Tesla Battery Degradation

Springboard Data Science Career Track

Capstone Project 1

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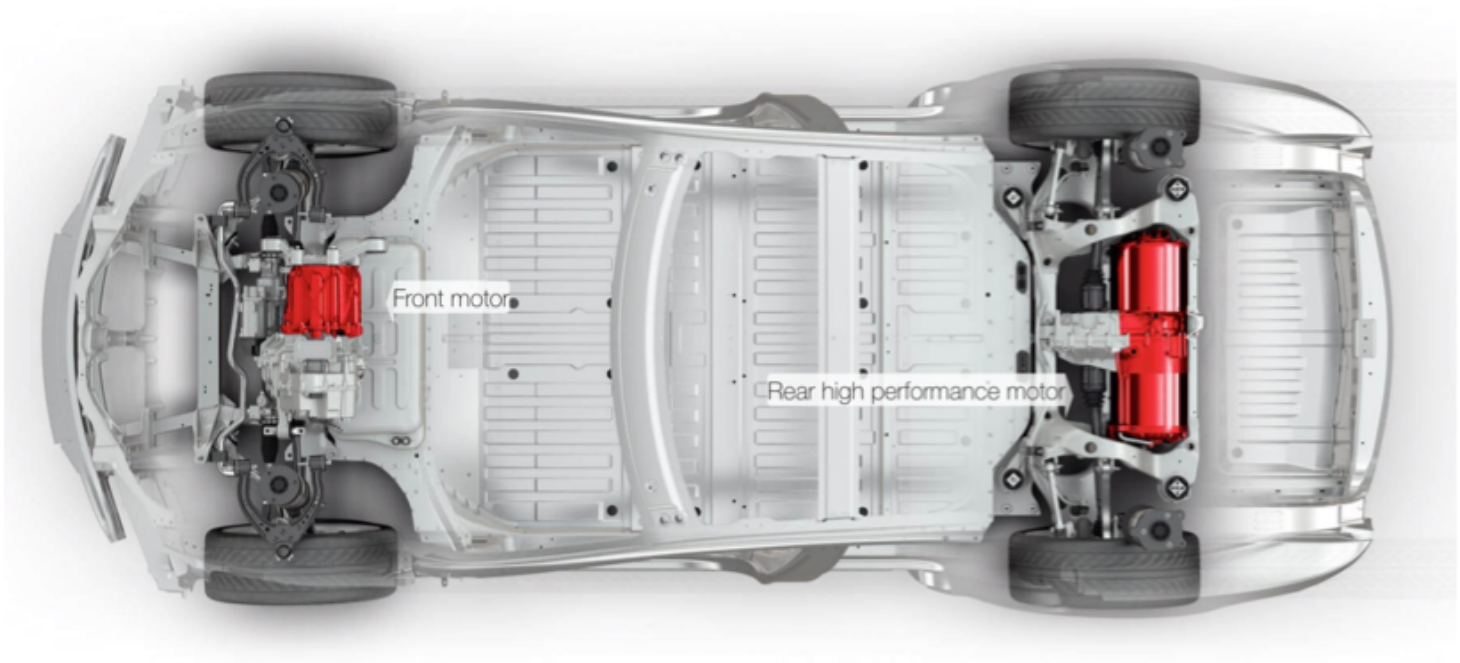
The Tesla Model S was the top-selling plug-in electric car worldwide in 2015 and 2016

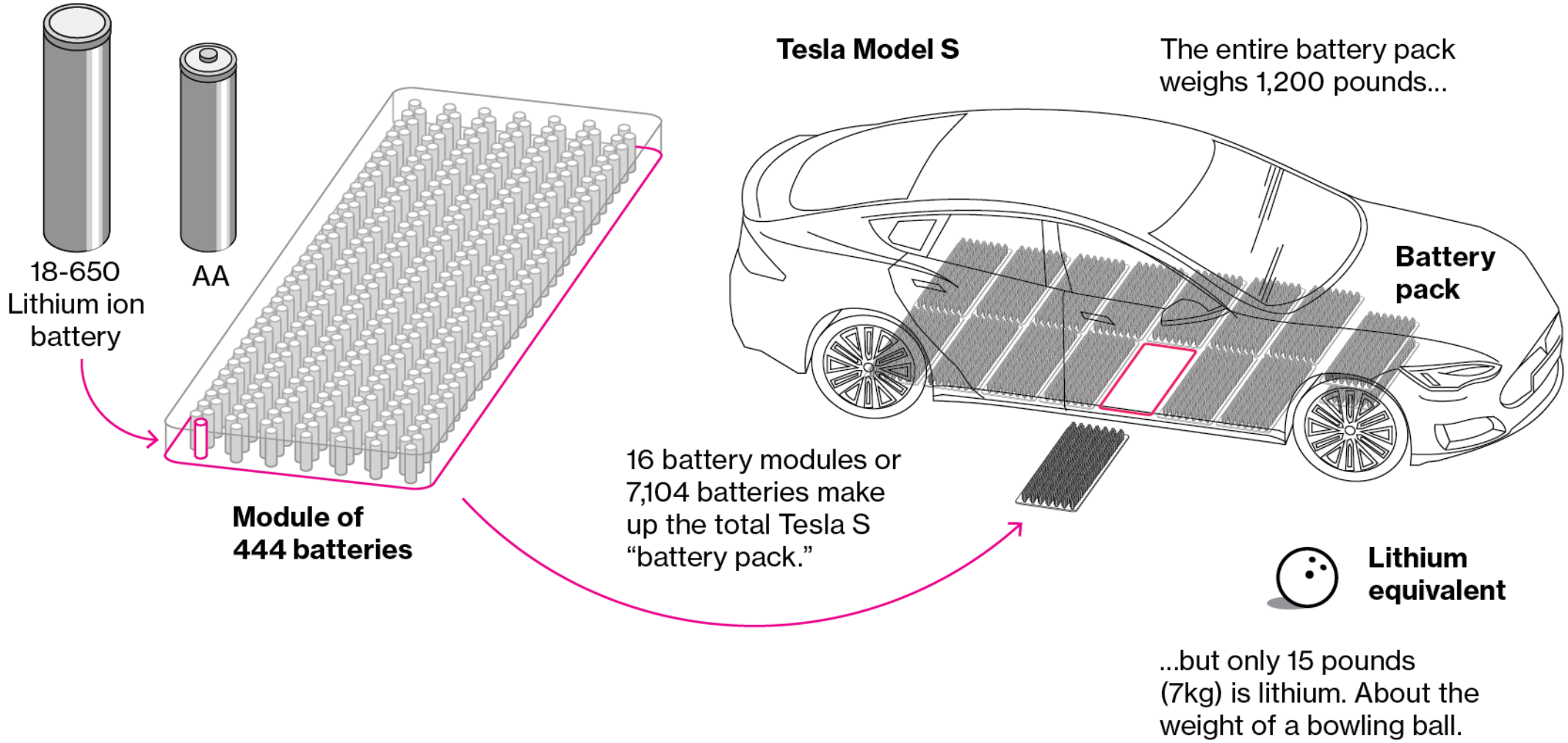


The Model S exists in several versions, differing in energy capacity (battery size), power (motor size), and equipment. Battery size determines the car range in miles.

Every Tesla driver is provided with a warranty for battery failure which doesn't cover degradation

Degradation – the decrease in battery capacity over time which leads to the decrease in range (miles) that a Tesla driver can drive before he has to re-charge his battery again.

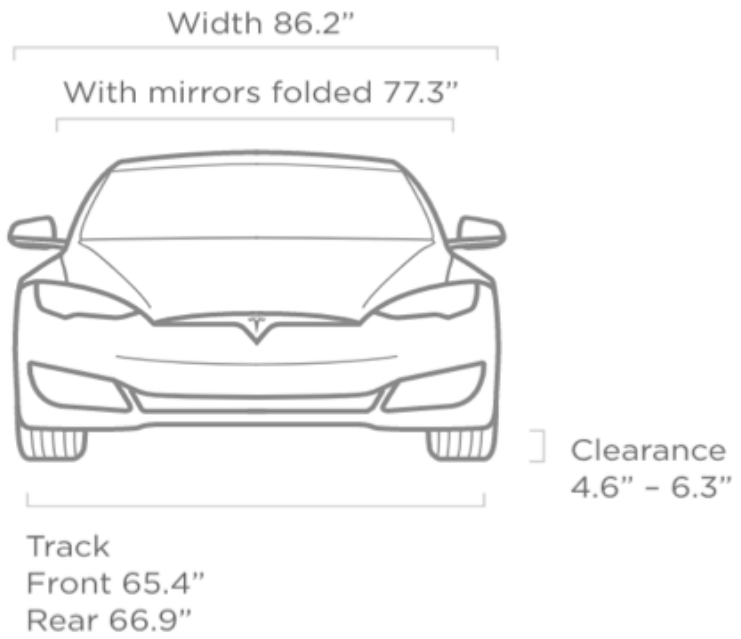
Performance of Li-ion batteries can be impacted by cycling, elevated temperatures, and aging



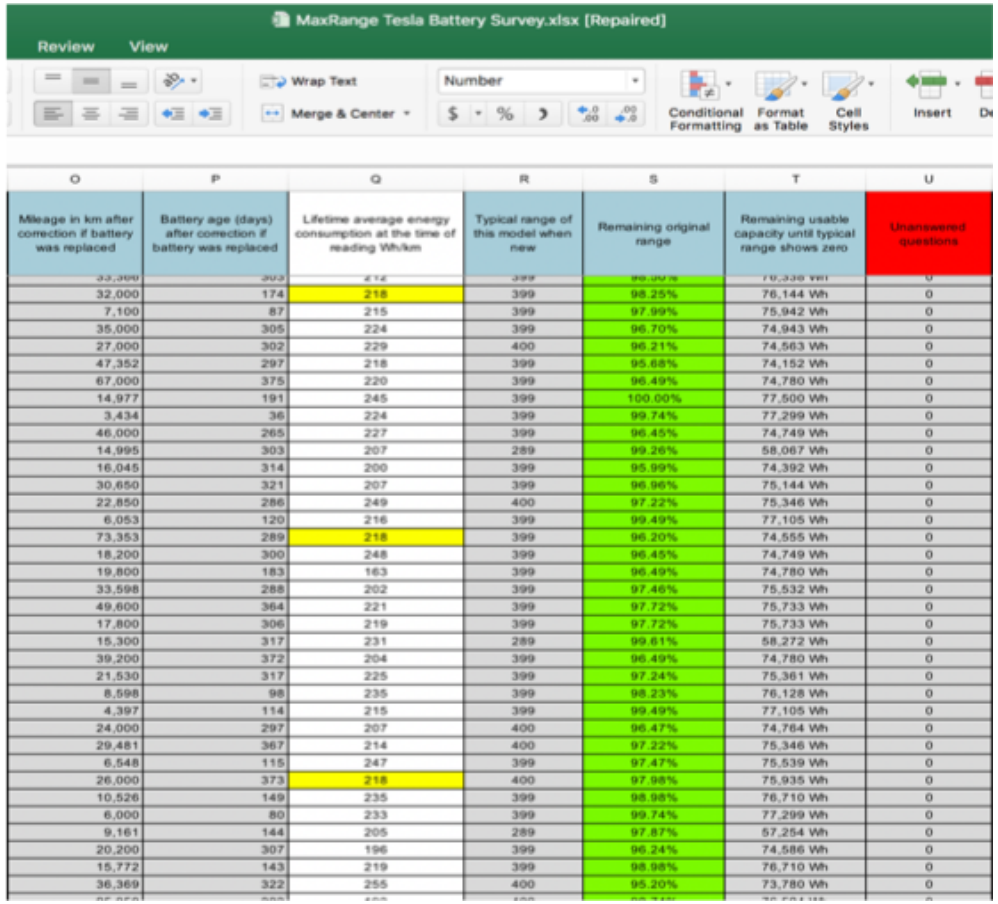
My goal is to develop a model that can predict the expected **battery degradation**

My target audience: Tesla drivers/future owners interested in prevention of battery degradation

My target audience: electric car manufacturers



The data set represents Tesla Model S Survey taken by drivers in Asia, Europe, Canada, and USA



O	P	Q	R	S	T	U
Mileage in km after correction if battery was replaced	Battery age (days) after correction if battery was replaced	Lifetime average energy consumption at the time of reading Wh/km	Typical range of this model when new	Remaining original range	Remaining usable capacity until typical range shows zero	Unanswered questions
32,000	174	218	399	98.25%	76,144 Wh	0
7,100	87	215	399	97.99%	75,942 Wh	0
35,000	305	224	399	96.70%	74,943 Wh	0
27,000	302	229	400	96.21%	74,563 Wh	0
47,352	297	218	399	95.68%	74,152 Wh	0
67,000	375	220	399	96.49%	74,780 Wh	0
14,977	191	245	399	100.00%	77,500 Wh	0
3,434	36	224	399	99.74%	77,299 Wh	0
46,000	265	227	399	96.45%	74,749 Wh	0
14,995	303	207	289	99.26%	58,067 Wh	0
16,045	314	200	399	95.99%	74,392 Wh	0
30,650	321	207	399	96.96%	75,144 Wh	0
22,850	286	249	400	97.22%	75,346 Wh	0
6,053	120	216	399	99.49%	77,105 Wh	0
73,353	289	218	399	96.20%	74,555 Wh	0
18,200	300	248	399	96.45%	74,749 Wh	0
19,800	183	163	399	96.49%	74,780 Wh	0
33,598	288	202	399	97.46%	75,532 Wh	0
49,600	364	221	399	97.72%	75,733 Wh	0
17,800	306	219	399	97.72%	75,733 Wh	0
15,300	317	231	289	99.61%	58,272 Wh	0
39,200	372	204	399	96.49%	74,780 Wh	0
21,530	317	225	399	97.24%	75,361 Wh	0
8,598	98	235	399	98.23%	76,128 Wh	0
4,397	114	215	399	99.49%	77,105 Wh	0
24,000	297	207	400	96.47%	74,764 Wh	0
29,481	367	214	400	97.22%	75,346 Wh	0
6,548	115	247	399	97.47%	75,539 Wh	0
26,000	373	218	400	97.98%	75,935 Wh	0
10,526	149	235	399	98.98%	76,710 Wh	0
6,000	80	233	399	99.74%	77,299 Wh	0
9,161	144	205	289	97.87%	57,254 Wh	0
20,200	307	196	399	96.24%	74,586 Wh	0
15,772	143	219	399	98.98%	76,710 Wh	0
36,369	322	255	400	95.20%	73,780 Wh	0

Download from Google Drive in a form of **“MaxRange Tesla Battery Survey.xlsx”** file

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Use Python to import and inspect the data for separate spreadsheets from different locations

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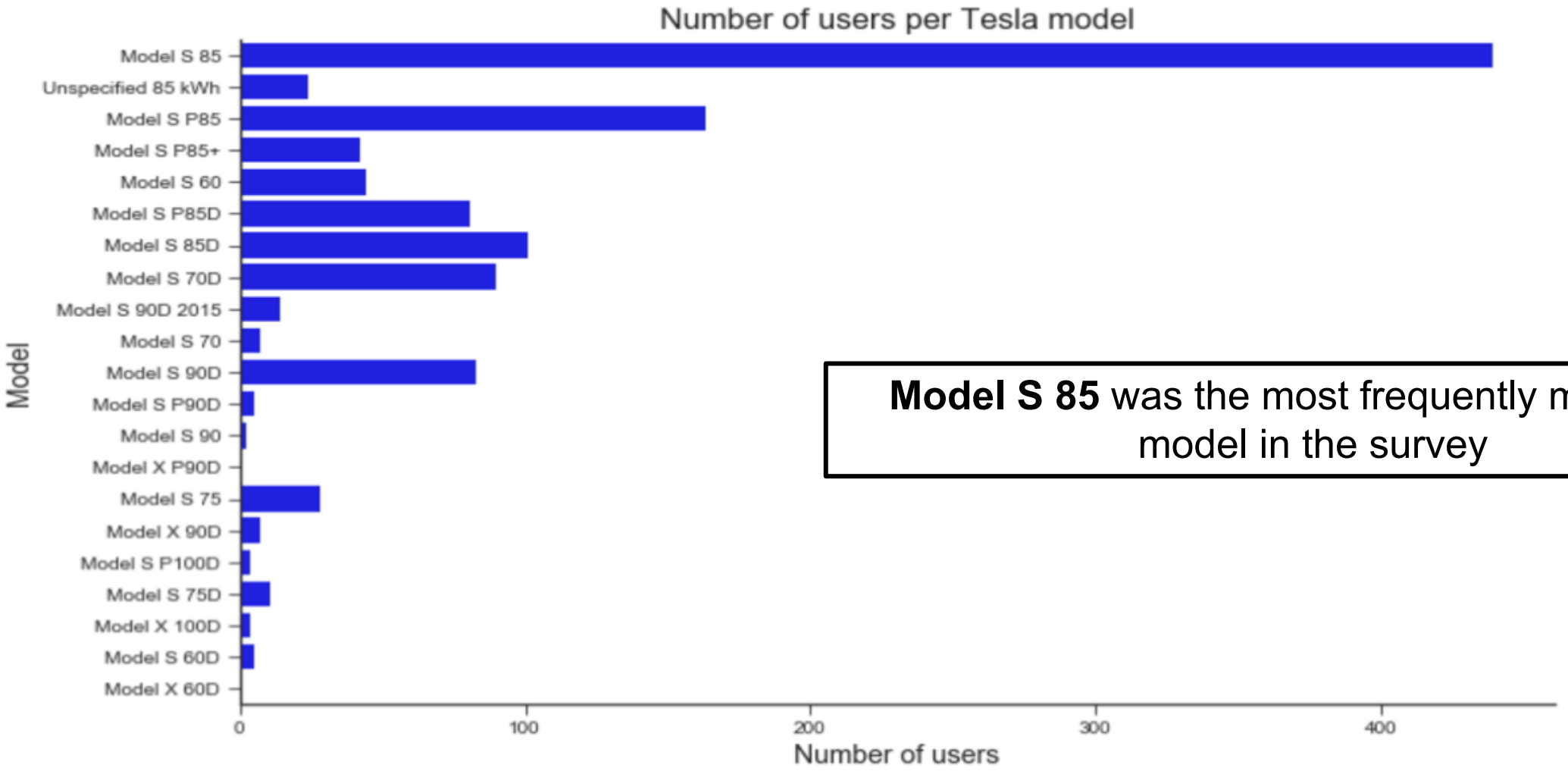
Resolve any missing, invalid, or corrupted rows

The resulting master data frame contains 1152 observations and 36 columns which represent answers provided by Tesla drivers

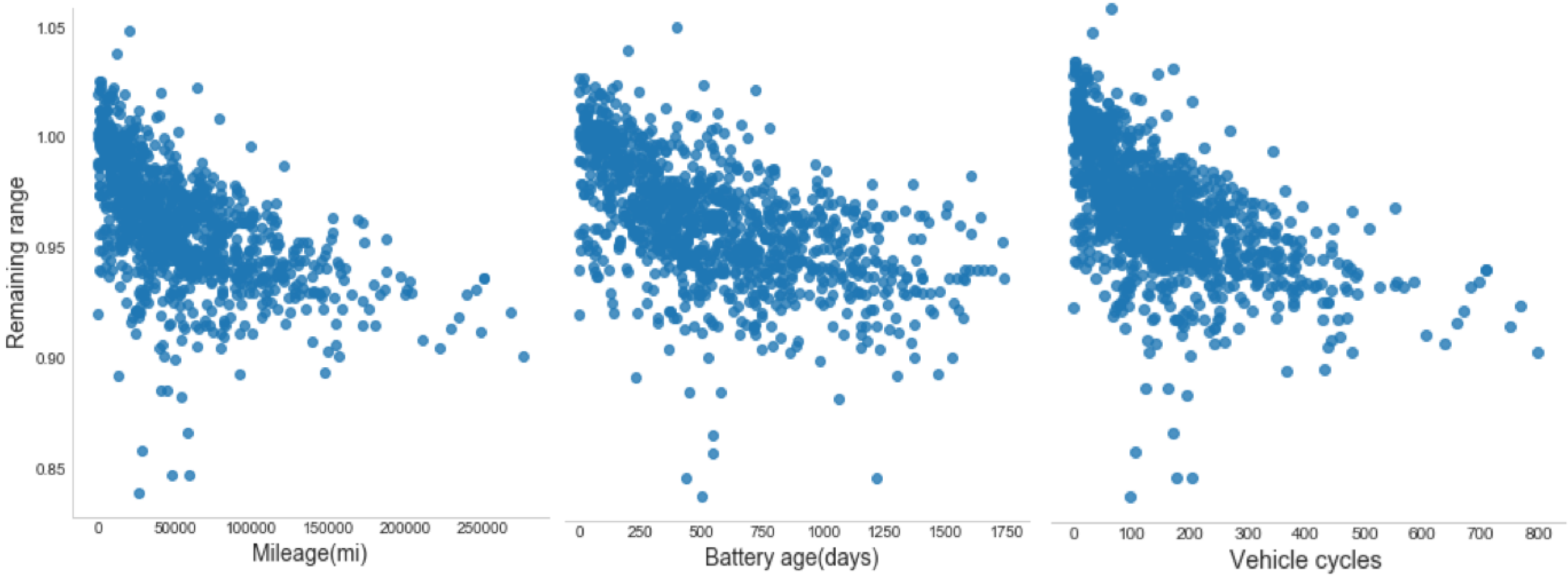
	id	username	location	manufacture_date	range_reading_date	model	mileage	mileage_per_day	range_at_full	ran
1146	1147	Simon Mac	UK	2014-05-21	2015-10-23	Model S 60	10500.0	20.2	180.0	
1147	1148	memesweeper	UK	2015-10-12	2016-11-02	Model S 85D	34653.0	89.3	256.0	
1148	1149	gyroscope	UK	2015-05-14	2016-11-20	Model S 85	45959.0	82.5	231.0	
1149	1150	tes	UK	2015-03-02	2016-12-14	Model S 85	37895.0	57.9	238.0	
1150	1151	4dme	UK	2016-06-20	2016-12-24	Model S 85	16800.0	89.4	242.0	
1151	1152	Justin	UK	2016-01-06	2017-04-25	Model S 85D	49129.0	103.2	266.0	
1152	1153	Patrick	UK	2014-12-30	2017-04-17	Model S 85	49900.0	59.4	239.0	
1153	1154	Gary	UK	2017-03-17	2017-04-22	Model S 60D	2271.0	61.4	205.0	

EDA helped us to determine the correlation between the target variable (remaining range in %) and other variables

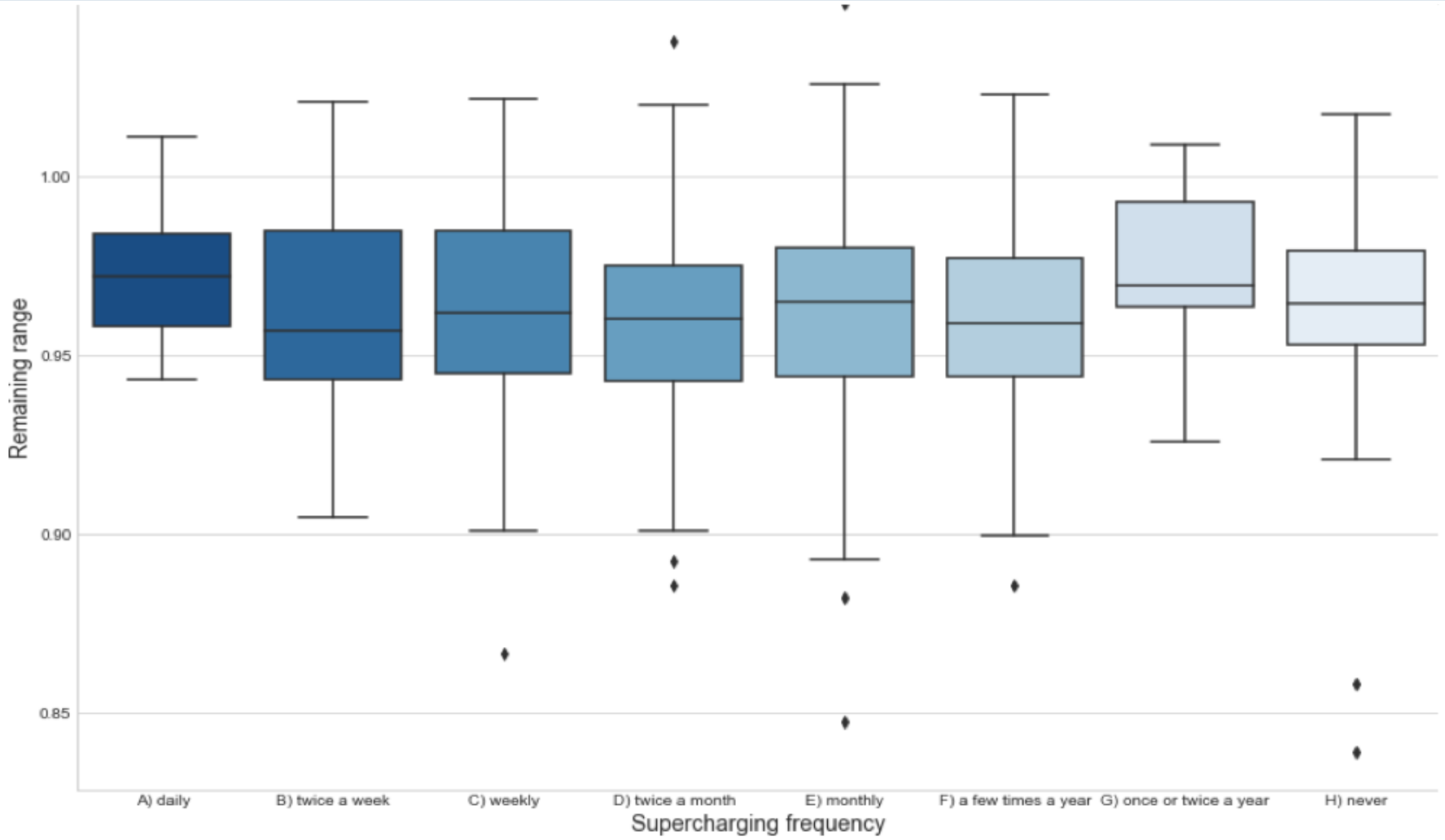


Model S 85 was the most frequently mentioned model in the survey

The total mileage of a car, battery age, and vehicle cycles are negatively correlated with the remaining range



Supercharging frequency and location had no impact on remaining range



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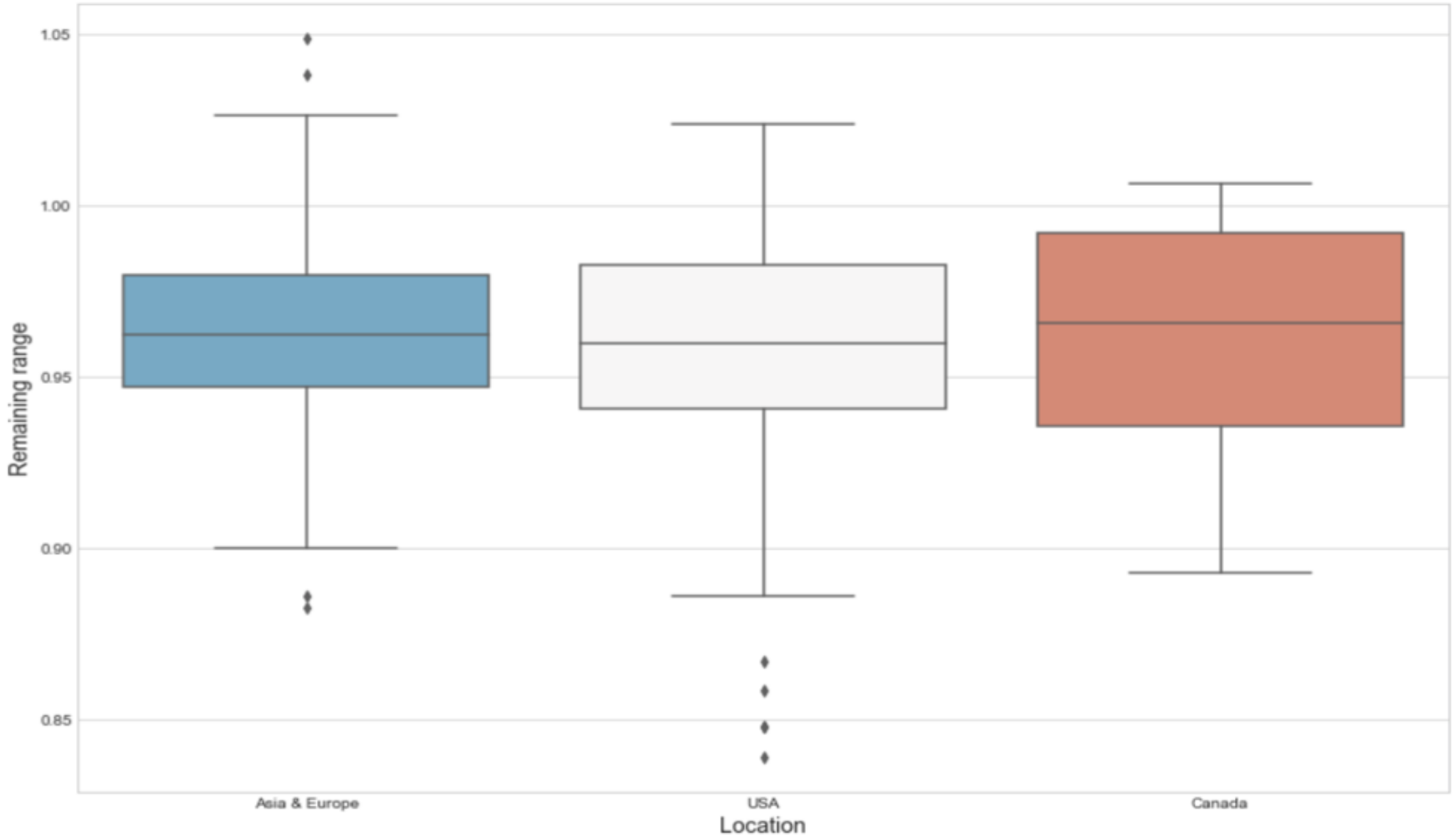
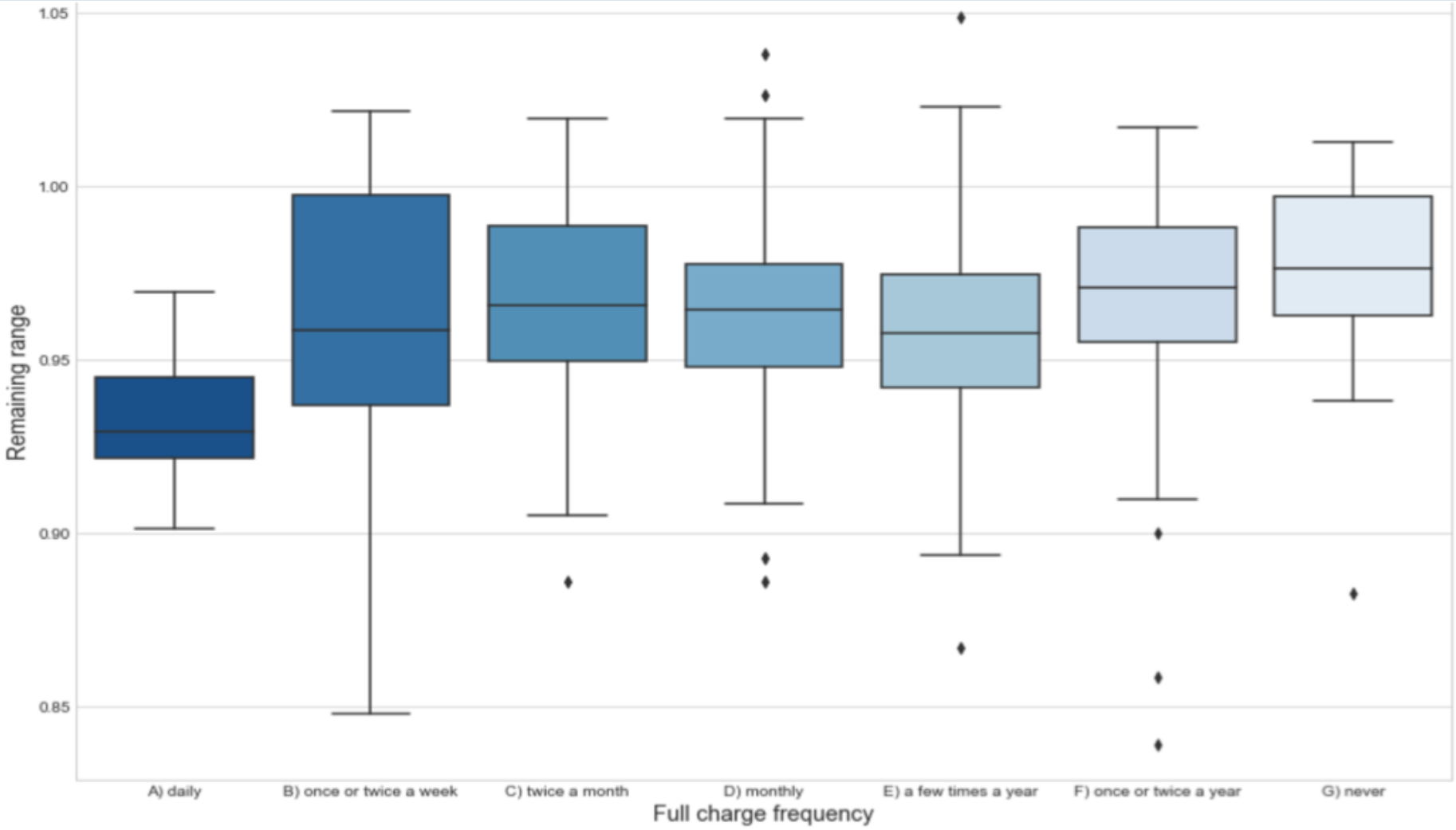
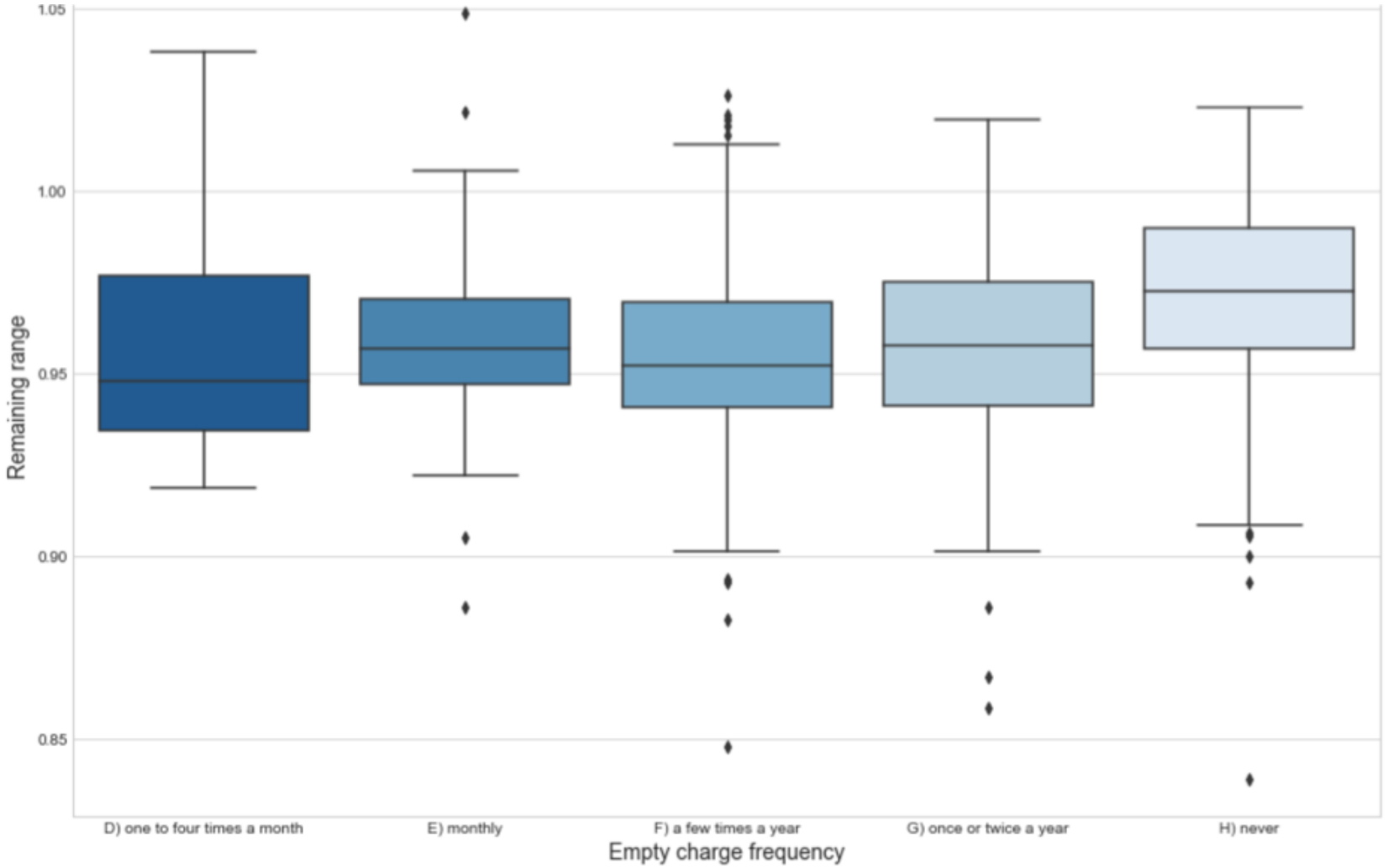


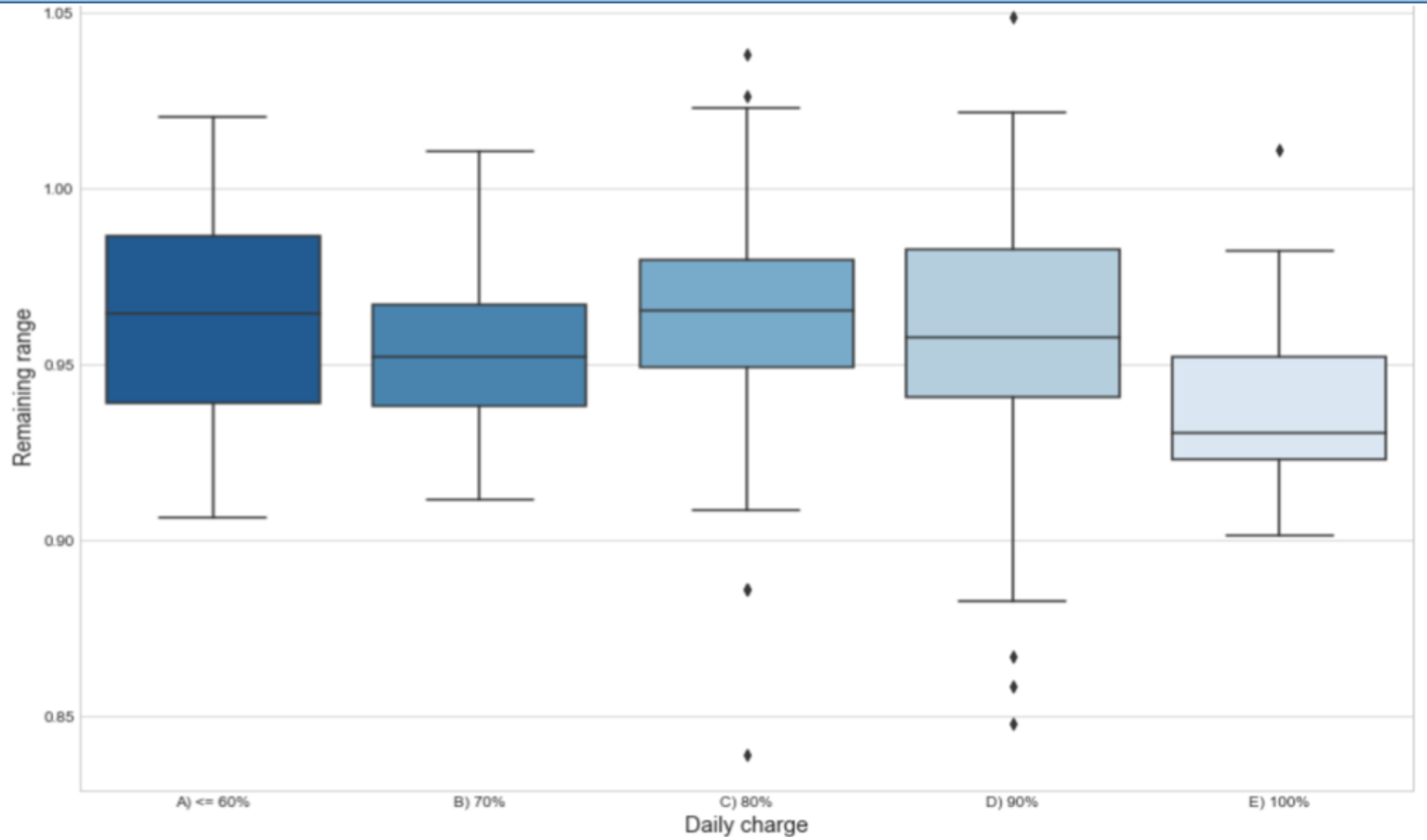
Having a fully charged battery on a daily basis was shown to contribute to battery degradation



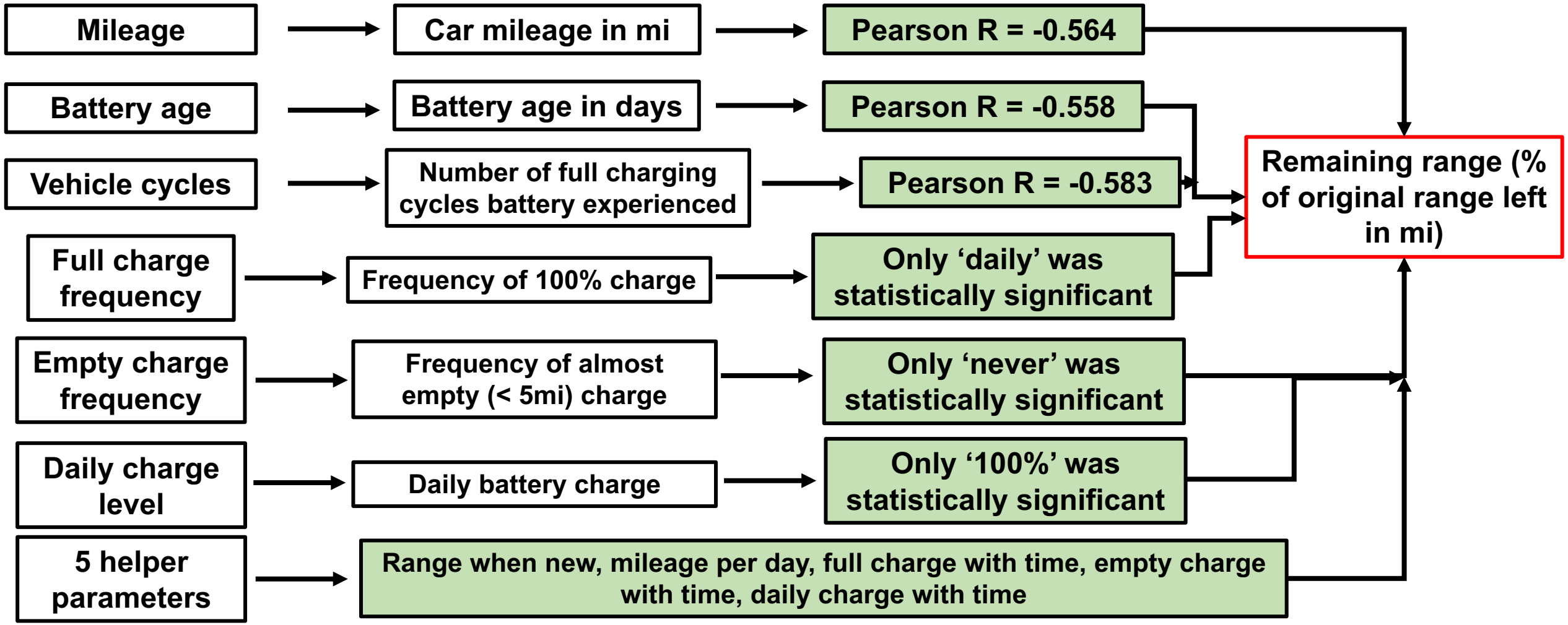
Never discharging the battery fully was shown to be beneficial for remaining range



Daily charge level of 100% contributed to decrease in remaining range



It was determined that 11 parameters can be used to predict remaining range



Remaining range was predicted using Linear, Ridge, Elastic Net, and Random Forest Regression in Sklearn

Imputation of missing values using logistic regression (96 for full charge frequency and empty charge frequency; 253 for daily charge)

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Converting full charge frequency, empty charge frequency, and daily charge to Boolean

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Dividing the data frame into train/test

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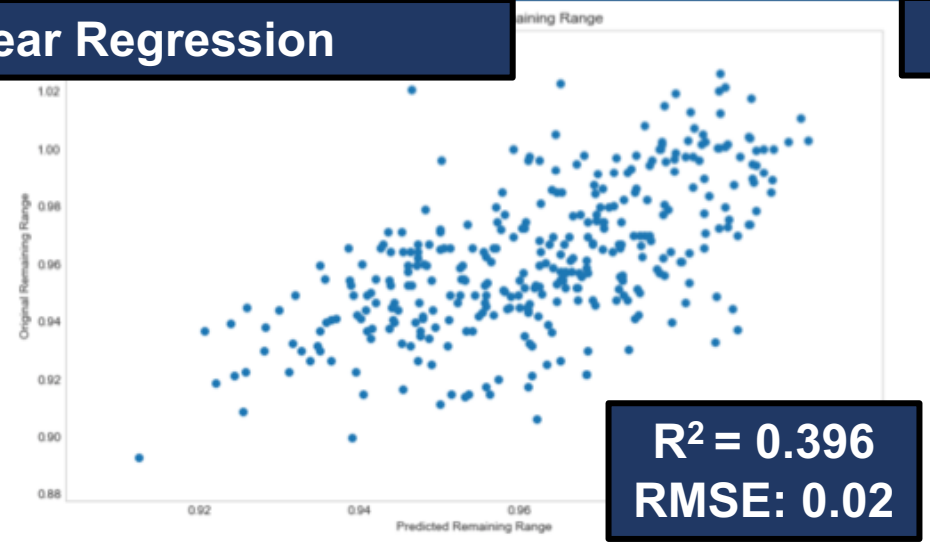
Fitting train/predicting test

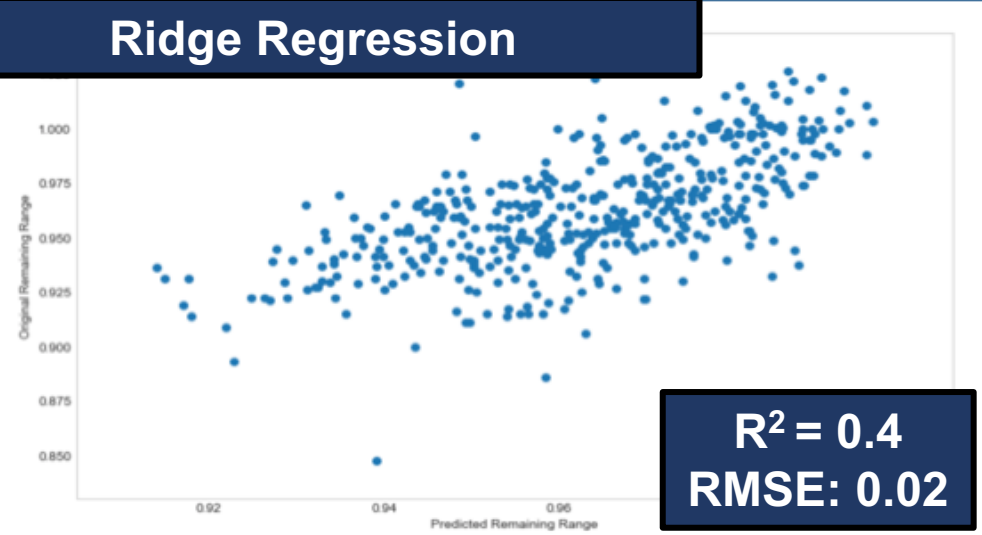
The resulting regression models were evaluated using R^2 and Root-Mean-Squared-Error

Linear Regression



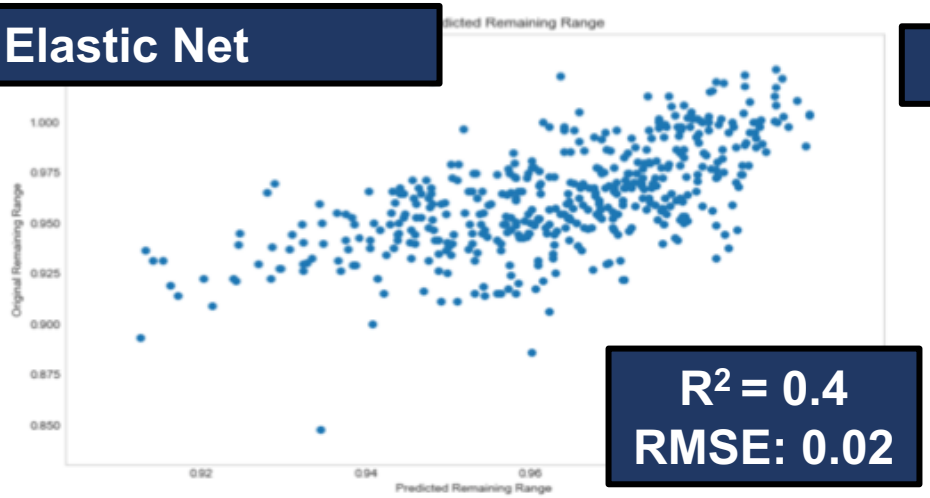
$R^2 = 0.396$
RMSE: 0.02

Ridge Regression



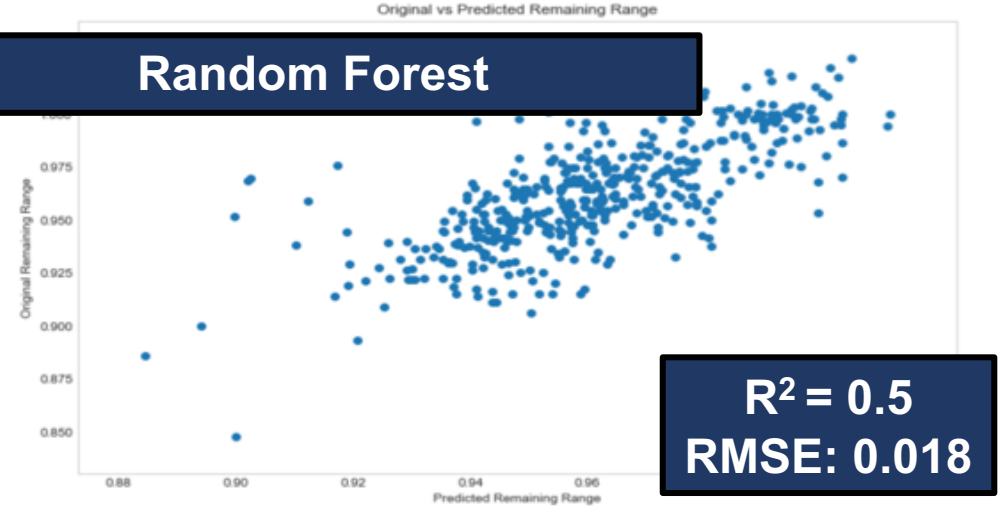
$R^2 = 0.4$
RMSE: 0.02

Elastic Net



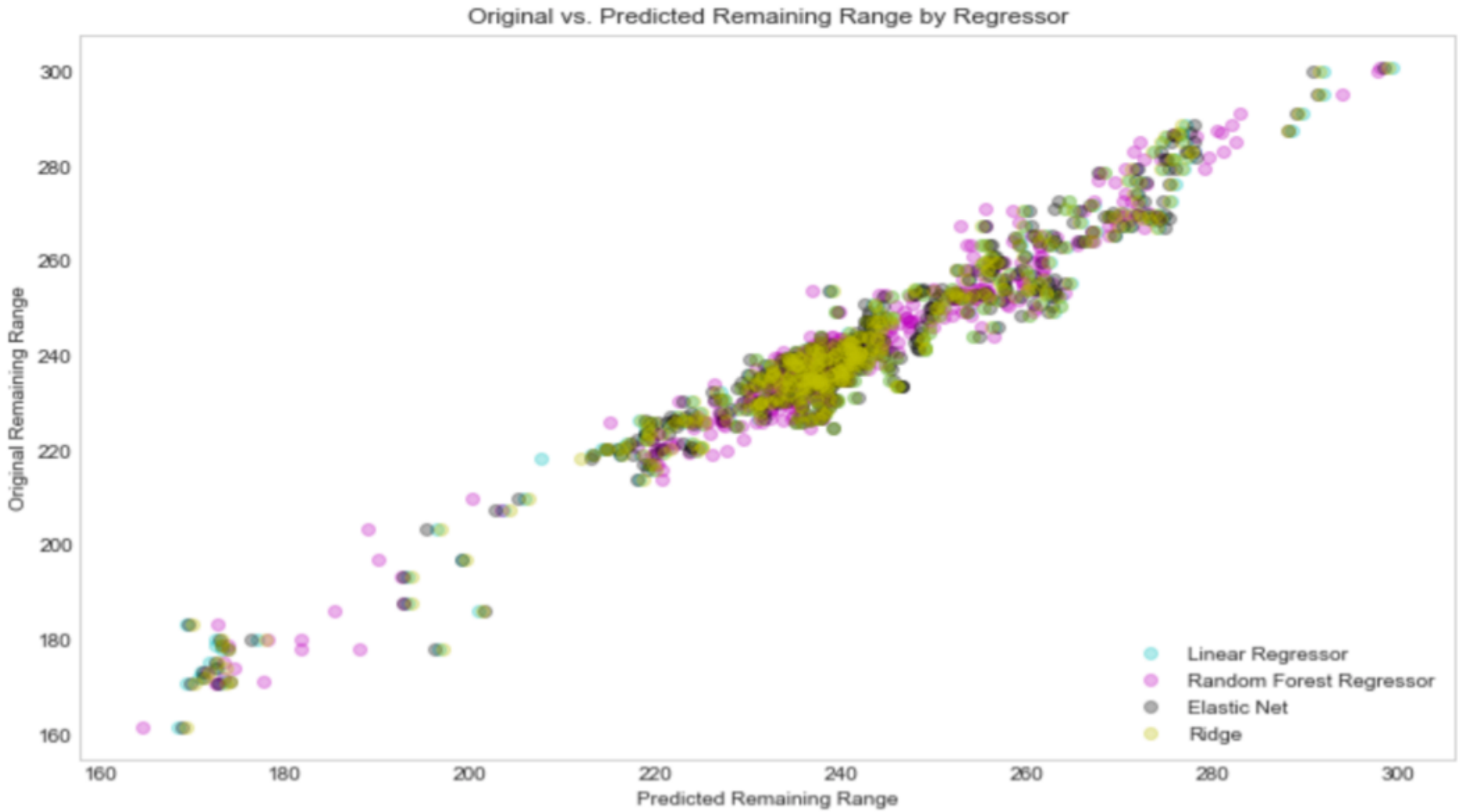
$R^2 = 0.4$
RMSE: 0.02

Random Forest



$R^2 = 0.5$
RMSE: 0.018

Prediction for remaining range in miles was more accurate as it used original range for approximation

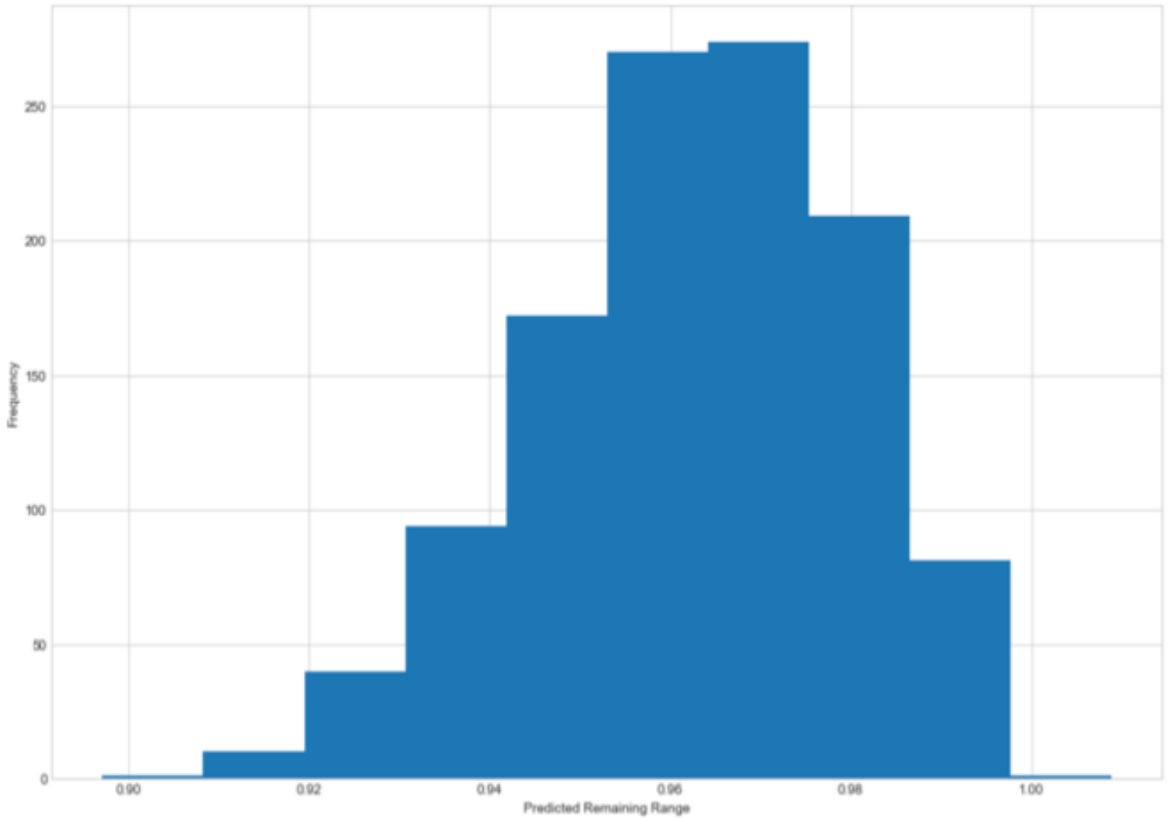


Predicting different car models separately increased the accuracy of the model

Regression results for predicting remaining range (in %) of Tesla Model S 85

Regression	R^2	RMSE
Elastic Net	0.421	0.019
Ridge Regression	0.447	0.018
Linear Regression	0.453	0.018
Random Forest	0.61	0.016

Random Forest modeling resulted in the highest R^2 and the lowest RMSE



The majority of Tesla Model S owners do not have to worry about battery degradation

Recommendations

- **Make optional survey questions mandatory (charge frequency related)**
- **Obtain more observations for different model types**
- **Add information about average battery temperature**
- **Perform prediction separately for different models**