

The Impact of Electric Vehicle Charging Stations on Consumers

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ABSTRACT

New York currently has an inadequate supply of electric vehicle (EV) charging stations for drivers, despite the considerable efforts made by the local and national government to encourage the environmental benefits of EV usage. This study investigates the extent to which the scarcity of charging stations is inhibiting the widespread adoption of EVs on Long Island. A survey was conducted with a representative sample of the Long Island population to analyze which individuals were impacted most significantly. The findings suggest that the charging process, including cost and time, was not the problem. Rather, those without access to home charging and individuals who travel long distances were impacted the most. To remedy the situation, New York policy makers need to allocate more resources towards the expansion of the charging network and enhance consumers' knowledge about the environmental benefits of EVs.

Introduction

EVs have become increasingly popular in the United States during recent decades due to their various environmental benefits. The manufacturing of EVs rapidly accelerated in 2010 when Tesla received a \$465 million loan from the Department of Energy for production (Matulka, 2014). Tesla's subsequent success sparked other automakers including Chevy and Nissan to release their own EV fleet. According to the National Resource Defense Council (NRDC), the cost effectiveness of EVs led drivers to spend about 60% less each year on fuel (Lindwall, 2022). This appealed to consumers and EV sales surged. The Recovery Act created a nationwide charging infrastructure in order to keep up with the growing demand of EVs. However, consumers are concerned with the barriers inhibiting adoption of EVs, specifically the charging infrastructure. If there are not enough charging stations, EVs become extremely inconvenient as drivers are not able to obtain fuel as easily as a gas powered vehicle. A solution to this problem is imperative or the environmental benefits of EVs will not be received.

Literature Review

Environmental Benefits of EVs

EVs have been proven to be more beneficial for the environment than gas powered vehicles. EVs emit no carbon dioxide when driving, so there is no tailpipe attached to the vehicle. In about one year, an EV can save an average of 1.5 million grams of carbon dioxide being emitted into the atmosphere per car compared to gas powered vehicles (EDF Energy, 2020). This creates a substantial difference in the efforts to reduce greenhouse gasses (GHG) to fight climate change. The extent of the benefit EVs have on the environment is dependent on the location of the vehicle. Some areas generate energy that releases limited GHG, and other areas may use a different method of electricity generation that releases more GHG (U.S. Department of Energy, 2019). There are some misconceptions about EVs emitting more pollutant overtime when compared to gas powered vehicles because of the production process. MIT

Researcher Andrew Moseman found that the creation of the lithium-ion batteries for EVs requires fossil fuels to mine the minerals needed. This results in higher GHG emissions for EVs during the production process when compared to gas powered vehicles (Moseman, 2022). However, a study done by Maxwell Woody determined that even if the production of the EV releases more GHG than that of gas powered vehicles, this difference will be offset in a period of about 1.4-1.9 years of driving. From that point moving forward, the EV will be significantly more efficient and beneficial to the environment than gas powered vehicles (Woody et al., 2022).

Assimilation with Legislation

Legislation passed by the state and federal governments have allowed for EVs to become more popular in the United States. Mathilde Carlier found that there has been an increase in the number of EVs purchased from 2021 to 2022 by about 100,000 units per quarter (Carlier, 2022). This growth can be directly attributed to the Inflation Reduction Act passed in 2022. This was introduced by the federal government and provides incentives and tax breaks for individuals who purchase EVs (The White House, 2022b). The CHIPS and Science Act passed in 2022 also boosted EV sales by supporting federal production of semiconductors and domestic manufacturing (The White House, 2022a). New forms of legislation have allowed for increased access to purchase EVs. Public transportation has also started to become electrically powered. The Bipartisan Infrastructure Law authorized up to \$108 billion for the creation of a zero-emission fleet of public transportation (The White House, 2022b). The Paris Agreement of 2015 committed countries to reduce greenhouse gas emissions and pollution by at least 40% by 2030 compared to the 1990 levels (United Nations, 2015). The US Government has acknowledged that an increase in EVs will assist in reaching this goal, which is why new legislation supporting EV sales gets passed.

Barriers to Adoption of EVs

Regardless of the environmental benefits that are experienced when purchasing an EV, there are many barriers that hinder the growth of EV sales. EV batteries lead to many ethical and functionality concerns. Consumers are distressed about the copious amounts of energy required in order for minerals to be extracted from the ground to create these batteries (Crawford, 2022). There is no current plan to recycle the lithium-ion battery which causes individuals to become concerned with the environmental impacts of the landfills that these batteries are being stored in. The higher vehicle purchase price is another prevalent concern with EVs. Research published in the journal Energy Policy by Axsen and Kurani stated that the upfront cost of EVs is generally higher than that of gas powered vehicles (Axsen & Kurani, 2013). The charging of EVs is another significant barrier hindering EV adoption. According to a study by Anthony Patt and research associates in 2019, individuals who have access to a private garage or parking space were twice as likely to be willing to purchase an EV than those who would park their car in the street (Patt et al., 2019). This shows that if there is no direct access to home charging, then the EV becomes more inconvenient for individuals. Further studies have been conducted on charging stations for EVs and their functionality. In a study conducted by David Rempel and research associates, they determined that out of a group 657 charging stations in San Francisco, over 22% were non-functioning or experienced technological malfunctions (Rempel et al., 2022). This problem needs to be addressed as access to charging stations is the most vital component of EVs.

Types of Charging

There are three main types of EV charging stations. The first is Level 1 charging stations, which do not require any hardware installation, and they can be plugged into the majority of outlets (Duke Energy, 2022). This charger is most effectively used for overnight charging and low-mileage daily driving for vehicles with smaller batteries. Level 1 charging stations are not very powerful as for 8 hours of charging, about 40 miles of driving range can be restored (United States Department of Energy, 2019). Level 2 charging stations are often found in public areas such as rest stops, shopping centers, and restaurants. The majority of ports in the United States are Level 2 charging stations which can be used to charge a vehicle from empty to full within about 10 hours. Also, these chargers need to be installed by a qualified electrician (Duke Energy, 2022). The most effective and fastest option to charge an EV is a DC Fast Charger. These chargers typically provide up to about 250 miles of range for the car per hour and can charge nearly eighty percent of the car's battery within about 20-30 minutes (United States Department of Energy, 2019).

Tesla charges are DC fast charges and there are many of these charging stations spread across the nation. However, EVs that are not Teslas cannot use these stations without a special adaptor which currently is not available at most locations. There is clearly a need for greater accessibility to DC Fast Charges to make the charging experience for an EV more efficient and allow for greater assimilation of EVs into the current car market.

Current State of EVs on Long Island

As seen by Rempel's study, there are currently problems with EV charging stations in the United States. More specifically, according to EVAdoption, a company that provides rigorous analysis of EV data, New York currently has a ratio of 16.19 EVs to charging stations (Charging Stations by State , 2021). This is below the national average and highlights a large problem since New York is attempting to increase the presence of EVs by passing new legislation. New York is trying to increase the amount of EVs driven, but is not installing the charging infrastructure to support these sales. This problem can be seen more specifically on Long Island as well. Nicole Larson, a team member who analyzes charging stations at Ford Motors, went to Long Island malls and found error messages when testing the charging stations in the parking lot (Chokshi, 2022). If charging stations are not properly working, consumers may be holding back from purchasing an EV which prevents the access environmental benefits of these vehicles. Research done by Marco Giansoldati in Italy and Tarei Pradeep Kumar in India has shown that if there is a lack of access to charging stations, consumers face a barrier to adopt EVs (Giansoldati et al., 2020; Tarei et al., 2021). This identifies a gap in the field of knowledge as there has been no study conducted on Long Island testing the extent to which charging stations impact consumers' opinions on EVs. The researcher hypothesizes that the lack of access to functioning charging stations in causing individuals to not purchase an EV. This leads to the research question: To what extent is the lack of access to functioning high speed charging stations a deterrent to the widespread adoption of electric vehicles on Long Island?

Methodology

Rationale

For this study, a survey was conducted to analyze the barriers of EVs and the impact of EV charging stations on consumers on Long Island. The sample size for this study needed to be substantial in order to represent the Long Island population, which is currently about 7.56 million people. Interviews, due to their time-consuming nature, would not be as viable of a solution and could result in an inadequate sample size. Uninfluenced responses are crucial to gather the most accurate results about the opinions of EV charging stations. When using a survey, anonymity for the respondent is achieved as the only acknowledgement of their personally identifiable information would be a signature of their initials at the bottom of the informed consent. Respondents may not feel as comfortable sharing personal opinions in face-to-face interviews, but a survey can create a sense of privacy. A survey also allows respondents to participate at their convenience, which can assist in increasing the response rate.

Sampling

The population being surveyed for this study was adults on Long Island who are over the age of 18. Only individuals with driver's licenses were intended to participate in this study because this is the population that could be looking to purchase an EV either during the time of the study or in the near future. As stated before, the rationale for choosing Long Island as a population for this study is due to the lack of charging stations in New York and particular problems with these charging stations on Long Island. Convenience sampling was used in order to acquire participants. This is a non-probability method where no patterned approach is used when looking for participants. Due to the ease of gathering participants, a general sense of the range of opinions on EV charging stations can be determined. Despite this, convenience sampling is not probability sampling so it does not result in complete unbiased and generalizable data. There is a possibility of false representation of the population, but this method is still effective for this study because it allows the researcher to look at the population of Long Island as a whole, rather than restrictive subgroups.

Participants were obtained through posters and Facebook posts. They were oriented with a brief description of the research being conducted on the top of the page and the requirements needed to be met in order to participate. For the posters, a QR, which was linked to the informed consent portion of the survey, was printed under the text. The Facebook posts had a direct link attached which was also linked to the same portion of the survey.

Survey

The survey was conducted on google forms and all of the responses were automatically uploaded to google sheets to be analyzed. There were three segments of the survey for this study: an informed consent page, questions pertaining to demographics and EV barriers, and statements regarding EV charging stations. In order to participate in this study, a signature of the initials of the participant would have to be given. This acknowledges that the respondent is fully aware of the purpose of the survey, their right to withdraw from the study at any time, and that all responses to this survey are anonymous. Age of the participants was the only information gathered regarding demographics. This was to determine the level of similarity amongst the population gathered and the actual Long Island population. Next, the survey asked which barriers, if any, were holding the respondent back from purchasing or leasing an EV for their next vehicle. This would allow the researcher to determine which barriers inhibiting EV adoption are most prevalent on Long Island.

The main segment of the survey was about EV charging stations. The data gathering technique used was based on a study done by Marco Giansoldati, a professor in Economic Policy at the University of Trieste, Italy. In Giansoldati's study, he looked at all of the barriers influencing the low uptake of EVs in Italy and used survey statements with a likert scale to generate data. From this survey, the extent to which barriers influenced Italian consumers' opinions about EVs was determined, which proves that the method was effective. For the survey conducted in this paper, seven statements were used to allow the researcher to see the extent to which EV charging stations impacted consumers' opinions. These statements had different scenarios regarding the EV charging process which looked at factors such as cost, accessibility, and convenience. Based on the study done by Giansadalti, a scale of agreement ranging from 1-4 was used to quantify the results. The response on the scale will indicate how opinionated the respondent is and whether they agree or disagree with a particular statement (Figure 1). If a respondent did not have any opinion about the statement, they were instructed to leave that portion blank.

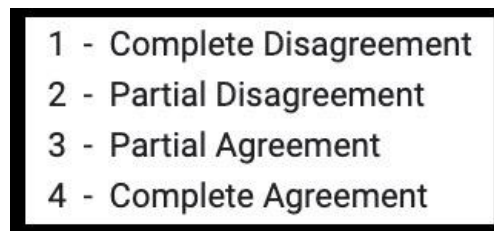


Fig 1
Scale of Agreement

t-Test for Statistical Significance

A t-test was used to determine whether EV charging stations actually had an impact on a particular statement from the study. A two-tailed one-sample t-test was conducted to see the similarity of responses from a population impacted by a lack of EV charging stations to that of a population with no issues regarding EV charging stations. This would test for a difference in both directions from the standard value or critical t-value. Figure 2 shows the formula to calculate the t-value where \bar{x} is the sample mean, μ_0 is the expected mean, s is the sample standard deviation, and n is the sample size. Using a t-distribution chart, the degrees of freedom for the statement and the t-value are used to see if the p-value is less than .05.

$$t = \frac{\bar{x} - \mu_0}{s / \sqrt{n}}$$

Fig 2
Test Statistic Equation

The null hypothesis for each statement was that there is no statistical difference between the results of the expected population and the population that was impacted by a lack of EV charging stations. An alpha level (α) of .05 was used, and if the p-value calculated is less than α , the data is statistically significant, so the null hypothesis is rejected. A valid conclusion can be made about a particular statement if the data is statistically significant.

Results

A total of 167 participants responded to the survey with a median age of 42.5 years and a mean age of 48.56 years. A diverse sample was collected in terms of age range with 35-50 years old comprising 31.1% of the sample and being the largest group. The remaining age ranges were relatively evenly distributed, with 24.6% aged 18-34, 21.6% aged 51-64 years old, and 22.8% aged 65+ years old.

Table 1 - Survey Response Data

#	Statement	Respondents	1	2	3	4	Mean	Median
1	I believe that the current number of charging stations is too low in my area	164	4.9%	17.1 %	34.8%	43.3%	3.165	3
2	I am worried that the price of electricity for home charging could lead to a significant increase in my bill	163	38.0%	32.5%	21.5%	8.0%	1.994	2
3	The electric car poses a problem of where to charge and at what cost, especially for those who do not own a garage or driveway	166	7.2%	10.8%	28.9%	53.0%	3.277	4
4	The construction of a home charging infrastructure is a complicated and expensive process	163	21.5%	31.9%	29.4%	17.2%	2.423	2
5	New York State Government should increase investments to expand the availability of plug-in EV charging stations on Long Island	164	4.3%	7.3%	23.2%	65.2%	3.494	4

6	The need to charge frequently makes the electric car very impractical for daily use	161	39.1%	34.2%	20.5%	6.2%	1.938	2
7	Using an electric car for long distances is difficult due to the lack of charging stations along the highways	166	6.0%	17.5%	29.5%	47.0%	3.175	3

The statements above were those given in the survey. Measures of central tendency were used to provide an accurate description of the data collected. The statements resulted in varying response totals because participants were not required to answer if they did not want to give an opinion. The mean of the data for statements 1, 3, 5, and 7 was towards the agree to strongly agree portion of the scale resulting in a value above 3. The mean of the data for statements 2 and 6 was towards the disagree to strongly disagree portion of the scale resulting in a value below 2. Statement 4 was not swayed toward a particular section of the scale as the mean response was 2.423, which is close to the midpoint of the scale. The median was used as another form of numerical value to represent the agreement levels of the population surveyed for each statement.

Table 2 - T-Test for Statistical Significance

Statement #	σM	t-value	df	p-value	Null Hypothesis
1	0.07	9.66	163	< .00001	Reject
2	0.08	6.74	162	< .00001	Reject
3	0.07	10.82	165	< .00001	Reject
4	0.08	0.97	162	0.17	Accept
5	0.06	15.71	163	< .00001	Reject
6	0.07	7.75	160	< .00001	Reject
7	0.07	9.37	165	< .00001	Reject

The standard deviation of the responses for each statement was calculated in order to determine the standard error of the mean (σM). Using σM the t-value was calculated. The degrees of freedom was about 162 for each statement and a t-distribution chart was used. Since the test was two-tailed, the critical t-value was determined to be 1.65 from the chart. All of the statements received a t-value above the critical value except for statement 4. The p-value for all statements except for statement 4 was below α , which leads to the data being statistically significant. When the data is statistically significant, the null hypothesis is rejected. For statement 4, the data was not statistically significant because the p-value of .17 was greater than α , so the null hypothesis was accepted and there can be no distinct conclusion made.

Table 3 - Barriers to EV Adoption

Barrier	Respondents	Percent of Total
Price of Vehicle	80	53.0%

Not Enough Public Charging Stations Available	70	46.4%
Insufficient Driving Range	38	25.2%
Long Charging Times	38	25.2%
No Domestic Charging Options	35	23.2%
Not Knowledgeable Enough About EVs	35	23.2%
Other	29	19.2%

The barriers that inhibit an individual from purchasing an EV were evaluated in the survey. “Price of Vehicle” was the most prevalent barrier for the population in this study. The significant concern over the price of EVs is a factor that is vital to acknowledge when looking at barriers on Long Island. The lack of public charging stations available was chosen the second most frequently with 46.4% of the total respondents indicating this would prevent them from purchasing an EV. The rest of the barriers had a similar number of people selecting them at 19.2% - 25.2% of total respondents. In addition, some barriers were seen to have significant spikes depending on age range.

Discussion

The results indicate that the population surveyed is a representative sample of Long Island. The median respondent age for this study was 42.5 years old, and according to New York State Comptroller, the median age on Long Island is 41.25 years old (DiNapoli, 2019). Despite the use of convenience sampling, this increases the validity of the data gathered as the population surveyed was similar to that of the actual Long Island population.

The statements indicated that there were strong opinions towards the current situation of EV charging stations (Table 1). Based on statement 1, respondents generally agreed that the number of charging stations on Long Island were too low. This could be a direct deterrent to someone purchasing an EV and prompts the need for an increase in functioning charging stations available. Statement 2 proved that the price of electricity for home charging was not a factor that respondents were particularly concerned about and generally disagreed with the statement. In spite of this, respondents believed that charging is a worry for those who do not own a garage or driveway as seen from statement 3. Due to the fact that they cannot install home charging stations, they would need to go out in order to charge their vehicle. However, if there are not enough functioning high speed charging stations available, the EV becomes very inconvenient, which further proves the need for more charging stations. For statement 4, the t-test determined the data was not statistically significant, so there was no conclusion that could be made about the construction of home charging stations. Statement 5 indicated that respondents strongly agree that there should be an increase in investments by the New York State Government to expand the availability of charging stations. This expansion will notably improve the current situation by allowing significantly easier access to charging stations. Based on statement 6, the respondents generally disagreed that the need to charge frequently makes an EV impractical for daily use. Since charging is not seen to be inconvenient, this further exemplifies that it’s not the process itself that is the problem, it’s the accessibility of the charging stations on Long Island. The last statement indicated that using an EV for long distance traveling is difficult due to the lack of charging stations along the highway. An extensive network of charging stations on Long Island would be able to remedy this problem.

The barriers to the adoption of EVs were also an important component of the survey. Price of vehicle was seen to have the greatest impact on the respondents decisions to purchase an EV. This was mainly seen in people 18-34 as nearly 76% of all respondents in this age group selected this barrier. Since many people in this age group may have recently exited formal education and are beginning the transition to the workforce, they may not have as much money available to purchase an EV as the other age groups. Not enough public charging stations available was the

next most prevalent barrier with a 46.4% selection rate. This further proves that EV charging stations are an important factor preventing people from purchasing an EV and needs to be addressed.

Limitations

Despite this study helping determine the extent to which charging stations have an impact on consumers on Long Island, there are limitations to the conclusions drawn. Convenience sampling could be a factor that decreases the validity of the results. This sampling method was not based on random-probability, introducing bias within participants' responses. If a random sample of participants was gathered, selection bias would have been eliminated and the data would have better represented the entire Long Island population. However, this was not an extremely significant limitation as the median age of the population surveyed was analogous to that of the actual population.

A vital factor that was not taken into account was the socio-economic status of the respondents. The study looked at Long Island as a whole and did not specifically target certain demographics, leading to slight overgeneralization of the results. A New York census report determined that Nassau County's median income level was \$15,000 greater than Suffolk County, and Nassau County's median home value was about \$80,000 greater than Suffolk County (DiNapoli, 2019). Responses to the study could have been strongly influenced by the difference in economic status between counties on Long Island. If this were taken into account, a more precise location of where consumers are impacted the most by the lack of EV charging stations could have been determined.

Future Direction

EV charging stations have been seen to have a significant impact on consumers, which impacts their decision to purchase an EV. Nonetheless, studies conducted by researcher Lance Noel and his colleagues have been congruent with the findings in this study that there are many other barriers inhibiting widespread EV adoption (Noel et al., 2020). These barriers include the price, driving range, and charging times of EVs. It would be extremely valuable to understand the extent to which these barriers are impacting consumers and determine what action could be taken in order to mitigate their effects. As shown in Table 3, price of an EV was the most prevalent barrier preventing a consumer from purchasing a vehicle, further proving the need for more research to analyze the extent of this issue. Other factors such as income level, gender, and county could all be evaluated to see the correlation between EV barriers and population demographics. The researcher would then be able to determine where resources should be allocated to remedy the situation.

Long Island has experienced a lack of sufficient functioning high speed charging stations, but this problem is not limited to this geographical area. The study conducted by EVAdoption showed that many other locations in the United States were experiencing similar situations to that of New York (Charging Stations by State, 2021). Future research could determine what factors are impacting consumers the most in these areas, which would allow for the environmental benefits of EVs to be further experienced everywhere in the United States. A random sampling method is recommended for future studies in order to avoid conclusions not completely representing the sample population.

Conclusion

The hypothesis that the current state of EV charging stations is hindering the widespread adoption of EVs on Long Island was proven to be true. The sample gathered was predominantly representative of that of Long Island due to the median age of participants. A lack of EV charging stations was seen to be the second most prevalent barrier holding consumers back from purchasing an EV. Charging stations were already known to be a barrier for EV, but this study determined how individuals were impacted by this barrier. The findings suggest that the charging process itself was not the issue. If EV charging stations were accessible, cost and time of charge would not be a barrier for a consumer

to purchase an EV. However, there was a strong agreement that the current number of charging stations on Long Island was inadequate. This creates a problem for those who do not own a garage or driveway as home charging is not an option in this setting and EVs are not suitable for their needs. Individuals who need to commute along highways found EVs inconvenient due to the lack of nearby charging stations. It is imperative that the New York State Government accept the responsibility of the lack of EV charging stations. The environmental benefits of EVs are numerous and increasing their adoption is critical to fighting climate change. As a result, new legislation passed by the New York State government is essential to allocate more resources towards expanding the charging infrastructure on Long Island.

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