are also affected by different psychotropic drug use by drivers, [17], [18], [19].

Although several studies deal with the link between climate factors and bad driving, resulting in an increased number of car accidents, some studies point, however, to the fact that poor weather conditions can lead to cautious driving, so to a reduced number of fatal accidents.

On the edge of controversial research leading to different insights based on the contexts in which research was conducted, this study aims to create a deep understanding of how climate changes affect the number of accidents in the context of Tirana, Albania.

By focusing on localized climate patterns, this study adds to the scarce body of literature on the regional effects of climate change on road safety, a largely overlooked area in global climate research.

Though this work focuses mainly on Tirana, much of the data reveal offer knowledge pertinent to issues fitting under the umbrella of causes which affect road safety, as similar weather induced accident trends are observed globally. These insights are particularly valuable, as climate induced public health challenges evolve. The following sections provide detailed explanations of the data and methodology, followed by results and a discussion of their broader implications.

2 Materials and Methods

This section outlines the methodologies and data employed in this study. Initially, a description of the Tirana region in Albania is provided. Following this, the paper delves into the specifics of the road accident data sourced from one of Albania's largest insurance companies, Intersig. Public Data from Albania Institute of Statistics are also used along with meteorological data, including various indices. The paper also discusses the application of a distributed lag non-linear model (DLNM) in this research.

2.1 Tirana Region

The study was located in the district of Tirana, which is situated in the central western part of the country and the Balkan Peninsula. Predominantly a lowland region, some southern areas rise up to 275 meters; the average altitude for this region is about 110 meters. The total area sums $1,652km^2$, which is a remarkable proportion for the country of Albania. The district is home to approximately 900,000 people, which is the highest population density of all regions in the country, making up about 32.9% of the entire national population of Albania, as indicated by recent statistics, [20], [21], [22] .

The pace of urbanization in Tirana is just above that of the nation. Data from recent studies show that Tirana has one of the highest car ownership rates in Albania. In 2021, the district registered the highest number of vehicles, 35% of the whole country, up by 4.4% compared to 2020, [23].

This exceeds the average rate in most of Europe and is evidence of the high urban density in the district. In fact, in terms of road safety, Albania has one of the highest rates of road accident deaths per million inhabitants in Europe, and the figures of the capital, Tirana, while slightly below the national average, are indicative of a worrying trend: all too many are proving fatal (World Health Organization, 2021, [24].

2.2 Car accidents Database

The car accident database, used for this research, was received from an insurance company located in Albania, named Intersig Insurance Company. It contains complete records of traffic incidents in different places in Albania and dates from January 2016 to November 2023. Some personal IDs and vehicle license plate numbers were cleaned out from the data due to privacy reasons. After that, the data set consists of a total of 9,288 car accidents.

In addition to the data on car accidents presented by Intersig Insurance Company, historical weather data was also carefully integrated to strengthen the findings. In this study, to create a realistic view of weather conditions in time moments of accidents, we used historical data extracted from Weather API by Open Meteo [25]. Based on the time and location data for each accident recorded, we were able to retrieve weather conditions for the precise time point of accidents. The data collected were processed according to the calculation of several indicators, representing high-impact weather conditions regarding car accidents.

We decided to narrow our research by focusing on some of the weather variables, choosing specifically temperature, precipitation, and cloud cover. The decision was made based on previous research that indicated a significant impact of these variables related to the frequency of accidents and the severity of damage. This process resulted in the creation of an extensive data set that can be used to produce meaningful information on how weather conditions can affect the number and severity of accidents.

The maximum daily temperature, which represented the highest temperature recorded on the day of the accident, was the first indicator to be established. This parameter has been linked in a number of studies to the higher risk of accidents brought on by physical exhaustion and dehydration, [25], [26], [27].

The level of precipitation, which represents the amount of rain measured in millimeters per day, was the second indicator that was designed. Due to decreased vision, several studies highlight the dangers of driving in rainy conditions, [28], [29], [30], [31].

Cloud coverage, represented as a percentage, was the third indicator that was developed. Due to its effect on visibility, cloudy weather has been identified in numerous studies, [32], [33], as the primary cause of auto accidents.

In order to examine the relationship between meteorological conditions and accident occurrence more precisely, we performed an exact matching with accident time for each of these parameters.

An in-depth analysis of the patterns that car accidents follow over time was conducted for the city of Tirana. Figure 1 gives a meaningful illustration of the spatial distribution of accidents for different administrative units, which reveals clear regional variations. This visualization seems to be of great importance when it comes to highlighting the disparities between regions and the need for further study and major intervention strategies.

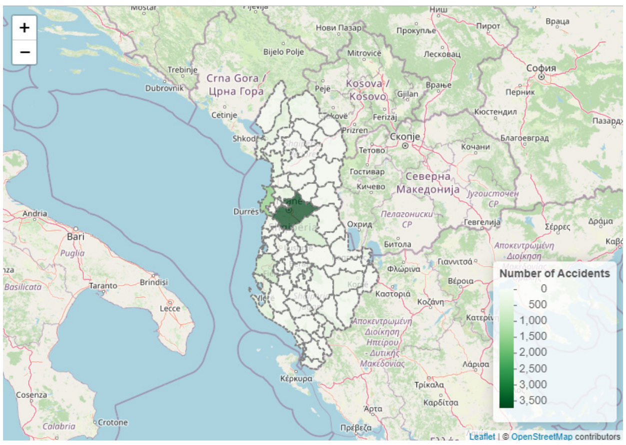

Figure 1: Spatial distribution of car accidents across the administrative units of Albania.

Focusing on Tirana, the main site of accidents occurrence, we performed a temporal analysis in this area, examining very carefully the patterns of car accidents. Figure 2 illustrates the results of the temporal analysis. To consolidate our findings, we narrowed our analysis to the summer months (June - August), typically characterized by increased traffic, the results shown in Figure 3. Combined with the heat map in Figure 2, these illustrations offer valuable insight into the trends that car accidents follow, especially during the peak summer months.

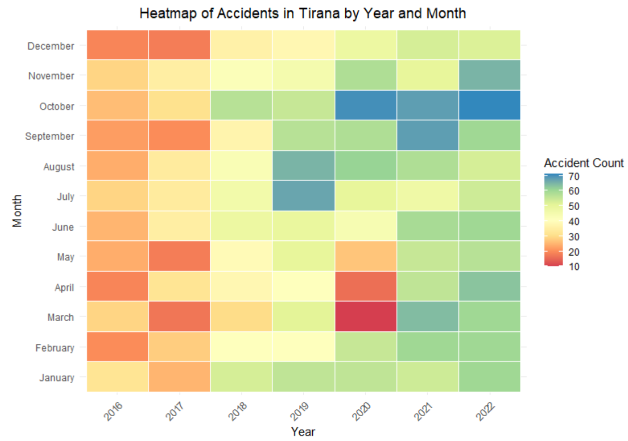

Figure 2: Heatmap of Accidents in Tirana by Year and Month

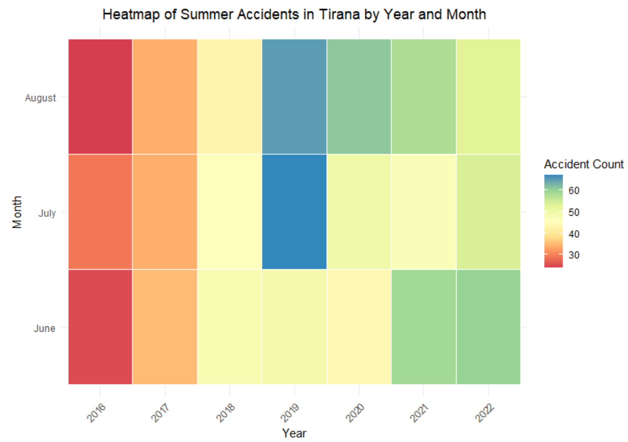

Figure 3: Heatmap of Accidents in Tirana by Year for summer period

2.3 Implementation of Distributed Lag Nonlinear Model (DLNM)

As the next logical step to check for the immediate and delayed effect of weather factors on accidents, we fitted the previously created weather indicators to a distributed lag non-linear model (DLNM). Using this model, we were able to better understand the complex relationship between changing weather conditions and their influence on accidents. To make the implementation of the model in R language faster and more effective we chose to use the *dlnm* package, [34], [35]. The selection was based on various studies which recommend the library for its efficiency to identify sophisticated interactions such as short and long-term effects of temperature on accident rates, [36].

Data Preparation: To meet the requirements for model usage, we used the *dplyr* package [37] to wrangle the data set to include daily counts of accidents from cars, together with the average values of the weather indicators mentioned previously.

Model calibration: The temperatures were centered by model, gathering around average daily temperatures from dataset, making possible the comparison between accident risk of occurrence as per region "normal" weather conditions. We used a quasi - Poisson regression model since this model seems to fit well for the situations when over dispersion needs to be addressed. This was clearly our case, as the variability in accident counts notably exceeded standard expectations.

DLNM Methodology: The idea behind DLNM model is to utilize cross-basis functions for each of the weather indicators, which makes possible the capture of nonlinear effects in a two-direction way, [38], [39]. In our study, using DLNM methodology we modeled relative risk (RR) of accidents at a given temperature (T) over a lag period (L) so to investigate how the variations in temperature affect car accidents. Saying so, the model we use in this research makes possible the analysis of existing relationships between temperatures in extremes and road accidents, incorporating lagged effects on behalf of how weather conditions in the time of accident may influence accident risks in subsequent days. In our study we used a lag period of 7 days, based on evidence from various studies on how weather conditions may affect accident occurrences for several days. The choice of a 7 day lag period made it possible to capture both immediate and delayed effects of temperature in car accidents. Beside that, the model accounted even for other weather variables or potential confounding factors. Many researches indicate that extreme weather conditions can impact the reaction of drivers elevating so the accident risk, [40], [41], [42]. Based on these indications, we decided to use the 7 days time frame which makes possible the evaluation of weather's impact not only in the accident day but also in subsequent days, [35], [38], [39].

In this paper we have included a simplified illustration on how to calculate relative risk RR, as per enabling readers acquire a better understanding of methodology used. In the equation below, we have calculated relative risk based on T which stands for effect of temperature on accidents across a lag period of L days:

$$RR(T, L) = \exp\left(\sum_{l=0}^{L} \beta_l \cdot f(T)\right)$$

In the above equation β_l are the corresponding coefficients for each lag day, while $f(T)$ is a nonlinear function of temperature, i.e spline, [30], [35].

We used the model to make predictions for a wide spectrum of temperatures. The results of this process are shown in Figure 4. From the figure can be noticed that accident risk follow a nonlinear trend, reaching its peaks for extreme temperatures. Risk begins to rise at temperatures below $10°$ and above $25°$, reaching its highest point at approximately $35°$. Figure 4 illustrates a "U-shaped" curve, with the blue line representing the average relative risk across temperature variations. This emphasizes that extreme temperatures, both low and high, are linked to an increased risk of accidents.

Cold Weather ($< 10°$): In low temperatures, the increased risk of accidents is probably due to icy or wet roads, making it harder to control vehicles.

Hot weather ($> 25°$): In contrast, extreme heat might cause fatigue, discomfort, or slower reaction times of the driver, all of which contribute to higher accident rates.

The model also reveals that the impacts of temperature do not end when the thermometer changes—they can persist for several days. This lagged effect underscores the importance of planning for both immediate and delayed impacts of extreme weather on road safety.

These findings align with research from other regions, showing similar patterns of increased accident risks at both high and low temperatures, [40], [41], [42]. Whether it is snowy winter conditions or scorching summer heat, extreme weather significantly increases accident risks, making it a crucial factor to address in road safety strategies.

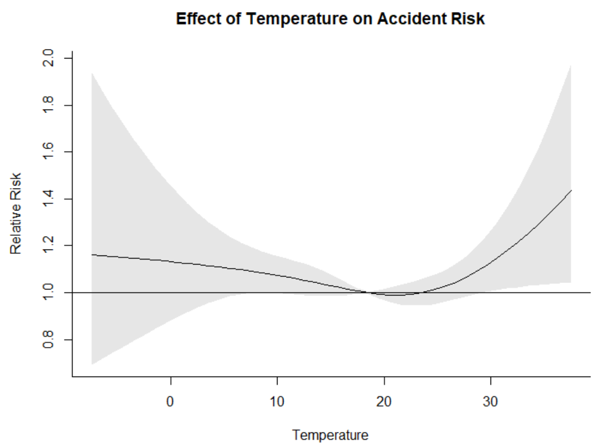

Figure 4: Effect of temperature on Accident Risk (line represents average values)

Figure 4 gives clear evidence that extreme temperatures are related to accident risks in a non-linear relationship between them. The results of the DLNM model shown in the figure confirm an elevated risk of car accidents for temperatures below $10°$ and higher than $25°$, reaching a peak at approximately 35°. In Figure 4, we have added a blue line representing the average values of relative risk based on variations in temperature.

We also noticed that the lag structure used in model reveals the fact that effect of extreme temperatures extends over several days, a result that is consistent with various papers studying similar patterns ([40], [41], [42]). This makes research findings a strong signal that policymakers must take into account these delayed effects when planning road security. When it comes to low temperatures, the elevated risk of accidents is likely related to reduced vehicle control caused by icy or wet road conditions. However, increased risk at high temperatures may be driven by different factors, such as driver's discomfort and slower reaction when driving.

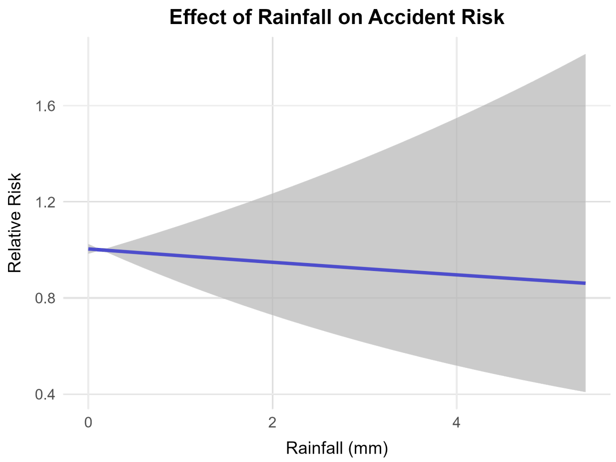

Figure 5: Effect of Rainfall on Accident Risk (blue line represents average values)

When studying the effect of rainfall on road accidents, we noted the following pattern. As shown in Figure 5 there is a slight decrease in the risk of accidents with increasing rainfall, depicted by the blue line in the figure. This trend seems to be so because drivers are usually more careful while on the road during rainy conditions. However, results show that confidence intervals widen at larger rainfall levels, suggesting a larger variability due to a small number of data points that correlate with heavy rainfall events. Our results agree with findings from various articles that indicate that conditions such as light to moderate rainfall lead to safe driving behavior, while heavy rainfall poses a threat to safety, [43], [44], [45], [46].

The effect of the amount of cloud cover on the risk of accidents was also investigated, providing a set of results concerning the nature of the relationship between cloud cover and road safety. From Figure 6 is evident that the relative risk of

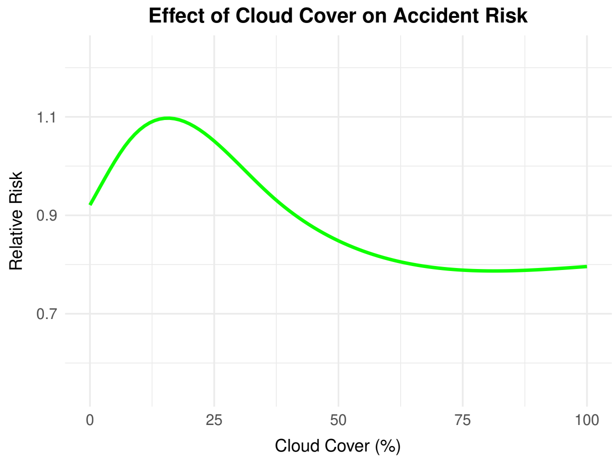

Figure 6: Effect of Cloud Cover on Accident Risk

accidents increases with increasing cloud cover from 0% to approximately $20 - 25\%$, then decreases after reaching its peak. This nonlinear trend indicates that a moderate amount of cloud coverage may actually increase the likelihood of an accident occurrence, probably due to poor visibility, which can directly affect drivers perception and response. Similar tendencies have been identified in other works for various regions: moderate cloudiness or fog has been linked with a higher rate of accidents since drivers have a low visibility or misjudge the situation, [10], [47], [48], [49], [50].

Drivers may not be fully aware of the dangers of low visibility during moderate cloud coverage or fog. However, as density and coverage improve, the weather becomes more stable, and drivers start acting more responsibly and cautiously by turning on headlights. Heavy cloud cover seems to also increase driver attention, known also as the psychological effect of dreary sky. These results align with various articles indicating that uniform weather conditions make driving behavior more predictable, thus reducing the risk of accidents. However, we need to emphasize that for extreme cloud coverage, both minimal or extensive, the intervals of confidence widen, reflecting greater unpredictability due to limited data per clear weather or fully overcast conditions.

3 Results

The study showed that there was a complex relationship between weather variables such as temperature, rainfall, cloud cover, and road safety in Tirana. By applying the distributed delay nonlinear model (DLNM), the research adequately addressed the short- and long-term effects of these weather factors on the accident risk.

Temperature: In the given work, we show that there is a U-shaped relationship between temperature and accident rate, with the latter condition increasing at extreme temperatures. Temperatures below 10° or above 25° dominated the majority of cases, and the highest density was toward 35°.

This pattern shows the key issues drivers experience while driving on icy roads and during a hot climate due to weakness and slow reaction. The results shown in Figure 4 align with the corresponding patterns in other studies.

Rainfall: Surprisingly, the slight and moderate rain had been found to share an inverse relationship with the accident rate, most probably because of driver's recklessness during non-rain weather. As precipitation levels tended to increase, the confidence intervals increased, implying a likelihood of greater variability. It can be postulated that this is due to the fact that there are few data points corresponding to extreme rainfall events in the dataset. Figure 5 graphically shows how the nature of accident risk is affected by various amounts of rainfall as well as the stability of the risk.

Cloud Cover: It was interesting to examine the effect of cloud coverage on accident risk. For moderate cloud coverage ($< 50\%$), the chances of accidents increased, which may be explained by vision problems or difficult lighting conditions. For increased cloud cover levels, the resulting accident risk declined and subsequently became more constant most probably due to the lesser variability in weather conditions during the day and more responsible driving.

There was also a variation in accident rates within the year following an inverse pattern of weather conditions, where there were more accidents in the winter season characterized by extreme cold weather and regular inconsequent rains. For the summer season, there was a second hump in the occurrence of accidents as a result of heat and increased traffic during the revenue season.

What this paper seeks to establish is how different weather factors positively or negatively influence the occurrence of car accidents. The results of this study highlight the need for camp and intervention to inform the public about risks related to severe weather conditions. Visual aids such as Figure 4, Figure 5 and Figure 6 provide useful information to improve road safety in Tirane based on weather conditions.

4 Discussion

The results of the present study improve the important influence that weather conditions have on road safety in Tirana, Albania. There is an intricate relationship between several meteorological factors and the risk of road accidents. The discussion following will explore the implications of these results, compare them with the existing literature, and suggest possible interventions to mitigate weather-related road accidents.

Several analogous studies in different parts of the world have reported similar non-linear relationships between temperature and road accidents. For instance, studies conducted in Poland and South Korea indicated high risk at low and high temperatures. This would then explain why adverse temperatures, be they hot or cold, are negatively associated with driver performance, hence increasing accident rates. In addition, the apparently optimal average temperature regarding the risk of accidents at temperatures of around 35° agrees with previous investigations that emphasized the adverse effects of sun radiation on drivers, in terms of lost focus, fatigue, or even response time.

The significant but still low negative association with the risk of an accident and increased precipitation, in contrast, is somewhat counterintuitive and hence probably begs more research. The reality is that, while heavy rain would be expected to generally heighten risk due to accidents from diminished visibility and road traction, it seems that drivers are more likely to take cautious actions under wet conditions, hence negating heightened risk. This agrees with findings from other studies that increased frequency of light to moderate rainfall has contributed to more safety while driving, with the confidence interval widening at higher levels of rain, indicating the need for further research with increased datasets.

There was a nonlinear impact on road safety by cloud cover; regarding cloud cover, moderate cloud cover had the highest association with accidents. This is also supported by the outcome of research in other parts of the world, where cloud cover was found to create intense visual conditions, including glare or low contrast, which hinders driver perception and reaction time. The reduction in accident risk observed with an increased level of cloudiness could be attributed to increasing vigilance by drivers and, hence, the use of headlights with higher levels of cloud cover.

The implications for road safety management in Tirana are that the strong effect of temperature in this analysis may be taken to suggest the need for targeted interventions for the most extreme weather conditions. Public campaigns and road safety advisories might be sent out on infrastructure improvement, such as better road signage and maintenance, to decrease the risks associated with hot and cold weather. In this context, the findings regarding rainfall suggest that drivers tend to adopt safer practices under such conditions.

However, the analysis also underscores notable deficiencies in road infrastructure, emphasizing the need for improvements to address rain-related issues such as hydroplaning. Additionally, further awareness should be enhanced among drivers through education programs about the significance of speed adaptation and following distance adjustment in various precipitation scenarios.

The relationship between cloudiness and risk to road users suggests that efforts must be made to ensure a secure road environment with relatively clear visual conditions. This could involve better street lighting and encouragement for the usage of daytime running lights or automatic headlights to increase visibility, especially in areas where partial cloud cover is more likely.

Even if this paper may provide some new insight into weather factors and their related impact on road safety in Tirana, there are some important limitations to be acknowledged. The data set to be analyzed, while representative, is probably not exhaustive of those factors that can contribute to road traffic incidents. Those can include traffic volume, road conditions, and driver behavior. Including these variables in explaining the factors that can contribute to a road accident will improve future research. The data of historical weather on which this research was entirely dependent could not have included the effects of sudden weather changes, such as extreme, which could be more relevant to road safety. Future research can include using real-time weather data and advanced modeling techniques in the early prediction of such events.

Declaration of Generative AI and AI-assisted technologies in the writing process

The authors wrote, reviewed and edited the content as needed and They have not utilised artificial intelligence (AI) tools. The authors take full responsibility for the content of the publication.

References:

[1] J. Skea, P. R. Shukla, A. Reisinger, R. Slade, M. Pathak, and A. A. Khourdajie, *Climate Change 2022: Mitigation of Climate Change*, Intergovernmental Panel on Climate Change (IPCC), 2022.

[2] N. S. Diffenbaugh and M. Burke, "Global warming has increased global economic inequality," *Proceedings of the National Academy of Sciences*, vol. 116, no. 20, pp. 9808–9813, 2019.

[3] C. Zhao, B. Liu, S. Piao, X. Wang, D. B. Lobell, Y. Huang, and P. Ciais, "Temperature increase reduces global yields of major crops in four independent estimates," *Proceedings of the National Academy of Sciences*, vol. 114, no. 35, pp. 9326–9331, 2017.

[4] C. Mora, B. Dousset, I. R. Caldwell, F. E. Powell, R. C. Geronimo, C. R. Bielecki, and C. Trauernicht, "Global risk of deadly heat," *Nature Climate Change*, vol. 7, no. 7, pp. 501–506, 2017.

[5] K. Hayes, P. Berry, and K. L. Ebi, "Factors Influencing the Mental Health Consequences of Climate Change in Canada," *International Journal of Environmental Research and Public Health*, vol. 16, no. 9, p. 1583, 2019.

[6] S. Clayton, C. M. Manning, K. Krygsman, and M. Speiser, *Mental Health and Our Changing Climate: Impacts, Implications, and Guidance*, American Psychological Association and ecoAmerica, 2017.

[7] A. Cunsolo and N. R. Ellis, "Ecological grief as a mental health response to climate change-related loss," *Nature Climate Change*, vol. 8, no. 4, pp. 275–281, 2018.

[8] M. Burke, F. González, P. Baylis, S. Heft-Neal, C. Baysan, S. Basu, and S. Hsiang, "Higher temperatures increase suicide rates in the United States and Mexico," *Nature Climate Change*, vol. 8, no. 8, pp. 723–729, 2018.

[9] H. L. Berry, T. D. Waite, K. B. G. Dear, A. G. Capon, and V. Murray, "The case for systems thinking about climate change and mental health," *Nature Climate Change*, vol. 8, no. 4, pp. 282–290, 2018.

[10] H. J. Zar and M. E. Levin, "Allergy and climate change," *Current Allergy and Clinical Immunology*, vol. 31, no. 4, pp. 228–233, 2018.

[11] G. D'Amato, C. Vitale, M. Lanza, A. Molino, M. D'Amato, and L. Cecchi, "Climate change and allergic respiratory diseases: an update," *Current Opinion in Allergy and Clinical Immunology*, vol. 19, no. 1, pp. 1–6, 2019.

[12] K. A. Prather, T. F. Mar, and G. Lin, "Air pollution, pollen, and respiratory disease: implications for climate change," *Current Opinion in Immunology*, vol. 60, pp. 227–232, 2020.

[13] T. Kjellstrom, B. Lemke, and M. Otto, "Impact of climate conditions on occupational health

and related economic losses: A new feature of global and urban health in the context of climate change," *Asia Pacific Journal of Public Health*, vol. 31, no. 4, pp. 667–674, 2019.

[14] K. B. Lee and J. Y. Oh, "Impact of climate change on road traffic accidents in Korea," *Transportation Research Part D: Transport and Environment*, vol. 88, p. 102574, 2020.

[15] T. Usman, S. A. Khan, and B. Smith, "Climate change and road traffic accidents in Australia: A time series analysis," *Environmental Research Letters*, vol. 16, no. 11, p. 114009, 2021.

[16] J. Green, C. J. Gordon, A. R. Jones, M. R. Sim, S. Weller, and K. Sullivan, "Psychotropic drugs and risk of heat-related hospitalisation: a study of community-dwelling older people in Australia," *Australian and New Zealand Journal of Public Health*, vol. 43, no. 4, pp. 408–414, 2019.

[17] M. V. Rudorfer and J. S. Warner, "Psychotropic medications and climate change: a new frontier of challenges," *Journal of Clinical Psychiatry*, vol. 82, no. 5, pp. 20–24, 2021.

[18] D. L. Buckeridge, M. Hatzopoulou, B. M. Kuhn, J. Low, and M. Evans, "Urban heat islands and heat-related mortality in an aging population: Implications for health," *Science of the Total Environment*, vol. 703, p. 134567, 2020.

[19] Institute of Statistics, Albania (INSTAT), *Population and Housing Census 2021: Preliminary Results*, INSTAT, 2021.

[20] A. Musaraj and E. Kodra, "Urbanization and regional development in Albania: Demographic trends and policy implications," *European Journal of Geography*, vol. 11, no. 3, pp. 68–84, 2020.

[21] F. Guzzetti and E. Fatori, "Land use and population density in Albania: A regional comparison," *Journal of Balkan Geography*, vol. 4, no. 1, pp. 22–35, 2019.

[22] Institute of Statistics, Albania (INSTAT), *Tirana Region Statistical Yearbook 2022*, INSTAT, Tirana, Albania, 2022.

[23] World Health Organization (WHO), *Global Status Report on Road Safety 2021: Country Profile - Albania*, World Health Organization, Geneva, Switzerland, 2021. Available from: `https://www.who.int/publications/i/item/9789240030451`.

[24] Open-Meteo, *Open-Meteo Historical Weather API*, 2023. Available at: `https://open-meteo.com/en/docs/historical-weather-api`. Accessed: 2023-08-11.

[25] W. Lee, J. Kim, and K.-Y. Choi, "The impact of extreme heat on road traffic accidents in South Korea: Implications for climate change adaptation," *Accident Analysis & Prevention*, vol. 130, pp. 18–26, 2019.

[26] X. Yu, Y. Zhang, Y. Xiao, S. Zhang, and H. Chen, "High temperatures and traffic accidents in China: A time-stratified case-crossover study," *Environmental Research*, vol. 185, p. 109449, 2020.

[27] S. G. Kim, S. H. Kim, and H. I. Kim, "Effects of rainfall intensity and pavement conditions on traffic accidents: A case study," *Journal of Safety Research*, vol. 69, pp. 1–8, 2019.

[28] J.-L. Martin and E. Lagarde, "Impact of rainfall on traffic accident severity on road segments: A panel data analysis using copula-based random-effects models," *Accident Analysis & Prevention*, vol. 135, p. 105367, 2020.

[29] L. Staplin, K. Lococo, and M. Kosaka, "The impact of weather-related variables on traffic crashes: a study of Iowa, US," *Transportation Research Part D: Transport and Environment*, vol. 93, p. 102752, 2021.

[30] Y. Guo, X. Fang, S. Feng, Z. Xu, X. Liu, and W. Wang, "Effects of heavy rainfall on traffic accidents in Beijing, China," *PLoS ONE*, vol. 14, no. 12, p. e0225431, 2019.

[31] Y. Sun, M. Liu, and W. Zhou, "Effects of weather conditions on car accidents: The impact of cloud cover and visibility on driver performance," *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 74, pp. 280–292, 2020.

[32] X. Wu, R. Zhang, and Y. Li, "Impact of cloud cover on driving safety: A study based on traffic accident data and weather conditions," *Journal of Transportation Safety & Security*, vol. 11, no. 2, pp. 184–200, 2019.

[33] R Core Team, *R: A Language and Environment for Statistical Computing*, R Foundation for Statistical Computing, Vienna, Austria, 2023. Available at: `https://www.R-project.org/`.

[34] A. Gasparrini and B. Armstrong, "Redefining the association between temperature and

mortality: The case of England and Wales," *Journal of Epidemiology & Community Health*, vol. 67, no. 9, pp. 826–829, 2013.

[35] A. Gasparrini, B. Armstrong, and M. G. Kenward, "Distributed lag non-linear models: A modelling framework to capture non-linear associations," *BMC Medical Research Methodology*, vol. 10, no. 1, p. 103, 2010.

[36] A. Gasparrini, "Distributed lag linear and non-linear models in R: the package dlnm," *Journal of Statistical Software*, vol. 43, no. 8, pp. 1–20, 2011.

[37] H. Wickham, R. François, L. Henry, and K. Müller, *dplyr: A Grammar of Data Manipulation*, R package version 1.1.3, 2023. Available at: https://CRAN.R-project.org/package=dplyr.

[38] B. Armstrong, "Models for the relationship between ambient temperature and daily mortality," *Epidemiology*, vol. 17, no. 6, pp. 624–631, 2006.

[39] A. Gasparrini, Y. Guo, M. Hashizume, E. Lavigne, A. Tobias, A. Zanobetti, J. Schwartz, M. L. Bell, H. Kan, Y. Honda, *et al.*, "Mortality risk attributable to high and low ambient temperature: a multicountry observational study," *The Lancet*, vol. 386, no. 9991, pp. 369–375, 2015.

[40] F. Sera, B. Armstrong, A. Tobias, A. M. Vicedo-Cabrera, C. Åström, B.-Y. Chen, M. de Sousa Zanotti Stagliorio Coelho, P. M. Correa, J. A. Crucci, D. Holt, *et al.*, "How urban characteristics affect vulnerability to heat and cold: A multi-country analysis," *International Journal of Epidemiology*, vol. 48, no. 4, pp. 1101–1112, 2019.

[41] C. Linares and J. Díaz, "Impact of high temperatures on hospital admissions: comparative analysis with previous studies about mortality (Madrid)," *European Journal of Public Health*, vol. 20, no. 1, pp. 97–102, 2010.

[42] L. Zhou, J. Zhang, J. Wang, and Q. Liu, "The impact of rainfall on road traffic accidents and casualties in Guangzhou, China," *Accident Analysis & Prevention*, vol. 132, p. 105288, 2019.

[43] S. Jung, X. Qin, S. Han, and K. B. Lee, "Rainfall and road traffic accidents: A systematic review and meta-analysis," *International Journal of Environmental Research and Public Health*, vol. 17, no. 15, p. 5407, 2020.

[44] J. W. Kim, Y. K. Lee, and S. Park, "Impact of varying rainfall intensities on road safety: A case study using traffic and weather data from South Korea," *Transportation Research Part D: Transport and Environment*, vol. 92, p. 102725, 2021.

[45] K. Blincoe, R. N. Bird, and D. M. Brookes, "Influence of rainfall on crash risk: A comparison of different rain intensity metrics and temporal rainfall patterns," *Journal of Safety Research*, vol. 70, pp. 133–140, 2019.

[46] A.-K. Andersson and L. Chapman, "The influence of fog and low visibility on traffic accidents in Sweden," *Accident Analysis & Prevention*, vol. 122, pp. 278–285, 2019.

[47] H. Wang, M. A. Quddus, and S. G. Ison, "Cloud cover and road accidents: A multivariate analysis in the context of the UK," *Journal of Transportation Safety & Security*, vol. 12, no. 7, pp. 822–839, 2020.

[48] R. Xu, Y. Zhang, J. Li, and M. Wang, "Impact of cloud cover on road traffic accidents: A case study in Eastern China," *Transportation Research Part D: Transport and Environment*, vol. 91, p. 102701, 2021.

[49] R. Karthik and R. Anand, "The effect of fog and cloud cover on road accidents in urban areas: Evidence from a developing country," *Journal of Safety Research*, vol. 67, pp. 189–198, 2018.

[50] Y. Huang, Z. Peng, X. Luo, and X. Wu, "The influence of weather conditions on road safety: A comprehensive analysis based on the structural equation model," *Accident Analysis & Prevention*, vol. 132, p. 105241, 2019.

Contribution of Individual Authors to the Creation of the Scientific Article (Ghostwriting Policy)

Endri Raco led the development of the research methodology, contributed to data analysis, and provided oversight throughout the project.
Etleva Beliu conducted statistical testing, validated results, and managed the citation and referencing framework.
Kleida Haxhi performed data curation, quality checks, and preprocessing, and collaborated on data interpretation.
Oriana Zacaj designed the graphical illustrations, implemented software tools for data visualization, and contributed to result presentation.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

The publication of this article has been financially supported by the Scientific Research Fund of the Polytechnic University of Tirana.

Conflict of Interest
The authors have no conflicts of interest to declare that are relevant to the content of this article.