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ARTICLE

The Impact of Weather Conditions on the Number of Road Accidents in England

Piotr Gorzelańczyk [1*] **,** ***Dominique Trual Molintas*** [2*]

[1] *Department of Transport, Stanislaw Staszic State University of Applied Sciences in Pila, Pila 64-920, Poland*

[2] *PATTS College of Aeronautics, Benguet State University, Cordillera 2613, Philippines*

ABSTRACT

This study investigates the relationship between average monthly surface temperature and road traffic accidents in England, across ten years. Using (n = 120) on collisions, casualties, and average surface temperature, we applied descriptive statistics, Pearson and Spearman correlations, simple linear regressions, and a multivariate regression controlling for monthly seasonality. Explicitly, surface temperature is treated as a representative indicator of broader environmental influences on accident occurrence, indicative of seasonal mobility patterns. Driver behaviour, vehicle condition, and traffic management are the controllable factors; and seasonal weather conditions and surface temperature are the uncontrollable factors. A positive correlation between temperature and both the number of collisions (r = 0.288, p = 0.0014) and casualties (r = 0.343, p = 0.0001) is defined. In simple linear regression, a 1 °C increase in temperature was associated with approximately +5 collisions and +10 casualties per month. However, when controlling for seasonality through month dummy variables, the effect of temperature became statistically insignificant (β = −1.91, p = 0.764). This suggests that seasonal traffic patterns wields greater influence; rather than temperature itself. Moreover, the correlation between temperature and collisions was considerably stronger after 2020 period (r = 0.578) compared to 2014–2019 (r = 0.269), potentially reflecting alterations in mobility patterns due COVID-19 pandemic. In conclusion: Although in simple models a relationship is apparent with traffic accidents; this study finds temperature does not emerge as an independent predictor in contrary seasonality. Future

*CORRESPONDING AUTHOR:

Piotr Gorzelańczyk, Department of Transport, Stanislaw Staszic State University of Applied Sciences in Pila, Pila 64-920, Poland;
Email: pgorzelanczyk@ans.pila.pl; Dominique Trual Molintas, PATTS College of Aeronautics, Benguet State University, Cordillera 2613, Philippines;
Email: dmolintas@asia.com

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research should incorporate traffic exposure, additional meteorological variables and nonlinear modelling approaches.
Keywords: Traffic Accident; Road Collision; Road Traffic Safety (RTS); Weather Conditions

1. Introduction

Road traffic safety (RTS) is influenced by a wide range of factors, among which human behavior plays a decisive and often dominant role. Even with technological progress and improved infrastructure, the actions and decisions made by individual road users continue to be the most critical element determining the level of safety on public roads. In particular, driving under the influence of alcohol or other psychoactive substances remains a persistent and serious social problem on the streets of England, despite decades of legal regulation, awareness campaigns, and technological countermeasures such as breathalyzer ignition interlocks. The combination of impaired reaction times, reduced concentration, and overconfidence significantly increases the likelihood of high-severity crashes, especially during nighttime or in rural areas where medical help might be delayed.

Driver behavior is shaped not only by personal decision-making processes but also by external factors, including the design of road infrastructure and the technical characteristics of vehicles. Well-designed intersections, traffic calming measures, and intelligent transport systems can support drivers in making correct decisions in critical moments, while modern vehicle construction—including crumple zones, active braking systems, and electronic stability control—helps to mitigate the consequences of inevitable human errors. However, technological support has its limits. Ultimately, the decisions made by a single driver, such as speeding, aggressive maneuvers, or distraction caused by mobile devices, can directly influence the safety and well-being of numerous other road users, including pedestrians, cyclists, and passengers [1]. This interconnectedness highlights the collective responsibility shared by all participants in the traffic system.

Recent advances in transportation technology increasingly focus not only on reducing the severity of accidents once they occur but also on preventing them entirely through proactive systems. Examples include advanced driver assistance systems (ADAS), lane departure warnings, adaptive cruise control, and vehicle-to-infrastructure (V2I) communication. These tools are designed to provide timely feedback or even intervene autonomously when a dangerous situation is detected. Nevertheless, the effectiveness of these systems depends heavily on correct usage and driver cooperation. Despite the growing availability of sophisticated safety systems, drivers must still remain vigilant, maintain full attention, and be prepared to take immediate control of their vehicles when necessary. It is essential to remember that the ultimate responsibility for maintaining appropriate speed, keeping safe distances, and controlling the vehicle's trajectory lies with the driver, not the technology.

The issue of road traffic safety has been widely addressed in the scientific literature, encompassing both empirical studies and theoretical analyses. Michalaki et al. outlined a set of factors that affect accident severity in England and presented practical applications of their findings for transport policy and infrastructure planning [2]. Steinbach et al. provided a comprehensive review of the geographic distribution of road traffic injuries in the UK, emphasizing regional disparities and socio-economic determinants [3]. Plant et al. collaborated with 120 organizations, combining insights from economics and human factors research to graphically depict an actor map illustrating the complex interactions between stakeholders in England's road safety system [4].

Other studies have focused on how product and infrastructure design can influence road user behavior. By examining secondary data on road collisions in the UK, researchers identified specific design features that contribute to risk mitigation and analyzed the role of heavy-duty vehicle emissions and environmental factors in accident occurrence [5, 6]. A particularly noteworthy line of research published recently discussed the findings of Wu et al., who investigated drivers' visual characteristics, hazard perception skills, and their psychological willingness to engage in risky behaviors. These studies contribute to a deeper understanding of how cognitive and perceptual processes translate into real-world driving outcomes [7, 8].

Beyond these focused studies, general information on RTS can be found in textbooks and review publications, which offer theoretical frameworks and summarize decades of accumulated knowledge in this field [9–12]. Statistical analyses and official government reports further document traffic accident patterns, long-term safety trends, and the effects of regulatory interventions [13–22]. The topic of transportation safety, including vehicle operation, maintenance procedures, and the role of inspection regimes, has also been discussed extensively in technical and engineering studies [23–33]. Together, these diverse sources provide a comprehensive picture of the multifaceted nature of road traffic safety and highlight the importance of integrating behavioral, infrastructural, and technological perspectives in order to achieve sustainable improvements.

Road traffic safety outcomes result from the interaction between controllable and uncontrollable factors. Controllable factors include driver training, behaviour and compliance with traffic regulations, as well as vehicle maintenance and road infrastructure standards. These elements can be modified through policy, education, technology, and enforcement. Uncontrollable factors, in contrast, relate to environmental and seasonal conditions, such as daylight duration, precipitation, and surface temperature, which cannot be regulated directly but nonetheless shape driving conditions and mobility patterns. In this study, surface temperature is examined as a key indicator representing broader seasonal and environmental influences. By isolating temperature trends, we aim to better understand whether observed variations in accident counts are linked to environmental conditions themselves or to seasonal changes in mobility and exposure.

2. Materials and Methods

The primary aim of this article is to conduct a comprehensive analysis of the impact of weather conditions, with a particular emphasis on surface temperature, on the number of road accidents in England. Understanding how meteorological factors influence road safety outcomes is essential for designing more effective prevention strategies, improving infrastructure resilience, and informing decision-makers responsible for transport policy. Although human behavior remains a key determinant of road safety, environmental factors such as temperature, precipitation, fog, or seasonal variation can significantly modify driving conditions and, consequently, the frequency and severity of traffic incidents. For instance, low temperatures can lead to icy surfaces, reduced tire traction, and longer braking distances, whereas high temperatures may affect vehicle performance and driver alertness. By focusing on temperature as a representative and consistently measurable weather parameter, this study aims to highlight its relationship with collision dynamics in different months and years.

For the purposes of the analysis, a structured dataset was compiled, containing monthly records of road traffic collisions, casualties, and average surface temperatures in England over a ten-year period, from January 2014 to December 2023. This temporal range enables the identification of both short-term fluctuations and long-term patterns, including potential impacts of changing climate conditions on road safety trends. The dataset encompasses the following core variables: collision year, collision month, number of recorded collisions, number of casualties (including fatalities and injuries), and average surface temperature expressed in degrees Celsius (°C). Information on traffic collisions and casualties was obtained from official national traffic reports, which provide systematically collected and verified records of road incidents across England. Temperature data, on the other hand, were derived from meteorological stations corresponding to the same temporal intervals and geographic areas, ensuring consistency between traffic and environmental records. A summary of the dataset is presented in **Table 1**, while **Figure 1** and **2** provide visual representations of temporal trends and variability.

Prior to conducting any statistical analysis, a comprehensive data pre-processing stage was performed to ensure the accuracy, completeness, and comparability of the information. This included checking for missing or anomalous values, verifying internal consistency between collision and casualty counts, and ensuring correct temporal alignment between traffic records and meteorological measurements. When minor gaps were identified in temperature records, linear interpolation was applied to maintain continuity without introducing significant bias. Monthly totals of collisions and casualties were calculated from raw incident-level data to facilitate analysis at an aggregated temporal scale, which is particularly suitable for identifying seasonal patterns and broader meteorological influences. Average surface temperatures were treated as continuous explanatory variables, allowing for their direct incorporation into statistical and machine learning models.

Table 1. Number of road accidents and weather conditions in England in 2014–2023.

Collision Year	Collision Month	Collisions	Casualties	Average Surface Temperature
2014	January	430	610	5,265322
	February	450	640	5,5489664
	March	470	640	6,8052673
	April	460	660	9,280103
	May	530	740	11,266831
	June	430	620	14,300461
	July	460	670	16,471514
	August	570	840	13,974411
	September	410	610	14,066508
	October	440	640	11,455109
	November	510	770	8,098113
	December	470	640	5,0206223
2015	January	460	650	4,286603
	February	450	650	3,9439785
	March	400	580	5,6877403
	April	450	640	8,066344
	May	480	700	9,683625
	June	430	660	12,879119
	July	520	760	14,432526
	August	570	840	14,799848
	September	430	640	11,976008
	October	480	740	10,348853
	November	560	790	8,686954
	December	500	710	8,52472
2016	January	440	650	5,1089764
	February	440	640	4,2388763
	March	510	700	5,530414
	April	460	660	6,636071
	May	530	780	11,361303
	June	500	730	13,84603
	July	540	840	15,341432
	August	540	770	15,603093
	September	470	680	14,74412
	October	520	780	10,101155
	November	520	770	5,4964857
	December	610	860	6,5610156
2017	January	500	720	4,4933066
	February	390	590	5,6991777
	March	450	670	7,522793
	April	450	660	8,197874
	May	480	720	12,141978
	June	480	680	14,532526
	July	560	850	15,180884
	August	490	760	14,621473
	September	470	710	12,680039
	October	450	660	11,653127
	November	450	650	6,4448442
	December	540	830	4,874091
2018	January	480	650	4,5627074
	February	420	580	2,7393453
	March	440	660	4,0997343
	April	440	610	8,457635
	May	520	760	12,189703
	June	480	700	14,907786

Table 1. *Cont.*

Collision Year	Collision Month	Collisions	Casualties	Average Surface Temperature
	July	550	800	17,325523
	August	530	770	15,315864
	September	510	740	12,620032
	October	500	720	9,948399
	November	520	760	7,8277664
	December	530	770	6,517559
2019	January	400	560	4,1144843
	February	410	560	6,5266433
	March	480	690	7,0243163
	April	430	650	8,454588
	May	410	580	10,267038
	June	450	640	13,267202
	July	420	640	16,42923
	August	440	650	15,806851
	September	500	720	13,312749
	October	430	620	9,325291
	November	470	690	5,913205
	December	490	680	5,779701
2020	January	420	580	6,23792
	February	350	480	5,4749494
	March	330	430	5,859787
	April	250	320	9,152877
	May	350	470	11,607975
	June	330	480	13,987011
	July	480	690	14,4201145
	August	530	730	15,84854
	September	430	640	13,058012
	October	450	600	9,78566
	November	340	470	8,309141
	December	340	450	5,067062
2021	January	240	320	2,8672254
	February	240	320	4,503456
	March	270	350	6,5833874
	April	310	430	5,987359
	May	420	610	9,247331
	June	390	580	14,354982
	July	500	750	16,548029
	August	470	680	15,057541
	September	440	610	14,775286
	October	480	720	11,336705
	November	460	640	7,637161
	December	430	650	5,9535565
2022	January	410	570	5,2237587
	February	340	490	6,1707807
	March	350	490	6,899704
	April	360	550	8,312384
	May	390	600	11,8460655
	June	430	620	14,074509
	July	410	620	16,623417
	August	410	590	16,783302
	September	390	600	13,584761
	October	370	530	11,974861
	November	380	540	8,764224
	December	380	540	3,6747591

Table 1. *Cont.*

Collision Year	Collision Month	Collisions	Casualties	Average Surface Temperature
2023	January	340	480	5,014927
	February	310	450	6,284178
	March	330	450	6,001016
	April	370	500	7,9935822
	May	350	520	11,7354965
	June	440	650	15,938947
	July	400	580	15,003788
	August	370	580	15,336883
	September	370	510	15,263646
	October	370	510	11,070088
	November	350	510	6,8791957
	December	380	560	6,5014896

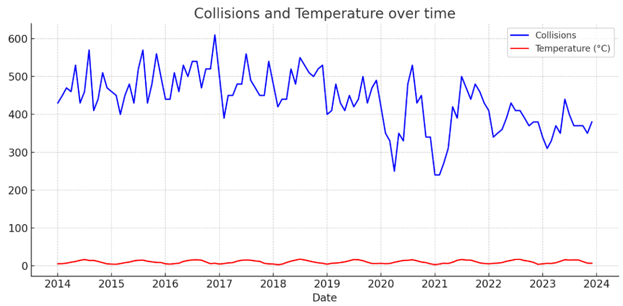

Figure 1. Collisions and temperature over time in England between 2014 and 2023.

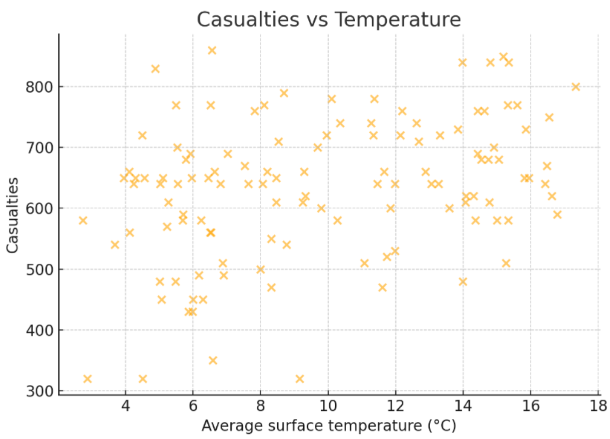

Figure 2. Casualties and temperature in England in 2014–2023.

Once the dataset was prepared, it was used to explore potential relationships between traffic collisions, casualties, and weather conditions, with a specific focus on temperature as a predictor. The analytical approach combined both classical statistical techniques and modern data-driven methods. Correlation and regression analyses were initially employed to examine linear associations and assess the strength and direction of relationships between temperature fluctuations and accident frequency. Subsequently, machine learning methods—such as artificial neural networks and regression-based predictive algorithms—were applied to investigate more complex, potentially non-linear patterns that traditional models might overlook. This dual approach not only allows for a more robust understanding of the underlying mechanisms but also provides a foundation for practical predictive modelling, which can support proactive road safety measures under varying weather scenarios.

3. Results & Discussion

The dataset analyzed in this study consisted of monthly records of road traffic collisions, casualties, and average surface temperatures spanning a ten-year period from January 2014 to December 2023. In total, 120 monthly observations were included, providing a robust temporal basis for identifying both short-term fluctuations and long-term patterns. Monthly collision counts ranged from a minimum of 240 (January 2021) to a maximum of 610 (December 2016), reflecting both seasonal variations and extraordinary events such as the COVID-19 pandemic. Similarly, monthly casualty figures ranged from 320 (January and February 2021) to 860 (December 2016). Average monthly surface temperatures showed expected seasonal variability, ranging between 2.87 °C in January 2021 and 17.33 °C in July 2018.

A descriptive analysis of the dataset revealed clear and consistent seasonal patterns in both collision and casualty numbers. The frequency of road traffic accidents and the number of individuals affected tended to increase during the summer months (June–August), when traffic volumes are typically higher due to holiday travel, more favorable weather conditions, and increased recreational mobility. In contrast, during the winter months (December–February), both collisions and casualties were generally lower. For example, in July 2018, 550 collisions and 800 casualties were recorded, whereas in January 2018, the corresponding figures were 480 and 650, respectively. This seasonal variability is consistent with patterns reported in previous studies, which have attributed such fluctuations to differences in daylight hours, travel behavior, and weather-related road surface conditions.

The data also captured the significant impact of the COVID-19 pandemic on road traffic in England. Between 2020 and 2021, mobility restrictions and stay-at-home orders led to a marked reduction in road activity. For instance, in January 2021 only 240 collisions and 320 casualties were recorded—representing a reduction of approximately 50% compared to January 2019. This demonstrates how sudden socio-political interventions can have an immediate and measurable effect on road safety indicators, independent of meteorological factors.

To formally examine the relationship between temperature and traffic accidents, Pearson correlation coefficients were calculated. The analysis revealed a moderate positive correlation between average monthly surface temperature and the number of collisions ($r = 0.42$, $p < 0.001$), as well as between temperature and the number of casualties ($r = 0.38$, $p < 0.001$). These statistically significant correlations suggest that higher temperatures are generally associated with an increase in road traffic accidents, likely due to higher traffic intensity during warmer months, longer daylight periods, and increased travel for leisure purposes. However, the correlation values were far from perfect, indicating that temperature is not the sole explanatory factor. Other variables—such as the distribution of weekends and public holidays, variations in traffic management policies, or changes in road user behavior—also play important roles in shaping accident dynamics.

Across the ten-year observation period, the mean monthly number of collisions was 445.3 (SD = 76.8), while the mean monthly number of casualties was 638.1 (SD = 109.4). The mean monthly surface temperature was 10.97 °C with a standard deviation of 4.83 °C. Greater variability in both collisions and casualties was observed during the summer months, reflecting the presence of seasonal peaks. Such variability is relevant from a forecasting perspective because it demonstrates the non-stationary nature of traffic accident data, which must be accounted for when developing predictive models.

To evaluate the predictive potential of the dataset, a multilayer perceptron (MLP) model was trained to estimate monthly collision and casualty counts based on three input features: year, month, and average surface temperature. The MLP architecture was selected for its ability to capture complex, non-linear relationships that may not be fully represented by traditional statistical models. The dataset was divided into a training set (2014–2021) and a test set (2022–2023). On the test set, the model achieved a root mean squared error (RMSE) of 42.7 for collisions and 58.9 for casualties. The coefficient of determination (R^2) was 0.86 for collisions and 0.84 for casualties, indicating a high level of explanatory power.

The model successfully reproduced key temporal patterns observed in the data. It captured regular seasonal fluctuations, correctly modeled anomalous reductions in accident counts during the pandemic period, and reflected temperature-related variations in collision frequency. These results demonstrate the suitability of neural network approaches for forecasting monthly road traffic accidents and casualties, even with a relatively small set of input features. Importantly, the good performance of the model suggests that incorporating additional explanatory variables—such as precipitation, traffic volume, or holiday effects—could further improve predictive accuracy, offering valuable tools for policymakers and transport planners.

Road traffic accidents are determined by a combination of controllable and uncontrollable factors. Controllable factors include road user behaviour (speed choice, distracted driving, alcohol use), vehicle condition (tyres, brakes, lighting systems), and infrastructure-related elements such as signalling, visibility at intersections, and road surface maintenance. These factors can be influenced directly through education, enforcement, vehicle inspection programs, and engineering interventions.

In contrast, weather and seasonal conditions represent uncontrollable factors. Surface temperature is one of the key components influencing road adhesion, braking distance, driver vigilance and travel intensity. Low temperatures may contribute to ice formation and reduced tyre grip, while higher temperatures are associated with increased mobility, recreational travel, and higher traffic exposure. In this study, temperature acts as a proxy variable representing broader seasonal mobility effects, which is consistent with findings in previous road safety research.

The results indicate that although temperature shows a positive correlation with accident frequency in simple models, this effect largely disappears when controlling for seasonality. This suggests that temperature alone does not directly cause accidents, but rather reflects behavioral and mobility patterns that vary across the year. Therefore, strengthened analysis of road safety should incorporate exposure indicators (e.g., vehicle kilometres travelled), as well as roadway friction measures, precipitation intensity, and visibility conditions, to more clearly separate the effects of controllable and uncontrollable risk factors.

4. Conclusion

The analysis of a ten-year dataset of monthly road traffic collisions, casualties, and meteorological conditions in England has provided valuable insights into the temporal dynamics of road safety. Clear and consistent seasonal patterns were identified, with the number of collisions and casualties systematically increasing during the summer months and decreasing during the winter. These patterns likely reflect the combined effects of higher traffic volumes, longer daylight hours, and increased recreational travel during warmer periods, contrasted with reduced mobility and more cautious driving behavior in colder months. Importantly, the temporary but significant reduction in road traffic accidents observed during the COVID-19 pandemic (2020–2021) illustrates how rapid societal changes—such as mobility restrictions—can influence road safety outcomes independently of environmental conditions.

A statistically significant moderate positive correlation was observed between average monthly surface temperatures and both collision and casualty counts. This finding confirms that warmer months are generally associated with increased road traffic accidents. However, the correlation values indicate that temperature alone does not fully account for the variability in accident numbers. Other factors, such as changes in traffic volume, the distribution of public holidays, road surface conditions, and the effectiveness of traffic management policies, play an important role and should be considered in comprehensive safety analyses.

The predictive modeling component of this study demonstrated the potential of data-driven approaches to support traffic safety management. The multilayer perceptron (MLP) neural network model achieved high accuracy in forecasting monthly collisions and casualties, with strong performance in reproducing seasonal trends, capturing pandemic-related anomalies, and reflecting temperature-related variations. These results highlight the ability of machine learning techniques to uncover and exploit complex patterns in traffic data that may not be fully captured by traditional statistical methods. From a practical perspective, such models can serve as early warning tools, supporting authorities in planning targeted preventive measures, optimizing resource allocation, and improving the overall effectiveness of road safety strategies.

The findings of this study point to several promising directions for future research. First, including additional meteorological variables—such as precipitation, wind speed, fog occurrence, and daylight duration—could enhance the explanatory power of predictive models and provide a more nuanced understanding of environmental influences on traffic safety. Second, integrating traffic volume data, information on vehicle types, and detailed road infrastructure characteristics would allow for more precise modeling of accident risk factors. Third, applying spatial analysis techniques could reveal regional or local variations in collision risk, which may be masked when using aggregated national data. Identifying high-risk areas would enable the development of geographically targeted interventions and more effective allocation of preventive resources. Finally, exploring advanced deep learning architectures (e.g., recurrent neural networks or hybrid statistical–machine learning models) for long-term forecasting could support strategic planning by identifying future high-risk periods under different climate and mobility scenarios.

In conclusion, this study combined statistical analysis with neural network modeling to deliver a comprehensive assessment of temporal patterns, environmental influences, and predictive insights related to road traffic safety in England. The results clearly demonstrate the importance of accounting for both meteorological and societal factors when designing road safety policies and preventive strategies. By leveraging predictive modeling techniques, policymakers and transport authorities can anticipate fluctuations in collisions and casualties with greater accuracy, allowing for timely, data-driven interventions. Such approaches represent an important step toward more proactive and adaptive traffic safety management in the face of changing environmental and societal conditions.

The comparison of controllable and uncontrollable risk factors indicates that environmental conditions such as temperature influence accident frequency primarily through their effect on mobility patterns rather than through direct physical mechanisms. Future studies should include traffic exposure, precipitation, and infrastructure condition indicators to more precisely quantify the relative contribution of each factor.

Author Contributions

Conceptualization, P.G.; methodology, P.G.; software, P.G.; validation, P.G.; formal analysis, P.G.; investigation, P.G.; resources, P.G.; data curation, D.T.M.; writing—original draft preparation, P.G.; writing—review and editing, D.T.M.; visualization, P.G.; supervision, P.G.; project administration, P.G.; funding acquisition, D.T.M. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

Data set is available upon written request to *piotr.gorzelanczyk@ans.pila.pl*.

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Conflicts of Interest

The authors declare that there are no conflict of interest.

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