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Traffic monitoring and warnings for winter roads

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Abstract

This master thesis reports on the research of how weather affects driving patterns during the winter. By utilizing Python, data was analyzed to show how much different weather phenomena affects the total amount of traffic. Showing how things like precipitation, temperatures, wind, snow depth affects said amount. The result of the analysis shows the effect the various weather conditions have on car behaviour and considers what measures should be taken to ensure road safety.

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1 Introduction

1.1 Background

Norway is a country that has a wide range of weather. Be that warm summers or cold winters. This shift in temperature and climate has a big effect on how we behave and how we travel. This is especially true during winter, where the ice and snow can cause issues for drivers, and sometimes close roads. This is an issue as, the combination of Norway being elongated and mountainous, often results in there only being one possible road for someone to travel on, and rerouting options being virtually nonexistent. And even if there are potential options, bureaucracy and budget might not always make expansion of the road network feasible. This is not as much of a problem in the southern parts of the country, where options for alternate paths are plentiful. However, the further north you get in Norway, the scarcer the potential options become. With the main road that serves as the primary connection point being E6. Combine this with an overall lack of options when it comes to trains and planes in the north, and you have a lot of reliance on the roads to be working for the economy to function. As such there are a lot of roads that are extra important, as them shutting down for any reason can cause trouble, be that for your everyday drivers, emergency vehicles or trucks transporting wares and food all over the country. One example of this is Saltfjellet. As can be seen on the figure 1.1 retrieved from [1]

Figure 1.1: Map displaying the road leading north from Mo i Rana over Saltfjellet

The figure shows the main roads of Norway and Sweden, with the gray line representing the border, and the orange roads being the primary roads of each nation. As can be seen, there are not a lot of options available, and you would need to take a detour if it is closed over any length of time. This effectively cuts the country in half. These closings are a lot more likely during the winter, as a combination of wind, and icy road, can create dangerous driving conditions that might lead to either crashes or cars being stuck due to bad traction. Something that requires a lot of maintenance, to try and help reduce the risks. Part of why this is an issue during the winter is that there is generally an uptick in the amount of wind as can be seen in the figure 1.2

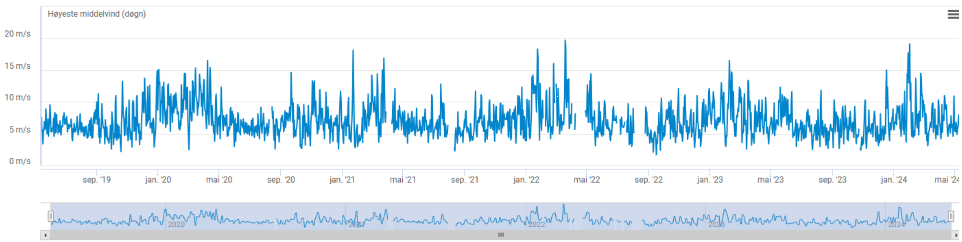

Figure 1.2: Average wind per day for the last 5 years on Saltfjellet

that has been retrieved from Norsk Klimacenter [2], which helps highlight the more windy months, that are usually around winter. Of course, while Saltfjellet is one of the more vulnerable points, due to being located on E6, there are a lot more places that are vulnerable. A lot of these points are in the more mountainous areas, which can create another issue, whereas if a car potentially gets stuck, or must stop and wait for the road to open, the low temperatures can also cause issues if people suddenly have to wait in places, and they are lacking proper clothing or their electric car runs out of power. This can cause a lot of uncertainty during the winter in places like Narvik where a lot of its road are vulnerable to bad weather.

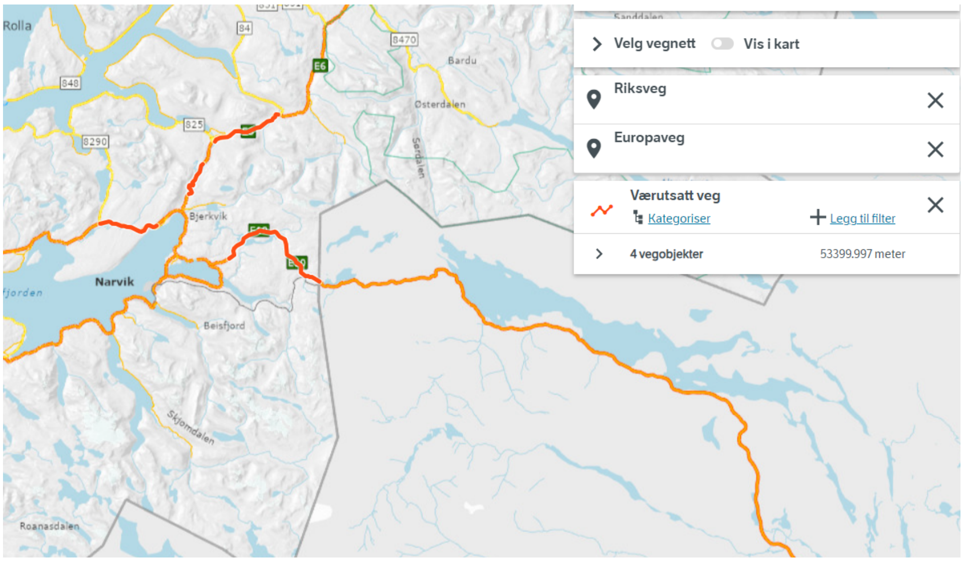

Figure 1.3: Map displaying the roads leading north east and west from Narvik, with areas that are vulnerable for bad weather being marked in red.

The figure 1.3 from [3] shows how all three different paths leading north are all vulnerable. Due to all of this, it is of particular interest of the government and Vegvesenet to create a system that can be used to create predictions and warnings based on weather patterns. One of the main projects surrounding this task is by Vegvesenet and is called «Forutsigbart framkommelige fjelloverganger" [4]. This project is planned to last from 2022 to 2026 and has 4 main work packages that are meant to help 23 mountain passes that are particularly exposed to be safer. These packages are first meant to help set up sensors to help monitor weather, and traffic conditions. Then the various IT solutions are meant to help give proper support to what decisions construction managers and road contractors should perform. And to give information to emergency vehicles, civilian cars, and transport vehicles, to help them make informed decisions. After all the necessary people have been informed, actions like expansions of the road and building of milling fields, avalanche structures, and other potential buildings are to be considered if there is a need and a budget. This is to be done in such a way that there will be an environment created where various innovations and ideas, can be potentially created and funded. Which is where this project comes into play as there is a desire to create a solution that can help both operating contractors and drivers. By collecting data when it comes to weather and driver behavior. This project is meant to help with trying to find a potential solution that can be used for further work. Not just in Narvik, but as a potential tool for usage all over the country.

1.2 Literature review

Naturally Norway isn't the only country in the world that has issues with bad driving conditions, some other countries like the US also needs to deal with icy roads and bad weather. And as such has come up with their own solutions as well. As can be seen by the study "Use of ice detection sensors for improving winter road safety."[5]. The study highlights how various camera technologies and sensor like Visible wavelength camera imaging and Infrared spectroscopy can be used to determine whether or not the road is too icy. Said sensors can then be connected to warning signs in what is called an Intelligent Transportation Systems (ITS). With one such system being implemented in Fredonyer Pass, California, resulting in a 15 percent reduction of annual crashes, and safety benefits that surpass 1 million dollars, being saved. These kinds of studies have also been performed in other Scandinavian countries like Finland, with studies such as "Effects of Weather-Controlled VariableSpeed Limits and Warning Signs on Driver Behavior", that was done on E18 [6], helps highlight effect of Variable Messaging Signs (VMS). Said signs having a noticeable effect on reducing the average speed of the drivers. With a noticeable bigger effect on drivers during the Winter, then During the Summer. Especially when it was adverse weather. There was also a bigger decrease in average speed, when the sign warned about something that wasn't immediately noticeable. In conjunction with this, some studies like the one performed on crashes in Germany between 2006 and 2017 called "Weather impacts on various types of road crashes: a quantitative analysis using generalized additive models[7]" has been used to better grasp the effect weather has on vehicles. By using a relative risk increase (RRI) to determine how likely a car was to crash when there was precipitation in comparison to when it wasn't any. This resulted in an overall crash increase, with Single-truck crashes showing the largest RRI with an 872.9 percent. increase in crashes. And While the thesis is primarily going to cover human drivers, as technology advances and self driving cars become more and more common, taking into consideration autonomous vehicles and making sure that they are able to properly handle the weather. This has been a topic for a while as can be seen from the study "The Impact of Adversary Weather Conditions on Autonomous Vehicles [8]". The study highlights how things like rain, snow and fog can negatively affect the radar of said cars.

1.3 Problem description

The main objective is to investigate several aspects of road condition monitoring, probability models, and traffic flow and -interaction. The results can ultimately be used in the development of a simulator for traffic scenarios specified by the Norwegian Public Roads Administration (Statens vegvesen).

The thesis project encompasses three main objectives:

1. Literature survey of the main problem areas, including prediction rates of road closings due to difficult driving conditions, and traffic flow changes.

2. Conceptualization and implementation of a simulator model with focus on traffic, analysis of routing- and flow problems, including feedback between systems and reporting (instrumentation and notifications/alerts).

3. Benchmarking and comparisons for possible case studies and evaluation with respect to real life data.

The project work is expected to make use of different data sources, such as cameras, weather data, and road condition measurements, including data of forecasted and real origin. This is done by taking advantage of the numerous sources and contacts that has been made available to either the public, or can be requested if necessary.

1.4 Research Questions

There are many ways to try and help give early warnings to drivers, in order to help give information ahead of time. Be that trough apps, websites or trough signs along the road. And while apps and websites can afford to have more in depth, signs usually need to be far more concrete and to the point. This is because having too much information can either lead to being a distraction if someone tries to read everything, or to someone passing by to quickly to comprehend everything, and thus not being informed enough. As such my model is designed to try and help understand the drivers to solve three main questions.

1.4.1 What weather affects driver behaviour the most?

In order to fully grasp how to warn drivers it is first important to understand how driver act and behave. As such finding out what might influence when it comes to driving. Due to that looking at what weather patterns might effect them the most and if these patterns possibly changes during the Holidays

1.4.2 How to best convey early warnings?

while understanding the full picture of what affect driving is important, its not always as simple as having the same type of message everywhere. Because, what might have a big effect on drivers in one place, might not always have a big effect on drivers in another place. As such knowing how to convey a warning is just as important as what to convey.

1.5 Limitations

There are naturally going to be some limitations as to what the model can and cannot be used for. As there is not always the same amount of information that can be retrieved from each weather station. Be that because of weather stations having different equipment, lacking equipment, or the stations being built at different times, resulting in lacking data from certain time periods. As an example. The sensor DST111 is commonly used by various weather stations to help measure the surface temperatures of roads, while the DSC211 Remote Road Surface State Sensor is sometimes used in tandem to give more accurate data. However the DSC211 is more expensive and thus less commonly used [9]

2

Method

The primary method I decided to use was to take in use a Principal Component Analysis. By using data from sources such as Frost and Trafikkdata Atlas, it would be possible to create a model where certain patterns related to driver behaviour and cars can be surmised. Said data can then be shown on a relevant map using Omnx and before all this information is then written to a pdf, that can be printed out to give an advised course of action. This is all done in pycharm using the python coding language and its libraries.

2.1 Variables

The first step of the process is to try and decide what variables to use. There are a lot of different variables and values that must be considered and as such I eventually decided on the six that can be seen in figure 2.1

Car Volume	To have a way to see directly how much the car amount changes from day to day
Wind Speed	Which is meant to help determine how much wind affect the behavior of drivers
Precipitation	To see how much Snow, Rain and Hail affects the drivers
Snow Depth	To also determine how much past snow laying on the ground affects the drivers
Temp	Helps show if the cold has much of an affect
Holidays	To help determine if there is a noticeable change in behavior during the easter.

Figure 2.1: The six chosen values that the model will take use off

And as this project is focused on winter roads, I chose to only retrieve data between the 1st of October and the 15th of May as that is when Vegvesenet has its winter readiness.

2.2 Trafikkdata atlas

Once the variables I am after has been decided it is necessary to then go retrieve them. This data is being retrieved from Vegvesenet own API [10] using a query to retrieve the data over a given time directly. By making a request for a certain place using a specific ID relating to an area, one can receive the given number of cars that have passed through. My program will primarily be concerned with daily drivers; however, it is possible to get hourly, monthly and yearly drivers if needed.

2.3 Frost

The way I chose to acquire the weather data was like how I got the number of cars. However, instead of using Vegvesenet's own API. I instead used the Frost. The Frost API provides free access to MET Norway's archive of historical weather and climate data [11]. This data includes quality controlled daily, monthly, and yearly measurements of temperature, precipitation, wind, snow depth and any other data I could need. Other information, like metadata about weather stations, is also available through the API. By using this it is possible to extract the exact weather conditions during a specified period. However, while there are a lot of options available. The amount of data is ultimately limited to what sensors and equipment exists at a given station.

2.4 PCA

Once all the data has been gathered, the information is then converted into a more usable format before I then use it to perform a PCA. Principal component analysis, or PCA, is a dimensionality reduction method designed to help reduce the amount of dimensionality of larger data sets. This is done to reduce the amount of data that is being used to help improve optimization. As such it can be used to help make visualization and analysis much easier for the programmer. This is to make it a lot easier to spot certain patterns when it comes to behavior. There are usually five steps in the process of a PCA[12]

2.4.1 Standardize the data

In order to make the data as usable as possible, the first step is to normalize it. This is done to make sure that each variable contributes equally to the system. This is to make sure that values with bigger ranges such as car volume, wont dominate the entire system. Thus everything is reduced to the same scale. This can be done either manually using the formula below

$$n = \frac{value - mean}{standarddeviation}$$

or it can be done automatically by using the already existing PCA library.

2.4.2 Create a covariance matrix

After the data has been standardized, we need to also see what the relation between each variable is. This is done by creating a covariance matrix in order to see if some variables are highly correlated in such a way that they contain redundant information. This matrix is n x n size big. With n representing the amount of dimensions being used.

2.4.3 Compute Eigenvectors and Values

In order to fully show the relation between the different variables, you need to create eigenvectors and eigenvalues. With Eigenvectors serving as the eigenvectors representing the parts of the covariance matrix where there is most variance, with the eigenvalues representing the amount of variance in each component. By ordering the eigenvectors in relation to the eigenvalues, it is possible to find out how significant each component is.

2.4.4 Create a feature vector

After we have ordered the eigenvectors and eigenvalues, we need to find out what parts to keep. By removing the eigenvalues with the lowest numbers it is possible to get the most amount of accuracy with the least amount of information. However one can still choose to keep each component. The remaining vectors are then combined into a matrix of vectors that we call Feature vector.

2.4.5 Display the data

Once the process is done, we use the feature vector to reorient the data from the original axes to the ones represented by the principal components. Which can then be used in order to analyze the data.

2.5 Experiments

When validating that the model works, it is important to try and collect the most amount of data as possible. This is best done by using data collected from places such as Bjørnfjell and Skitdalshøgda and using that data as a mean of creating a baseline, that can be used to infer drivers behaviours. By changing things like dates, and what variables are being used, a much more clear patter can be formed, to see what actions should be performed and what types of warnings to give in a given situation.

2.6 Osmnx

Once the PCA has been performed and information, has been documented, it is then important to ensure that it is easy for someone who might not be familiar with a given area, to be able to find out where the data is being taken from. By using the Omnx Python Library [13] it is possible to retrieve a map of a specified area. This is done by feeding it coordinates, or a name of a given area. So by also retrieving the latitude and longitude of the station you are asking for information, it is possible to pinpoint the exact area.

2.7 reportlab

And in the end, once all the data has been processed, a recommended action has been given, and a map of the are has been made, all this information, can so be written to a pdf using the Reportlab [14] python library. Said pdf can then be downloaded and distributed to the relevant people if necessary. When all of this comes together it should function like the model shown in figure 2.2. With my implementation of this model, being able to be found at [15].

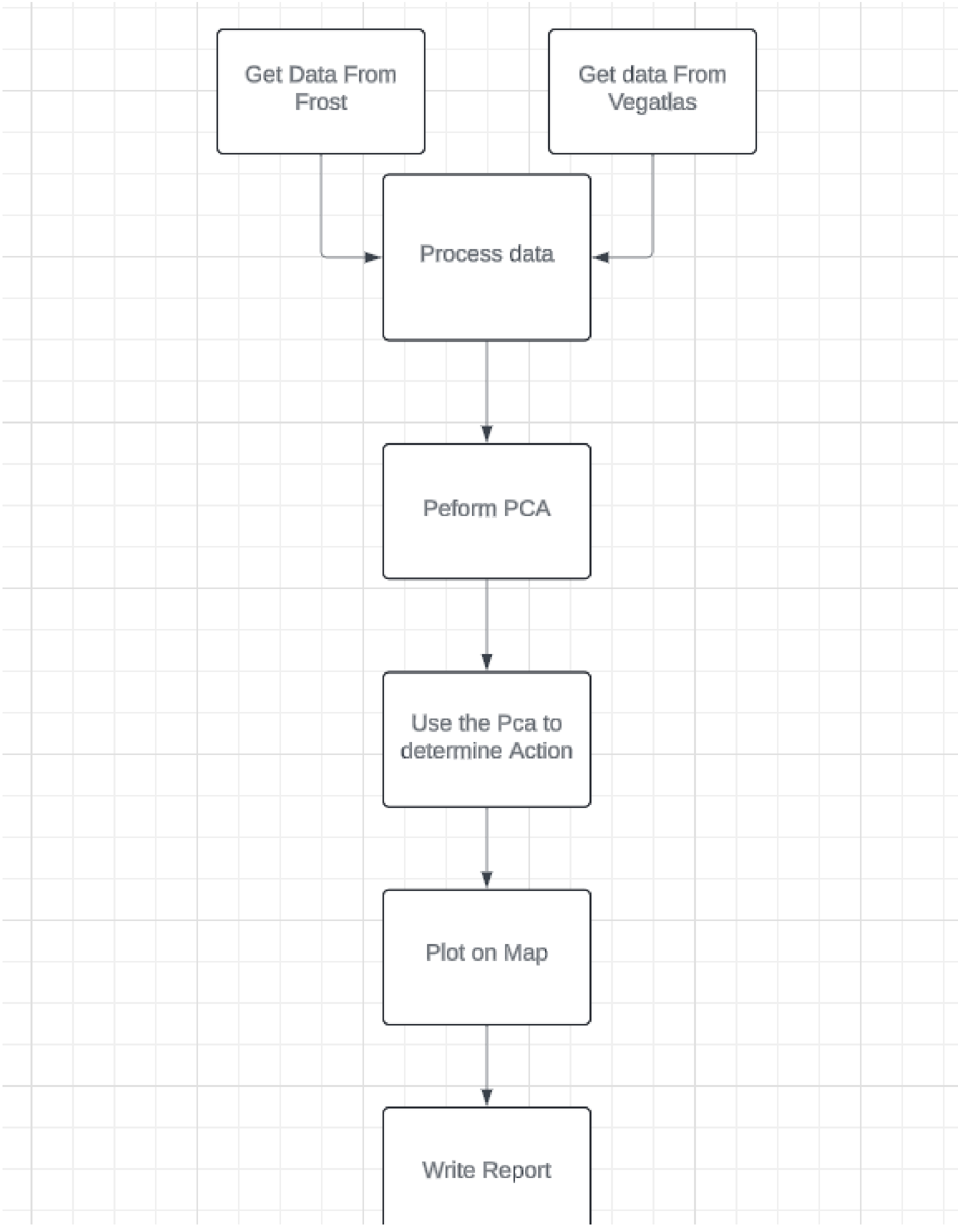

Figure 2.2: A flow chart displaying the proposed process of the model

3 Results

This chapter is dedicated to the result of PCA analysis performed on different areas and time periods, using the same weather types. These areas are all based on different mountain passes located around the country. The results was obtained by using the weather variables in table 2.1, unless specified otherwise. And The different mountain passes are found using Vegvesenet's own website[16]

3.1 What dates has the most cars

To make the most out of later data we first need to see what dates tend to have the most amount of cars.In order to do this, it was chosen to display the amount of cars each day for three winter readiness seasons in a row, as can be seen in the figure 3.1

There is a similar pattern to the amount of cars that are driving during each period, with a noticeable change in the period around April. As such the dates for Easter is chosen to be highlighted for each years. Which can be seen in figure 3.2.

With the dates that represents Easter perfectly aligning with the dates that has the highest increase in drivers. However, due to Easter not being a set date, the highest point of each year, becomes at different points, so in order to get the

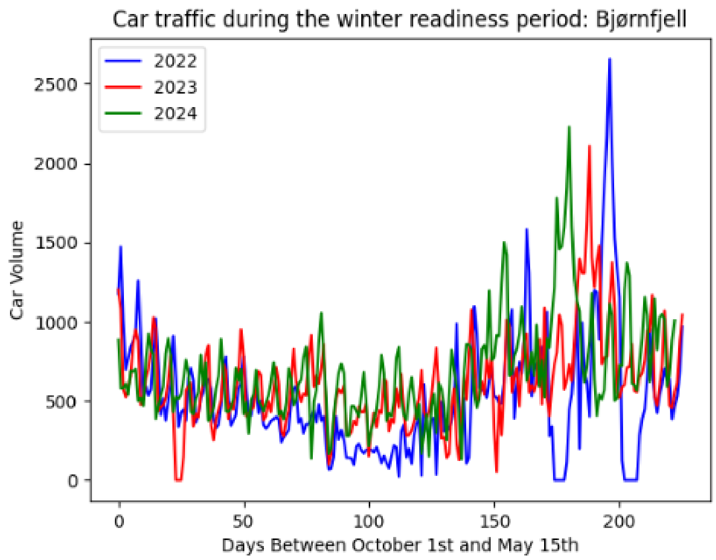

Figure 3.1: A graph showing the total amount of cars during three winter seasons from 2021 to 2024

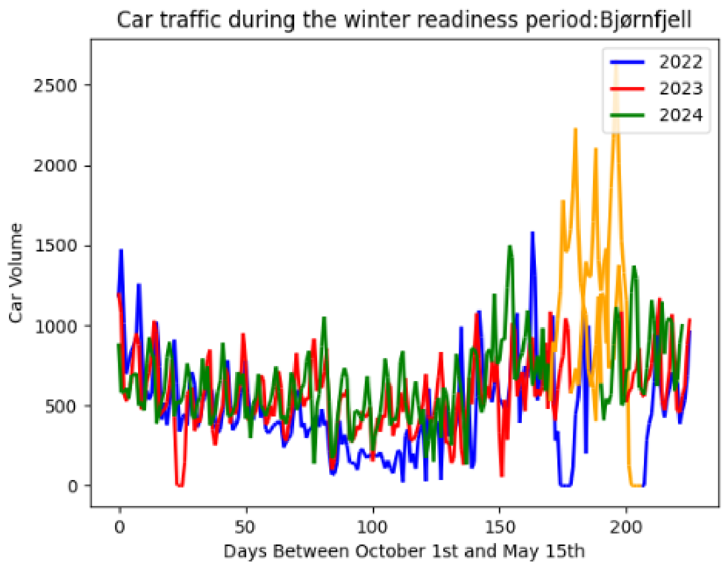

Figure 3.2: A graph showing the total amount of cars during three winter seasons from 2021 to 2024 with Easter highlighted in yellow

dates to line up, to see if there is any significant change between the years, the dates representing Easter was put together in the graph 3.3 below

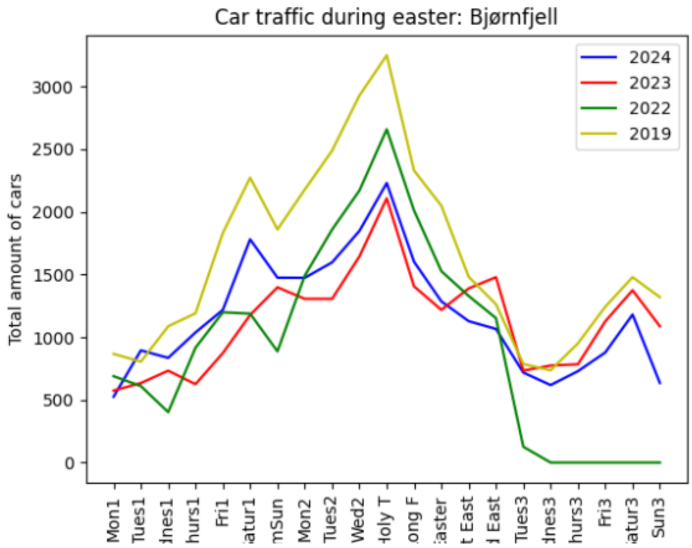

Figure 3.3: A graph showing the total amount of cars during four winter seasons

This graph 3.3 does show that even tho Easter does shift dates from year, to year, there is a clear pattern that forms in relation to the individual dates. With the only outlier being 2022, do to missing data resulting in zero cars being registered for some days. Bjørnfjell is of course not the only place in the country with this pattern. Other locations such as Filefjellet, has similar patterns, as can be seen on the figures 3.4 and 3.5 below.

The total car volume, following the same pattern, with Easter showing a significant increase in traffic.

In comparison the data from the same period, over Saltfjellet, can be seen on the following figure

Where the two graphs in 3.7 and 3.6 shows how as the winter goes on the traffic decreases, and as it goes towards summer it starts to increase again, with a slight increase during the Easter.

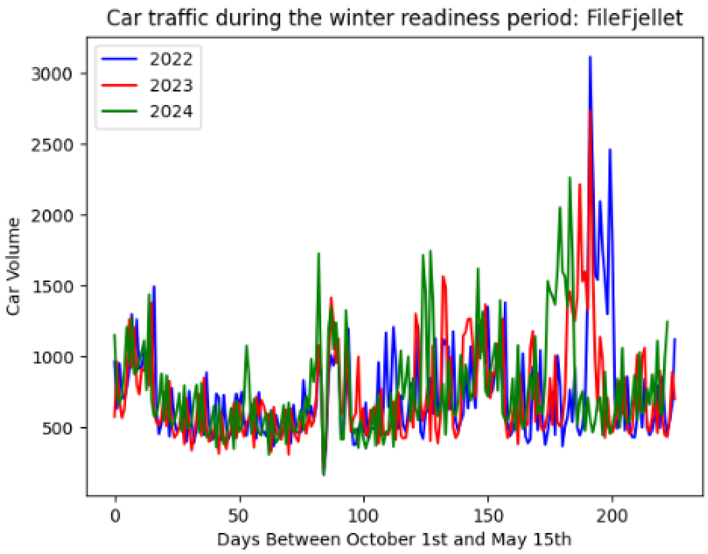

Figure 3.4: A graph showing the total amount of cars during three winter seasons from 2021 to 2024

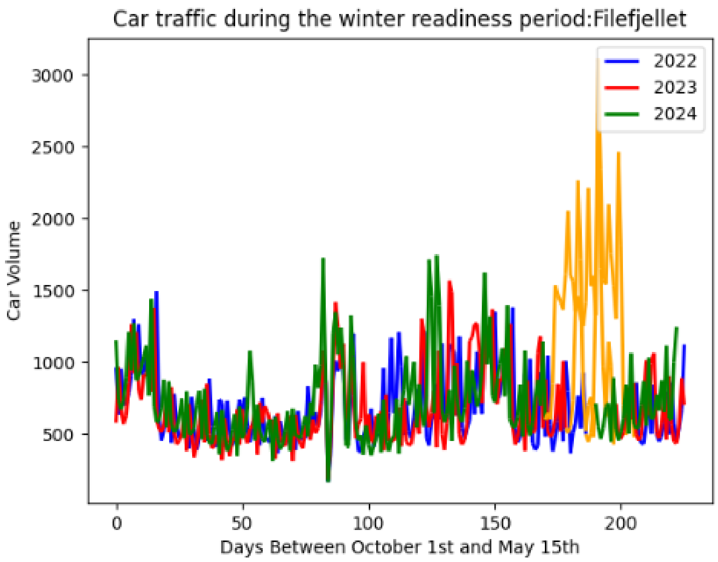

Figure 3.5: A graph showing the total amount of cars during three winter seasons from 2021 to 2024 with Easter highlighted in yellow

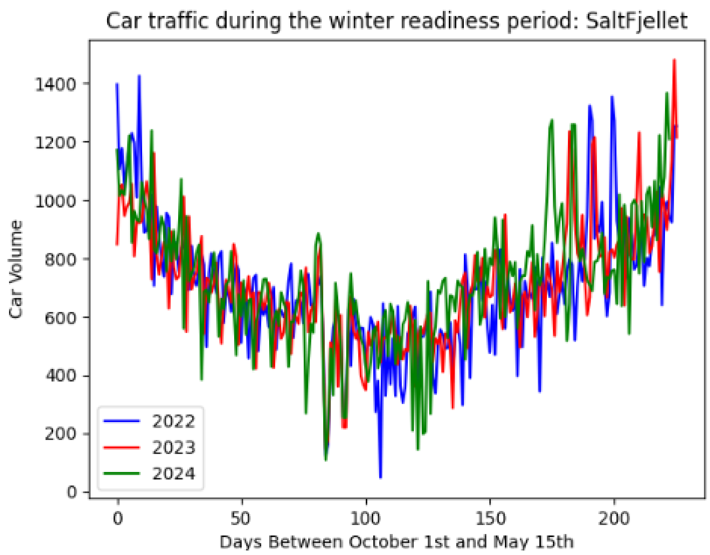

Figure 3.6: A graph showing the total amount of cars during three winter seasons from 2021 to 2024

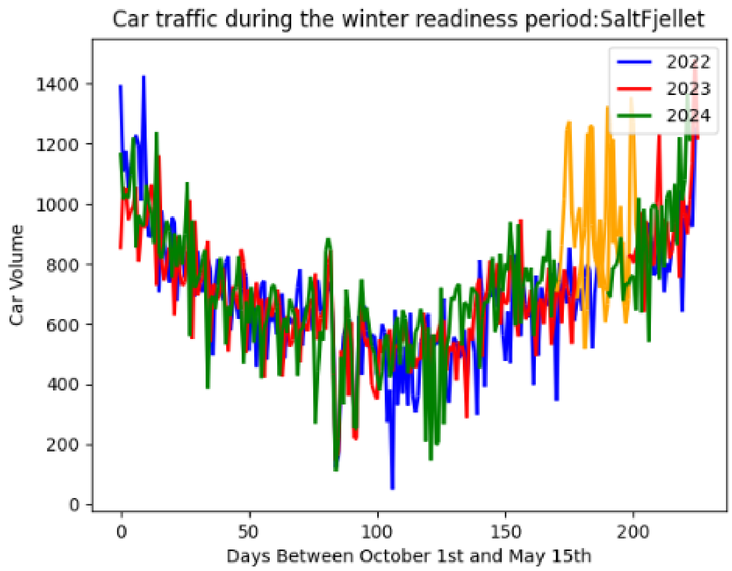

Figure 3.7: A graph showing the total amount of cars during three winter seasons from 2021 to 2024 with Easter highlighted in yellow

3.2 PCA performed on Bjørnfjell

The environment of Bjørnfjell serves is as mentioned rather important when it comes to traffic between Norway and Sweden, as such it is important to try and monitor peoples behaviour in order to predict future actions.

3.2.1 Explained variance of components of PCA

To see what components are needed and which components should be cut, we must first display the variance of each individual component.

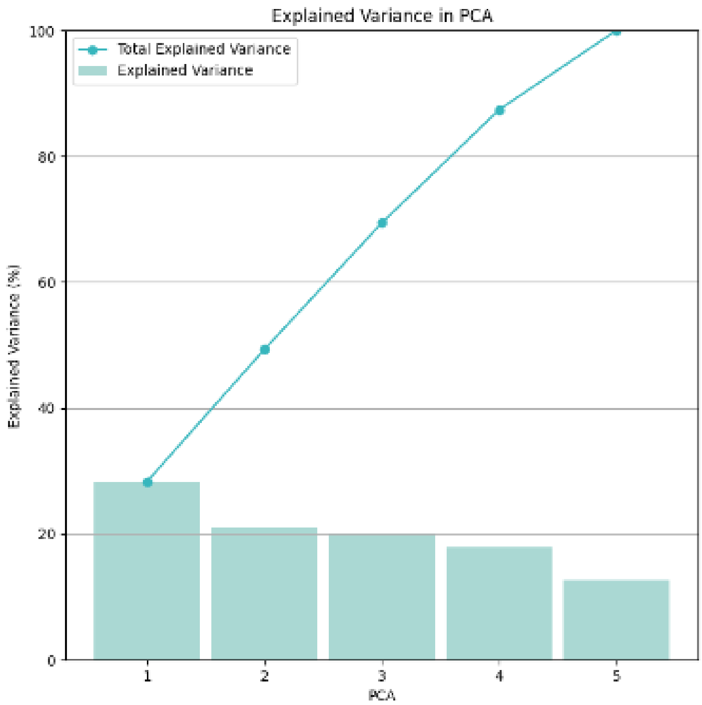

Figure 3.8: A graph showing the explained variance of the PCA with data from the three winter seasons from 3.1

This graph 3.8 helps show how much influence, each given principal component has to the overall accuracy of the PCA model, and how each component does play a significant part. To make sure that the significance of each component was properly taken into account, the program was run again, with the same amount of data, but during a different time frame, resulting in the figure 3.9below.

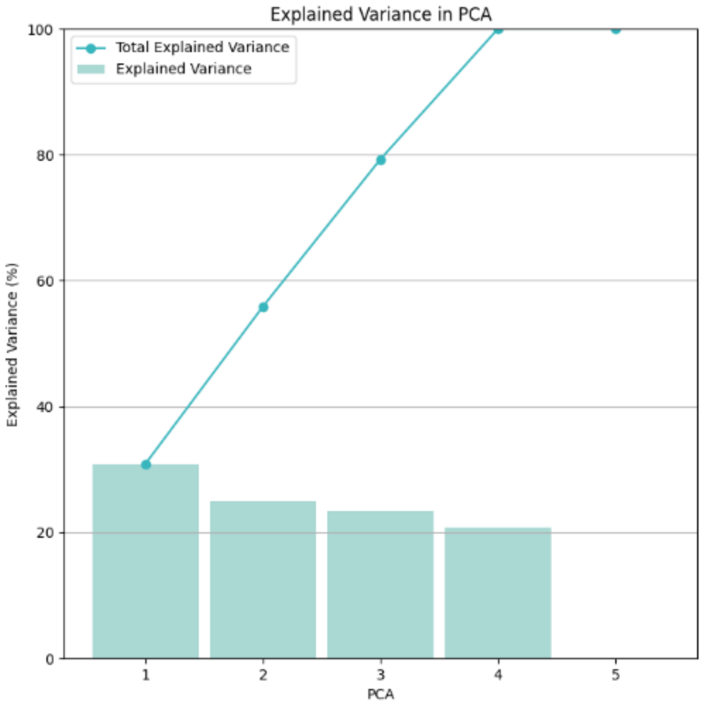

Figure 3.9: A graph showing the explained variance of a PCA with data taken from the summer months

This graph3.9 shows that during this time frame, not all of the components play a significant part and as component five is at zero percent contribution.

3.2.2 Biplot of PCA

Once we have confirmed that all the components are usable, we must then show the relation between each component. In order to properly show this correlation between the different variables, the data was put into a Biplot. Biplot is a type of scatterplot primarily used in PCA. Whereas the original data is represented by principal components that explain the majority of the data variance using the loading vectors and PC scores. The result of this can be seen in figure 3.10 below.

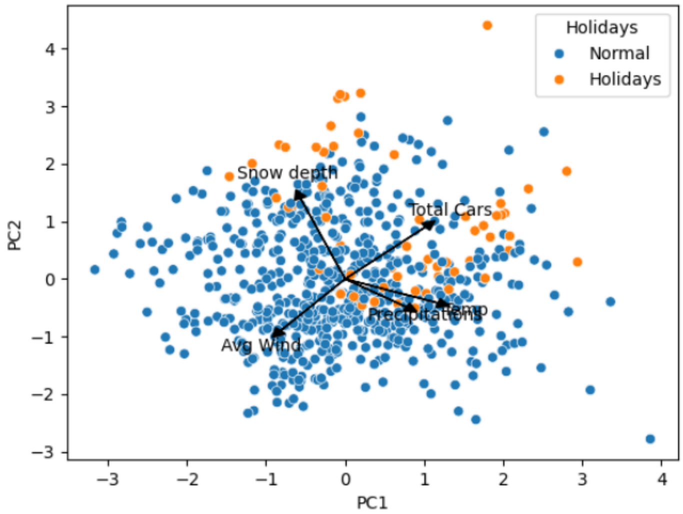

Figure 3.10: A Principal Component Analysis of Data that has been retrieved between from October 2021 to May 2024

The figure 3.10 shows the result of a PCA that has been performed on road and weather data on Bjørnfjell. With the axis representing the two first principal components, traffic volume and average wind speed. and the vectors representing each, eigenvector for each variable in the dataset. The arrangement of these vectors illustrates the relationship between the original features and the principal components. And each data point relating to a separate day with holidays referring to Easter. In order to make sure each year could be analyzed by itself, similar plots were made for each season. As can be seen in figure 3.11 below.

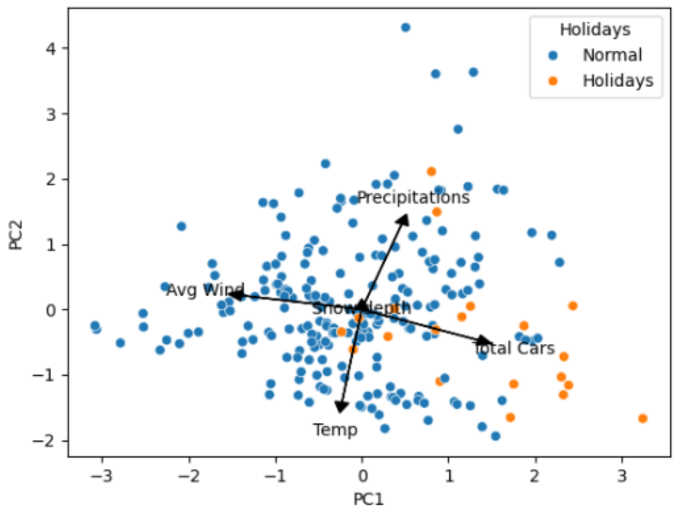

Figure 3.11: A Biplot representing the data retrieved from Bjørnfjell between October 2021 and May 2022

The figure 3.11shows the result of a PCA analysis that has been only performed on the time frame between October 2021 to May 2022. Further on, the same process was done for the next season, as can be seen in the figure 3.12 below.

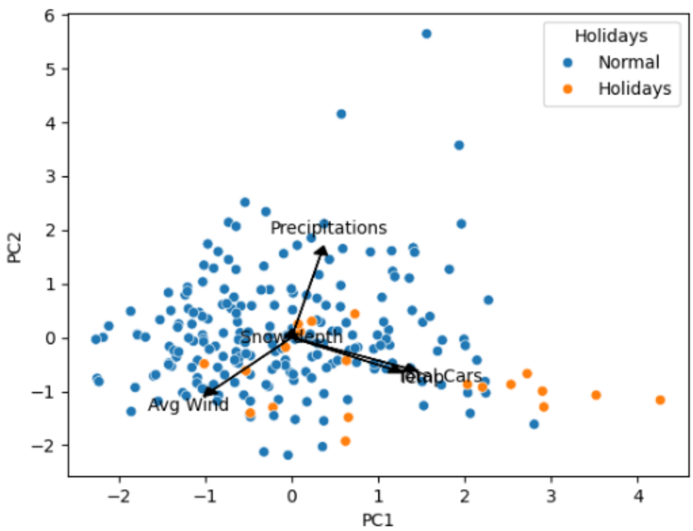

Figure 3.12: A Biplot representing the data retrieved from Bjørnfjell between October 2022 and May 2023

The figure 3.12 shows the result of a PCA that has been performed on road and weather data on Bjørnfjell and has a different relation between each vector than in the figure 3.11

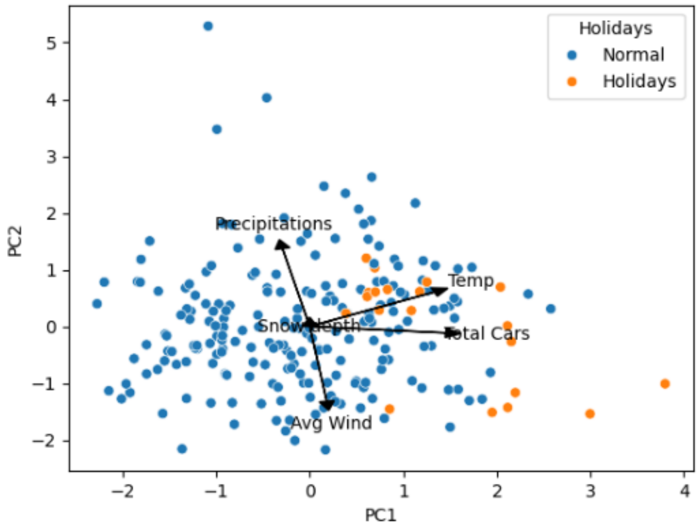

Figure 3.13: A Biplot representing the data retrieved from Bjørnfjell between October 2023 and May 2024

The figure 3.13 takes the same time of year, as 3.11 and 3.12, but during a different year.

The same process was used in order to retrieve data and peform a PCA on information from Filefjellet, the result of which can be seen in the figure 3.14 below.

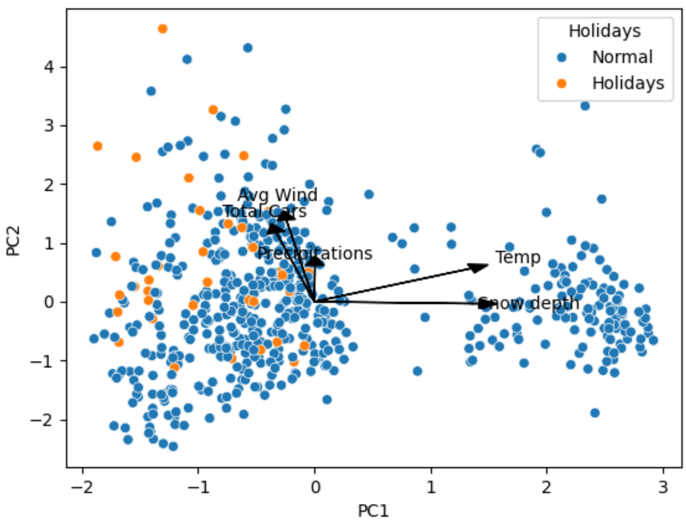

Figure 3.14: A Principal Component Analysis of Data about Filefjellet, in the time period, between October 2021 and May 2023

The figure 3.14 shows the Biplot of the data retrieved from Filefjellet, with the same dates and parameters as 3.10.

3.2.3 Heatmap of PCA

In order to show the relation between each variable and component more clearly, a heatmap representing each value was constructed, as can be seen in the figure 3.15.

Figure 3.15: Heatmap of the PCA

The heat map shows the relation between each component in a clearer way, with lighter colors meaning a negative relation and darker colors meaning a positive relation.

4 Discussion

This chapter comments and discusses the thesis and its results from the Results chapter. Before looking at the results simulation. Python is used for this thesis because it is easy to use and handles both text and numerical parameters elegantly. Having access to packages such as matplotlib, numby and Json makes converting data into graphs and tables a lot easier.

4.1 PCA analysis of Variance graph

As the whole point of a Principal Component Analysis is to reduce the amount of data used while retaining as much accuracy as possible, it important to see if all the components being used are of importance. This is done by creating a variance explanation graph as can be seen in figure 3.8. By looking at each bar in the bar chart it is possible to determine which components are more important to the overall accuracy of the model, and which ones can be safely removed to increase performance. To do this, you need to look for sudden drops between the bars, as that signifies that the accuracy provided by that component is a lot less. This can best be seen on the graph 3.9 that has been made using the summer months as a source. There is no snow on the ground during the period this graph represents, and as such one of the bars represents 0 percent of the overall accuracy and could be safely removed. However, as can be seen on the graph 3.8 from the winter months. There is no snow on the ground, and while it doesn't have the biggest effect, it still has enough effect on the accuracy to not remove. If one were to do all of this properly, one would instead of just having a couple variables, use all of them, and the systematically remove them one by one. Doing it in this way would produce the most optimal result, but would require a lot more computational power, and would therefore slow down the program significantly.

4.2 PCA analysis of Biplot and Heat-map

When it comes to analyzing the four main bi-plots from the figures 3.11, 3.12, 3.13, and 3.10 two things to keep in mind. For starters dots on the map that are close tends to have the same values and depending on if they are positive or negative on the various axis's, they tend to have stronger effects. The other is that the angle that is between the various vectors represents how much each vector is related to each other. With the closer two vectors are being representative of both being correlated. With two of them being at 90 degrees from each other meaning that they aren't likely to have any correlation, and the closer they are to 180 degrees, usually meaning that they are negatively related. Also, Holidays in this scenario represents the days shown in the graphs in figure **??** and **??**, with Normal days being all the other days. By using this analysis there are a few patterns that emerges. For starters wind and total amount of cars are the two vectors that are the most opposed to each other. With them pointing in either completely different directions, or somewhat different directions. This does correlate with what has been explained earlier as wind is usually the most dangerous element when it comes to bad weather, and as such motorists are less likely to drive if the wind is high. Temperature on the other hand is the opposite as higher temperatures seems to make it more likely for drivers to travel. Precipitations and now depth does seem to be neutral in comparison, snow depth being so neutral is likely due to all the days with no snow on the ground, reducing the actual effect it has. This is also well illustrated on the heat-map in figure 3.15. Here it is a lot clearer as the numbers of the heat-map represents the correlation between the different variables and components. With negatives being a negative influence and positive being a positive influence. While this is an example on a road where no real rerouting options exists, it is also important to take into consideration places further south, and how weather might affect them. As can be seen on the figure from 3.14 where it seems to be the opposite. With an increase in wind seemingly having a positive effect on the amount of cars that drives. This is likely due to how Filefjellet is a lot more safe to drive over than the surrounding mountains do to the tunnel . As pointed out in the Article from Teknisk Ukeblad [17], Filefjellet is closed a lot less than the surrounding paths, and thus is more commonly used during bad weather. It is also likely why there are two such distinct clusters, as there isn't as much of a stable flow, as over Bjørnfjell.

4.3 Difference between normal days and Holidays

It is to be expected that there are more drivers during the holidays, as such all the plots 3.11, 3.12 and 3.13. the fact that all the holidays values seem to cluster further along the PC1 axis while remaining relatively the same as the other points on the PC2 axis supports this, with the variance between these values likely being due to how big the difference can be between some of the days. As can be seen in the two figures 3.5 and 3.2. While there is not as big of a difference in 3.7. This is likely do to how Bjørnfjell being right next to Riksgrensen and Filefjellet having a skiing center. Thus resulting in some cars being counted two times in one day as they go to and from the areas, while Saltfjellet, its mostly just being passed trough.

4.4 Early Warnings

As can be seen by comparing the figures in 3.11, 3.12, 3.13 and 3.10, while there is some patterns that can be gleamed, the overall effect weather has on the total amount of cars shifts drastically from year to year. With some variables like wind, usually having a more significant effect on behaviour. However this creates some issues when it comes to drivers. As pointed out in the article "Effects of Weather-Controlled Variable Message Signing on Driver Behaviour [6]". With people often not taking into consideration other weather patterns such as how high amounts of precipitation combined with sudden low temperatures, can make the roads slippery. Thus resulting in the underestimating how dangerous the road conditions are. There is always gonna be a risk involved with people not being properly informed. As such the best way to try and have as accurate warnings as possible is trough Variable Message Signs (VMS). By connecting the VMS to programs that use weather data, trough various programs and models. One can use more localized weather data in order to get the full picture of how the weather and road conditions are gonna be in the future. Something that can be portrayed a lot easier on a VMS, than a regular road sign. And as the article points out. Messages conveyed trough a VMS tends to affect the drivers behavior for longer stretches, thus resulting in more safe driving.

5

Conclusion

This thesis has researched the possibility of creating a PCA to analyze and find out what is most going to have the biggest effect on driver behaviour. The results from the PCA analysis makes sense and are mostly what is to be expected, from past reports of bad weather. With lots of wind being the biggest factor, while other things like precipitation and temperatures also playing a part. Unfortunately, there has been no actual live experiments performed during this thesis, and as such it is not possible to say with certainty that the model can be accurately used to predict outcomes and give drivers an effective warning ahead of time. What weather to expect and how people are going to drive is of course, not always going to be completely accurate as the personal behavior of each driver plays a big part. Also while the model can give some idea given certain parameters. Trying to create a more effective prediction is going to require a lot more data to be fed into the PCA and for a more robust model to be made.

5.1 Future Work

The most important next step for this research would be to further refine the prediction process. In its current state it is only able to find what factors are more likely to affect driving patterns, not using future weather to predict upcoming events. Said prediction process needs to be refined and expanded upon. After that a more practical experiment should be performed to test the actual usefulness of the model and if people listen to it. Further on more refinements should be made to further increase accuracy. And in the end it should be expanded to also take into consideration alternate routes if available, and tell the drivers about them, if they exist.

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