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# Evaluating the climatic factors affecting road accidents - a case study in Poland

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***Keywords:*** factors affecting road accidents, road accident, weather conditions.
***Abstract:*** Globally, the number of traffic accidents is declining year. The epidemic has been the primary factor influencing its score in recent years. This figure is still quite high, though. Because of this, every attempt should be taken to lower the quantity of traffic incidents. The article's goal is to examine the likelihood that certain variables, which are dependent on weather, will have an impact on the quantity of traffic accidents. Ten measuring sites in Poland were chosen at random for this purpose, and the number of accidents at each location was examined. Based on the study, it can be stated that overcast and rainy days, together with favourable weather conditions, have the greatest impact on the number of traffic accidents. Furthermore, the likelihood of a traffic collision rises by 29% and 20%, respectively, in overcast and rainy skies. For this reason, special care should be taken to minimize road accidents.

## 1 Introduction

Every nation has a serious societal issue with road accidents. A number of variables, including speed, alcohol usage, weather, and other factors, can contribute to traffic accidents. The World Health Organization [1] reports that road accidents claim the lives of over 1.35 million people year, millions more of whom are seriously injured and have long-term health repercussions. Economic losses are also a result of accidents. Globally, the number of traffic accidents is declining year. The epidemic has been the main factor affecting this score in recent years. This number is still quite high, though (Figure 1). Every day, there are about 62 traffic incidents with an average of 62 fatalities and 72 injuries.

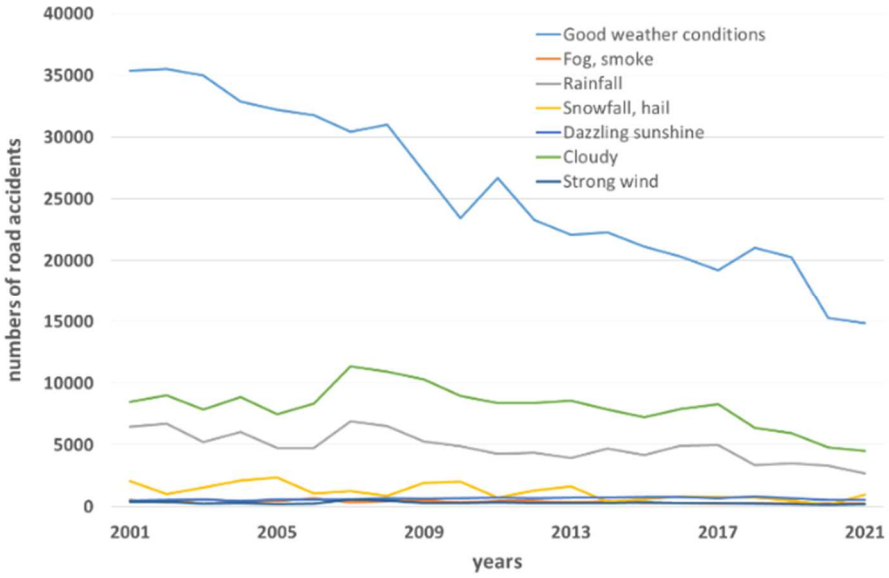


*Figure 1 Number of road accidents in Poland according to weather conditions from 2001 to 2021 [2]*

The aforementioned occurrences are linked to higher medical expenses, the requirement for car and road infrastructure maintenance, and detrimental environmental effects including oil spills. Because of this, every effort should be made to prevent traffic accidents in order to lower their frequency. Finding the variables influencing the quantity of traffic accidents is one way to do this [2,3].

According to studies by Zhai et al. and Holland et al., pedestrians are less protected than passengers in cars, which puts them at the highest risk of being involved in a traffic collision. They also sustain severe injuries among all those involved in traffic. Another of their investigations revealed that the severity of pedestrian injuries is influenced by variables such alcohol use, driver age or gender, illumination, road conditions, pedestrian conduct, accident site, vehicle, speed, and adverse weather [4-7]. More serious accidents on the roadways are frequently caused by bad weather and poor illumination, particularly at pedestrian crossings [7-9]. But this varies according on the field of study. For instance, it was demonstrated in the paper [10] that meteorological conditions typically have minimal impact on traffic accidents. This study subject can also be found in the works of Masello et al. [11] and Becker et al. [12], where the authors presented a model of the likelihood of traffic accidents based on the time of day and the meteorological conditions. The relationship between weather conditions and road accidents was also analysed in the work of the [13-25].

Apart from decreasing the frequency of traffic accidents, the current weather also influences traffic volume and driver behavior, including how quickly they respond to traffic circumstances [16,26-27].

In his research, Eisenberg [18] examined the connection between precipitation and road accidents in the United States and demonstrated that inclement weather is associated with a higher number of traffic accidents.

Brodsky and Hakkert [28] examined a related subject and discovered that accident rates rose by 100% in the presence of rain, whereas in Denmark the rise was only about 10%. Fridstrøm et al. [16], on the other hand, discovered that rainfall had no influence on the change in the number of traffic accidents in Sweden and Norway. Conversely, in Poland, the majority of road accidents happen when the weather is nice. Moreover, the frequency of traffic accidents rises with rising temperatures and favorable weather [2,27,29].

For the purpose of this work, it was assumed [30]:

- good atmospheric conditions are:
  - air temperature > 3ºC,
  - no precipitation,
  - wind < 5.5 m/s,
  - visibility > 10 km,
  - pressure difference over the day < 8 hPa.
- Bad weather conditions (if one of the following factors is met) are:
  - slippery pavement (temperature < 3ºC and occurrence of precipitation),
  - heavy rain (temperature > 0ºC, precipitation > 3 mm),
  - snowstorm (temperature < 0ºC, precipitation > 3 mm),
  - strong wind (wind > 10 ms/s),
  - dense fog (visibility < 300 m).

In their study, Masello et al. offered an alternative method of examining traffic incidents. They investigated how driver assistance technologies may raise traffic safety. The investigation was carried out in a variety of weather and traffic scenarios.

The relationship between the three elements of traffic (the so-called safety triangle) is also influenced by atmospheric conditions. These elements are the vehicle (its technical state, traffic speed, load), the environment (road infrastructure), and the human being (and his psycho-motor state, fatigue, stress, and concentration) (Figure 2).

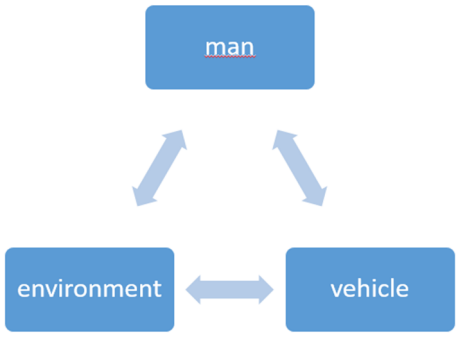


*Figure 2 Safety triangle*

It is possible to draw a variety of inferences from the literature research on the likelihood of a traffic accident given the current weather conditions. A few researches evaluate their detrimental effect on the quantity of traffic accidents. However, a lot of academics assert that this impact does not exist. It has been acknowledged that there is a need to evaluate the variables influencing the quantity of traffic accidents. Because of this, the article's goal is to evaluate the significance of the influence of particular atmospheric conditions on the likelihood of a traffic collision. Because of this, it is possible to ask: What impact do meteorological conditions have on the quantity of traffic accidents? To do this, ten measuring sites in Poland were chosen at random, and the following data were examined for each location: the quantity of accidents in relation to the weather at the time of the incident.

## 2 Equations

This paper's objective is to evaluate the impact of specific climatic variables (such as fog, high wind, cloud cover, sunshine, snow, and rain) on the likelihood that a traffic accident will occur at the examined measurement point. The following algorithm was used to calculate the likelihood of a traffic collision for this purpose:

- 10 measurement points on different types of national and provincial roads in Poland were randomly selected.
- The following parameters were determined for the selected points:
    - Location of the measuring point.
    - Type of road on which the measurement point is located (national road, voivodeship road).
    - Geographical coordinates.
    - Traffic speed at the point under analysis.

The study employed the CART approach. The CART approach is built on two key components: regression trees, which are used to forecast the value of the target variable and are defined by a continuous type target variable, and classification trees, which are used to classify classes and are characterized by a categorical target variable. The fundamental idea behind the CART algorithm is that data is divided at the nodes based on a single decision variable, and that data splitting stops when an answer to one question has no bearing on the answer to another. The CART technique is typified by recursive binary splitting, which consistently splits a parent node into two daughter nodes. Because the classification error of each layer is determined after the divides are made, there will be some variability in the final category [31].

The investigation also made use of Minitab software. Statistical software called Minitab is used globally to evaluate data and enhance goods and services. Among the many options the application offers for efficient analysis is an interactive assistant that may aid at any point during the process.

### *2.1 Selection and location of sites*

Ten randomly chosen places in Poland were examined to ascertain the effect of specific meteorological conditions on the likelihood of a traffic collision (Table 1).

*Table 1 Coordinates of measurement points [32]*

| | Measurement Point | Road signage | Longitude of the point | Latitude of the point |
|---|---|---|---|---|
| **point1** | Piła - Wojska Polskiego | DW 179 | 16.732301 | 53.151436 |
| **point2** | Piła - Poznańska | DK 11 | 16.752994 | 53.126343 |
| **point3** | Piła - Al. Piastów | DK 11 | 16.737967 | 53.150107 |
| **point4** | Piła - Niepodległości | DK 11 | 16.737933 | 53.163308 |
| **point5** | Manowo | DK 11 | 16.287356 | 54.132729 |
| **point6** | Mścice | DK 11 | 16.080240 | 54.219427 |
| **point7** | Sianów | DK 6 | 16.302716 | 54.230299 |
| **point8** | Strzekęcino | DW 167 | 16.165485 | 54.099837 |
| **point9** | Sucha Koszalińska | DW 203 | 16.266325 | 54.260465 |
| **point10** | Szczeglino | DW 206 | 16.384696 | 54.180654 |

We examined the following information for these points: number of accidents varying according to the weather at the time of the incident (Figure 3, Figure 4). Both national (DK 6 and DK11) and provincial (DW167, DW179, DW 203, and DW206) highways were used to choose the spots. The maximum allowed speed for vehicular traffic at all presumptive measuring stations was 50 km/h.


*Figure 3 Measurement points within the city of Pila [33]*


*Figure 4 Measurement points in Koszalin County [33]*

## 3 Results and analysis

The current study has used data from ten locations in different sections of Poland. A table (Table 2) that displays the frequency of accidents in a certain type of environment and atmospheric conditions across all locations has been created based on the accident data.

The data makes it abundantly evident that the two main causes of traffic accidents in the majority of the locations are high levels of cloud cover and precipitation. As a result, additional information has been gathered, as shown in Table 3, which provides the total proportion of different climatic conditions that cause traffic crashes regardless of location. As is evident, comparable information is also shared by the general statistics, namely that rain and overcast skies are the factors that contribute to an increased frequency of accidents. The total proportion may not equal 100% since numerous incidents occur in locations with different climates.

*Table 2 Percentage of accidents in different locations under different environmental conditions*

| Locations | Climatic condition | Average rate of accidents (%) |
|---|---|---|
| 1 | Fog | 0 |
| | Strong Wind | 0 |
| | Cloudy Sky | 32.26 |
| | Sunshine | 1.08 |
| | Snowfall | 1.08 |
| | Rainfall/Precipitation | 19.35 |
| 2 | Fog | 0 |
| | Strong Wind | 1.28 |
| | Cloudy Sky | 29.49 |
| | Sunshine | 3.85 |
| | Snowfall | 1.28 |
| | Rainfall/Precipitation | 15.38 |
| 3 | Fog | 0 |
| | Strong Wind | 2.17 |
| | Cloudy Sky | 19.57 |
| | Sunshine | 6.52 |
| | Snowfall | 6.52 |
| | Rainfall/Precipitation | 21.74 |
| 4 | Fog | 0 |
| | Strong Wind | 3.85 |
| | Cloudy Sky | 23.08 |
| | Sunshine | 0 |
| | Snowfall | 0 |
| | Rainfall/Precipitation | 26.92 |
| 5 | Fog | 0 |
| | Strong Wind | 0 |
| | Cloudy Sky | 28.57 |
| | Sunshine | 0 |
| | Snowfall | 0 |
| | Rainfall/Precipitation | 14.29 |
| 6 | Fog | 0 |
| | Strong Wind | 0 |
| | Cloudy Sky | 35.29 |
| | Sunshine | 0 |
| | Snowfall | 0 |
| | Rainfall/Precipitation | 0 |
| 7 | Fog | 0 |
| | Strong Wind | 0 |
| | Cloudy Sky | 47.83 |
| | Sunshine | 0 |
| | Snowfall | 0 |
| | Rainfall/Precipitation | 4.35 |
| 8 | Fog | 0 |
| | Strong Wind | 0 |
| | Cloudy Sky | 0 |
| | Sunshine | 0 |
| | Snowfall | 0 |
| | Rainfall/Precipitation | 100 |
| 9 | Fog | 0 |
| | Strong Wind | 0 |
| | Cloudy Sky | 25 |
| | Sunshine | 25 |
| | Snowfall | 25 |
| | Rainfall/Precipitation | 0 |
| 10 | Fog | 0 |
| | Strong Wind | 0 |
| | Cloudy Sky | 50 |
| | Sunshine | 0 |
| | Snowfall | 0 |
| | Rainfall/Precipitation | 0 |

*Table 3 Proportion of road accidents based on climatic conditions*

| Climatic condition | Overall average rate of accidents (%) |
|---|---|
| Fog | 0 |
| Strong Wind | 0.73 |
| Cloudy Sky | 29.109 |
| Sunshine | 3.645 |
| Snowfall | 3.388 |
| Rainfall/Precipitation | 20.203 |

In this study, we've tried to create a model that can tell us how likely it is that traffic accidents would occur given certain weather conditions. This may be combined with information on driver behavior, road layout, and other factors to provide a more comprehensive picture of the precise likelihood of a traffic crash. Two mathematical techniques, namely logistic regression and classification/decision trees, can be employed to simulate the likelihood of traffic accidents according to weather conditions. The likelihood of this road collision event was determined using the CART, or Classification and Regression Tree, approach since probability is a continuous event that can lie anywhere between 0 and 1. The greater accuracy and predictability of the CART model over the logistic model is another important factor. The CART analysis was carried out using Minitab software. The regression tree study took into account every possible climate circumstance. Even if early research has shown that some weather conditions do not function as triggers for car collisions, it is nevertheless vital to include these aspects when forecasting the occurrence of crashes. Undoubtedly, it can be stated that these elements will decrease the accuracy of the model; nonetheless, they will not impair the predictability of the road collision incidents in general. According to the preliminary analysis's findings, six trees is the ideal amount for the highest R-square. Additionally, with six trees, the Mean Absolute Percentage Error (MAPE) is at its lowest—that is, just 0.7%. The selection criteria for the six trees are displayed in Figure 5, and the tree itself is shown in Figure 6. Figure 6 illustrates how the first two branches of the tree show that a cloudy sky and rainfall have an entirely different crash forecast, with a mean of 25%, compared to 1.9% for all other conditions combined. Once more, the tree tries to branch off the variables that affect collisions on the roads. For instance, among the two severe variables, rain and overcast skies together account for 20–21% of collisions and almost 29–30% of crashes. Comparable figures are also observed for other irrelevant parameters.

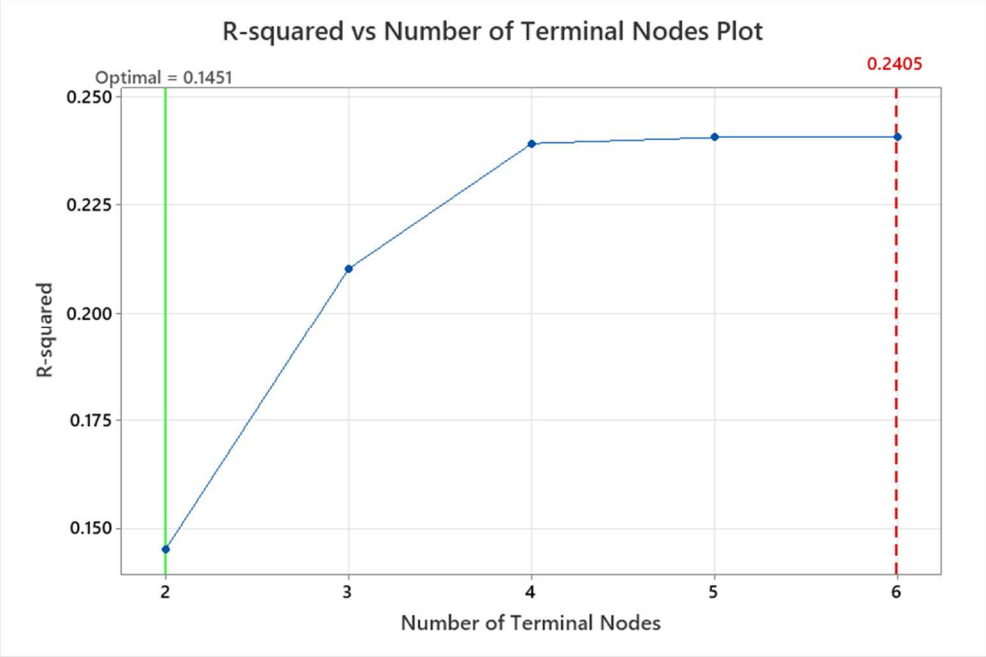


*Figure 5 Number of trees required for highest R-squared value.*

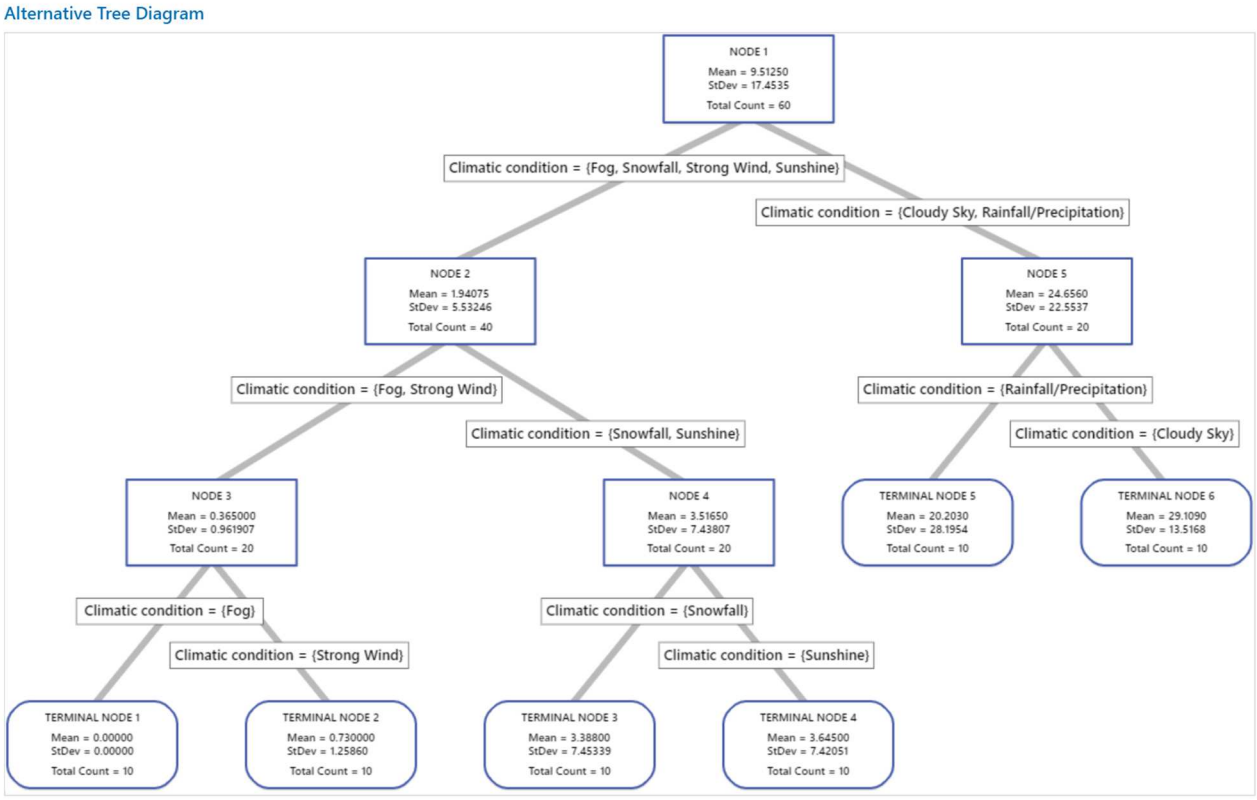


*Figure 6 Regression tree for predicting road crashes under different climatic conditions*

The predict option in Minitab software's CART analysis allows it to forecast the occurrence of dependent variables depending on the data that is supplied. In this study, we've tried to forecast the likelihood of traffic accidents occurring in a given weather scenario. Figure 7 shows pictures illustrating how to determine the likelihood of a traffic accident occurring in a given set of meteorological circumstances.

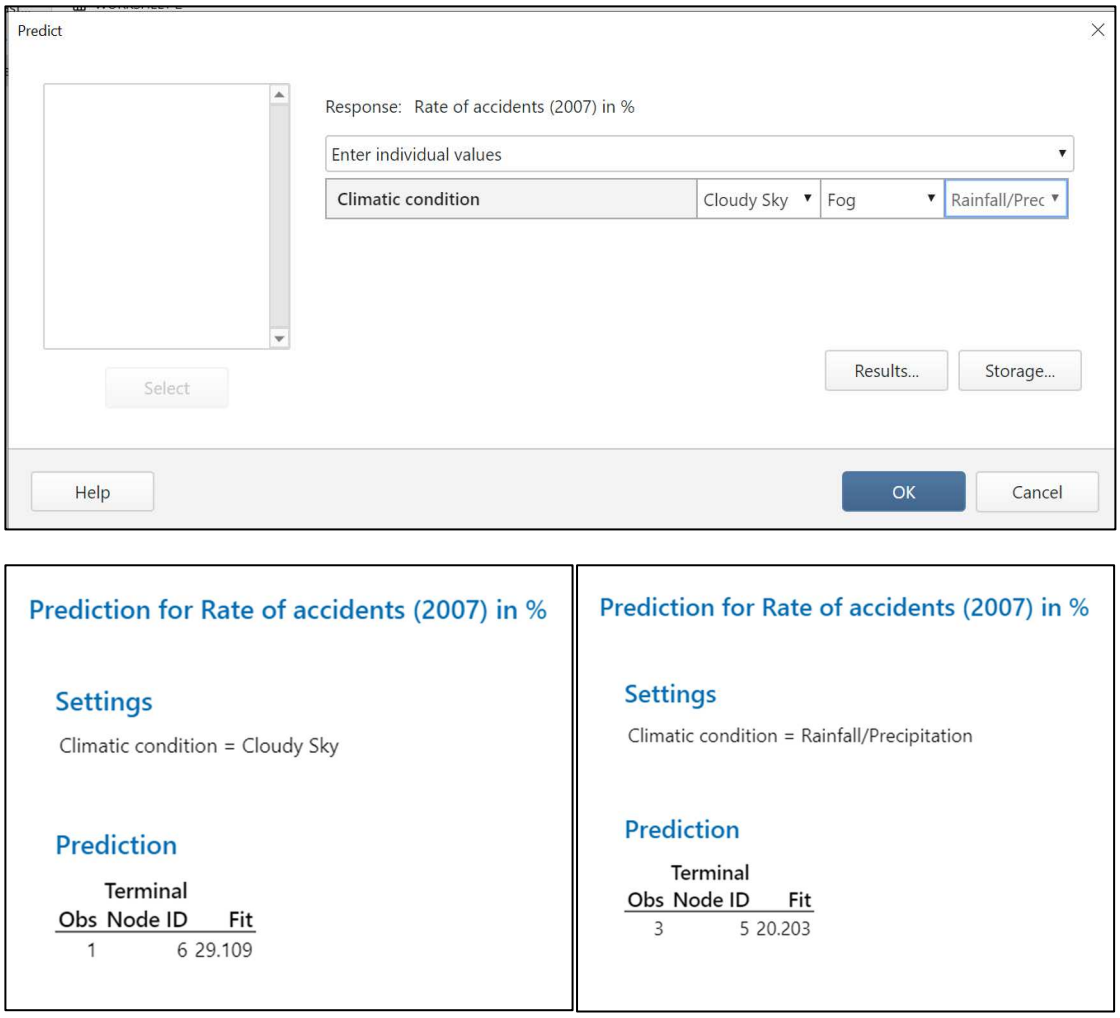


*Figure 7 Screenshots from Minitab software for predicting road crashes*

According to historical data for the area, Figure 7 shows that the likelihood of a traffic collision rises by 20% in the event of rain and by 29% in the case of cloudy sky. When applied at a specific site based on historical data, these probabilities will be highly helpful in recommending tactical actions to lower the number of traffic accidents.

## 4 Conclusion

The factors influencing the quantity of road accidents are examined in the article. This is a historical issue that impacts road safety, as is widely recognized. throughout order to do this, ten measuring sites throughout Poland were chosen at random, and the number of accidents at each location was examined. The study data reveal a higher frequency of road accidents on gloomy and rainy days. Minitab software and CART analysis were used in the investigation. The research indicates that the most significant influences on the frequency of traffic accidents are overcast and rainy days and favorable weather conditions. Furthermore, the likelihood of a car collision rises by 29% and 20%, respectively, with cloud cover and rain. The authors' subsequent thoughts will focus on a more thorough examination of other variables that may have an impact on the quantity of traffic accidents.

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