Power Outages and Extreme Weather:

An Exploration of its Effect on the United States

Sean Fang, Jonah Curran, Samantha Greene, Delaney Prescott

Maggie L. Walker Governor's School
for Government and International Studies

Modeling the Future Challenge

Dickson Benesh

March 11, 2022

Contents

Chapter 1

Introduction and Background Information

1.1 Background Information

America is a very technologically driven country, and with these demands for constant power, it is no surprise that power outages can massively disrupt the world around us. In recent years, the issue of power outages has not only affected households, but also businesses. These important institutions are often losing increasingly large amounts of money due to prolonged power outages. A study from the Berkeley National Laboratory indicates that an average of $79 billion is lost every year due to power outages. [Hamachi LaCommare and Eto, 2006] Among these power outages, the biggest cause of this problem is due to inclement weather and severe storms. A study looking at the causes of power outages showed that extreme weather accounted for nearly 80% of all such events in recent years. [Editors, 2014] As such, it is clear that improvements in infrastructure can help modify the outcomes of this event, thereby mitigating the cost and impacts on the people of America.

The image below shows a downed power line. One of the major causes of such downed lines is due to natural occurrences such as trees falling on these lines. Trees fall down for a variety of reasons, many of which are weather related. Ice storms in the winter can cause ice and snow to accumulate on the trees, making them heavier than usual and causing them to tumble. Additionally, strong winds can push down trees, and this can happen at any time of year. [Editors, 2021]

Figure 1.1: A downed power line in Richmond, Virginia

1.2 Project Overview and Problem Statement

1.2.1 Project Overview

Whenever there is a weather alert that comes on the TV, many people immediately start to worry about whether their power will go out. With the absence of power, many American households are put at a stand still - no lights, no air conditioner, no fridge! It becomes a ticking time bomb until the food in the freezer goes bad, or one's phone battery goes out. In addition to everyday people suffering from power loss, the companies that provide the power lose money whenever there is a large storm. It is in their best interest to get the power restored as soon as possible - or prevent it from going out in the first place.

1.2.2 Problem Statement

Power outages are a major problem for both businesses and the American people. This project analyzes the plans and policies the government can make in order to help mitigate the losses incurred due to power outages. Our model depicts which parts of the United States are affected the most by power outages. From this model, we are able to determine which areas need the most attention when looking for solutions to the power outage epidemic. Our solutions include structural changes to limit the effects of severe weather on power lines, as well as possible procedural changes that allow for quicker response when the power does go out. These solutions are also cost effective because even though they have a large initial cost, over time that money will be gained back because there will be less lost from power outages.

1.2.3 Our Work

The United States was split up into nine regions based on climate in order to compare data with similar climate characteristics. We wanted to ensure that the data we were comparing was similar so that our results could be as accurate as possible.

We determined our recommendations based on the areas that were impacted the most by downed lines. Using our climate regions, we made suggestions that would mitigate the weather struggles of the respective areas. For example, building underground power lines may not be the best solution for the northeast, since the land is very rocky and it would be hard to bury large power lines. On the contrary, underground lines may be perfect for the southeast, where there are many harsh weather conditions above ground that could be avoided, and the soil is easily worked.

Chapter 2

The Model

2.1 Data Identification and Processing Methodology

This section will detail the methods of determining valuable data to develop our model. Several different data sources were needed in order to model environmental impact on power availability, namely weather and power outage data. Using the gathered data, we filtered, cleaned and processed out the important information so that modeling techniques could be applied with greater reliability and accuracy.

2.1.1 Data Identification and Processing

In identifying our data, our team sought to find data solely from 2015 to 2020. This time frame was chosen as the data would better reflect the current business practices and power usage while still providing enough power outage data to produce consistent results.

Power outage data was an important part of modeling impact of weather. As such, we sought data that was statistically significant to truly identify major trends of power outages over large areas. Our data for power outages was pulled from the Department of Energy's yearly summaries of Form DOE-417 reports. Energy companies are required to report electrical disturbances meeting certain criteria using this form, and the report summaries provide categories for outages, making it easy to isolate weather-related incidents. For each region-year(2015-2020) for our climate regions, the number of customers affected and the number of outages were recorded. A representative portion of the power outage data can be seen below:

Year	2015	2016	2017	2018
Number of Outages	78	74	69	71
Customers Affected	6504367	5325969	16030181	15697164

In addition, weather data was needed in order to perform any modeling or simulation of our problem. As such, our weather data was collected by using a Python program to generate queries into NOAA's climate database. This database allows searches by weather station with desired data points. In our case, average wind speed, fastest 2-minute wind speed, total precipitation, and average temperature were used as the research conducted showed that these factors had the most relevance to outages. [Editors, 2021]

Processing

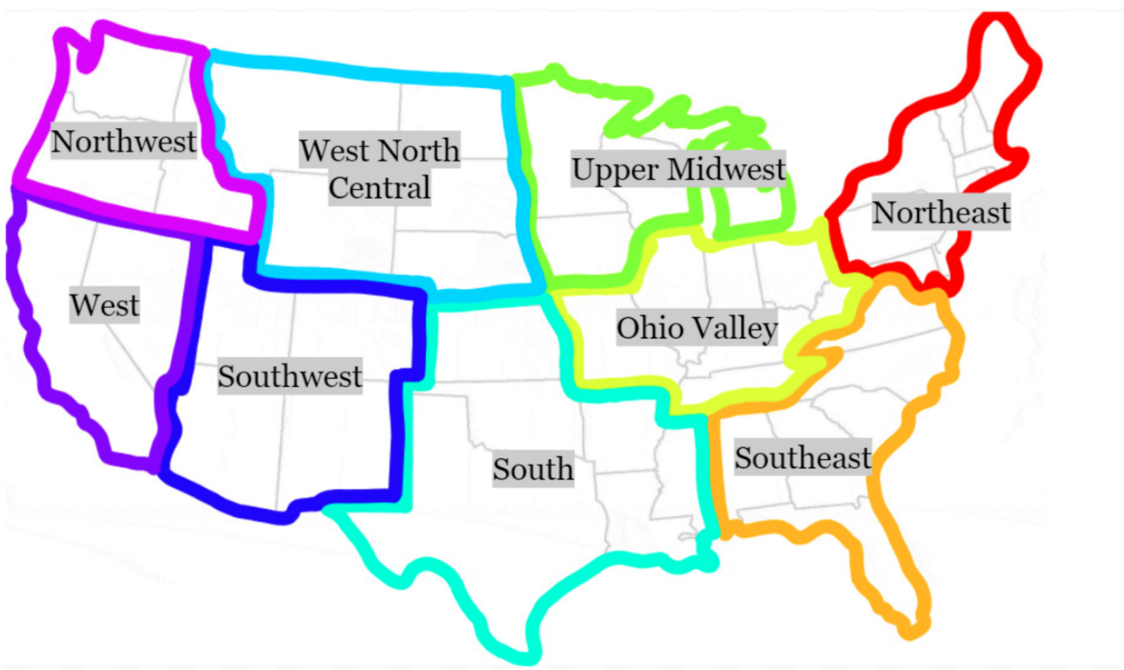

Figure 2.1: The Climate Regions used during our Modeling

In calculating general weather trends related to power outages, we found it appropriate to divide the United States into separate regions of similar Climate, as detailed by the NOAA, where states having similar climates are grouped into regions. [US,] As an example, the climate patterns regarding Washington State are drastically different compared to those present in Washington D.C. due to the largely varied location and regional climate. However, comparing Washington State to Oregon created much more logical data, which was grouped by similar characteristics. Additionally, the final data that was modeled were the values obtained from averaging the separate factors from weather stations located in each region's five largest population centers. This was done primarily under the idea that large population centers are the areas most susceptible to large outages, so focusing on mitigating these areas would provide indications to the most meaningful changes that can result in fewer outages.

As a part of processing the power data, the yearly summaries of the power outages were combined into one sheet. These datapoints were then filtered, and the outages characterized with severe weather was further isolated to provide more detailed data for modeling. After which, the generated data was separated into the Climate Regions for further processing

2.2 Assumptions

- Assumption 1: The reporting criteria for Form DOE-417 did not change between 2015-2020.
- Justification: The reporting criteria has to have some form of consistency, otherwise the data processing would be meaningless in finding trends for the future.
- Assumption 2: The outages in which an unknown number of customers were affected was assumed to not affect our model.
- Justification: Not every form report included the number of customers affected, but the proportion of cases of unknown customers affected remained relatively constant throughout the dataset. Thus, since the regions were affected equally, the year-to-year model had very little impact from this factor.
- Assumption 3: The climate of the five largest population centers was representative of the entire region.
- Justification: Using population centers inherently weights population-dense areas more than rural areas. This actually helps our model, as this weight helps better represent the number of affected customers; Extreme weather in

a city will have a larger effect on affected customers than the same weather in an empty national park.

2.3 Mathematics Methodology & Analysis

The first model produced from the data was a multiple-regression used to determine a relationship between our weather data and power outages. In this model, the variables with model p-values greater than the designated threshold of 0.05 were removed, as the correlation between this factor and the customers affected in a power outage were not very high. As such, our final regression model determined affected customers as a function of two of the four gathered weather variables: total precipitation and average temperature.

In our model, the Total Precipitation had a positive correlation, while the Average Temperature had a negative correlation. This means that an increase in the precipitation in a region correlates with a higher power outage volume, while a lower Average Temperature also correlates with a higher power outage volume.

Chapter 3

Conclusions

3.1 Risk Characterizations

In our data, it was found that Total Precipitation and Average Temperature were the largest contributors towards volume of power outages that occurred. These factors largely correlate with previous research, so in this section, we plan to further extend our research to analyze the risks that cause power outages. The first factor is an uptick in precipitation. A region may struggle with supplying power if muddy grounds and heavy rains cause unstable power lines to tip and potentially become cut off. Additionally, trees are more likely to fall on power lines when the weather causes unstable grounds. Temperature has a large factor too, as a lower temperature tends to correlate with increased ice and snow formation. These factors, when paired with the increased precipitation will cause heavier power lines that may be unstable due to the increased weight that must be carried. These factors all contribute toward a higher power outage rate, which we seek to mitigate in the next sections.

3.2 Recommendations

Two of the regions that had the biggest impacts were the northeast and the south. This was shown by peaks in the data.

3.2.1 The South

The peak in the south is likely the result of hurricane Harvey that hit Texas in 2017, as the peak was from that same year. Harvey was one of the most destructive hurricanes to affect Texas in recent history, as it caused severe damage for the duration of the storm through high winds, severe flooding, and large amounts of rainfall. [US Department of Commerce, 2021] Because of the massive impact this hurricane had on the south, we decided to evaluate possible solutions that would mitigate the effects of the factors involved in major hurricanes.

One very effective mitigation strategy would be to migrate all of the lines underground. Underground power lines have proven to be far safer than above ground ones, as the risk of power outages, hurricanes, electrocution, and wildfires are reduced. [Feldman, 2021] In addition, underground power lines are safe from flying debris resulting from tornadoes or high winds that would normally down an above ground power line. Although one of the drawbacks is the cost of installing them, in the long run, electrical companies may save money by implementing them, as there will be far less money lost due to power outages.

3.2.2 The Northeast

The other peak is located in the northeast. The peak is from 2021, when there was a major winter storm in the New England area. Contrary to the south, the best response to this would not be to implement underground lines, as the ground in New England varies significantly in elevation and is made up of rocks, which make it difficult to construct in. With winter storms, the major cause of downed lines is trees. Trees that are located near power lines become heavy with snow and ice, and eventually fall over - taking the lines down with them. This is why our recommendation would be to remove trees around power lines in the northeast climate region. Many power lines are located near large patches of trees that are likely to collapse when severe weather occurs. By removing these trees, the risk of widespread power outages decreases dramatically. However, the area where trees are removed would also depend on the type of power line present. Distribution lines, which are found in neighborhoods, are more likely to be downed by trees, and are located much closer to residential areas. Transmission lines, on the other hand, are larger, more stable structures less likely to be affected by fallen trees.

3.2.3 Alternate Solutions

Structural alterations like migrating underground are difficult for smaller distribution power lines, due to their location within neighborhoods and close to residential buildings. Although replacing above ground lines with underground ones may have many benefits, it is also extremely costly to install, which is a major drawback to many power companies. Additionally, cutting down so many trees would be very costly and not be good for the wildlife that lives in the surrounding trees. If either one of our previous suggestions does not work, whether that be for economic or other reasons, then an alternative solution could be to train more efficient personnel to respond to outages. This could be applied to any of the regions - not just the south or northeast. With a more qualified group of responders, an outage could be resolved in much less time. This method would be most effective for smaller storms, as transportation in hurricanes is nearly nonexistent, but nonetheless should be considered as a less expensive means to achieve less down time from outages.

Bibliography

[US,] Geographical reference maps.

[Editors, 2014] Editors, C. C. (2014). Weather-related blackouts doubled since 2003: Report. Technical report.

[Editors, 2021] Editors, D. (2021). Causes of power outages.

[Feldman, 2021] Feldman, J. (2021). Why aren't power lines underground: Here's what to know. *Electrocution Lawyers, PLLC*.

[Hamachi LaCommare and Eto, 2006] Hamachi LaCommare, K. and Eto, J. H. (2006). Cost of power interruptions to electricity consumers in the unitedstates (u.s.). Technical report.

[US Department of Commerce, 2021] US Department of Commerce, N. (2021). Hurricane harvey its impacts on southeast texas. Technical report.