Study of the effects of climatic conditions on

alcohol consumption and factors influencing road

accident fatalities

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*Abstract*—In this paper, two distinct studies were conducted. In the first study, the effects of weather on the alcohol consumption pattern were studied. Data mining and machine learning models of Multiple Linear Regression and Support Vector Regression were used to conduct this study. This study concluded that alcohol consumption in the state of Iowa, USA is not correlated to temperature, rainfall, and snowfall.

In the second study, the factors affecting the road accident fatality in the state of Iowa were studied. Data mining and machine learning models of Logistic Regression, Naïve Bayes Classifier, and Support Vector Machines were used in this study. This study concluded that the factors that affect road accident fatality are the major cause of an accident, crash manner, surface conditions of the road, drug alcohol involvement, light conditions, weather conditions, vehicles, number of occupants, and the extent of property damage.

Both these studies were conducted for the state of Iowa, USA and the datasets used in this study comprised the details of weather, alcohol sales, and road accidents.

Keywords—data mining, alcohol consumption, weather, climate, road accidents, fatalities

# Introduction

## Effects of climate on alcohol consumption

Alcohol is an integral part of many cultures and traditions across the world. Alcohol is consumed in social settings like weddings, funeral, festivals, etc. or in casual settings where friends and family get together to have a few drinks. It is a general notion that alcohol consumption is higher during the winters or on colder days. Ventura-Cots et al [1] studied the relation of colder climate, specifically the mean temperature and the hours of sunshine on alcohol consumption. This study found that there is a positive correlation between cold climate and alcohol consumption in the USA. Another study by Hagstr¨om et al [2] analyzed the effects of fewer sunlight hours on alcohol consumption and found that there was a positive correlation between colder climate and alcohol consumption in Southern European countries, however, the Northern European Nordic countries showed a negative correlation between colder climate and alcohol consumption.

Causal studies on the effect of colder climate on human physiology were conducted by Haight and Keatinge [3] and Beker et al. [4]. Berker et al. found that colder climate stimulates the adrenoceptors in the body which promotes heat conservation which leads to cutaneous vascular constriction (narrowing blood vessels) and decreased blood supply to the peripheral organs (skin and muscles). This leads to the feeling of cold and shivering in a cold climate. Haight and Keatinge studied the effects of alcohol on the human body and found that it affects the thermoregulatory mechanism in the body which increases the peripheral (skin and muscle) temperature of the body.

Beau Freunds et al. [5] in their study of alcohol ingestion and temperature regulation during cold exposure note that scientific research lacks agreement on the effects of alcohol on the thermoregulation of the body. Add more details.

From these studies, we can infer that the correlation of colder climate on alcohol consumption might be specific to geographic areas and hence it warrants a study into the effects of colder climate on alcohol consumption for the state of Iowa, USA.

**Research question:** How are alcohol sales correlated to weather in the state of Iowa, USA?

## Predicting fatalities in road accidents

Road safety and road accidents have been a concern since the advent of motorized vehicles in the early 20th century [6]. Accidents are caused due to human error as well as unfavorable weather, road condition, lighting conditions, junction type, etc. [7]. Road accident injuries and fatalities are a concern for those involved in the accident as well as the first response teams and emergency medical services (EMS). This study aims at predicting the fatality in an accident based on the weather conditions, lighting conditions, road surface type, the severity of an accident, collision type, major cause of the accident, etc. This prediction can prove to be vital for the EMS and rescue(expand on this – find a paper if possible) operations in times where bad weather conditions are foreseen to affect the road conditions. EMS can chart their quick response based on this prediction as well as prioritize the response in case of multiple accidents at multiple locations. This can also be effective in improving weather warnings for road transportation.

**Research question:** How are road accident fatalities related to weather conditions, light conditions, the severity of the accident, the influence of drug and alcohol, the major cause of an accident, extent of property damage, and road conditions?

# Related Work

## Effects of climate on alcohol consumption

Ventura-Cots et al [1] conducted a study of the relation between colder climates specifically the mean temperature and the number of hours of sunshine and alcohol consumption. Countries were categorized into tropical, dry, temperate, continental, and polar in their study, and religious subgroups that affected the alcohol consumption were removed from the study to avoid bias. The study was conducted in many countries with a focus on the US and its 3142 counties. Since the US is a vast geographic area, some areas like Hawaii and Florida which are recreational areas may have a deep cultural correlation with alcohol consumption. The overall results confirmed that in the U.S., the colder climate had a positive correlation with alcohol consumption i.e. the colder the climate higher the consumption of alcohol. Even though a strong correlation of alcohol consumption and the colder climate was found in this study, Ventura-Cots et al note that other factors, such as religion, economic, educational, or cultural influences, may also have a major impact on some regions.

Hagstro¨m et al [2] conducted a similar study specific to Sweden. This study applied a generalized additive model, adjusted for the region to study the association between mean sunlight hours and mean temperature with mean alcohol consumption. Their study found a non-linear inverse association between mean temperature and mean alcohol consumption. They did not find any association between mean sunlight hours and mean alcohol consumption. This contrasted with the Southern European countries where they saw a positive correlation between cold climate and alcohol consumption. This shows that the relation between climate and alcohol consumption may be dependent on the geographies.

Jepsen P and Grainge MJ [8] extend the study of Ventura-Cots et al and they found that mean temperature and hours of sunlight may not have a direct correlation on the consumption of alcohol. Other confounding factors of religion, culture, education, and other socio-cultural factors have a greater effect on alcohol consumption behavior in a region. However, since a geographic location, its sociocultural factors, and the mean temperature and hours of sunlight cannot be separated, alcohol consumption can easily be attributed to temperature instead of the sociocultural factors.

Beau J. Freund et al [5] mention of reports that show a benefit in the ingestion of alcohol during cold weather which led the German and Russian military leaders to recommend alcohol consumption is small doses during World War II. The effects of alcohol consumption in extreme cold are also presumed to protect against cold-related injuries like frostbite while also improving sleep and reducing discomfort. This study also analyses the confounding factors that may have resulted in the conflicting scientific findings on the effects of alcohol on the thermoregulatory mechanism in the body. These factors include the quantity of alcohol ingested, the severity of the cold stress, the nutritional state of the individual, composition of the drink, body composition of the individual, and alcohol tolerance of the individual. This study also found that nearly all subjects reported less discomfort during cold exposure following alcohol ingestion even though the core body temperature was lower.

Delaney L et al [9] in their study of drinking patterns in Ireland studied the drinking habits and patterns of students from University College Dublin (UCD). They note in their study that historically when heating was a major problem in Irish homes the notorious weather of Ireland must have played a part in culturally making excessive drinking seem normal. However, other factors influence this drinking pattern as well - namely religion, the role of English cultural influence, and the brewing and distilling industry.

## Predicting fatalities in road accidents

Liling Li et al [10] studied the road accident fatalities using data mining techniques and with a focus on providing better emergency medical services (EMS) to the victims of road accidents. Their study found that environmental factors like weather, road surface, and light conditions do not affect the fatality rate whereas other factors like driver being drunk or not, type of collision location of the collision have a strong association with fatalities.

Pisano et al [11] studied the U.S. highway crashes in adverse weather conditions and found that the weather has a significant impact on road safety. Almost a quarter of road accidents in the US are weather-related. Their study concluded that more research is needed on weather-related crashes to help understand the factors affecting the crashes and to take preemptive measures to avoid fatalities.

N. F. Fadilah Yaacob, N. Rusli and S. N. Bohari [12] used the ordinary least square (OLS) regression to study the accidents in the Kedah state in Malaysia. The effects of unfavorable weather such as heavy rainfall, wind, temperature and road surface on road accidents were studied. They found that specific weather conditions of cold weather, medium wind speeds and low to medium rainfall were a contributing factor in most of the accidents.

M. Zheng et al. [13] studied the traffic accident severity prediction based on neural networks and they proposed a novel approach to accident severity prediction based on the TASP-CNN model, especially the FM2GI algorithm. Their results showed that drinking and driving, seatbelt use, vehicle type, collision type, contributing circumstances leading to driver/vehicle action, number of vehicles involved in the accident, and accident location were the key determinants of injury severity outcomes in accidents. The neural network TASP-CNN model proved to be better than the traditional statistical models of K-nearest neighbor algorithm (K-NN), Naive Bayes' classifiers, Logistic regression, Gradient boosting and Support vector machines in predicting the severity of the accidents.

X. Xia, B. Nan and C. Xu [7] studied the real time traffic accident severity prediction using data mining and machine learning. They studied the traffic accidents in Seattle from the year 2010 to 2015. Machine learning models that were used in this study are: Naïve Bayes, Random Forest, MLP and AdaBoost. They built classification models to predict the accident severity into two classes: Property Damage only and Injury Collision. Data preprocessing was done prior to application of machine learning models. The performance of their models was significant with AdaBoost performing the best with an F1 score of 0.86 and AUC of 0.91. While the Naïve Bayes performed the worst among the models chosen with a F1 score of 0.81 and AUC of 0.88.

A picture containing table, sitting, lot, many

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# Data Mining Methodology

Both studies were conducted in accordance with the cross-industry process for data mining (CRISP-DM) methodology as it provides a structured approach to a data mining project. Each step of the CRISP-DM is detailed below for both the studies.

## Business understanding

### Effects of climate on alcohol consumption

Objective – This study aims to predict alcohol sales based on the weather in the state of Iowa, USA. This prediction can be used to forecast the alcohol consumption (sales) based on weather forecasts. Also, since alcohol consumption in cold weather increases the chances of a person suffering from hypothermia and frost bite[14], this prediction can prove to be an early warning system for emergency medical services if a sudden drop in temperature is expected.

Tools and techniques - Statistical computing language R is used to perform data pre-processing and model building. Machine learning techniques of multiple linear regression and support vector regression are used to predict alcohol consumption (sales).

### Predicting fatalities in road accidents

Objective - The objective of this study is to analyze the relationship between a fatality in a road accident and the weather conditions, road conditions, cause of an accident, type of impact, number of cars involved in an accident, light conditions, etc. This information and prediction can be important for emergency medical services and local police departments in their decision making process and prioritizing the early response teams.

Tools and techniques - Statistical computing language R is used to perform data pre-processing and model building. Machine learning techniques of Logistic Regression, Naïve Bayes Classifier, and Support Vector Machine are used to predict the road accident fatality.

## Data understanding

### Effects of climate on alcohol consumption

Data collection - The alcohol sales data was acquired from the Iowa state government website. This dataset provides data for every sale made to a dealer by the state of Iowa. Each sale entry consists of data fields of date and time, store name, store location, item purchased, category of alcohol, quantity, volume, and price of alcohol sold. This dataset was in comma-separated values (CSV) format and had 4464376 rows and 24 columns.

National Centers for Environmental Information - This dataset gives location and station wise data of climate conditions of temperature, humidity, precipitation, snowfall, etc. Data is available from multiple stations spread over the state of Iowa, USA. This dataset had a lot of missing values as every station reports a particular type of data. This data was consolidated by date and county to get a concise dataset. The raw data was split over two CSV files with 10773 and 106654 rows and 62 columns and was downloaded from the National Centers for Environmental Information portal.

Iowa State has winters during the months of December, January, and February. The time series of alcohol sales was plotted for 2015 and 2016 to see if there is any seasonality to show that alcohol sales increase during the winters.

Moving average of 5 was used to smooth the time series plot. The red boxes show the sales in the month of December whereas the orange boxes show the sales in the month of January. The alcohol sales peak in December and then drop considerably in January. This can be attributed to the festivities in the month of December.

The weather datasets follow the Global Historical Climatology Network (GHCN) - daily documentation format. This is a well-defined documentation method and is used by GHCN which is an integrated database of climate summaries from land surface stations across the globe. Every data column has an associated attributes column which contains information about the data collection time and quality of data. The column names are in the GHCN abbreviation format. The documentation from GHCN was used to understand the values in each column. Factors like minimum and maximum temperature, precipitation, and snowfall were used in this study.

### Predicting fatalities in road accidents

Data collection - The road accident data was acquired from the Iowa state government website. This dataset has a record of every accident in Iowa state. This dataset was in comma-separated values (CSV) format and had 1048575 rows and 37 columns. The details and circumstances of every accident are recorded in this dataset.

The accidents dataset contains details like Department of Transportation (DOT) case number, Crash Date, Location information, Major Cause, Crash Manner, Crash Severity, Surface Conditions, Drug or Alcohol involvement, Light Conditions, Weather, Roadway Junction, First Harmful Event, Number of Vehicles and Occupants, etc.

## Data preparation

### Effects of climate on alcohol consumption

Cleaning the alcohol sales data - The date column was first converted to a standard format using the anytime package. The dataset was then filtered to use the data for the years 2015 and 2016. This data had 99348 missing county values. County values play an important part in this study as the alcohol and weather datasets are combined using Date and County information. These 99348 missing country values were populated using the FCC census API using the latitude and longitude information present in the data.

**API Request example:**

https://geo.fcc.gov/api/census/area?lat=42.63390&lon=-96.29007&format=json

**API Response example:**

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      "lon":-96.29007

},  
   "results":[

      {

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         "bbox":[

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            42.633361,  
            -96.285638,  
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A close up of a white wall

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         "rea":"REA003",  
         "Fig":"Map of Iowa with red dots representing locations of weather station in red and alcohol stores in yellow."         "rpc":"RPC003",  
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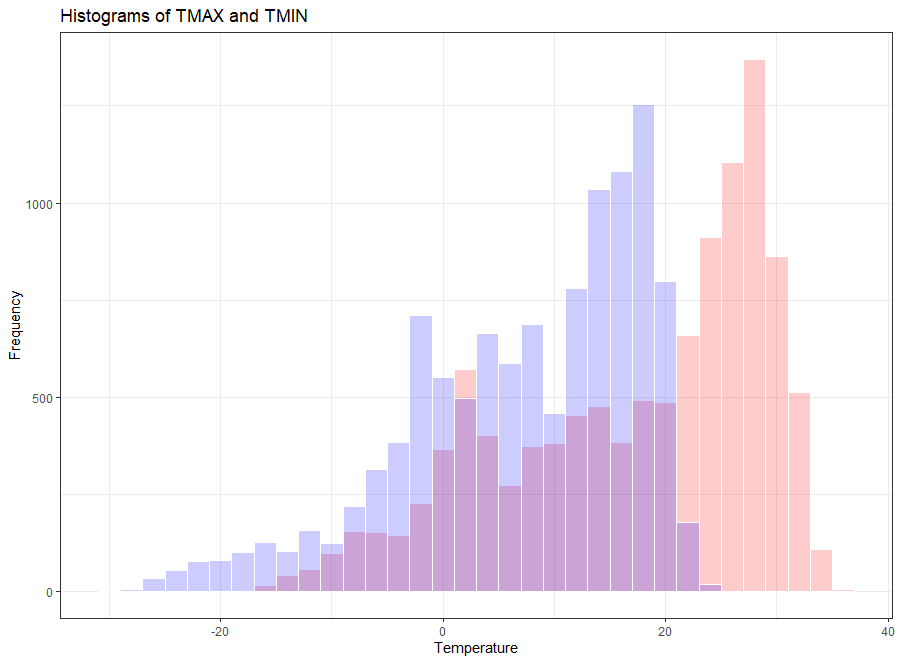
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An aggregate dataset was created from this dataset. Sales of all the stores in a county for a date were added to give a single row per day per county which gives the total sales of liquor in a county by date.

A screenshot of a social media post

Description automatically generatedTemperature, precipitation, snowfall, and wind data were used in this study. From the histogram of temperatures, it is seen that the minimum and maximum temperatures have a similar distribution with different means. The histograms of precipitation and wind also give an idea about their distribution.

### Predicting fatalities in road accidents

The road accidents dataset had very little noise and missing values. The Occupants (number of occupants involved in the accident) column had outliers that seem to be errors. The accidents that contained more than 30 occupants were removed from the study to reduce erroneous variance in the model. The occupants still had a few outliers in the data however they are attributed to a greater number of cars involved in an accident.

From the descriptive graphs about the major cause, light conditions, and road surface conditions it is seen that most of the fatalities in a road accident occurred in daylight and on dry road conditions. Also, the major cause of road accident fatality is a loss of control while driving. All these factors lead us to believe that adverse weather and road conditions are not the A screenshot of a cell phone

Description automatically generatedmajor factors of road accident fatality. There is some other confounding factor that causes more accidents during ideal driving conditions. As pointed out by N. F. Fadilah Yaacob, N. Rusli, and S. N. Bohari [12] in their study of road accidents in Kedah, people are more cautious when the weather and road conditions are bad whereas they are relaxed and casual when the conditions are good. Although this might seem contrary to what should be happening, this is an important causality to consider in this study.

One additional column for Fatality was added to the data which takes a binary value of 0 or 1. The value of this column is 0 if there is no death in an accident and it is 1 if there is a death in an accident.

## A screenshot of a computer Description automatically generatedModeling

### Effects of climate on alcohol consumption

A picture containing object, light, parked, table

Description automatically generatedRegression analysis was conducted in this study to predict alcohol consumption based on weather conditions like temperature, snowfall, and precipitation. The following regression models were implemented:

#### Multiple Linear Regression

Multiple linear regression is a supervised parametric model that tries to fit a straight line that explains the variance in the dependent variable based on the variance in the independent variables. The equation of the hyperplane is as follows in this study:

*Yi (Alcohol Sales in USD) = B0 + B1 (precipitation) + B2(Snowfall) + B3(Snow depth) + B4(Minimum Temperature) + B5(Maximum Temperature) + B6 (wind speed)*

Ridge, Lasso, and Elastic Net regularization techniques were also applied in this study to reduce overfitting by adding a penalty parameter that aims to add a penalty term to reduce overfitting. K-fold cross-validation was also undertaken to avoid the overfitting of the model.

Multiple regression was chosen for this study as it offers easy and fast implementation and fast training of the model. Regularization parameters can also be added to the model to avoid overfitting.

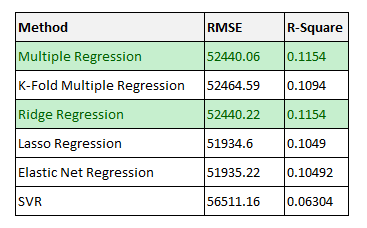
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#### Support Vector Regression

In contrast to ordinary least squares (OLS), the objective function of support vector regression (SVR) is to minimize the coefficients — more specifically, the L2-norm (L2 norm is calculated as the square root of the sum of the squared vector values) of the coefficient vector — not the squared error.

SVR is a non-linear regression model whereas Multiple Linear Regression is a linear regression method. SVR was chosen for this study to check how a non-linear regression method performs in contrast to a linear regression method.

### Predicting fatalities in road accidents

This study was conducted to predict road accident fatalities based on the accident circumstances and the environment of the accident. This dataset is unbalanced as the number of accidents with fatalities is very small as compared to the number of accidents without fatalities.

#### Logistic Regression

The target variable is a binary variable, Fatality which takes a value of 1 in case of an accident-related death and 0 if there was no death in the accident. Logistic regression predicts the probability of occurrence of an outcome. The probability threshold of 0.5 is usually used to separate the outcome. However, since predicting a fatality in an accident is more important than predicting a non-fatal accident, a probability threshold of 0.4 was used in this study. Chi-square tests were conducted on the dependent and independent variables and the independent variables were found to correlate with the dependent variable.

Also, to remedy the unbalanced dataset, weights were used while building the logistic regression model. Since the dataset was unbalanced in a 1:35 ratio, weight of 1 was added to accidents with no fatality and a weight of 30 was added to accidents with fatality. Logistic regression was performed with and without weights. The results of both these models are discussed in the evaluation section below.

Logistic regression was chosen in this study as it is designed to work on data where the dependent variable is binary in nature.

#### Naïve Bayes

Naive Bayes is a generative model (it considers the conditional probability of the observations given that the target variable holds true) in contrast to Logistic Regression which is a discriminative model (it considers the conditional probability of the target variable given an observation holds true).

Naïve Bayes was chosen in this study as it works best when the independent variables are not dependent on each other and because it is not sensitive to irrelevant data.

Naïve Bayes was implemented with and without Laplace smoothing. Laplace smoothing was implemented as a fail-safe method so that the model does not classify inaccurately if the test data was never seen in the train data before. That is, since Naïve Bayes works on probabilities this smoothing prevents the model from generating infinite probability when the probability of the factor in the denominator is 0. Laplace smoothing generated a slightly better result with a recall of 0.8659 against the recall of 0.8547 achieved without Laplace smoothing.

#### Support Vector Machine

SVM uses a maximal error margin threshold to calculate the hyperplane that will divide the data into distinct classes.

Both Linear and Radial kernels were used to build SVM models. Both of these models were evaluated to check which one performs better in this study.

SVM was chosen for this study as it uses kernel trick to solve complex data problems and because outliers can be handled with a soft margin.

# Evaluation

## Effects of climate on alcohol consumption

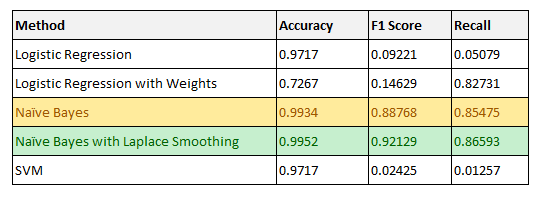
For this study, a sample data of two years 2015 and 2016 was chosen for both the alcohol sales and weather. This data was reduced even further by performing an inner join on these datasets using the common data column of Date.

Multiple Regression with regularization techniques and cross-validation was performed in this study. The weather parameters like temperature, wind, snow, and precipitation do not show any significant correlation to alcohol consumption in the state of Iowa, USA as can be seen from the evaluation metrics below.

This means that either the alcohol sales in Iowa are not related to weather conditions or the alcohol sales do not deviate from the mean as much to generate any significant results.

## Predicting fatalities in road accidents

The dataset of accidents obtained for this study contained the accident data from the year 2008 to 2018. A sample of the years 2015 and 2016 was chosen for this study.

A close up of a map

Description automatically generatedThe dependent variable in this study is Fatality. 1 represents the accidents in which there was a fatality and 0 represents an accident where there are no fatalities.

A close up of a map

Description automatically generatedThis dataset is highly unbalanced, and hence we cannot use accuracy to evaluate the model performance. Here predicting death in a road accident is more important than predicting the accidents which do not have death. That is why Recall and F1 score along with Area Under Receiver Operating Characteristics (AUROC) are used to evaluate the model performance.

In the study of road accident fatalities, the correct detection of a fatality is more important than the correct detection of a non-fatal accident. To correctly evaluate the models for this criterion, I used the recall for detection of a fatality in the test dataset as a metric of evaluation. Three classification models were used in this study, Logistic Regression, Naïve Bayes, and Support Vector Machine. From the evaluation metrics mentioned above, we can see that the Naïve Bayes model outperforms the rest of the models.

The recall for detection of a fatality in an accident is 85.45% in Naïve Bayes classifier. This means that the model detects a fatality in an accident correctly 85.45% of the time. Which seems like a reasonably well-performing model.

# Conclusion and Future Work

## Effects of climate on alcohol consumption

This paper looked at the effects of weather conditions like temperature, wind, precipitation and snow on the consumption of alcohol in the state of Iowa, USA. The analysis concluded that there is no significant relation between weather conditions and the pattern of alcohol consumption.

The main problem during data gathering and cleaning was with the unavailability of a proper source of weather data. The weather data from the National Centers for Environmental A screenshot of a cell phone

Description automatically generatedInformation portal had many parameters that were not usable due to lot of NA values.

Future studies on this topic can refer to a more reliable weather data source that provides details of other weather parameters like humidity, sunshine time, weather type, etc. The alcohol stores and weather stations are not evenly distributed in the state of Iowa as can be seen from figure. Weather and alcohol sales data can be appropriately weighted to provide a standardized measure across the whole state. Also, future studies can check if there exists a relation in weather with the type of alcohol like Whiskey, Beer, Rum, etc.

## Predicting fatalities in road accidents

The results of this study determine that there is a relation between the weather conditions, road surface conditions, severity of collision, number of vehicles, type of collision, major cause, light conditions, extent of property damage and if drugs and alcohol were involved in an accident to whether there will be a fatality in the accident. The Naïve Bayes classification outperforms other classification models of Logistic Regression and SVM.

Future studies on this topic can take into consideration the geographic accident information as well as the geo-hotspots of accidents as can be seen from the accidents map in figure. Other features like day and time can be used to find a pattern in the accidents over a week, month or a year. Future studies can also take into consideration the Emergency Medical Services (EMS) and study the relation between a road accident fatality and the EMS quick response process.

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