STAT 5740 Final Report

Which Electric Vehicle Brands Are the Best?

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1. Introduction

As global warming and greenhouse gas emissions become increasingly important topics on the world stage, one industry in particular is experiencing a revolution: the automobile industry. Due to a demand for alternatives to today's fossil fuel powered automobiles, competition in the electric vehicle sector is booming. As a result, the number of electric vehicles in the market has proliferated at a rate never seen before. But how will consumers choose the best electric vehicle? Do the properties of the vehicle change under different conditions? There are many standards used to evaluate electric vehicles, including acceleration time, safety, weight, battery, charging time, life span, and many more. The challenge of determining the best electric vehicle brands is a daunting one, but still attractive to data analysts. In this study, we will use SAS to explore various questions related to electric vehicles, and return a performance ranking based on electric vehicle data pulled from the Electric Vehicle Database.

2. Data

Sources

Our data has a sample of 194 electric vehicles on market up until 2022. The data was collected manually from ev-database.org by Mo Shiha. Each row contains one entry including the unique id of cars, their brand, unique web link as well as other properties such as ranges in various weather/road conditions, basic technical specifications, battery capabilities, and more. We evaluated the electric cars' performance by first exploring different aspects of the vehicles based on the available data. Based on these analyses, we then gave a comprehensive summary and overall performance evaluation of the cars.

Variables:

Original Variables From Data:

id : unique identifier
Make : brand of the car
link : source url
City - Cold Weather : range in Km under cold weather conditions (-10 degrees) in cities
Highway - Cold Weather : range in Km under cold weather conditions (-10 degrees) on highways
Combined - Cold Weather : range in Km under cold weather conditions (-10 degrees) combined
City - Mild Weather : range in Km under mild weather conditions (23 degrees) in cities
Highway - Mild Weather : range in Km under mild weather conditions (23 degrees) on highways
Combined - Mild Weather : range in Km under mild weather conditions (23 degrees) combined
Acceleration 0 - 100 km/h : acceleration from 0 to 100 Km per hr in seconds

Top Speed : Top speed in Km/h
Electric Range : Advertised electric range in Km
Total Power : Total capacity of the battery in KW
Total Torque: Total Torque of the car N·m
Drive : Rear, Front, AWD
Battery Capacity: Battery Capacity(kWh)
Charge Power: Charge Power (kW AC)
Charge Speed: Charge Speed (km/h)
Fastcharge Speed: Fastcharge Speed (km/h)
Length : Car lengths in mm
Width : Car width in mm
Height : Car height in mm
Wheelbase : Wheelbase in mm
Gross Vehicle Weight (GVWR) : Gross weight of the car in Kg
Max. Payload : Maximum amount of weight that the car can safely carry
Cargo Volume : Cargo volume of the car in litters
Seats : Number of seats

New Variables Created:

Specific Question 1:
Avg_Range: (City - Cold Weather + City - Mild Weather +'Combined - Cold Weather + Combined - Mild Weather + Highway - Cold Weather + Highway - Mild Weather)/6
Avg_City: (City - Cold Weather + City - Mild Weather)/2
Avg_Highway: (Highway - Cold Weather + Highway - Mild Weather)/2
Avg_Combined: (Combined - Cold Weather + Combined - Mild Weather)/2
Avg_Cold=(City - Cold Weather + Combined - Cold Weather + Highway - Cold Weather)/3
Avg_MildW=(City - Mild Weather + Combined - Mild Weather + Highway - Mild Weather)/3;

Specific Question 2:
Charge_Time: Electric Range / Charge Speed
Fastcharge_Time: Electric Range / Fastcharge Speed
Average_Normal_and_Fastcharge_Time: (Charge_Time + Fastcharge_Time) / 2

Specific Question 4:
RangeScore: Electric Range / Total Power

Brief Summary

In Table 1, there are 34 brands of electric vehicles with sample sizes ranging from 1 to 24. Renault electric vehicles appear to have the best average range per battery power. Mercedes electric vehicles have both the best average actual range and the best advertised electric range. We found that the average actual range and the advertised electric range for each brand is fairly consistent, although the advertised electric range tends to be slightly lower than the average actual range. By comparing the mean of average normal/fast charge time, we see that Mini has the best performance. However, Dacia scores best in terms of acceleration time. A more convincing conclusion can be drawn from a particular car brand if it has more sample sizes.

Make	Sample Size	Range per battery power Mean	Average Actual Range (Km) Mean	Advertised Electric Range (Km) Mean	Average Normal and Fast Charge Time Mean	Acceleration Score Mean
Audi	16	1.65	364.01	360.94	4.55	0.002301
BMW	8	1.44	440.42	438.13	4.94	0.001802
CUPRA	4	2.38	359.17	355.00	3.85	0.003292
Citroen	11	2.20	225.30	220.00	4.61	0.004369
DS	1	2.60	262.50	260.00	3.92	0.004405
Dacia	1	4.70	160.83	155.00	2.67	0.014692
Fiat	8	2.35	218.33	214.38	3.48	0.004805
Ford	7	1.63	416.67	411.43	5.08	0.002189
Genesis	4	1.48	376.25	371.25	4.17	0.002053
Honda	2	1.60	171.67	170.00	3.05	0.004645
Hongqi	2	0.91	334.58	330.00	4.86	0.001809
Hyundai	5	2.29	348.50	343.00	3.82	0.003420
JAC	1	2.65	230.00	225.00	4.22	0.006417
Jaguar	1	1.29	386.67	380.00	5.05	0.001798
Kia	6	2.04	353.06	349.17	3.86	0.003079
Lexus	1	1.57	238.33	235.00	4.84	0.003341
MG	8	2.38	322.81	318.75	4.21	0.003681
Mazda	1	1.59	170.83	170.00	2.01	0.004578
Mercedes	24	1.97	458.61	456.04	5.08	0.002314
Mini	1	1.33	184.17	180.00	1.90	0.004113
Nissan	1	2.13	344.17	340.00	6.02	0.003224
Opel	6	2.37	241.53	236.67	4.54	0.004258
Peugeot	12	2.25	229.10	224.58	4.55	0.004505
Polestar	2	1.91	415.83	410.00	4.39	0.002390
Porsche	18	1.01	418.19	416.11	4.54	0.001412
Renault	5	3.14	324.00	320.00	1.94	0.004756
Seres	1	2.25	274.17	270.00	5.22	0.004310
Skoda	5	2.57	389.67	386.00	4.10	0.003223
Smart	2	1.41	347.50	342.50	3.76	0.002352
Subaru	1	2.22	360.00	355.00	6.73	0.002706
Tesla	4	1.19	453.13	448.75	4.35	0.001691
Toyota	8	2.35	270.83	267.50	5.62	0.003920
Volkswagen	13	2.56	391.54	387.69	4.43	0.003302
Volvo	4	1.55	343.33	338.75	4.13	0.002412

Table 1: Sample size and mean summary statistics across electric car brands

3. Specific Questions

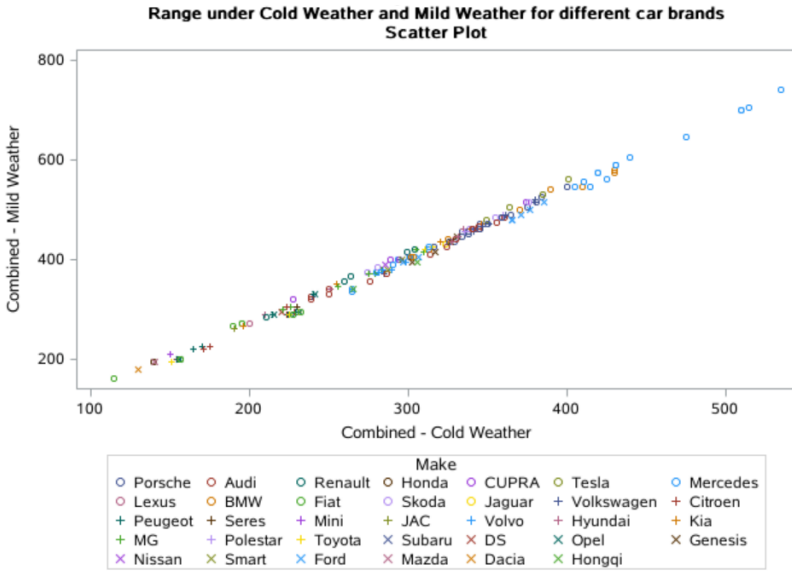
a. Specific Question 1 (Yunjie Li)

a.1 From a statistical point of view, is range under good weather condition generally longer than those under bad weather conditions for the same car? Similarly, is range among cities generally longer than ranges on highways?

a.1.i. Methods

Firstly, the relationship between range and weather/road conditions can be visualized. Preliminary conclusion can be drawn based on data visualization. Then from a statistical point of view, a paired T-test using SAS procedure PROC TTEST (SAS Institute, Inc., 2018) can be conducted between good and bad weather conditions as well as between cities and highway road conditions, as ranges under different weather/road conditions are measured on the same cars.

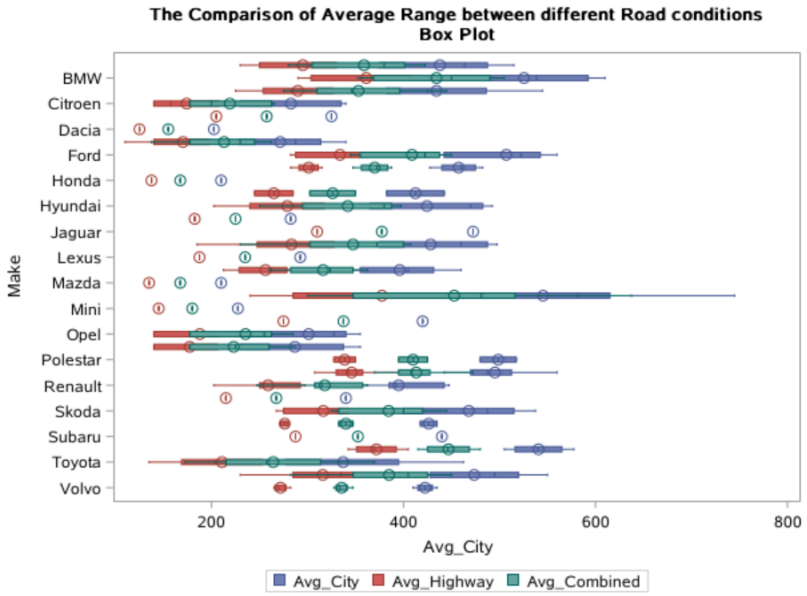
a.1.ii. Results



Plot 1: Ranges under Cold vs Mild Weather for car brands

Firstly, visualize the relationship between mild and cold weather of different car brands in plot 1. Ranges under mild weather are typically longer than those under cold weather. Most car brands have a range of 200 to 400 km in cold weather, but can sustain around 400 to 600 km under mild weather conditions. The top average ranges are all from Mercedes brand, which perform outstandingly well under both weather conditions.

Then visualize the ranges between different car brands under different road conditions(regardless of weather) using box plot 2. For all brands, ranges in City are longer than combined road conditions, and ranges in highway are smallest.



Plot 2: Ranges under different road conditions for car brands

Overall, from data visualization, it seems that ranges are longer under mild weather and city road conditions. The confirmation of the preliminary conclusion should be made based on statistical tests.

Obs	Difference	Estimate	95% Confidence Interval	T-Value	P-Value
1	Avg_MildW - Avg_ColdW	109	(104,114)	43.94	<.0001

Table 2: Paired t-test difference between average range under mild and cold weather conditions

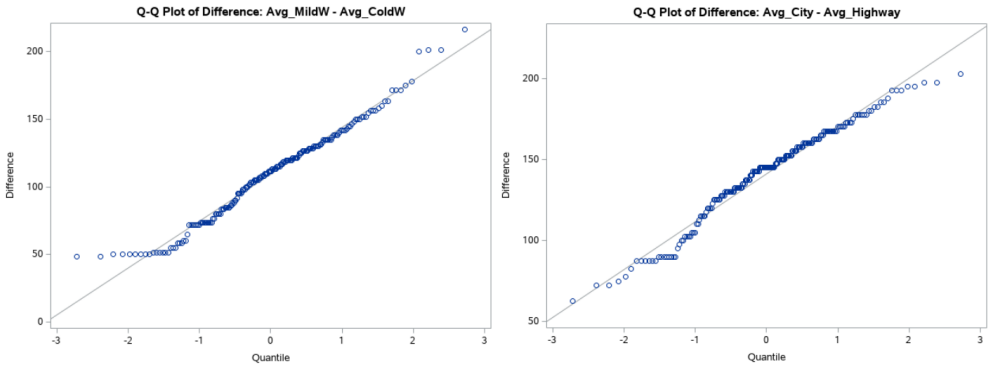
Obs	Difference	Estimate	95% Confidence Interval	T-Value	P-Value
1	Avg_City - Avg_Highway	141	(137,146)	66.76	<.0001

Table 3: Paired t-test difference between average range under city and highway road conditions

From table 2, the results of paired t-test indicate that the average difference between ranges under mild weather and ranges under cold weather conditions is 109 km, and the difference does not equal 0 (P-value < 0.001). I am also 95% confident that range under mild weather on average is between 153 and 166 larger than range under cold weather conditions.

From table 3, the paired t-test results show that the average difference between ranges under city and highway road conditions is 141 km, and the difference does not equal 0

(P-value < 0.001). I am also 95% confident that range under city is between 137 and 146 larger than range under highway road conditions.



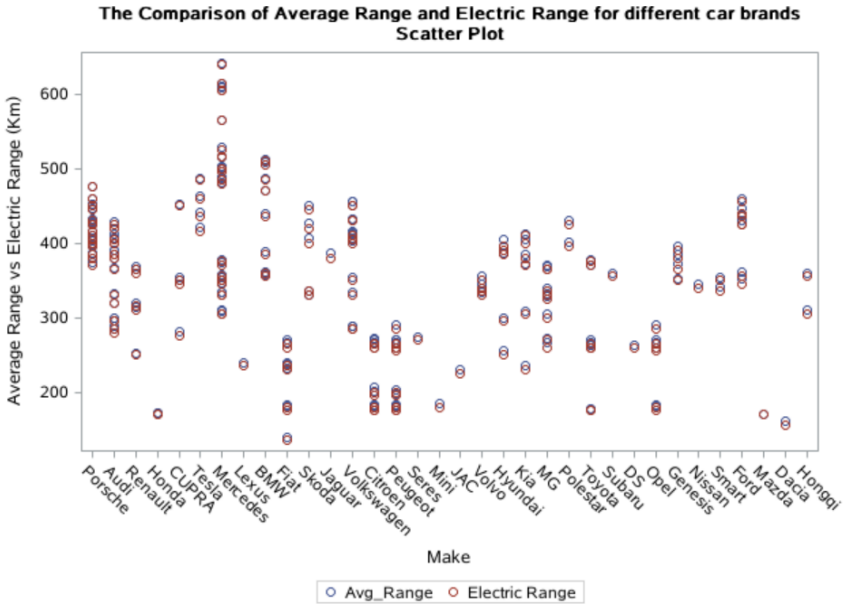
Plot 3: Q-Q plot of difference of range between mild and cold weather (left) and city and highway (right)

Assumption assessment: With 194 observations, the estimates and test are robust to mild violations of normality assumption. In Q-Q plot 3 on the left, we could see most observations fall relatively close to the straight line, suggesting that the observed differences of two groups do not deviate a lot from a normal distribution. In Q-Q plot 3 on the right, we could see a little bit more fluctuation around the straight line, however, as mild violations of normality assumption is tolerable, I can not think the assumption is wrong.

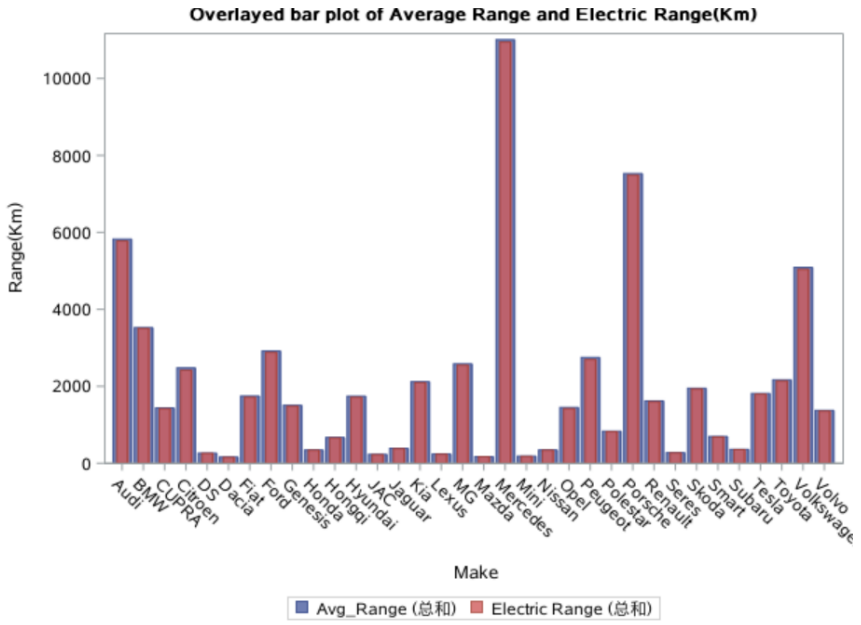
a.2 From a statistical point of view, is average actual range (calculated by averaging all actual range values under different weather/road conditions) positively correlated with Electric Range (Advertised electric range)?

a.2.i. Methods

Firstly, visualize the relationship between average actual range and electric range of different car brands in plot 4 and 5. In plot 4, electric range are shown in red circles while average ranges under combined weather/road conditions are in black. There are much overlap between electric range and actual range. Also, well-known luxury car brands such as Mercedes, BMW and Porsche have both average and electric ranges better than budget brands like Fiat. Similar conclusions can be drawn from plot 5.



Plot 4: Average range vs electric range for different car brands(Scatterplot)



Plot 5: Average range vs electric range for different car brands(Overlay bar plot

From data visualization, it seems that the association between average range and electric range is very strong and well-known luxury car brands tend to have better ranges than cheaper ones. In order to confirm the authenticity of question **a.3**, statistical test should be performed.

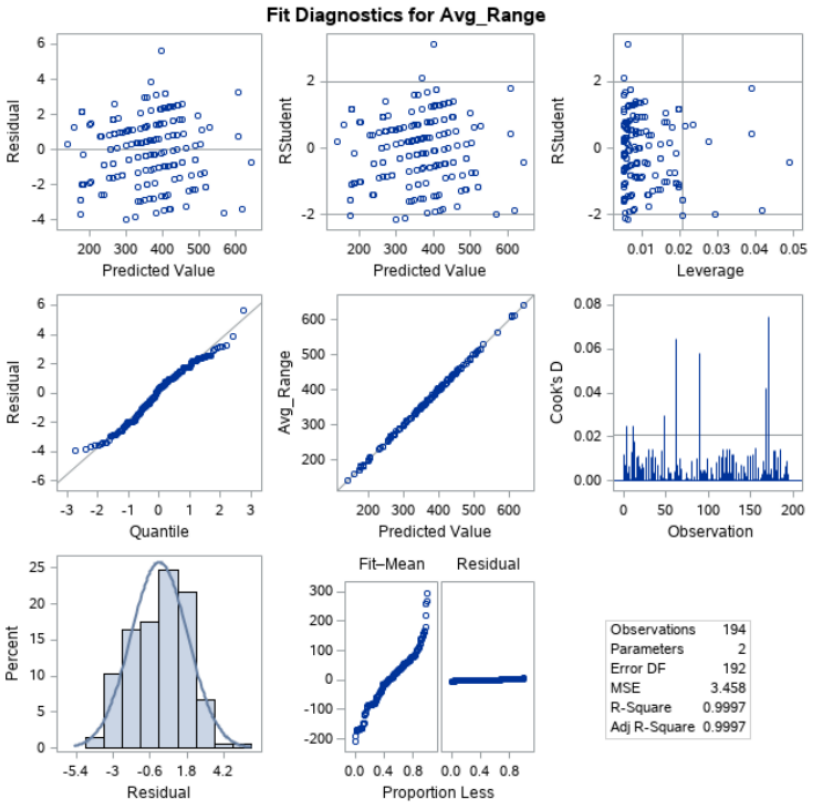
As this question explores the association between two continuous variables (Avg_Range) and Electric Range, a linear regression using SAS procedure PROC REG (SAS Institute, Inc., 2018) can be performed by regressing Avg_Range on Electric Range. The results of linear regression fit with 95% Confidence intervals for model parameters and type III tests of null hypothesis that all parameters equal 0 can be analyzed.

a.2.ii. Results

Variable	Parameter Estimate	Standard Error	95% Confidence Interval	T-Value	P-Value
Intercept	5.26293	0.47541	(4.33,6.20)	11.07	<.0001
Electric Range	0.99556	0.00132	(0.99,1.00)	754.06	<.0001

Table 4: Linear Regression between Average Actual Range and Electric Range results

From the result of linear regression, the p-value is very small (<0.0001), suggesting that there is strong evidence that the average range is linearly associated with electric range in kilometers. The sign of the linear coefficient is positive, indicating a positive correlation between Avg_Range and Electric Range. The parameter estimate of Electric Range signifies that given a one-kilometer increase in Electric Range, the mean of the Avg_Range (average actual range) also increases 0.99556 km. The parameter estimate of intercept represents that the mean value of the Avg_Range is 5.26293km when Electric Range value is equal to 0. Also I am confident that an increase of 1 km in electric range will bring an increase of 0.99 to 1.00 km in actual average range, on average. This confidence interval includes 1.00, which means that the increase in Electric Range could translate to an equivalent increase in average actual range for the car.



Plot 6: Fit diagnostic plot for Linear Regression

Assumption assessment: From the diagnostic plot 6, I can not find evidence against the assumption that errors are independently and normally distributed. Specifically, the upper left plot suggests a random scatter of residuals around 0; The upper center plot indicates that most residuals fall within two standard errors of 0. There seems to be two outliers potentially. Also, the center left Q-Q plot indicates that most residuals fall along a straight line, so the normality assumption is not violated grossly.

b. Specific Question 2 (Kaylyn Jiang)

Since we are considering electric vehicles, which differ from normal vehicles in that they are powered by electricity rather than gasoline, it is important to consider the charging capabilities of each brand of electric vehicle. In this section, we explore and answer the question: which brand of electric vehicle has the best overall charging capabilities?

i. Methods

First, we explored which brands of electric vehicle had the fastest Average_Normal_and_Fastcharge_Time, the description of which can be found in the data section. This was assessed by figure XX1, which shows the mean Average_Normal_and_Fastcharge_Time for each brand. We then compared the mean Average_Normal_and_Fastcharge_Time for each brand of electric vehicle using the PROC ANOVA procedure (SAS Institute, Inc., 2018). Specifically, we investigated the difference in the mean Average_Normal_and_Fastcharge_Time between each brand. Our null hypothesis was that the mean Average_Normal_and_Fastcharge_Time for all brands were the same. Our alternative

hypothesis was that at least one of the mean Average_Normal_and_Fastcharge_Time was different from the others. Since the ANOVA procedure only tells us if the means are different, we specified an ad-hoc test to find out exactly which groups have means that are different. Because the group sample sizes are not equal, we used the Scheffe method as it is the most flexible method.

ii. Results

According to Figure 1, we found that the electric vehicle brands Mini and Renault had the fastest mean Average_Normal_and_Fastcharge_Time. Thus, when we conducted the ANOVA procedure, we were most interested in whether these two brands differed from the others.

Table 5.1 contains the confidence intervals for differences in mean Average_Normal_and_Fastcharge_Time between Mini and other electric vehicle brands. We notice that all of the confidence intervals contained zero, indicating that the difference in mean Average_Normal_and_Fastcharge_Time between Mini and the other electric vehicle brands is not significant. Table 5.2 contains the confidence intervals for differences in mean Average_Normal_and_Fastcharge_Time between Renault and other electric vehicle brands. We notice that there is a significant difference in mean Average_Normal_and_Fastcharge_Time between Renault and two other brands: Toyota and Mercedes.

Although we were primarily interested in investigating the charging capabilities of Mini and Renault, we also looked at the confidence intervals of other brands. None of the other brands, however, had differences that were significant. Since Renault has the second fastest mean Average_Normal_and_Fastcharge_Time and is the only brand with a significantly different mean Average_Normal_and_Fastcharge_Time, we conclude that Renault has the best overall charging capabilities.

Lastly, looking at Figure 2, we notice that the distribution of each brand does not appear to be normal. Additionally, if we observe the frequency of each brand in Table 6, we notice that the sample size for each brand ranges from as low as one to as large as twenty four. Both of these characteristics of the dataset may contribute to a violation of the normality assumption required by the ANOVA procedure.

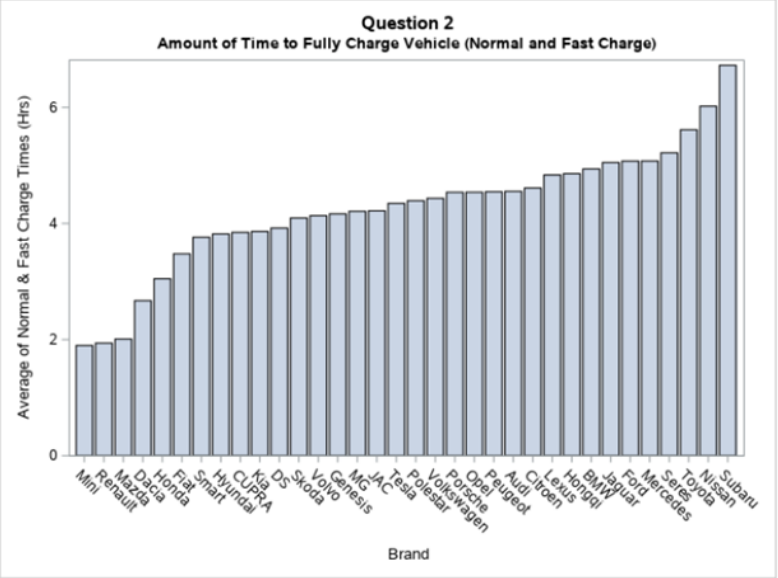


Figure 1: Bar chart comparing the mean Average Normal and Fast Charge Time for each brand

Comparisons significant at the 0.05 level are indicated by ***.

Make Comparison	Difference Between Means	Simultaneous 95% Confidence Limits	
Mini - Subaru	-4.8273	-12.6178	2.9633
Mini - Nissan	-4.1230	-11.9135	3.6676
Mini - Toyota	-3.7183	-9.5612	2.1246
Mini - Seres	-3.3198	-11.1104	4.4708
Mini - Mercedes	-3.1791	-8.8015	2.4433
Mini - Ford	-3.1780	-9.0671	2.7112
Mini - Jaguar	-3.1537	-10.9443	4.6369
Mini - BMW	-3.0420	-8.8849	2.8009
Mini - Hongqi	-2.9596	-9.7064	3.7872
Mini - Lexus	-2.9372	-10.7277	4.8534
Mini - Citroen	-2.7130	-8.4667	3.0408
Mini - Audi	-2.6562	-8.3345	3.0221
Mini - Peugeot	-2.6477	-8.3814	3.0859
Mini - Opel	-2.6407	-8.5908	3.3094
Mini - Porsche	-2.6397	-8.2994	3.0200
Mini - Volkswagen	-2.5362	-8.2529	3.1805
Mini - Polestar	-2.4949	-9.2417	4.2520
Mini - Tesla	-2.4499	-8.6089	3.7091
Mini - JAC	-2.3209	-10.1114	5.4697
Mini - MG	-2.3111	-8.1541	3.5318
Mini - Genesis	-2.2674	-8.4264	3.8915
Mini - Volvo	-2.2369	-8.3959	3.9221
Mini - Skoda	-2.1972	-8.2318	3.8373
Mini - DS	-2.0228	-9.8133	5.7678
Mini - Kia	-1.9650	-7.9152	3.9851
Mini - CUPRA	-1.9502	-8.1091	4.2088
Mini - Hyundai	-1.9220	-7.9565	4.1126
Mini - Smart	-1.8660	-8.6128	4.8808
Mini - Fiat	-1.5790	-7.4219	4.2639
Mini - Honda	-1.1501	-7.8969	5.5967
Mini - Dacia	-0.7723	-8.5629	7.0183
Mini - Mazda	-0.1107	-7.9012	7.6799
Mini - Renault	-0.0414	-6.0760	5.9931

Table 5.1: Simultaneous Confidence Intervals for Difference in mean Average_Normal_and_Fastcharge_Time (Mini)

Comparisons significant at the 0.05 level are indicated by ***.

Make Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
Renault - Subaru	-4.7859	-10.8204	1.2487	
Renault - Nissan	-4.0815	-10.1161	1.9530	
Renault - Toyota	-3.6769	-6.8173	-0.5364	***
Renault - Seres	-3.2784	-9.3129	2.7562	
Renault - Mercedes	-3.1377	-5.8458	-0.4296	***
Renault - Ford	-3.1365	-6.3621	0.0891	
Renault - Jaguar	-3.1123	-9.1468	2.9223	
Renault - BMW	-3.0006	-6.1411	0.1399	
Renault - Hongqi	-2.9182	-7.5271	1.6908	
Renault - Lexus	-2.8958	-8.9303	3.1388	
Renault - Citroen	-2.6715	-5.6427	0.2997	
Renault - Audi	-2.6148	-5.4372	0.2076	
Renault - Peugeot	-2.6063	-5.5386	0.3259	
Renault - Opel	-2.5993	-5.9350	0.7364	
Renault - Porsche	-2.5983	-5.3831	0.1865	
Renault - Volkswagen	-2.4948	-5.3937	0.4041	
Renault - Polestar	-2.4534	-7.0624	2.1555	
Renault - Tesla	-2.4085	-6.1039	1.2869	
Renault - JAC	-2.2795	-8.3140	3.7551	
Renault - MG	-2.2697	-5.4102	0.8708	
Renault - Genesis	-2.2260	-5.9214	1.4694	
Renault - Volvo	-2.1955	-5.8909	1.4999	
Renault - Skoda	-2.1558	-5.6398	1.3282	
Renault - DS	-1.9813	-8.0159	4.0532	
Renault - Kia	-1.9236	-5.2593	1.4121	
Renault - CUPRA	-1.9087	-5.6041	1.7867	
Renault - Hyundai	-1.8805	-5.3646	1.6035	
Renault - Smart	-1.8246	-6.4336	2.7844	
Renault - Fiat	-1.5376	-4.6781	1.6029	
Renault - Honda	-1.1087	-5.7176	3.5003	
Renault - Dacia	-0.7309	-6.7654	5.3037	
Renault - Mazda	-0.0692	-6.1038	5.9653	
Renault - Mini	0.0414	-5.9931	6.0760	

Table 5.2: Simultaneous Confidence Intervals for Difference in mean Average_Normal_and_Fastcharge_Time (Renault)

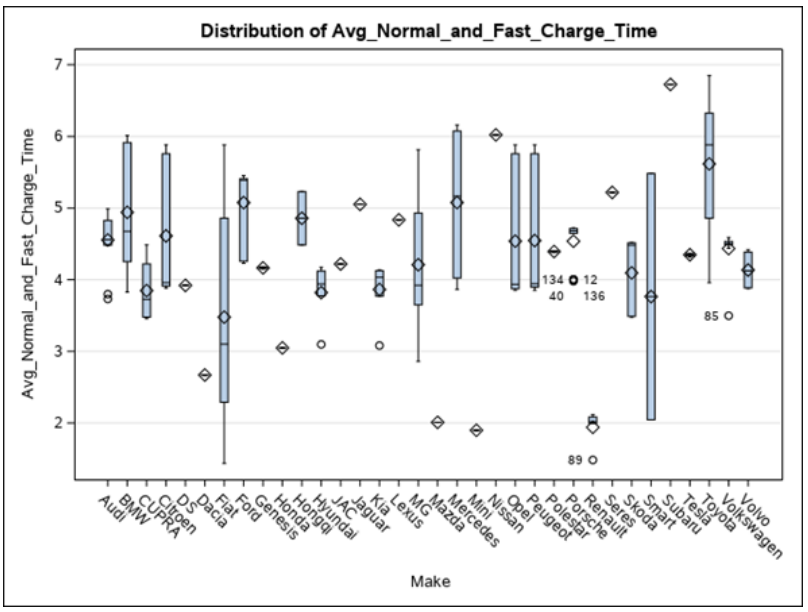


Figure 2: Distribution of Average_Normal_and_Fastcharge_Time for each Brand

The FREQ Procedure

Make	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Audi	16	8.25	16	8.25
BMW	8	4.12	24	12.37
CUPRA	4	2.06	28	14.43
Citroen	11	5.67	39	20.10
DS	1	0.52	40	20.62
Dacia	1	0.52	41	21.13
Fiat	8	4.12	49	25.26
Ford	7	3.61	56	28.87
Genesis	4	2.06	60	30.93
Honda	2	1.03	62	31.96
Hongqi	2	1.03	64	32.99
Hyundai	5	2.58	69	35.57
JAC	1	0.52	70	36.08
Jaguar	1	0.52	71	36.60
Kia	6	3.09	77	39.69
Lexus	1	0.52	78	40.21
MG	8	4.12	86	44.33
Mazda	1	0.52	87	44.85
Mercedes	24	12.37	111	57.22
Mini	1	0.52	112	57.73
Nissan	1	0.52	113	58.25
Opel	6	3.09	119	61.34
Peugeot	12	6.19	131	67.53
Polestar	2	1.03	133	68.56
Porsche	18	9.28	151	77.84
Renault	5	2.58	156	80.41
Seres	1	0.52	157	80.93
Skoda	5	2.58	162	83.51
Smart	2	1.03	164	84.54
Subaru	1	0.52	165	85.05
Tesla	4	2.06	169	87.11
Toyota	8	4.12	177	91.24
Volkswagen	13	6.70	190	97.94
Volvo	4	2.06	194	100.00

Table 6: Frequency Table of Dataset

c. Specific Question 3 ()

i. Methods

ii. Results

d. Specific Question 4 (Jae-Young Heo)

d.1 While the longest range is emerging as a big concern based on the purchase of electric vehicles, consumers usually consider whether the electric vehicles can run more than 300 miles on a full charge once when choosing an electric car. Previously, the Tesla model was the only electric car with more than 300 miles. However, these days, many companies around the world are introducing a variety of electric vehicles. The question is are there many cars that can run more than 300 miles on average? This might show the growth of the electric vehicle industry.

d.1.i. Methods

We conduct the hypothesis test to see if the population mean range is over 300. We used the PROC TTEST procedure to compute the one sample t test for a single mean. That is, the alternative hypothesis is that the population mean is more than 300, and the null hypothesis is that the population mean is equal to 300.

d.1.ii. Results

The results of one sample t-test shows Since the p-value is small, there is sufficient evidence to reject the null hypothesis and conclude that the mean range is more than 300 miles. From the 95% confidence interval, we also can be 95% sure that the mean range will be 333.6 miles to infinity. Therefore, we can say that the mean range of electric cars is more than 300 which shows the electric vehicle industry has grown up. One sample t-test assumes normality. As we can see from Figure 3, a q-q plot shows that there is little evidence of non-normality of the errors that seem to follow the line.

Variable	tValue	DF	Probt
Electric Range	6.26	193	<.0001

Table 7: T-test result for electric range mean

Variable	Mean	LowerCLMean	UpperCLMean	StdDev	LowerCLStdDev	UpperCLStdDev	UMPULowerCLStdDev	UMPUUpperCLStdDev
Electric Range	345.6	333.6	I	101.4	92.2002	112.6	92.0460	112.4

Table 8: T-test result for electric range mean

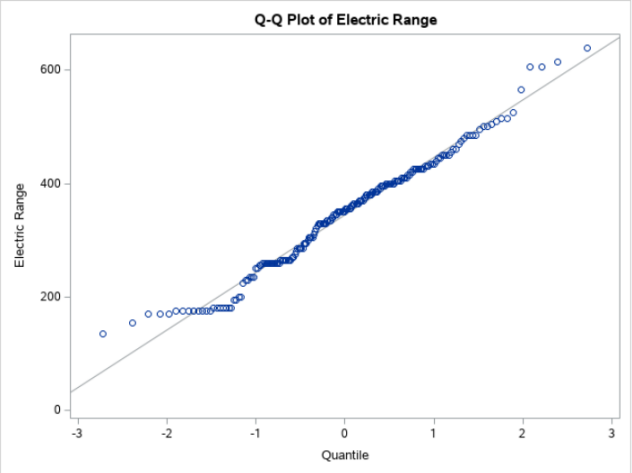


Figure 3: Assessment of the normal distribution assumption for the electric range

d.2 Also, we want to find out which brand of electric car has the longest range in respect of battery capacity on average.

d.2.i. Methods

To find the car brand which has the longest range average in terms of battery capacity, I created a new variable *RangeScore* that represents the range of the vehicle in terms of battery capacity, calculated by (RangeScore) = (Electric range)/(Battery Capacity). PROC MEANS procedure can show the descriptive statistics of the RangeScore grouped by each brand. After sorting by descending order, we could find which brand of electric car has the longest range related to the battery capacity.

d.2.ii Results

Table 9 confirms that Renault has the longest average range in terms of battery capacity among other electric car companies. However, as I calculated the mean range score for each company, we can find some limitations that each company has shown various numbers of electric cars which impacts the mean of range score. That is, the mean value can be influenced by the outliers and skewed distribution among their cars. For example, according to the dataset, one of the models with the highest range of Kia Motors is 380 miles, and the lowest range is 280 miles. According to Kia's official site, they are currently introducing 6 different electric vehicles. Largely, it can be divided into three basic cars and three cargo electric vans, and each of the models are requiring different performance depending on the usage and targeting customers. Therefore, there are too many things to consider in finding the best way to compare the best brand as the number of their models, policies, and aims vary in every company. One of the methods to compensate for this problem is to compare the range just with one of the highest range cars in each company. But we still have problem in representativeness

Range Score by Electric Car Brand

Obs	Make	NObs	RangeScore_N	RangeScore_Mean	RangeScore_StdDev
1	Renault	5	5	5.9518586228	0.2381151255
2	Dacia	1	1	5.7835820896	.
3	Mini	1	1	5.5214723926	.
4	Nissan	1	1	5.4838709677	.
5	Tesla	4	4	5.4725609756	0.3704822385
6	CUPRA	4	4	5.4243705744	0.2901169948
7	Hyundai	5	5	5.3806719195	0.4789903814
8	Kia	6	6	5.2614207494	0.2808457454
9	Polestar	2	2	5.2564102564	0.2719641466
10	MG	8	8	5.2373136691	0.406190312

Table 9: Range Score by Electric Car brands

4. Discussion

Specific Question 1: While the range of electric vehicles is a very important evaluation factor, we show that the range is affected by weather and road conditions. The paired t-test

confirms that ranges are longer under mild weather and city road conditions. Also the regression test proves that there is significant association between actual average range and electric range. The assumptions of above conclusions are not seriously violated. Also the conclusion returned by statistical tests corresponds to the results of data visualization.

Specific Question 2: After analyzing the mean Average Normal and Fastcharge Time for each brand and conducting an analysis on their differences, we have sufficient evidence to conclude that the mean Average Normal and Fastcharge Time for Renault is significantly lower than the other brands. Thus, we conclude that Renault's electric vehicles have the best overall charging capabilities.

Specific Question 3:

Specific Question 4: We conclude that we have sufficient evidence to conclude the average range among the models is more than 300 miles, and that confirms the growth of the electric vehicle industry. Also, Renault had the best overall longest range in respect of battery capacity.

General Conclusion: As a result of specific question 1, we can note that electric vehicles have limitations in performance depending on the weather and road conditions. Specifically, electric vehicles tend to perform better in mild weather conditions, and in city roads. Our general question is, despite these limitations, which electric vehicle brands are the best? According to the article "What do Consumers Really Want From an Electric Vehicle?", charging capabilities and electric vehicle range are the top priorities of consumers when purchasing electric vehicles. According to specific question 2, we found that Renault's electric vehicles charge significantly faster than electric vehicles of other brands. Additionally, according to specific question 4, we found that Renault has the longest range in respect to battery capacity. Thus we conclude that the best brand of electric vehicle is Renault.

Limitations: A limitation of our analysis is that we do not have enough data to offer a comprehensive analysis on all electric vehicles. For one, our dataset did not include all possible brands of electric vehicles. This can be reflected in the fact that Mitsubishi, one of the world's largest automobile manufacturers, was not included in the dataset. Additionally, as noted in Table 1, the sample sizes of each brand ranges from one to twenty four. These sample sizes are small, which can potentially contribute to assumption violations in our statistical analyses. Also, we find the limitation on representativeness and considering each company's various policies, and aims in their own business. That is, fast charging time and longer electric range cannot be the perfect discipline to evaluate the best electric car company because they are focusing on the customers' needs and industry trend, not just intended to make it faster and longer.

5. References

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