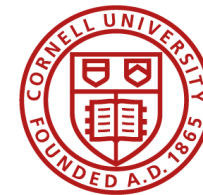


Six Sigma Project Optimization of Cornell EV Rental

Yue Wang yw477

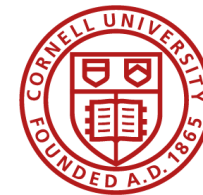


Cornell University

Overview

Overview → EV Background → Motivation → Existing Work → Methodology-Model Parameter → Methodology-Model Variables → Methodology-Model Constraints → Model Result → Sensitivity Analysis → Future Research

- Applied Six Sigma DMAIC methodology to guide through the project process
- Built optimization model to understand the economic effect of EV procurements and the layout of the charging stations
- Interpret the model results and the sensitivity analysis to give insights on the strategic planning for future development.



Cornell University

EV Background

Overview → **EV Background** → Motivation → Existing Work → Methodology-Model Parameter → Methodology-Model Variables → Methodology-Model Constraints → Model Result → Sensitivity Analysis → Future Research

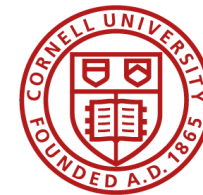
- Cornell Rental will considered PHEVs and BEVs
 - Plug-in hybrid electric vehicles (PHEVs)
 - Have ICE
 - Also have electrical motors
 - Options: BMW530e iPerformance, Ford C-MAX Energi, Mercedes C350e, Mercedes GLE550e, Toyota Prius Prime, Hyundai Sonata PHEV, Chrysler Pacifica Hybrid, Chevrolet Volt.
 - This 9 vehicles are the PHEV candidates of Cornell EV Rental vehicle procurements
 - All-electric battery electric vehicles (BEVs)
 - Solely powered by one or more electrical motors.
 - No ICE
 - Options: Mitsubishi i-MiEV, Mercedes B250e, Honda Clarity Electric, Hyundai Loniq Electric, Chevrolet Bolt, Tesla Model 3, Tesla Model S.
 - This 7 vehicles are the BEV candidates of Cornell EV Rental vehicle procurements



Motivation

Overview → EV Background → **Motivation** → Existing Work → Methodology-Model Parameter → Methodology-Model Variables → Methodology-Model Constraints → Model Result → Sensitivity Analysis → Future Research

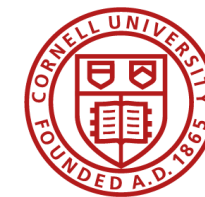
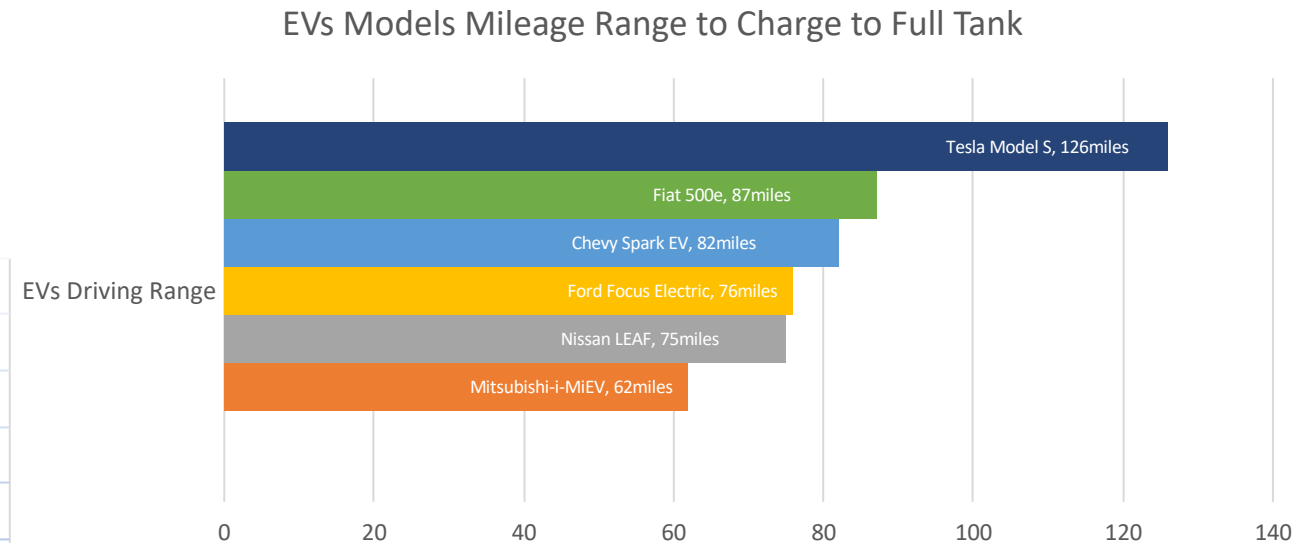
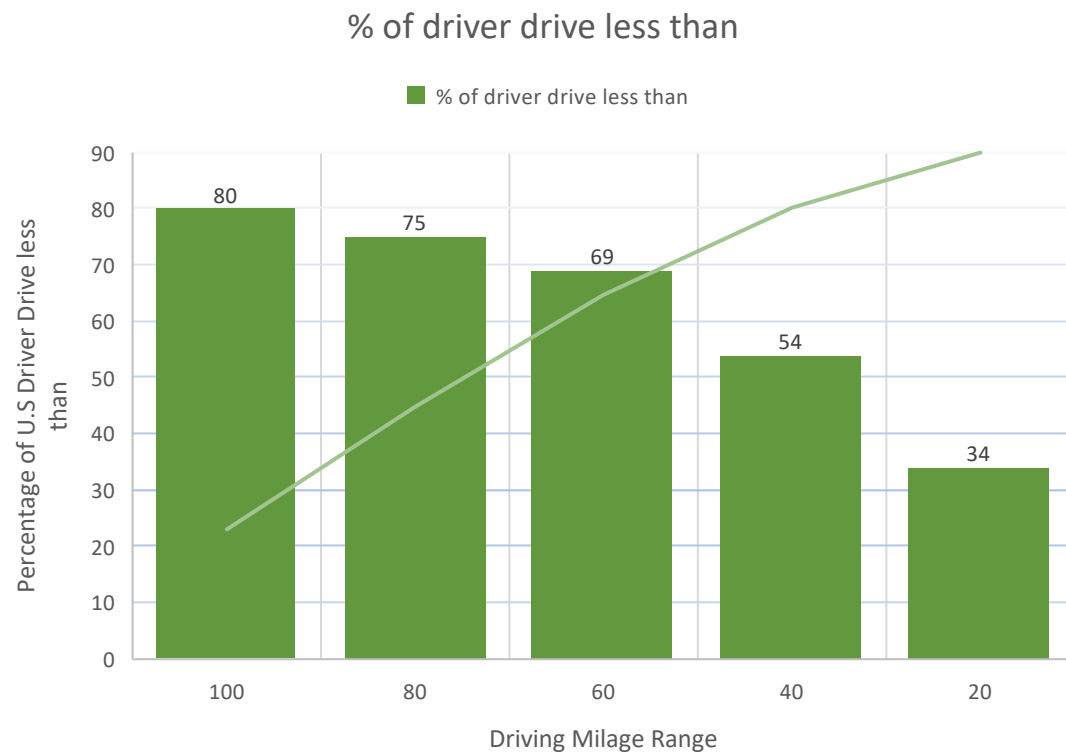
- In pursuit of zero-carbon emission community, one approach for Cornell is to reduce the carbon emission in transportation:
 - Define zero-carbon emission: using clean energy at the end process when the performances are delivered.
 - Eg. EV driving process/ manufacturing process
- EV Rental on campus performs the goal of reducing the carbon emission through:
 - Motivating and fully managing the clean energy vehicles used
 - Promoting the zero-carbon emission life style



Cornell University

Existing Work

Overview → EV Background → Motivation → **Existing Work** → Methodology-Model Parameter → Methodology-Model Variables → Methodology-Model Constraints → Model Result → Sensitivity Analysis → Future Research

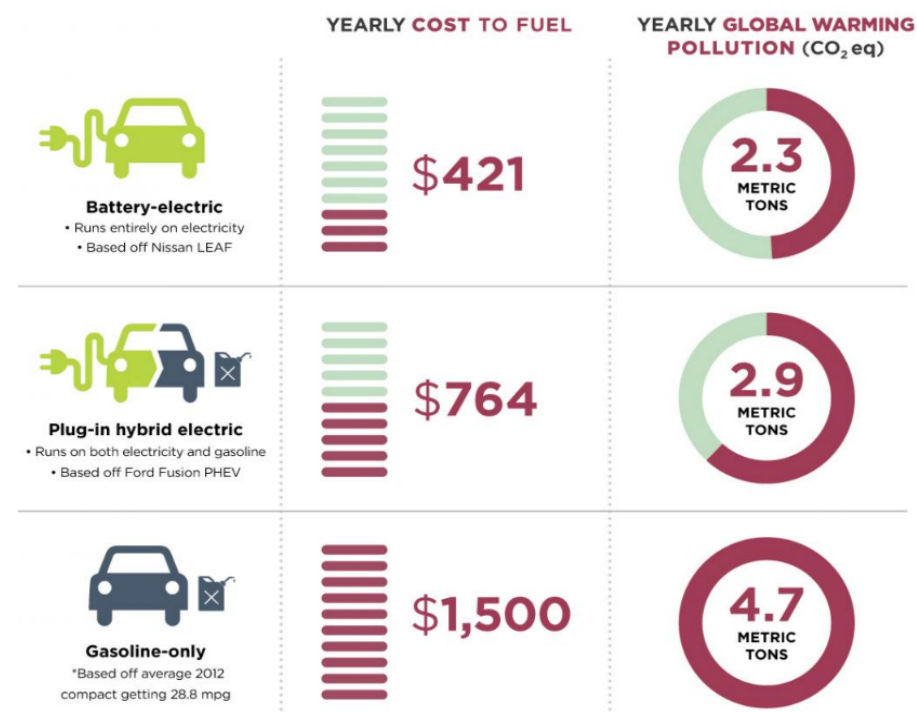


Cornell University

Existing Work

Overview → EV Background → Motivation → **Existing Work** → Methodology-Model Parameter → Methodology-Model Variables → Methodology-Model Constraints → Model Result → Sensitivity Analysis → Future Research

Charge Options	Charging Time	Unite Cost Range
AC Level 1	2-5 miles of range per hour	\$300 to \$1800
AC Level 2	10-20 miles of range per hour	\$400 to \$6500
DC Fast Charging	50-70 mile of range in less 20 minutes	\$10,000 to over \$40,000



Methodology-Model Parameters

Overview → EV Background → Motivation → Existing Work → **Methodology-Model Parameter** → Methodology-Model Variables → Methodology-Model Constraints → Model Result → Sensitivity Analysis → Future Research

Year Until Full Price Expectation				6
Expected Weeks Until Full Price				288
Charging Type:	Cost (\$)	Charge mile/hour	Utilization	Charge price/hour
Level 1	1000	3	60%	0.04
Leve 2	2000	15	60%	0.07
DC	20000	120	80%	0.48

Other related parameter:		User Type:	Mileage/day
Expected Maximum Hour for Charging Full with Level 1	8	Type 1	20
		Type 2	40
Expected Maximum Hour for Charging Full with Level 2	5	Type 3	80
		Type 4	100
Expected Maximum Hour for Charging Full with DC	6	Type 5	120
Reliable Parameter for PHEV (% increase to the revenue index)	0		
Luxury Parameter for vehicle price over \$50,000 (% increase to the revenue index)	0		

Weekly Rental Fee = Price of the vehicle/ Expected Weeks until Full price
Eg. BMW iPerformance
→ weekly rental fee = 51400/288=178

Hours needed to charge full tank of each vehicle that charged with different charging system is:
Electrical Range/ Charge mile per hour
Eg. BMW iPerformance
→ Hour needed to charge full tank with level 1 AC = 16/3 =5

Weekly Revenue of each vehicle charged with different charging type is:
Charge price per hour *Hour needed to charge full tank*7days* (type# mileage per day/electrical range)
Eg. BMW iPerfromance
→ Weekly Revenue Charged with Level 1 AC = 0.04*5*7*(20/16)=\$1.48/ week

Reliable Parameter and Luxury Parameter: indication of % usage increase of the vehicle.

Note: each type of charging station has its maximum hour for charging full tank. The if exceeds the maximum expectation hour, the charging method for the vehicle is not considered.

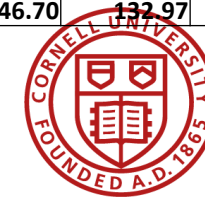


Methodology-Model Parameters

Overview → EV Background → Motivation → Existing Work → **Methodology-Model Parameter** → Methodology-Model Variables → Methodology-Model Constraints → Model Result → Sensitivity Analysis → Future Research

Index	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Revenue Paramaters	0-20miles				20-40miles			40-80miles		80-100miles		100-300 miles			
Vehicle	BMW530e iPerformance	Ford C-MAX Energi	Mercedes C350e	Mercedes GLE550e	Toyota Prius Prime	Hyundai Sonata Plug- In Hybrid	Chrysler Pacifica Hybrid	Chevrolet Volt	Mitsubishi i-MiEV	Mercedes B250e	Honda Clarity Electric	HyundaiLoniq Electric	Chevrolet Bolt	Tesla Model 3	Tesla Model S
Electric Range	16	19	20	20	25	27	33	53	62	87	89	124	238	220	210
Price/unit	51400	32950	45490	65550	27100	34600	41995	33220	22995	41450	37495	29500	37495	40000	70000
Revunue from Rental fee per week	178	114	158	228	94	120	146	115	80	144	130	102	130	139	243
(\$)Revenue from Charging fee/week (Level1)	+	1.48	1.48	1.48											
(\$)Revenue from Charging fee/week(level 2)		0.59	0.59	0.59	1.18	1.18	1.18	2.37	2.37						
(\$)Revenue from Charging fee/week (DC)	×	0.55	0.55	0.55	1.11	1.11	1.11	2.22	2.22	2.77	2.77	3.33	3.33	3.33	3.33
Reliable (PHEV) parameter	×	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Luxury Parameter		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Revenue Index	BMW530e iPerformance	Ford C-MAX Energi	Mercedes C350e	Mercedes GLE550e	Toyota Prius Prime	Hyundai Sonata Plug-In Hybrid	Chrysler Pacifica Hybrid	Chevrolet Volt	Mitsubishi i-MiEV	Mercedes B250e	Honda Clarity Electric	HyundaiLoniq Electric	Chevrolet Bolt	Tesla Model 3	Tesla Model S
Charged with Level 1 AC	179.95	115.89	159.43	229.08											
Charged with Level 2 AC	179.06	115.00	158.54	228.20	95.28	121.32	147.00	117.71	82.21						
Charged with Level DC	179.03	114.96	158.51	228.16	95.21	121.25	146.93	117.57	82.06	146.70	132.97	105.76	133.52	142.22	246.39



Cornell University

Methodology-Model Parameters

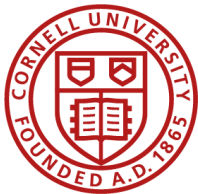
Overview → EV Background → Motivation → Existing Work → **Methodology-Model Parameter** → Methodology-Model Variables → Methodology-Model Constraints → Model Result → Sensitivity Analysis → Future Research

Revenue Index	BMW530e iPerformance	Ford C-MAX Energi	Mercedes C350e	Mercedes GLE550e	Toyota Prius Prime	Hyundai Sonata Plug-In Hybrid	Chrysler Pacifica Hybrid	Chevrolet Volt	Mitsubis hi i-MiEV	Mercedes B250e	Honda Clarity Electric	HyundaiLo niq Electric	Chevrole t Bolt	Tesla Model 3	Tesla Model S
Charged with Level 1 AC	179.95	115.89	159.43	229.08											
Charged with Level 2 AC	179.06	115.00	158.54	228.20	95.28	121.32	147.00	117.71	82.21						
Charged with Level DC	179.03	114.96	158.51	228.16	95.21	121.25	146.93	117.57	82.06	146.70	132.97	105.76	133.52	142.22	246.39

Decision Variables (# of model with Charge Type in a week)	BMW530e iPerformance	Ford C-MAX Energi	Mercedes C350e	Mercede s GLE550e	Toyota Prius Prime	Hyundai Sonata Plug-In Hybrid	Chrysler Pacifica Hybrid	Chevrolet Volt	Mitsubis hi i-MiEV	Mercedes B250e	Honda Clarity Electric	HyundaiLo niq Electric	Chevrole t Bolt	Tesla Model 3	Tesla Model S
Number Rented Charge with Level 1 AC	X1,1	X1,2	X1,3	X1,4	X1,5	X1,6	X1,7	X1,8	X1,9	X1,10	X1,11	X1,12	X1,13	X1,14	X1,15
Number Rented Charge with Level 2 AC	X2,1	X2,2	X2,3	X2,4	X2,5	X2,6	X2,7	X2,8	X2,9	X2,10	X2,11	X2,12	X2,13	X2,14	X2,15
Number Rented Charge with DC	X3,1	X3,2	X3,3	X3,4	X3,5	X3,6	X3,7	X3,8	X3,9	X3,10	X3,11	X3,12	X3,13	X3,14	X3,15

Total Revenue=sumproduct(Revenue Index Array, Decision Variable)

Objective: max. Total Revenue

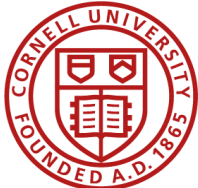


Methodology-Model Constraints

Overview → EV Background → Motivation → Existing Work → Methodology-Model Parameter → Methodology-Model Variables → **Methodology-Model Constraints** → Model Result → Sensitivity Analysis → Future Research

Constraints

	CDF	Numbers of Users of Each Types	Numbers of Users of Each Types (variables)
Type 1 User CDF	0.34	34	sum(X1...3, 1...4)
Type 2 User CDF	0.54	54	sum(X1...3, 5...7)
Type 3 User CDF	0.75	75	sum(X1...3, 8...9)
Type 4 User CDF	0.8	80	sum(X1...3, 10...11)
Type 5 User CDF	1	100	sum(X1...3, 12...15)
Total Potential Users (weekly)	100		



Model Result

Overview → EV Background → Motivation → Existing Work → Methodology-Model Parameter → Methodology-Model Variables → Methodology-Model Constraints → **Model Result** → Sensitivity Analysis → Future Research

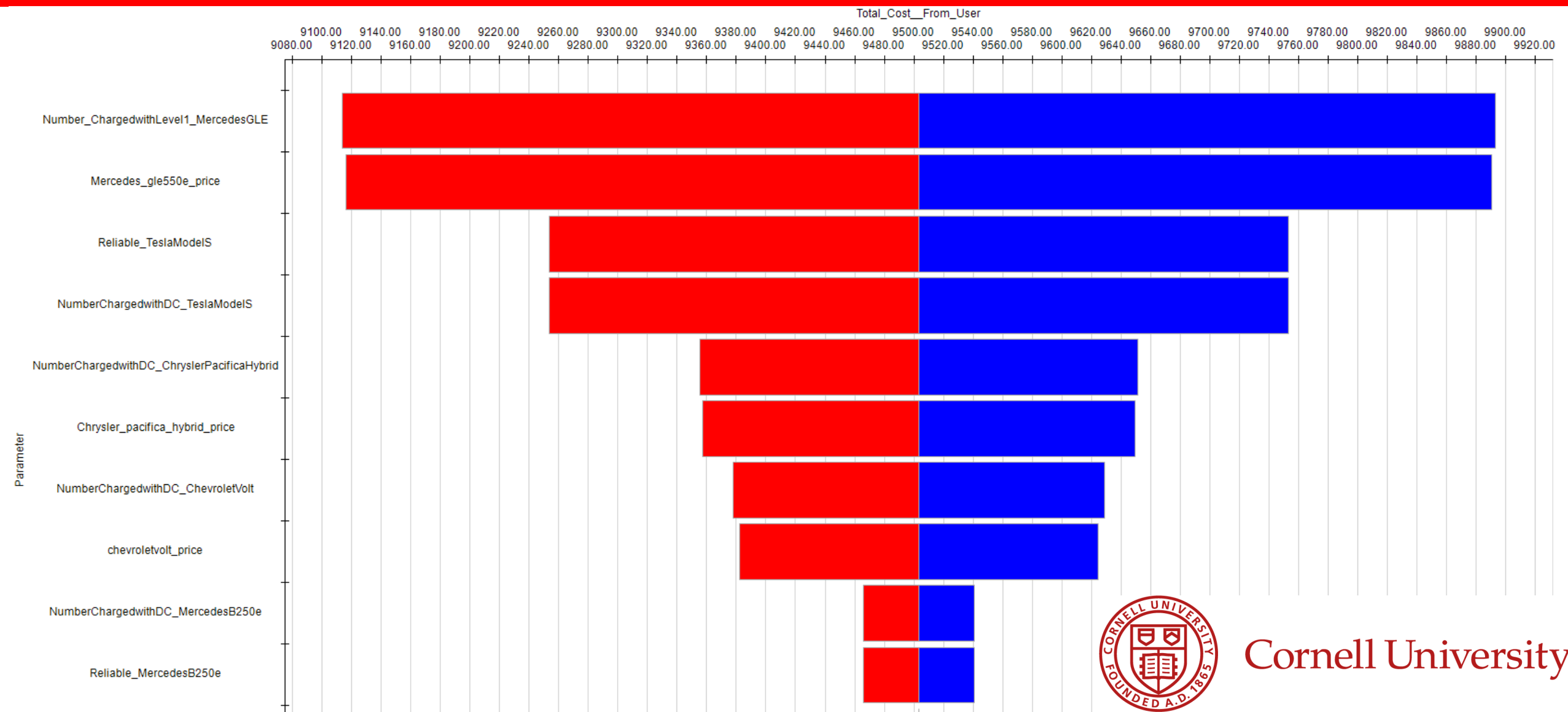
Decision Variables (# of model with Charge Type in a week)	BMW530e iPerformance	Ford C-MAX Energi	Mercedes C350e	Mercedes GLE550e	Toyota Prius Prime	Hyundai Sonata Plug-In Hybrid	Chrysler Pacifica Hybrid	Chevrolet Volt	Mitsubishi i-MiEV	Mercedes B250e	Honda Clarity Electric	Hyundai Ioniq Electric	Chevrolet Bolt	Tesla Model 3	Tesla Model S	Total
Number Rented Charge with Level 1 AC	0	0	0	34	0	0	0	0	0	0	0	0	0	0	0	34
Number Rented Charge with Level 2 AC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number Rented Charge with DC	0	0	0	0	0	0	20	21	0	5	0	0	0	0	20	66
Total	0	0	0	34	0	0	20	21	0	5	0	0	0	0	20	100
Total Minutes Charged with DC per Week	0	0	0	0	0	0	400	840	0	250	0	0	0	0	1200	

Final Decision of Number of DC Charge	2.00
Number of AC Level 1	34.00
Number of AC Level 2	0.00



Sensitivity Analysis

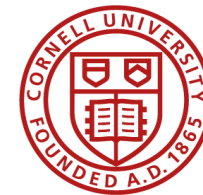
Overview → Background → Motivation → Existing Work → Methodology-Model Parameter → Methodology-Model Variables → Methodology-Model Constraints → Model Result → **Sensitivity Analysis** → Future Research



Project Extension

Overview → Background → Motivation → Existing Work → Methodology-Model Parameter → Methodology-Model Variables → Methodology-Model Constraints → Model Result → Sensitivity Analysis → **Future Research**

- Contract with local rental company
- Build Level AC 1 in the local apartment community (baring cost with the apartment community)
- Consider the Uncertainty effect of the parameters
 - EV Rental potential users in Cornell
 - Survey
 - Empathy Field Work
 - Forecasting method
 - Construction Cost in Range
 - Users behaviors
 - Survey
 - Forecasting method



Cornell University