An Analysis of Charging Station Data in the Dallas, Texas Metroplex

By: Jake Mammen

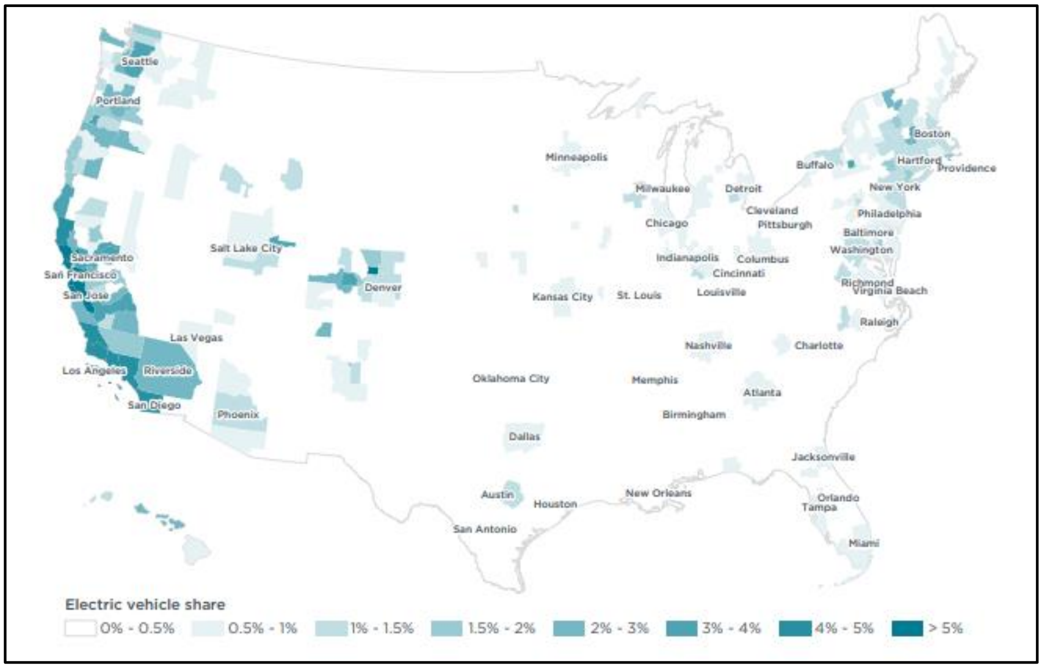
Abstract:

The electric vehicle continues to make tremendous strides and push the limits of the current infrastructure within the United States vehicle market. The transition from gas powered to electric powered transportation is starting to become more common across multiple states as technology within the electric vehicle market evolves, resulting in a larger electric vehicle footprint. This study will use a mixed methods approach and focus on following some of the methods in the Data Life Cycle to analyze various datasets. The different datasets included in this study will consist of data about electric vehicles, charging stations, demographics, and road networks in the Dallas, Texas metroplex area. Additionally, this study will draw from available literature and through review will provide insight on some of the issues the electric vehicle infrastructure in Dallas, Texas faces in comparison to the market as a whole. Furthermore, the analysis from the data will help illustrate the differences of where charging stations are located, types of charging stations, distances being traveled, and the differences of how demographics may influence the use of electric vehicles. This study will highlight the potential needs for improved charging station infrastructure as the electric vehicle demand continues to grow.

Introduction:

Electric vehicles are a fairly new form of vehicle that was first introduced in 2010 as an alternative to fuel powered transportation. One of the main reasons for introducing an alternative to fuel is to help reduce carbon emissions, which certainly remains atop the list of priorities for law makers across the country. This idea of electric vehicles isn't new, it has been around for a long time, however, the lack of advanced technology was a big limitation. In order to operate an electric vehicle, the vehicle itself needs battery power. Automakers attempted to implement the idea of putting batteries capable of high speeds and long distances, into cars. Unfortunately, there was not enough research and development to push those limits and make battery powered vehicles a sufficient enough reality. In an article titled, "The History of Alternative Fuels in Transportation: The Case of Electric and Hybrid Cars," Hoyer (2008) states that while these auto companies had ambitious ideas in the late 1970s, the technology was not advanced enough to make electric cars a sustainable option to gas powered cars. Back then, limitations are what kept the production of electric vehicles from becoming what they are today. Over the decades, technology has come a long way and there are more and more companies jumping on board to produce electric vehicles. The combination of advanced technology, improved legislation, and variety of automakers has resulted in a growing electric vehicle market. The transition from gas to electric over the course of the last several years has looked seamless, but ultimately the makers of electric vehicles and leaders of this country have had to overcome multiple barriers. A common struggle that producers and consumers share is related to one simple question, why should people be inclined to buy electric vehicles? The infrastructure that supports electric vehicles can't keep up with the rate at which more electric vehicles are being made and bought.

While the idea seems great and all, people are questioning whether or not it is worth purchasing a vehicle that may be unreliable when it comes to accessibility, affordability and efficiency.



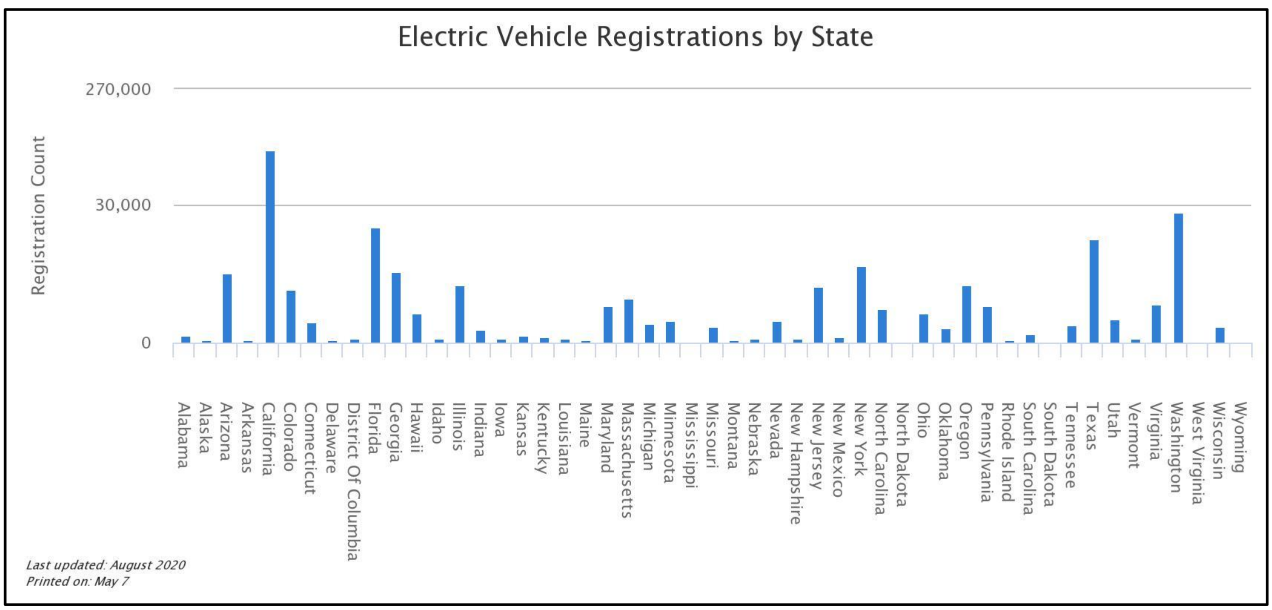


Figure 1A (Top) Electric vehicle share of new 2017 vehicle registrations by metropolitan area. New vehicle registration data from IHS Automotive. Sources: HIS Automotive and Peter et al. (2018) Figure1B (Right) This chart shows the vehicle registration counts of all-electric vehicles (EVs) by state as of December 31, 2018. Source: National Renewable Energy Laboratory (NREL). Data derived from IHS Markit light-duty vehicle registrations in 2018

Research suggests the majority of the electric vehicle footprint is located in bigger metropolitan areas such as San Francisco, Los Angeles, Denver, and Dallas. Additionally, the majority of people who own electric vehicles live in states such as California, Florida, and Texas. Figure 1A shows Dallas, Texas in the 0-0.5 percentile and while it's a small portion of the overall share in electric vehicles, there is some significance that can be found. Figure 1B explains that there have been just under 30,000 electric vehicle registrations in the State of Texas as of 2018. This research provides the basis for which this study aims to examine specifically the electric vehicle infrastructure in the Dallas, Texas metroplex and how it relates to the market as a whole. It also will explain the barriers both producers and consumers face moving forward.

Research Context/Background:

The demand for electric powered transportation has been driven by the need for a solution to climate change. Elon Musk, the founder, of Tesla which is one of the more well-known electric vehicle makers in the world, has be leading this charge to make transportation more environmentally friendly. However, it is not as easy as it may seem. Decades upon decades long research and development have propelled the electric vehicle to where it is today. The goal to reduce carbon emissions has resulted in an increased demand in electric vehicle sales (Beck et al. 2019). Metropolitan cities and large urban areas contribute heavily to the amount of carbon emissions put into the environment, which is why some law makers have grown concerned over the years. Electric vehicle production has benefited from new legislation across multiple countries by offering an immediate but complex solution (Martinez et al. 2017). Many researchers and scientists have examined the impacts electric vehicles have on the environment. While this would argue against the purpose of this study, it provides useful information on how to analyze similar data. Ultimately, the goal of this different type of electric vehicle research, is to investigate how the Life Cycle Assessment provides relevant information to stakeholders in the area of vehicle electrification. In the Life Cycle Assessment, different methodologies help give answers to some of the question's stakeholders have regarding all thing's electric vehicles through both quantitative and qualitative data analysis. Given those results it's easier to tease out general and robust conclusions (Nordelöf et al. 2014).

This study uses a different mixed methods approach, which includes both quantitative and qualitative data analysis while using the Data Life Cycle and literature review to be able to conclude how the Dallas, Texas metroplex electric vehicle infrastructure differs from others. The purpose of this analysis is to highlight the barriers and challenges those in Dallas, Texas will face when making the decision on whether to go electric or not.

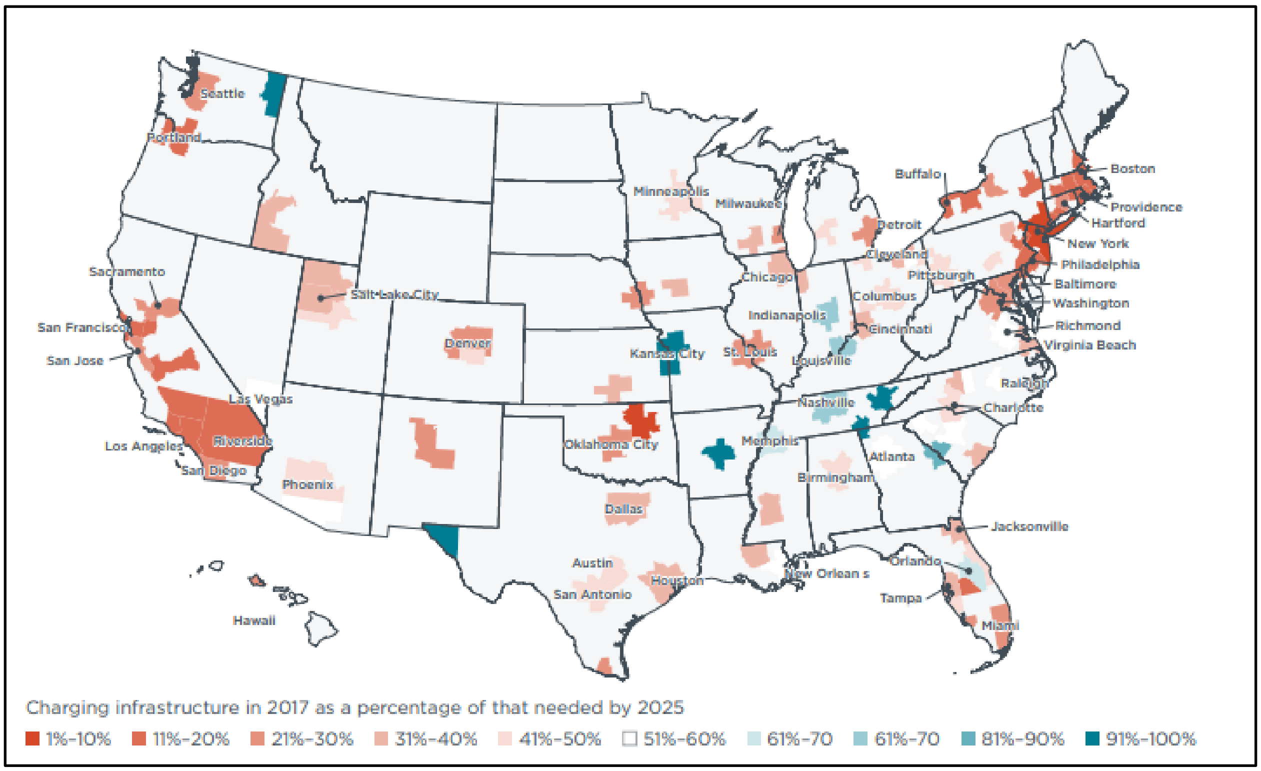


Figure 2. Charging infrastructure in 2017 as a percentage of that needed by 2025. Source: "Quantifying the Electric Vehicle Charging Infrastructure Gap Across U.S. Markets" (Nicholas et al. 2019).

In similar research the electric vehicle market growth has occurred where some of the challenges and barriers have been addressed by policy or legislation. Figure 2 illustrates the percentage of charging infrastructure needed by 2025 to sustain the growth of the electric vehicle market. The red shades indicate that less than 50% of the needed charging infrastructure had been installed as of 2017. Dallas, Texas is shaded red which means that the city is seeing substantial growth in the electric vehicle market however the need for more is certainly there. A group of researchers from the International Council of Clean Transportation chose to quantify the electric vehicle charging infrastructure gap across the different U.S. markets. This approach helps explain how driver behavior shapes the electric vehicle charging infrastructure ecosystem (Nicholas et. al 2019). While widespread distribution of electricity makes for a better overall experience, it won't answer those questions about accessibility and affordability. Ultimately, people want the freedom of being able to access these charging stations at anytime and be able to leave their vehicles unattended in public spaces. Overall, Nicholas et. al (2019) found that there are three conclusions, the need for more charging infrastructure, unevenness in planned infrastructure activities, and economic opportunities could lead to increased charger utilization.

The transition from gas to electric powered vehicles has been driven by the implementation of environmental policies. Metropolitan cities and large urban areas have seen an increase in electric vehicle sales, in large part due to the amount of carbon emissions being emitted within these types of areas.

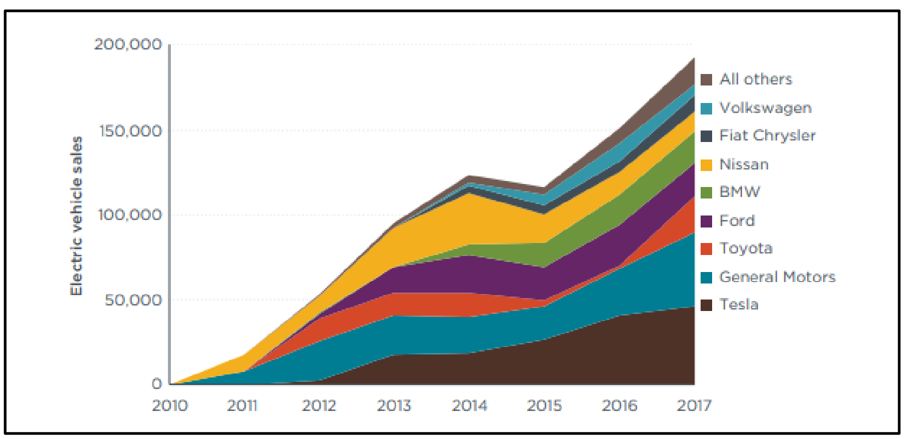


Figure 3. Automaker annual electric vehicle sales in the United States through 2017. Source: "The Continued Transition to Electric Vehicles in U.S. Cities" (Slowik et al. 2018).

Figure 3 shows electric vehicles sales have substantially increased over the last several years. Many automakers are offering different types of vehicles making it easier to want to transition over to electric powered transportation. Whether it is benefits such as tax incentives or perhaps the ability to go longer distances in an electric vehicle, electric vehicle sales continue to increase. However, the same barriers that are present in similar research and literature are preventing the transition from being accepted by all. In a study by Slowik et al. (2018), researchers use local level data to conduct a statistical analysis to determine the correlation between key electric vehicle support and market uptake. Additionally, they analyzed the availability of charging infrastructure and high-occupancy vehicle lane access. This analysis led to four distinct conclusions but perhaps the most important to note is that electric vehicles and various types of charging infrastructure grows in union (Slowik et al. 2018).

As the electric vehicle market continues to grow and the demand also follows suit, the need for improved charging infrastructure is a must. Researchers also agree that charging infrastructure plays a similar role in persuading consumers on whether or not to make the switch to electric. However, there are several factors that contribute to charging station deployment and power networking planning. In one study researchers aim to examine the behavior of consumers and how policy may influence them. During this study, researchers used linear regression models to look at correlations between policies and awareness. Overall, individuals who live in a Zero Emission Vehicle policy area, generally don’t ever consider buying an electric vehicle, because there as an insufficient amount of awareness on the benefits of electric vehicles. Additionally, there is no interior influence on those who live in households that already own an electric vehicle. Rather, a consumer’s desire to transition to electric is solely based on prior interest (Hardman et al. 2020).

Technology related to electric vehicles creates another difficult obstacle to deploy new charging stations throughout an area. There are multiple different types of models in which certain batteries require certain chargers. As a result, this could alter the amount of time being spent, as well as the cost when consumers head to the charging station. In a study about electric vehicles and charging stations, NASA stated that 50% of one-way commuters travel about 10 miles or less to work each day making electrics that more intriguing given their relatively short-range capabilities. Overall, the electric vehicle population is small compared to the rest of the vehicle market making the transition from gas to electric that much more difficult, due to a scarce number of available charging stations (Cave et al. 2014). Additionally, the difference in charging times could create more barriers to overcome. Owners of electric vehicles would rather use their charger at home then have to travel to find a specific charger for the type of battery that is within their vehicle (Council et al. 2015). The Committee on Overcoming Barriers to Electric-Vehicle (2015) argues that there should be no additional funding for charging station infrastructure until the relationship between electric vehicles and charging stations is assessed, which ultimately could lead to more issues.

Surprisingly enough, the availability of electricity or the capacity at which the power grid can handle demand, is another barrier influencing charging station infrastructure. Charging stations are a crucial part to the survival of electric vehicle market. In a journal article about charging stations and power network planning, a group of researchers use multi-objective modeling to examine the relationship between traffic flow across several networks and understanding the power loss in distribution networks. While this research differs from this study, it provides helpful insight on the deployment of charging stations. Liu et al. (2019) suggest that electric vehicles put a major stain on the power grid which could result in a negative impact on the system as a whole. In this experiment, one of the major issues stems from load capacity which ultimately influences where some charging stations are located. On the contrary, the combination of the traffic network and distribution network also solves the problem of the location of service facilities. In this study, the focus is similar in that traffic networks and distance traveled impacts the decision on whether or not to go electric. Liu et al. (2019) argues that using traffic flows can help simulate the charging demand and consider some restrictive factors such as maximum travel distance of electric vehicles. Similarly, Qiao et al. (2018) states that by using graph theories to look at geographic constraints, analysis can determine costs associated with electric vehicles and influence locations of charging stations. Lastly, correlations between public locations and travel characteristics heavily influence the promotion of electric vehicles and overall transition of electrification (Yun et al. 2019). Generally speaking, there are multiple challenges and barriers that contribute to the planning of charging station locations. As the demand for electric vehicles continues to grow, the installation of more charging stations needs to be at the forefront, in order to keep the transition alive. The next section of this report will cover the methods and procedures the study aims to follow to provide a thorough analysis of the charging station infrastructure in the Dallas, Texas metroplex.

Materials and Methods:

This study uses a different mixed methods approach which includes both quantitative and qualitative data analysis while using the Data Life Cycle and literature review to be able to conclude how the Dallas, Texas metroplex electric vehicle infrastructure differs from others. Specifically, this section will take a closer look at the quantitative and qualitative data analysis while using the Data Life Cycle.

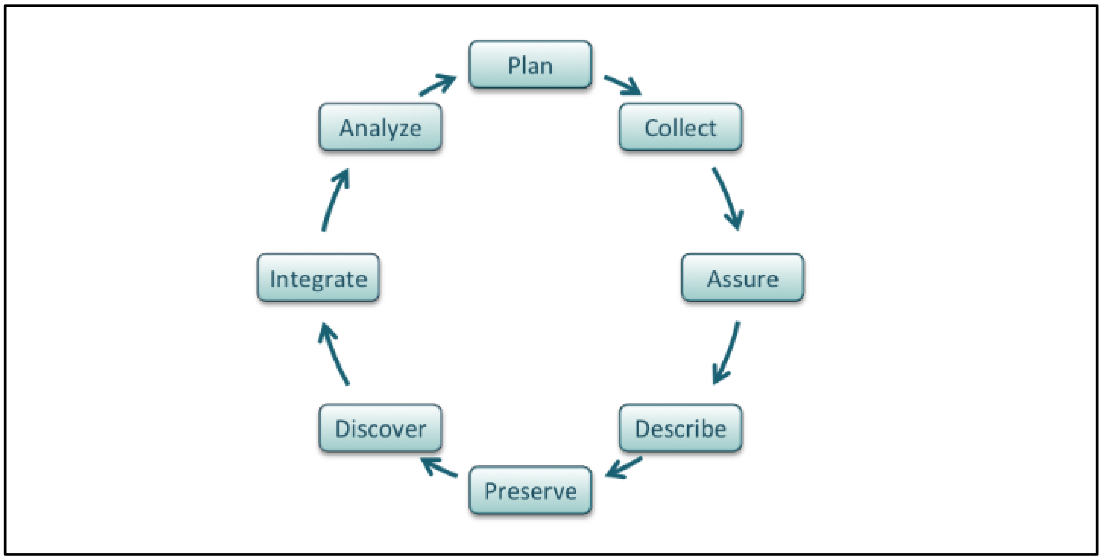


Figure 4. The data life cycle from the perspective of a researcher. Source: www.dataone.org

The plan component of the data life cycle describes the entire life cycle. This study focuses on some of the methods or steps seen in Figure 4, but not all. Since this study didn't include any other contributors some of the steps were able to be excluded during the planning process. However, if there were more than one contributor, some of the excluded steps could be found useful in later projects. The plan stage of this study started with a project proposal where the abstract, title, keywords, and ideas were written out (See Appendix A). During the plan stage, data was gathered from data sources through research and were recorded (See Data Sources). Data was carefully pulled from available GIS databases from multiple organizations and agencies which include The City of Dallas, The North Central Texas Council of Governments, The Bureau of Transportation Statistics, and the U.S. Department of Energy. From these databases this study will use eight shapefile feature layers such as, a collected point layer, a point layer of charging stations in Texas, a line layer of the 2019 highway network in Dallas, a line layer of the street network in Dallas, a polygon layer of neighborhoods in Dallas, a polygon layer of organization districts in Dallas, a polygon layer of counties, and a polygon layer of 2020 city regions in Dallas. The single dataset that was collected will serve as a primary dataset which consists of 43 features and four attributes. This particular dataset was gathered using the ESRI collector app, by inputting an address and submitting it as a point.

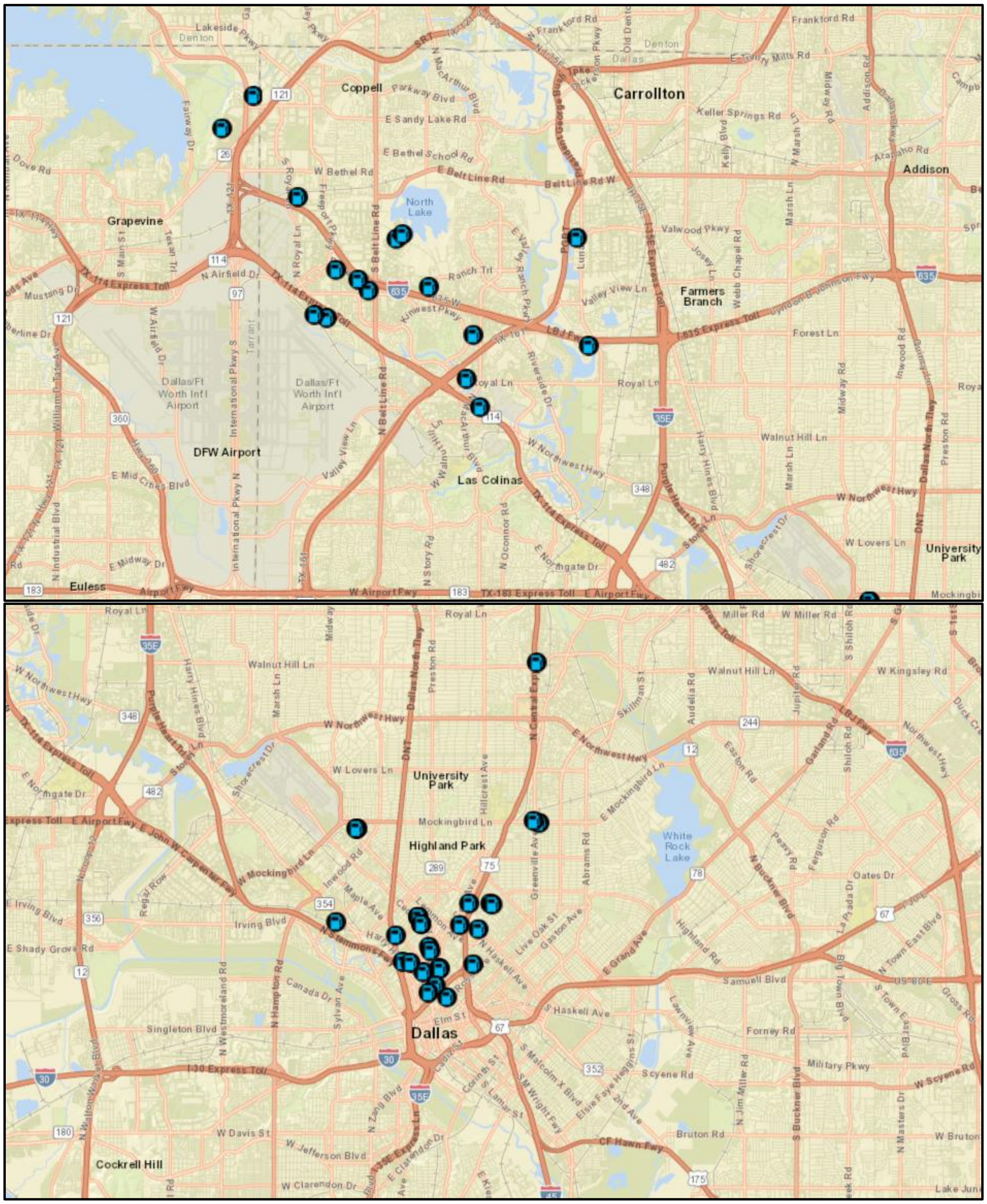


Figure 5A (Top) A map of collected data showing charging station locations in Irvine, TX. Figure 5B (Bottom) A map of collected data showing charging station locations in Dallas, TX. (ESRI ArcGIS Online and ESRI Collector app)

Figure 5A and Figure 5B are an illustration of the collect stage during the data life cycle. This primary data set along with the seven others will be used in the analysis portion. To ensure the accuracy of the data used in this study, the assure stage requires an inspection of the data. For this the United States Geological Survey Metadata wizard was used along with ArcGIS Online, and ArcMap. While this study used the Metadata wizard to check the quality of the data, it was found that ESRI's ArcMap was the most useful tool in assuring the quality of the data. Additionally, ArcMap was used the remaining stages of the data life cycle: Discover, Integrate, and Analyze. The Alternative Fuel Stations point layer from the U.S. Department of Energy had to be queried within ArcMap to reflect electric vehicle charging station locations within Dallas, Texas. I then created a new feature layer from that query and exported it as a new feature layer so that it could be used in the analysis.

During these final stages, it's important to note the geographic coordinate system being used to perform a successful analysis later on. In order to perform successful queries all of the gathered data being used needs to be converted into the same geographic coordinate system. Using Arcmap's properties option, the data frame where the layers are located can be selected and searched to find what geographic coordinate system it was being projected in, for Dallas, Texas the correct coordinate system being used is the GCS_WGS_1984 with an SRID of 4326. Ultimately the coordinate and SRID help define a location on the globe. Once all the data has been carefully looked over, the data can then be imported into PostgreSQL using a PostGIS data loader. However, before data could be imported a database had to be created. The name of the database for the purpose of this study was called Dallas. Each data file had to be in a shapefile format, otherwise it wouldn't be accepted into the PostgreSQL database. As each file was imported the SRID was changed to 4326 and then successfully imported into PostgreSQL. Since, some of the datasets used in this study had over 1000 total features, I chose to use PostgreSQL. The PostgreSQL software is very useful because it can operate and function using larger datasets unlike some of the other available software. The overall idea of this study is to take multiple datasets related to electric vehicle infrastructure in the Dallas, Texas metroplex and query it to see how it differs from other research. A quantitative and qualitative data analysis was performed to help determine this.

Results:

The first set of queries I conducted were simple SQL queries that consisted of avg(expression) aggregate to return the average (mean) of the values in a set of records. The first query included the cultural neighborhoods data. The reason I used this dataset was because it was one of few datasets that had a decent amount of demographic information associated with the Dallas, Texas area. The dataset included attributes such as Typology broken down into: Urban Core, Residential Arts, Non Traditional, and Mixed Urbanism. Additional attributes broken into variables to explain the typologies included T1_SFR which represents the percent of single-family residential properties. The avg(expression) query was applied to the T1_SFR variable to find the average of single-family residential properties in specific typology areas.

Typology	**Average**
Urban Core	0.03 or 3%
Mixed Urbanism	0.63 or 63%

Next, I looked at county data to get an idea of how large the area is. I took the county dataset and ran two separate queries one for Dallas County and another for Tarrant County, because much of the charging station data I used was in both of those counties. The ST_Area(geometry) command was used to find the area for both counties.

County	Area (in acres)
Dallas	5.5947e^5 or 909 m^2
Tarrant	5.5549e^5 or 902 m^2

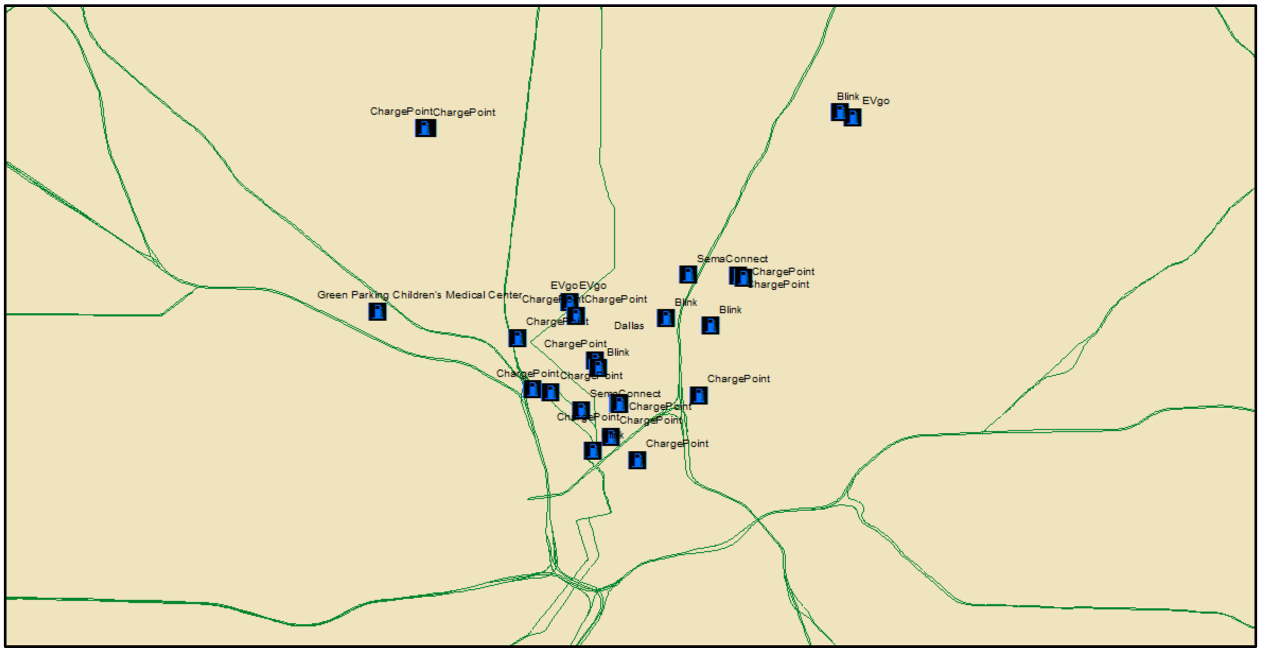
The streets and highway datasets were used next. I took both datasets separately and wanted to determine the lengths of both as they lie within Dallas. I ran ST_Length(linestring) query to return the length of those linestrings.

Type	Total Length (km)
Streets	30182.9015 km or 18754.225 miles

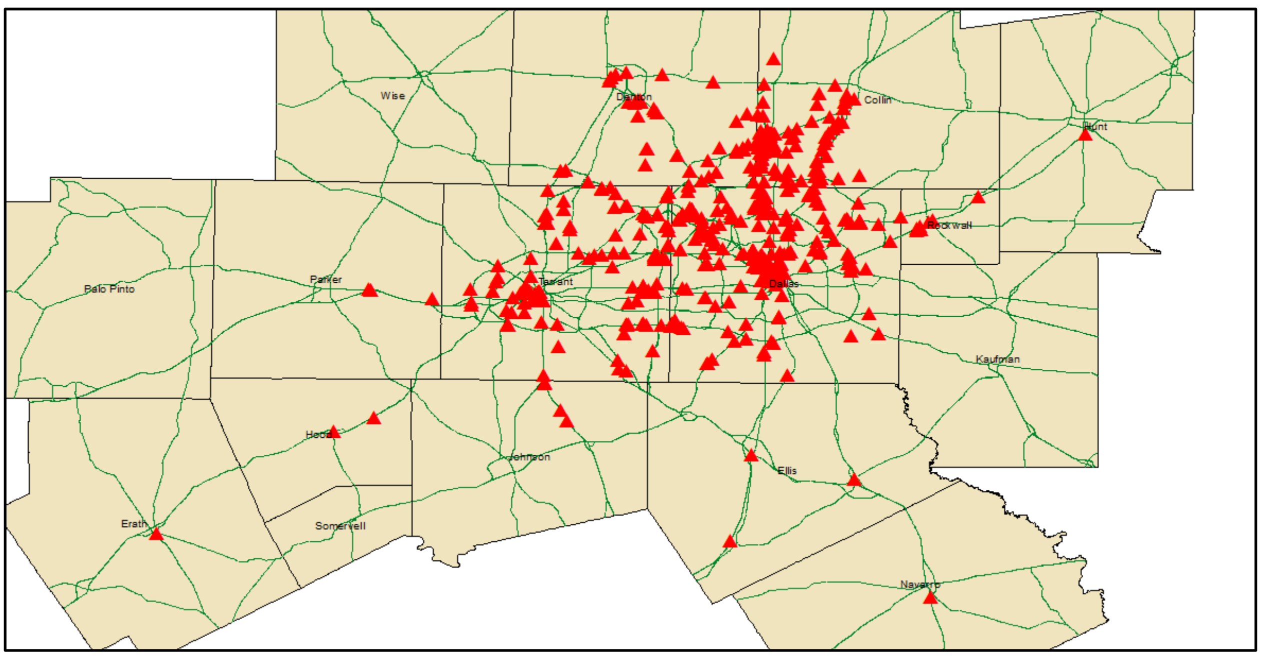
Additionally, I wanted to see what the lengths of two major highways that run through Dallas, Texas. Those two interstates are 75 and 35E. I used the query to pull the length of Interstate 75 and Interstate 35E separately but within Dallas County.

Highways	Length (miles)
Interstate 75	30 miles
Interstate 35E	40 miles

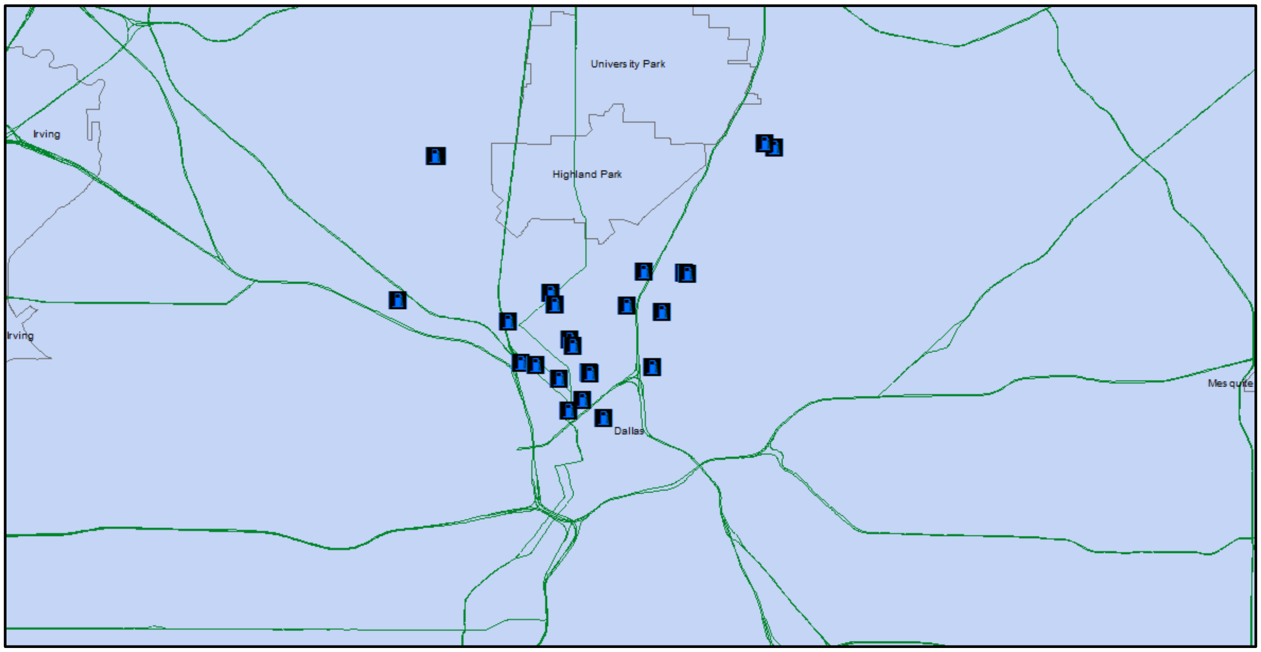
The data I collected was of charging stations with the Dallas, Texas downtown area. The map below shows those charging stations located throughout.

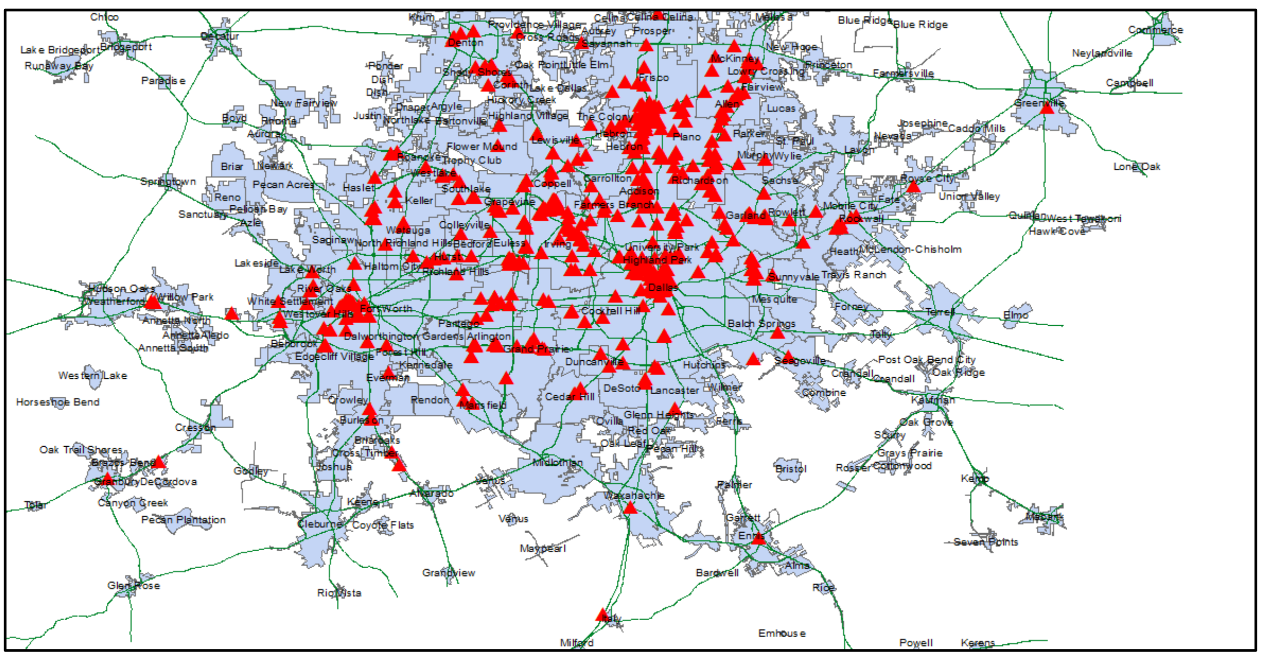


I then wanted to look at how these charging stations compare to other stations located through North Central Texas.



There are over 600 charging stations, in addition to the 43 charging stations I collected, that are located throughout North Central Texas. The majority of charging stations that were located in Dallas and Tarrant counties were within 10 miles of the closest highway. In the case of this study those highway networks would include Interstate 75 and Interstate 35E. Furthermore, there were concentrations of charging stations evident within certain city regions.





The majority of electric charging stations throughout central North Texas also follows suit, generally located near larger metropolitan areas and along major road networks even as you leave the Dallas, Texas city limits. The next section will discuss the results in more detail.

Discussion:

The results presumably answered some of the questions that were being brought up in the literature review. As the electric vehicle market continues to grow, the demand for more charging stations within larger metropolitan areas is needed. In reference to some of the literature Dallas, Texas as of 2017 is behind where they should be in regard to proper charging station infrastructure based on of demand. However, the results provided useful insight on the correlation between county, city, highway and street network has to charging station infrastructure. Overall, the datasets didn’t match up very well. Some of the attributes that were included within the datasets were irrelevant. However, the data was sufficient enough to accomplish the goals of what the study set out to get. Similar to what some of the researchers stated in the literature, the typologies within the cultural neighborhood dataset proved that the majority single-family residential properties were found in mixed urbanism areas. Additionally, the behavior of the individuals who live in these areas may have an influence on the willingness to transition over to electric powered transportation. The surface area of the two counties is relatively big compared to some of the other counties. Which mean’s there is a lot of area to have to cover between different counties and city regions. The highway networks within both Tarrant County and Dallas county stretch nearly on average 35 miles from city center. Therefore, ideally you would need a charging station every 10 miles in order to satisfy some of the consumers desires in wanting to change over to an electric vehicle. The data seems to support the claim of enough charging stations within a certain distance inside these two counties, however, once you leave these areas the charging stations become more scarce. It also highlights the claim that you can find more charging stations within urban areas as the cost may be lessened. Generally speaking, the data used in this study could have been better from a size and geographic reference standpoint. I found that using ESRI Arcmap to work through the data was slightly more beneficial than it was to use other tools.

Conclusion:

This purpose of this study was to take available data and perform data analysis to determine the differences within the charging station infrastructure in the Dallas, Texas metroplex. Over the last several decades the electric vehicle market has made tremendous strides in minimizing carbon emissions. The electric vehicle is a viable solution to poor air quality through metropolitan cities in the United States. However, as electric vehicle sales continue to rise the demand for charging station deployment across several of the zero emission policy states is well behind schedule due to social, economic, and political barriers. This study examined the differences in data between that found in similar literature. Ultimately this study found many similarities in the barriers and challenges being faced in large metropolitan areas across the United States. Perhaps the biggest concerns being the amount of charging stations, the type of charger, and the distance traveled still remain today. I think this study could be improved by find more current data. While it wasn’t that long ago, the data used was from 2017 or later. For those who want to look further into this, the suggestion would be to find more up-to-date datasets.

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Data Sources:

Bureau of Transportation Statistics: https://data-usdot.opendata.arcgis.com/

City of Dallas GIS Services: https://gis.dallascityhall.com/shapefileDownload.aspx

NCTOG Regional Data Center: https://data-nctcoggis.opendata.arcgis.com/

U.S. Department of Energy: Alternative Fuels Data Center
https://afdc.energy.gov/data/data/data/?q=electricity

Appendix A:

Term Project Proposal

Title: (Subject to change) An Analysis of Electric Vehicles (EVs) and Charging Station Data in Dallas, Texas.

Abstract:

The electric vehicle continues to make tremendous strides within the United States vehicle market. This changeover from gas to electric is becoming more common across multiple states as the hope for reducing carbon emissions can help improve an already changing climate. At first, the transition from gas to electric seemed far-fetched but over the last several years, charging infrastructure has made it more seamless. Whether it is benefits such as tax incentives or perhaps the ability to go longer distances in an electric vehicle, electric vehicle sales continue to rise. In order to account for the increase in sales and overall transition from gas to electric, states need to be sure they overcome the barriers for continued growth. Why should people be inclined to buy electric vehicles if the overall outcomes don't outweigh the current ones? The purpose of this study (or project) is to analyze different datasets which include data about electric vehicles, charging stations, and road infrastructure in Dallas, Texas. The data will help show where charging stations are located, the different types of charging stations, and distances being traveled. This study will draw from other literature and through review will give insight on the electric vehicle infrastructure in Dallas, Texas compared to other states. Additionally, it will highlight the potential needs for improved charging station infrastructure as the electric vehicle demand continues to grow and give insight to why the electric vehicles will be popular in the future.

Keywords: Electric Vehicles, Charging Stations, Charging Stations Infrastructure, Carbon Footprint, Convenience, Distance Traveled, and Affordability (Maybe Class)

Data Requirements: I have done some research and have tried to use several of the available datasets out there to help me complete this project. The following data sets I plan to use are as follows: The Alternative Fuels Data Center from the US Department of Energy database, The Geospatial database from the Bureau of Transportation Statistics, the 2017 Summary Statistics for Demographic Characteristics and Travel for the National Household Travel Survey database, The City of Dallas GIS database, and the Regional data center from the North Texas Central Council of Governments GIS database. Additionally, I plan to collect either photos with geo locator of the charging stations around the Dallas area, or perhaps something else that I am still thinking about. Most likely will go with the first option though for my data that I will personally collect. There will be a combination of different data types I presume. The most likely will be point, line, and polygon data from a combination of these datasets. For my personal data it will be raster data given the photographs or digital pictures I will be collecting. Unfortunately, given that I am still working through the datasets and determining what will be the most useful, I don’t have expected file sizes just yet. However, I recognize this will be an important piece of information that I will include in my final deliverable.

Process Requirements:

For this project I will use the Data Life Cycle to help complete the analysis of my data. I will begin the process of working with my data by starting with the Plan stage where I will plan out what databases I will pull from. The data has already been compiled from freely available GIS databases. I will download each dataset and note the type of data as well as how big the file sizes are. I will also document where the data came from so I can keep track of where to look and provide information for those reading my work on where to find the data for themselves. For my data that I will collect, it will have to also be documented and stored. I will use my phone to take pictures with the geolocator in operation. I will then create an CSV file (I believe) to have the data in a format I can then use. Once this is complete, I will move to the assure step of the process where I will ensure that my data is clean, concise, and accurate. To fulfill this process, I will either use Google's Open Refine or the Metadata Wizard offered by the USGS. This would be the moment in the cycle where we find out if there is any missing data. If that is the case then I will have to consider not using it or noting to the reader this data is not complete, therefore, no conclusions can be drawn. The next two steps are describe and preserve stages of the process where I will provide any necessary description if there is missing information. I can also preserve the data if I need to easily access it again or store it to come back to and work with. For those two steps I would us Git Bash or Git Hub. Next, I would use PostGres to discover and integrate my data. This is where I will perform certain spatial relationships to show how my data interacts with each other. From there we can start to explain and answer those questions being asked throughout my study. I plan to use multiple different spatial relationships within my study. Again, while the data hasn't been thoroughly looked through at this stage in the process, I will predict using spatial joins, intersects, touches, within, contains, distance, length, and geomfromtext. The idea here is to take the data I personally collect with the latitude and longitude and other related data and be able to join it with the other existing datasets. Then I will be able to perform those other geospatial relationships to determine distances from charging station to certain locations, etc. Lastly, to complete the analysis we will analyze the findings in the data by using ArcGIS, Arcmap, or by examining the attribute table. At this point in the study, I will hope to be able to obtain some insight on the electric vehicle infrastructure in Dallas, Texas.