Title
Cost Sensitivity and Charging Choices of Plug-in Electric Vehicle Drivers — A Stated Preference Study

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Publication Date
2024-12-01

DOI
10.7922/G2NP22S0

Data Availability
The data associated with this publication are available at:
https://doi.org/10.5061/dryad.vt4b8gv1t

Cost Sensitivity and Charging Choices of Plug-in Electric Vehicle Drivers – A Stated Preference Study

December 2024

A Research Report from the National Center for Sustainable Transportation

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National Center for Sustainable Transportation
A USDOT University Transportation Center

UC DAVIS
Institute of Transportation Studies

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. NCST-UCD-RR-24-33	**2. Government Accession No.** N/A	**3. Recipient's Catalog No.** N/A
4. Title and Subtitle Cost Sensitivity and Charging Choices of Plug-in Electric Vehicle Drivers – A Stated Preference Study		**5. Report Date** December 2024 **6. Performing Organization Code** N/A
7. Author(s) Lu Dong, https://orcid.org/0009-0004-6013-223X Scott Hardman, Ph.D., https://orcid.org/0000-0002-0476-7909 David S. Bunch, Ph.D., https://orcid.org/0000-0001-8728-7072 Stefan Mabit, Ph.D., https://orcid.org/0000-0002-3675-6884 Debapriya Chakraborty, Ph.D., https://orcid.org/0000-0001-9898-4068		**8. Performing Organization Report No.** UCD-ITS-RR-24-72
9. Performing Organization Name and Address University of California, Davis Institute of Transportation Studies 1605 Tilia Street, Suite 100, Davis, CA 95616		**10. Work Unit No.** N/A **11. Contract or Grant No.** USDOT Grant 69A3551747114
12. Sponsoring Agency Name and Address U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology 1200 New Jersey Avenue, SE, Washington, DC 20590		**13. Type of Report and Period Covered** Final Research Report (October 2022 – March 2024) **14. Sponsoring Agency Code** USDOT OST-R
15. Supplementary Notes DOI: https://doi.org/10.7922/G2NP22S0 Dataset DOI: https://doi.org/10.5061/dryad.vt4b8gv1t		

16. Abstract

California's Zero Emission Vehicle (ZEV) mandate targets all new Light Duty Vehicle (LDV) sales to be ZEVs by 2035. However, the current charging infrastructure is not well-developed in California, primarily serving households with home charging setups and leaving a noticeable gap in public charging facilities. This gap is seen as a significant barrier to Battery Electric Vehicle (BEV) adoption within California. This report explores driver charging behavior and their preference for public DC fast charging (DCFC), drawing on Stated Preference (SP) choice experiment data from a survey of 1,102 Plug-in Electric Vehicle (PEV) owners across California.

17. Key Words Electric vehicle, charging, choice, survey		**18. Distribution Statement** No restrictions.	
19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 31	**22. Price** N/A

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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Disclaimer

Acknowledgments

This study was funded, partially or entirely, by a grant from the National Center for Sustainable Transportation (NCST), supported by the U.S. Department of Transportation (USDOT) through the University Transportation Centers program. The authors would like to thank the NCST and the USDOT for their support of university-based research in transportation, and especially for the funding provided in support of this project. The authors would also like to thank Matthew Favetti for programming the survey used in this study, and NEXT10 foundation who provided additional funding to complete this research.

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EXECUTIVE SUMMARY

California's Zero Emission Vehicle (ZEV) mandate targets all new Light Duty Vehicle (LDV) sales to be ZEVs by 2035. To meet this goal public charging infrastructure will be needed to meet household travel needs, this will include charging at home, workplaces, and along travel corridors. This report explores driver charging behavior and their preference for public DC fast charging (DCFC) specifically on long distance trips. Results are from Stated Preference (SP) choice experiment data from a survey of 1,102 Plug-in Electric Vehicle (PEV) owners across California. The experiment investigates preferences for charging speed, distance to a charger, wait time at the charger, charging cost, and the presence of amenities at charging stations (e.g. restrooms, coffee shops, convenience stores). Utilizing the Apollo package, we estimate a Logit model to evaluate the utility functions of unlabeled choice alternatives. This approach helps quantify the trade-offs drivers are willing to make concerning charging cost (per 100 miles), charging time (per 100 miles), and other factors such as detour time, waiting probabilities, and wait time. Using results from the model we also estimate how much drivers are willing to pay for specific charging attributes and examine the interactions between these attributes, household income, and Battery Electric Vehicle (BEV) range.

The results show that for each 100-mile of charging and average income, drivers are willing to pay:

- $0.29 more per 1-minute reduction of charging time
- $0.50 more per 1 minute reduction on detour time
- $1.05 more for no chance of waiting to charge
- $0.38 more for 1 minute reduction on wait time to charge
- $2.56 more to charge at a location with restrooms
- $2.65 more to charge at a location with restrooms and convenience store
- $5.6 more to charge at a location with a combination of restrooms, coffee shops, and outdoor areas, particularly when the charging time exceeds 9 minutes

Considering the willingness to pay per kWh, we assume that the average electric car kWh per 100 miles kWh/100 miles is 34.6 (1).

- $0.0084 more per kWh for 1 minute reduction of charging time
- $0.0145 more per kWh for 1 minute reduction on detour time
- $0.0110 more per kWh for 1 minute reduction on wait time to charge

Our study also explores non-linear parameters within the utility function, assessing how BEV range and household income influence charging costs and times. Findings indicate that owners

of BEVs with longer ranges, such as Tesla owners, are willing to pay more for shorter charging times and are more tolerant of detour times, waiting times, and facility deficiencies. Additionally, the results suggest that enhancing amenities at charging stations—particularly with the inclusion of restrooms, coffee shops, and outdoor areas—appeals to respondents facing longer charging times (exceeding 9 minutes).

Introduction

California's Zero Emission Vehicle (ZEV) mandate sets a requirement for all new Light Duty Vehicle (LDV) sales to be ZEV by 2035. According to the California Energy Commission, ZEVs accounted for 25.02% of new light-duty vehicle sales in 2023, with projections indicating continued growth, reaching 35% by 2026 and 51% by 2027 (2). To support the increasing adoption of electric vehicles, California has implemented several policy actions to motivate the planning and deployment of charging infrastructure. For instance, California provides a range of rebates and grants for public and private entities to install EV charging stations through the California Electric Vehicle Infrastructure Project (3). Furthermore, in 2024, the California Energy Commission (CEC) approved a 1.9 billion USD investment plan for the next four years to accelerate the development of the charging infrastructure, anticipated to add 40,000 new chargers (4). Current research on EV charging infrastructure mainly focuses on optimizing the location of EV charging stations based on observed driving behavior(5,6). There are also some studies focusing on the demand side of charging infrastructure. Utilizing revealed choice data on BEV charging behavior, prior studies have identified factors driving the choice of charging location (home, work, or public) and the distribution of charging location preference over a week (charging patterns may differ between weekdays and weekends due to differences in travel needs) (7,8). Notable factors identified include the cost of charging, access to charging at home and the level of charger, commute pattern, availability of free charging at the workplace, public charger membership, recharge time, and charger congestion. Typically, for a PEV driver, there are tradeoffs among various attributes of vehicle charging operations such as cost, time, availability, convenience, and interoperability. Although cost and network access have been identified as major factors influencing the choice of public charging locations for PEVs, there is limited research on how consumers react to different pricing strategies for PEV charging and their access to EV charging networks. However, the charging price is a crucial part for PEV operation.

Home charging dominates day-to-day charging (routine charging), with 50%-80% of charging events occurring at home(9). Most EV owners have home charging access, and our survey indicates that over 94% of respondents have access to charging at or near their homes. However, home charging has less support for long-distance trips, and there is considerable uncertainty about how long-distance travel will work for EV-only households (10). Many PEV owners possess multiple vehicles and use ICE vehicles for long-distance trips. Considering the increasing investment in building fast-charging infrastructure along highway corridors, particularly aimed towards BEV drivers, and increasing BEV sales one may expect more BEV users to start taking their BEVs for longer trips. The tradeoffs in the location choice can be different than those associated with routine charging events, a fact often ignored in existing studies. The triggers for charging choices during long-distance trips can be different. For example, the importance of cost and charger availability, detour time, and recharging time can be higher. Long-distance trips are usually occasional and charging may also have to be planned differently (11–14). There are a limited number of studies with quantitative evaluation of factors driving charging preference for long-distance trips. Focusing on BEV drivers in California, in this project, we aim to fill these gaps in the literature by analyzing the tradeoff in charging choice decisions under the scenario of non-routine charging needs at fast charging stations usually on long-distance trips. Using stated preference (SP) choice experiments, we aim to study how individuals value both existing and hypothetical attributes of charging location in their charging decision. In a recent paper, Visaria et al. (15) used stated-choice experiments for regular charging and longer trips, to discuss the factors that influence the charging decisions of consumers that are relevant for policymakers and charging operators. Building on the framework established by Visaria et al., our research delves deeper into charging station attributes, focusing on the dynamics that influence the selection of fast-charging locations for long-distance trips. We examine the trade-offs between cost, recharge time, convenience regarding detour requirements, and charger availability.

Methods

To gain insights into EV drivers' preferences for fast charging during long-distance trips, we utilize data from an online survey aimed at plug-in electric vehicle owners. We designed four Stated Preference (SP) choice experiments for each respondent, each focusing on different attributes of charging stations. SP choice experiments allow us to investigate how individuals evaluate multiple attributes of the charging infrastructure in their choice decisions. In addition, this survey also gathered household-level data, including the types of PEVs owned by respondents—such as model, year, and brand—along with home charging access, BEV range, household income, gender, age, and other factors. The analysis involves exploring descriptive statistics and employing the Multinomial Logit (MNL) model to investigate the decision-making process.

The questionnaire survey was conducted in February and March 2024, targeting existing plug-in electric vehicle (PEV) owners. The respondents were sampled from respondents to prior UC Davis EV Center Surveys. Recruitment for those surveys was from Clean Vehicle Rebate Recipients, specifically targeting PEVs of model year 2015 and later. The survey was distributed to 4,120 PEV owners, of whom 1,265 began the survey. A total of 1,102 respondents completed the choice experiment, and 1,086 completed the entire questionnaire. This survey aims to quantitatively evaluate the factors influencing charging preferences for long-distance trips using stated preference (SP) data. The survey sample is a convenience sample and may not be representative of the entire EV market.

Data overview

The data for this study were collected through an online survey conducted between February and March 2024. Participants were recruited from an EV Center Database of EV driver email addresses. The addresses were collected in prior surveys of EV drivers who were originally recruited from clean vehicle rebate recipients by the California Air Resources Board. We recruited existing PEV owners because theoretically, existing adopters will have more concrete ideas on their preferences for charging, therefore providing more behaviorally accurate results. The survey consisted of several sections, including demographics, household vehicles, respondents' attitudes towards charging attributes, and the stated preference choice experiments. We targeted 4,120 existing plug-in vehicle (PEV) owners, with 1,265 respondents initiating the survey, 1,102 completing the choice experiments, and 1,086 finishing the entire survey. The first 1,000 participants who completed the survey received a $5 Amazon gift card. It should be noted that all respondents were PEV owners, ensuring they had experience with charging at home or in public locations. The choice experiments specifically focused on charging preferences for BEVs when used for long-distance travel. For the non-BEV but PEV owners, the experiments randomly assigned hypothetical BEVs to these respondents for the following choice tests, including “Your 250-mile BEV”, “Your 275-mile BEV”, “Your 300-mile BEV”, “Your 325-mile BEV”.

Demographic and vehicle attribute data from this survey is mainly shown in Table 1. It shows the current PEV owner’s electric vehicle and charging-related information, including BEV range, make (brand), home charging access, and home charging frequency.

Table 1. Demographic and vehicle attribute data

Revealed data	Description
Annual household income	1: less than $50,000 2: $50,000 to $99,999 3: $100,000 to $149,999 4: $150,000 to $199,999 5: $200,000 to $249,999 6: $250,000 to $299,999 7: $300,000 to $349,999 8: $350,000 to $399,999 9: $400,000 to $449,999 10: $500,000 or more
BEV range	Mainly from 208 miles to 333 miles
BEV make (brand)	Tesla; Chevy Bolt; Nissan Leaf; etc.
Home charging availability	Attached Garage; driveway; detached garage; carport; assigned parking in lot or garage; etc.
Home charging frequency	Exclusively at/near home; mostly at/near home; both at/near home and away from home; most away from home (60-90% of charging); exclusively away from home (90%-100% of charging)

Since the home is currently the primary charging location for electric vehicle owners, and potential buyers in the future may lack access to home charging, the survey included several questions that addressed scenarios where respondents did not have access to home charging facilities. The aim of this is to understand more about the difficulties in electric vehicle use without home charging access and preferences for public charging locations.

For the SP choice experiments, we focus on charging during long-distance trips, particularly emphasizing the use of public fast charging stations. Based on prior literature and our own knowledge and experience, the experiment was designed to include the following attributes:

charger type, charging cost, charging time, detour time to the charger, whether there is a chance of having to wait at the charger, the typical wait time (for those times where waiting is required), and the available amenities at the charging location. Table 2 presents the choice experiment attributes and levels used for each attribute.

There were two important considerations in establishing the units and levels for attributes: (1) the units and descriptions of recharging time and costs needed to be readily understandable by recipients, and (2) the ranges (minimum and maximum values) needed to cover the full 'space' of options that might possibly be of interest. The factors used to determine these ranges included: the possible ranges of BEVs on a full charge (based on a database of current BEVs, plus likely range values in the near future), the possible ranges of kW for charging unit technologies in the near future, the recharge times required by BEVs for different values of charging unit kW, and a range of electricity costs (in $/kWh). These values were combined to generate ranges of recharging costs (in $/100 miles) and recharging times (in minutes per 100 miles) produced by these various factors.

Note that, for any specific recharging cost (in $/100 miles) or recharging time (in minutes per 100 miles), the *total* cost and *total* recharging time could vary (in some cases, substantially) depending on the *range* of the BEV. Choice tasks were customized to produce values for total cost and total time as a function of the BEV being used by the respondent. The following summarizes additional details for the attributes used in the choice tasks:

Charger type (Label): Each charging option had one of the following two labels Fast (100-125kW) or Ultrafast (250-400kW). The attribute levels associated with these labels were constructed to be consistent with the kW range for each label. The context of the choice task therefore assumed that all options would be, at a minimum, 'fast,' i.e., Level 1 or Level 2 charging speeds were specifically excluded.

Charging cost per 100 miles in USD: In the choice tasks, the respondents saw the real charging cost based on the charging range, consistent with the stated assumption that respondents would recharge their BEVs from 20% to 80%.

$$total\ charging\ cost = \ charging\ cost\ per\ 100\ miles\ \times\ BEV\ range\ \times\ (80\% - 20\%)$$

Charging time in minutes: The attribute levels are in minutes per 100 miles. In the choice tasks, the respondents saw the total charging time based on their BEV range, consistent with the stated assumption that respondents would recharge their BEVs from 20% to 80%.

$$total\ charging\ time = \ charging\ time\ per\ 100\ miles\ \times\ BEV\ range\ \times\ (80\% - 20\%)$$

Detour time in minutes: the estimated detour time from their route required to go to the charging location.

Chance of waiting for charge: Respondents are assumed to have on-board information on whether or not waiting will be required when they arrive at the location (yes, or no). If 'yes,' an estimated typical waiting time (in minutes) is provided. Levels are 0, 4, 8, and 12 minutes.

Amenities facilities: Figenbaum and Nordbakke (16) found that amenities did affect how attractive a charging location was for users and they preferred a location with good facilities. In our choice experiments, we set different levels of facilities, including no amenities, having restrooms, having restrooms plus convenience store, and having restrooms, coffee shops/restaurants, play area, and outdoor space.

Based on these attributes, each respondent is shown four separate choice tasks. Each task requires a choice between two charging options (A or B). The context of the task precludes the option of continuing to drive on in search of other options.

Table 2. Choice experiment attributes and attribute levels.

Attributes	Attribute levels
Charger Type	Fast (100-125 kW)[1] Ultrafast (250-400 kW)[2] [1] if charge time is 15 or 20 mins per 100 miles. [2] if charge time is 5 or 10 mins per 100 miles.
Charging cost ($ per 100 miles)	4: $4 8: $8 18: $18 25: $25
Charging time **Minutes per 100 miles**	5: 5 minutes 10: 10 minutes 15: 15 minutes 20: 20 minutes
Driving detour from route (minutes)	2: 2 minutes 5: 5 minutes 10: 10 minutes 12: 12 minutes
Chance of waiting for charger	0: No chance of waiting 1: Possible chance of waiting
Typical wait time	0: No new text. Just the display from above: "No chance of Waiting" 4: 4 minutes 8: 8 minutes 12: 12 minutes
Facilities	1. No amenities 2. Restrooms only 3. Restrooms + Convenience Store 4. Restrooms, Coffee shop/restaurants, play area/green outdoor space

Table 3. Example choice experiment set up

(the content in the bracket [] is customized according to respondents' answer)

Assume you are making a long-distance trip (a "road trip") in your [2021 Chevrolet Bolt EV], you started your journey with 80% charge and have driven [155 miles] and the battery is now at 20% capacity (you have [52 miles] miles left). You must charge to reach your destination, and the following are two options with Fast Chargers nearby. Which one would you choose? (Reminder: You are charging from 20% to an 80% charge. That is, you are adding [155 miles] to reach a new range of [207 miles].		
	Charging Location A	**Charging Location B**
Charger Type	Fast (100-125 kW)	Ultrafast (250-400 kW)
Charging cost	$8 per 100 miles	$18 per 100 miles
	$12.43 total cost	**$27.97 total cost**
Charging time	20 min per 100 miles	5 min per 100 miles
	31.1 total minutes	**7.8 total minutes**
Driving detour from route (minutes)	10 minutes	5 minutes
Chance of waiting for charger	Possible chance of waiting	Possible chance of waiting
Typical wait time	0 minutes	12 minutes
Facilities	Restrooms only	No amenities
Choice	Charging location, A	Charging location, B

Analysis: Discrete choice models

Discrete choice models typically operate on the assumption that consumers are rational actors who aim to maximize personal well-being. We apply these models, based on Random Utility Maximization (RUM), to analyze the SP choice experiment data. Using the logit model with non-linear parameters, we analyze the survey data to identify which attributes of charging stations and demographic factors influence choices. As previously mentioned, our focus is on testing BEV charging for long-distance trips. For PHEV owners, we randomly assigned a hypothetical BEV to them. In our study, we include the non-linear parameters for logit model, we use the continuous interactions and elasticities mentioned by Axhausen et al (17): x means the attributes of chargers, including charging cost per 100 miles, and charging time per 100 miles.

$$f(y, x) = (\frac{y}{\hat{y}})^{\lambda_{x,y}} \qquad \text{Equation 1}$$

The primary methodological focus of this study is on the continuous interactions between charging attributes and sociodemographic factors such as income, as well as BEV characteristics such as range (18), as shown in Equation1. By incorporating respondent-specific income and BEV charging range into the elasticity formulation, we aim to gain a deeper understanding of the factors that influence utility. The utility model in this study primarily incorporates the attributes of each choice through a linear function, while allowing for non-linear interactions of charging cost per 100 miles and charging time per 100 miles with socio-demographic variables, including income and BEV range. Since each respondent completed four choice tasks, we converted the survey results into panel data, resulting in a total of 4,408 observations for the model regression.

Equation 2 shows us the utility function for charging choices, with linear function of seven attributes and non-linear effect of income as well as BEV range on charging cost and charging time.

$$U_j = \beta_{CC} \times CC_j \times f(inc, CC) \times f(dist, CC) + \beta_{CT} \times CT_j \times f(inc, CT) \times f(dist, CT) + \beta_l \times label_j + \beta_d \times detour_j + \beta_{cw} \times CW_j + \beta_{wt} \times WT_j + \sum_{i=1}^{4} \beta_{f,i} \times f_{i,j} + \varepsilon$$

Equation 2

Where,

- U_j represents the utility function for alternative j. In this study, we consider two unlabeled alternatives, a and b. These alternatives differ in certain attributes, such as charging time, charging cost, and other factors.
- CC_j refers to the charging cost per 100 miles, which is an attribute of charging alternative j.
- CT_j refers to the charging time per 100 miles, which is an attribute of charging alternative j.
- $f(inc, x)$ represents the income elasticity formulation associated with attribute x (charging cost and charging time).
- $f(dist, x)$represents the distance elasticity associated with attribute x (charging cost and charging time).
- $label_j$ represents the label effect, which is set to be 1 if the alternative is labeled as ultrafast, and 0 if labeled as fast.
- $detour_j$ represents the detour time to the charging location, treated as a continuous variable.
- CW_j is a dummy variable, set to 0 if there is no chance of waiting, and set to 1 if there is a chance of waiting.
- For chargers where there is a chance of waiting, the wait time (WT) is tested as an additional coefficient of CW.
- $f_{i,j}$ represents the facility level i for alternative j. In this choice experiment, there are four facility levels: no amenities, only restrooms, restrooms with convenience stores, and restrooms with coffee shops and outdoor play areas. Each level is represented by a dummy variable. It is important to note that the dummy variable for having restrooms is set to 0 when there are no amenities and 1 for all other facility levels.
- ϵ represents the error term in the utility function.

Results

Home charging availability and charging frequency

Figure 1 shows the distribution of home charging locations survey respondents had access to. Most home charging occurs in the garage attached to housing units, around 66%, with less than one-third of access points located in uncovered driveways. Only a small percentage of electric vehicle drivers use unassigned parking spaces in parking lots, carports, detached garages, on-street parking, or assigned parking spaces in parking lots. Figure 2 shows respondents reported charging behavior on an ordinal scale ranging from almost all of charging being completed at home to almost charging being completed away from home. Most survey respondents (64%) reported charging exclusively at or near home, with 20% reporting mostly charging at or near home, and less than 20% reported charging both at and away from home.

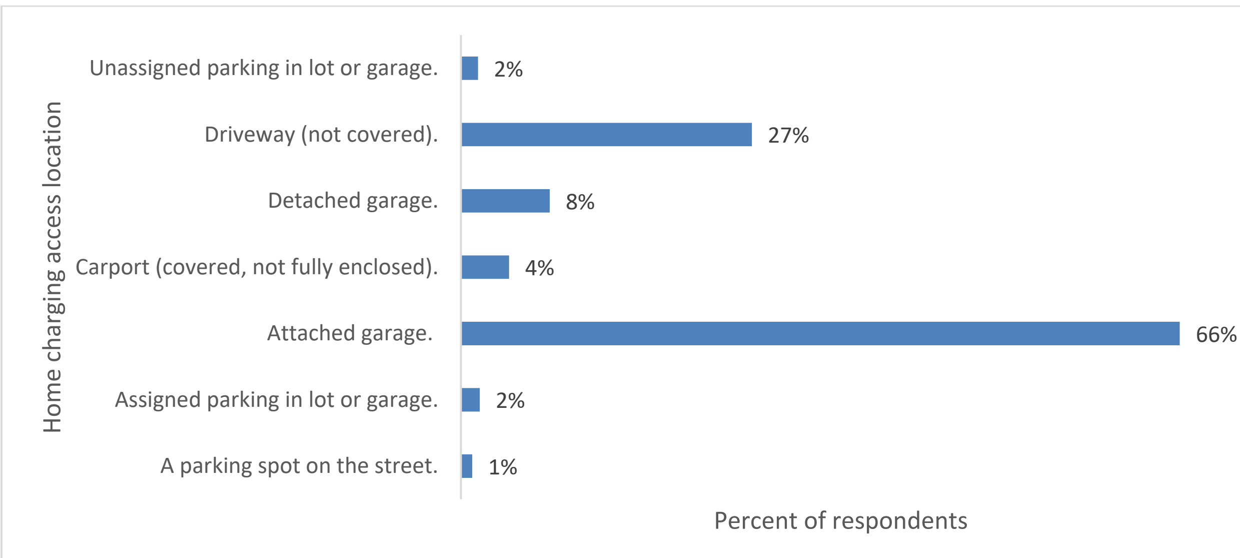

Figure 1. Location of home charging access for survey respondents

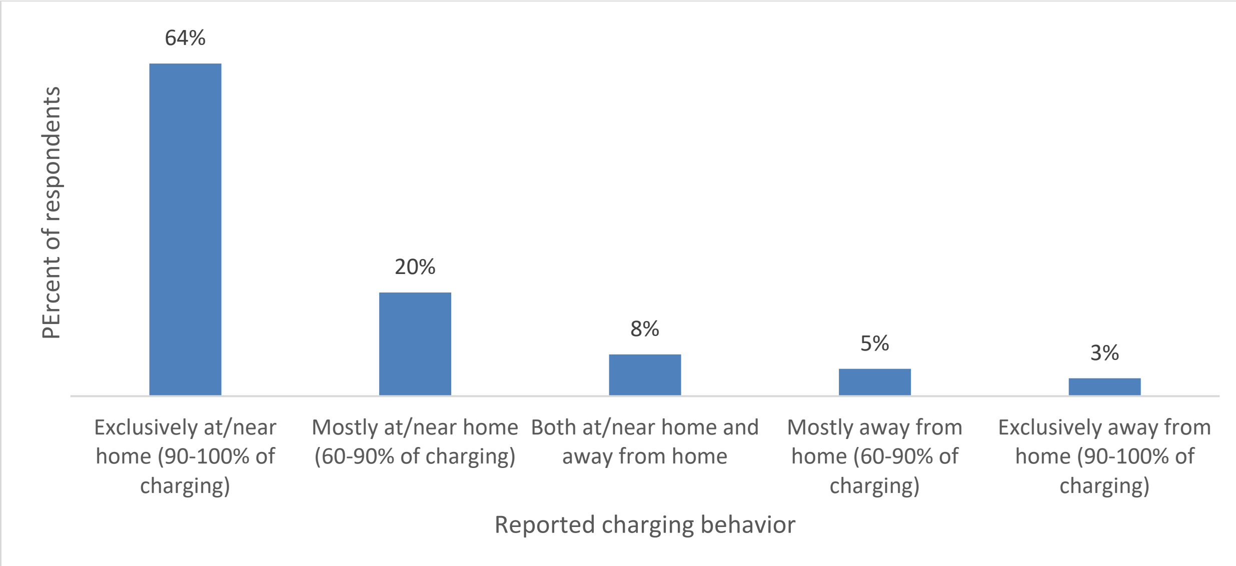

Figure 2. Distribution of reported charging usage for at home and away from home

Charging and travel behavior changes if there is no home charging access

The survey explored the impact of home charging access on respondents, asking them to imagine they lack access to home charging. Figure 3 shows responses to various statements regarding the absence of home charges. Although most respondents believe there are sufficient alternatives to home charging, about a quarter disagree. Despite recognizing other options, 69% feel that losing home charging would significantly affect their behavior. Over half agree that continuing to use their BEV would require major changes to the routine without home charging. Meanwhile, 43% would reconsider BEV ownership because of the lack of access to home charging. Most importantly, most are concerned about the high cost (66%) and inconvenience (84%) of non-home charging options. This survey also asked respondents about travel behavior changes if they no longer have access to home charging.

Figure 4 shows what electric vehicle buyers would change in their travel behavior if there were no home charging access. 35% respondents reported that they would replace their BEVs with a traditional vehicle if there is no home charging access, and 34% and 41% of respondents would replace their BEV with a PHEV or a traditional HEV, respectively. For the agreement with charging alternatives, 60% respondents agree that they would use more level 2 charging away from home, 91% Tesla owners reported that they would do more charging at Tesla super charging stations, while only 58% non-Tesla owners agree that they would do DC fast charging away from home, which indicates that Tesla owners have better knowledge on DC fast charging outside.

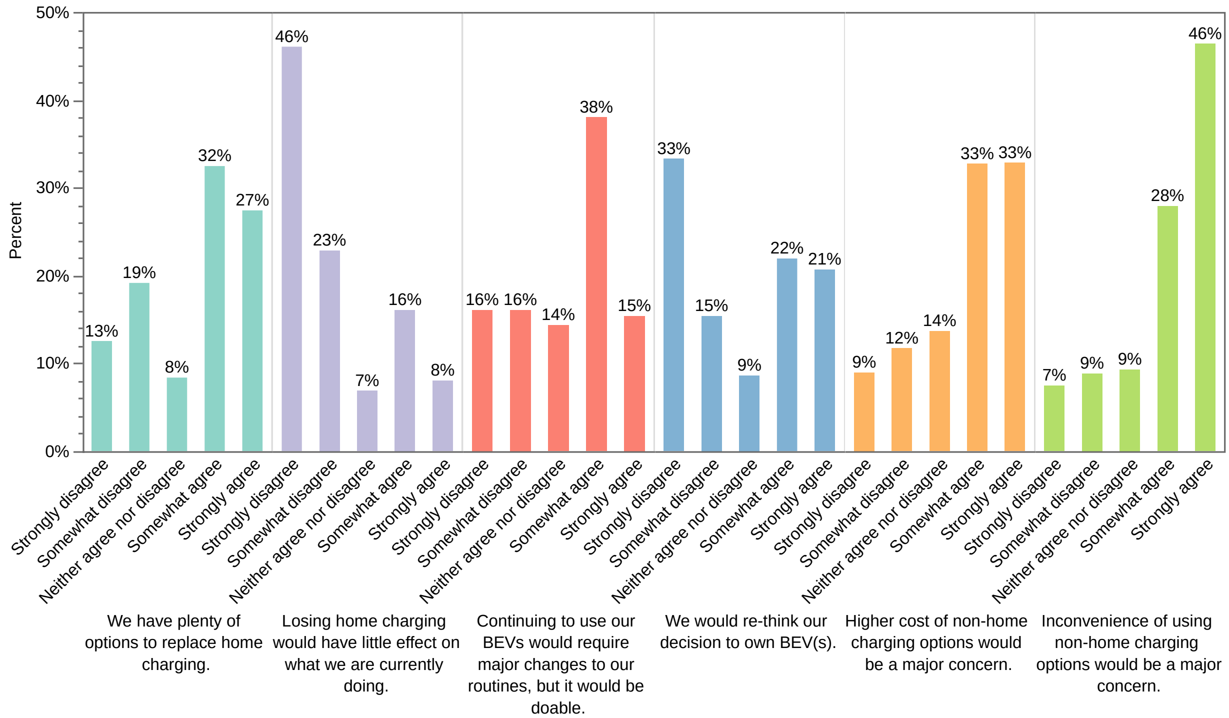

Figure 3. Impact of lacking home charging access on respondents' charging behavior

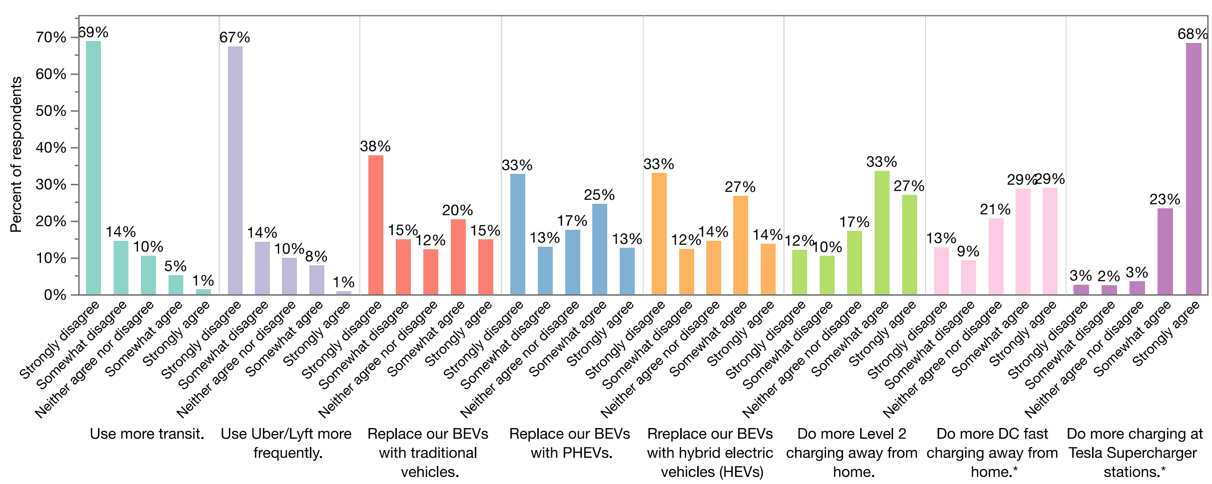

Figure 4. Impact of lacking home charging access on respondents' traveling behavior

Summary of BEV make

Figure 5 presents the distribution of BEV ranges, primarily concentrated between 233 and 358 miles on full charge. In our study on charging behavior during long-distance travel, we find that typical recharging is from 20% to 80% of full range, indicating 60% of BEV range would be charged.

Table 4 lists the major BEV manufactures and their average ranges. Over half of the respondents own Tesla with an average range of 303.5 miles, translating to approximately 182 miles per recharge, followed by Chevy Bolt and Nissan Leaf. For those without viable long-distance BEVs, our survey randomly assigned "Your BEV" for the subsequent charging choice experiments. The ranges of "Your BEV" include 250 miles, 275 miles, 300 miles and 325 miles.

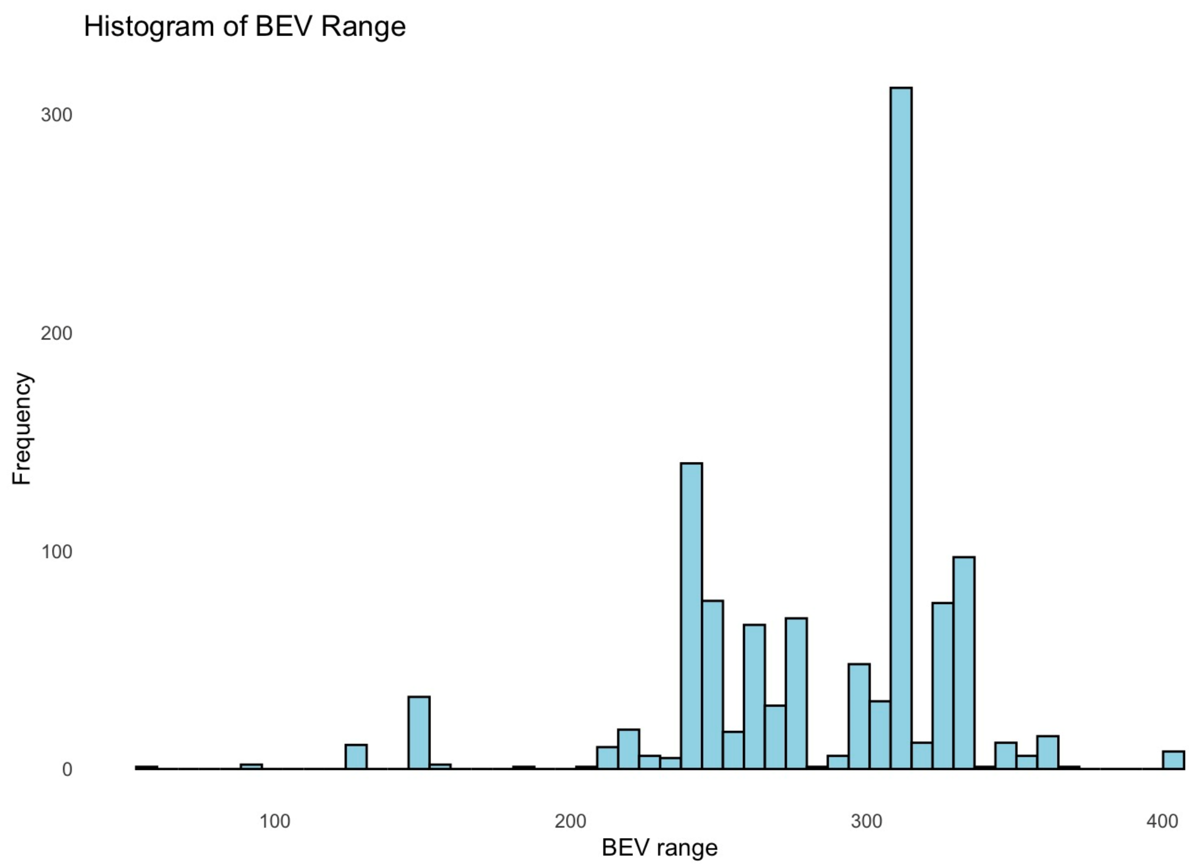

Figure 5. BEV range distribution for survey respondents.

Table 4. BEV make and average range in the survey sample

Make	Frequency	Percentage	Ave Range	Ave Range 60%
Tesla	648	58.2%	303.5	182.1
Chevy Bolt	111	10.0%	241.8	145.1
Nissan Leaf	48	4.3%	174.7	104.8
Other Make	120	10.8%	254.8	152.9
Substitute BEVs	187	16.8%	284.9	170.9
Total	1,114			
For respondents without a viable long-distance BEV, we randomly assign "Your BEV" with following ranges:				
Your 250-mile BEV	55			
Your 275-mile BEV	48			
Your 300-mile BEV	39			
Your 325-mile BEV	45			

Logit Model Results

Table 5 shows results for the Logit model for charging choice experiments, comparing two models, one without label and the other with label – fast/ultrafast. The analysis focuses on unlabeled binary charging choice experiments (charging choice a and charging choice b), each choice characterized by varying attributes, including labels, charging cost per 100 miles, charging time per 100 miles, detour time, chance of wait, and wait time. Additionally, we explored the effects of BEV range and income elasticity, as well as the impact of charging facilities, on these choices. Specifically, we explored the interaction between facilities featuring amenities with coffee shops and outdoor play areas, and the total charging time (more than 9 minutes). It is important to note that total charging time is calculated by multiplying the charging time per 100 miles by 60% of each respondent's BEV recharging range.

Table 5 details the coefficients of key variables affecting the charging choice. Model 2 illustrates that Charging stations labeled as "Ultrafast" have a positive coefficient, suggesting that respondents prefer these over stations labeled as "Fast". Both charging cost and charging time per 100 miles exhibit significant negative coefficients, indicating a preference for stations offering quicker and cheaper charging during long-distance travel. Additionally, the negative coefficient for detour time to charging stations, likelihood of waiting, and the average wait time further emphasize the importance of convenience in charging stations. The coefficients associated with different amenities also suggest that respondents favor charging stations located with restrooms, coffee shops, and outdoor play areas. Specifically, stations that feature restrooms, coffee shops and outdoor play areas tend to be highly preferred, particularly when the charge time is relatively long, more than 9 minutes. Model 2 led to a drop in log-likelihood by 912 units, and the adjusted R square is 0.3043, which indicates that this model quite fit the choice data. We also explored the impact of labeling on choice by comparing two simplified models, model 1 and model 2. From the comparison result, we can conclude that labeling primarily affect coefficient of charging time, rather than charging cost, detour time, or wait time. This suggests that respondents primarily focus on charging time when exposed to labels.

Because we cannot differentiate between the willingness to pay for charging time and label effects, as they influence each other's coefficients, we finally chose Model 1 for further trade-off analysis.

Table 5. Logit model Estimates for Public DC fast charging choices

	Model1 without label			**Model2 with label (fast/ultrafast)**	
Explanatory variable	Estimate		Rob.t-ratio	Estimate	Rob.t-ratio
Charging cost ($/100 miles)	**-0.132**	***	**-11.5**	**-0.128 *** **	**-11.3**
Ultrafast (label)				**0.350 *** **	**3.4**
Charging time (minutes/100 miles)	**-0.039**	***	**-4.6**	**-0.018 *** **	**-2.2**
Detour time (minutes)	**-0.066**	***	**-10.8**	**-0.067 *** **	**-10.6**
Charging cost range elasticity	**0.352**	***	**2.4**	**0.342 *** **	**2.4**
Charging time range elasticity	**1.494**	***	**4.1**	**2.242 *** **	**3.5**
Charging cost income elasticity	**-0.036**	***	**-2.7**	**-0.028 *** **	**-2.2**
Charge time income elasticity	**0.054**	***	**2.5**	**0.054 *** **	**2.1**
There is a chance of waiting (base = no chance)	**-0.138**	**	**-2.0**	**-0.136 ** **	**-1.9**
Typical wait time (if a chance of waiting) minutes	**-0.050**	***	**-4.5**	**-0.051*** **	**-4.4**
No facilities (base)	**0.00000**		**NA**	**0.00000**	**NA**
Presence of restrooms	**0.338**	***	**2.225**	**0.287 ** **	**1.9**
Convenience store (in addition to restrooms)	**0.349**	***	**4.776**	**0.337 *** **	**4.5**
Coffee shop/restaurants + green/outdoor play	**0.246**	*	**1.290**	**0.311 ** **	**1.6**
Coffee shop (etc.) x Total charging time > 9 minutes	**0.389**	***	**2.54**	**0.325 *** **	**2.1**
LL(final)	**-2048**			**-2042**	
Rho-squared vs equal shares	**0.31**			**0.31**	
Adj.Rho-squared vs equal shares	**0.30**			**0.30**	
AIC	**4121**			**4112**	
BIC	**4203**			**4201**	

Signif. codes: 0.001 ‘***’ 0.01 ‘**’ 0.05 ‘*’ 0.1 ‘.’

Tradeoffs

This section outlines the calculation of various willingness to pay (WTP) indicators. It highlights the trade-offs between time—represented by charging time, detour time, and wait time—and cost, denoted by charging cost, with a focus on how changes in income and/or BEV range influence the value of these trade-offs. Table 6 shows the WTP under different recharging range. The WTP at 100 miles recharging range and mean income omit the elasticity effect from

BEV range and income– the elasticity function equals to 1, and the WTP at 182.1 miles recharging range indeed include the elasticity of range for calculation. The findings from 100 miles recharging range and mean income suggest that under conditions of a 100-mile recharge range and average income, respondents are willing to pay an additional $0.29 to reduce charging time by one minute. For detour time, the WTP is $0.50 per minute reduction. The willingness to pay for no chance of waiting is $1.05. Given that there is a chance of waiting, the WTP for reductions in waiting times is $0.38 per minute. In terms of facilities, respondents are willing to pay an additional $2.56 for restrooms alone, $2.65 for restrooms combined with a convenience store, and $5.6 for a combination of restrooms, coffee shops, and outdoor areas, particularly when the charging time exceeds 9 minutes. The second column in Table 6 illustrates how the WTP multipliers for charge cost and charge time change when Tesla owners recharge their BEVs with 60% of the total range, equivalent to 182.1 miles. The findings suggest that Tesla owners place a higher value on shorter charging times, with their willingness to pay nearly double for reduced charge time. Conversely, they exhibit greater tolerance towards detour times, wait times and facilities.

We also explored the willingness to pay (WTP) for reducing charging time, detour time and wait time per 100 miles in relation to BEV range elasticity and income elasticity. In our sample, the BEV range primarily spans 200 to 400 miles, while annual household income mostly ranges from $100,000 to $300,000. Figure 6 shows the contour line of WTP for one minute charging time reduction in charging time based on different income and BEV range, highlighting that BEV owners with longer ranges are willing to pay more for shorter charging times. Conversely, BEV owners with higher income show a slightly lower willingness to pay for charging time reduction. Figure 7 and Figure 8 explore WTP for one minute reduction on detour time and wait time, respectively. They indicate that BEV owners with larger range are willing to pay less on wait time and detour time reduction, suggesting a higher tolerance on detour time and wait time. However, income only has a slight influence on WTP, showing that people with higher income are more tolerant to charging time but are more sensitive to detour time and wait time.

Table 6. Calculation of WTP indicators

Attributes	***WTP at 100 miles range recharge and mean income***		***WTP at 182.1 miles recharge (represented Tesla)***
	Value	t ratio	Value
Charge time (USD/minutes)	0.29	4.95	0.58
Detour time (USD/minutes)	0.50	8.57	0.41
Chance of waiting (USD for no chance of waiting)	1.05	1.95	0.84
Wait time (USD/minutes)	0.38	4.07	0.31
Presence of restrooms (USD for presents of restrooms)	-2.56	-2.21	-2.08
Presence of convenience store and restrooms	-2.65	-4.37	-2.14
Presence of outdoor play areas with interaction with charging time (>9 minutes)	-5.60	-4.07	-3.90
Distance on charging cost	$(\frac{100}{100})^{0.35168}$=1		$(\frac{182.1}{100})^{0.35168}$=1.23
Distance on charging time	$(\frac{100}{100})^{1.49375}$=1		$(\frac{182.1}{100})^{1.49375}$=2.45
Income on charging cost	$(\frac{198.85}{198.85})^{-0.03622}$=1		$(\frac{198.85}{198.85})^{-0.03622}$=1
Income on charging time	$(\frac{198.85}{198.85})^{0.05398}$=1		$(\frac{198.85}{198.85})^{0.05398}$=1
Multiplier			
Distance on charging cost	$(\frac{distance}{100})^{0.35168}$		
Distance on charging time	$(\frac{distance}{100})^{1.49375}$		
Income on charging cost	$(\frac{income}{198.85})^{-0.03622}$		
Income on charging time	$(\frac{income}{198.85})^{0.05398}$		

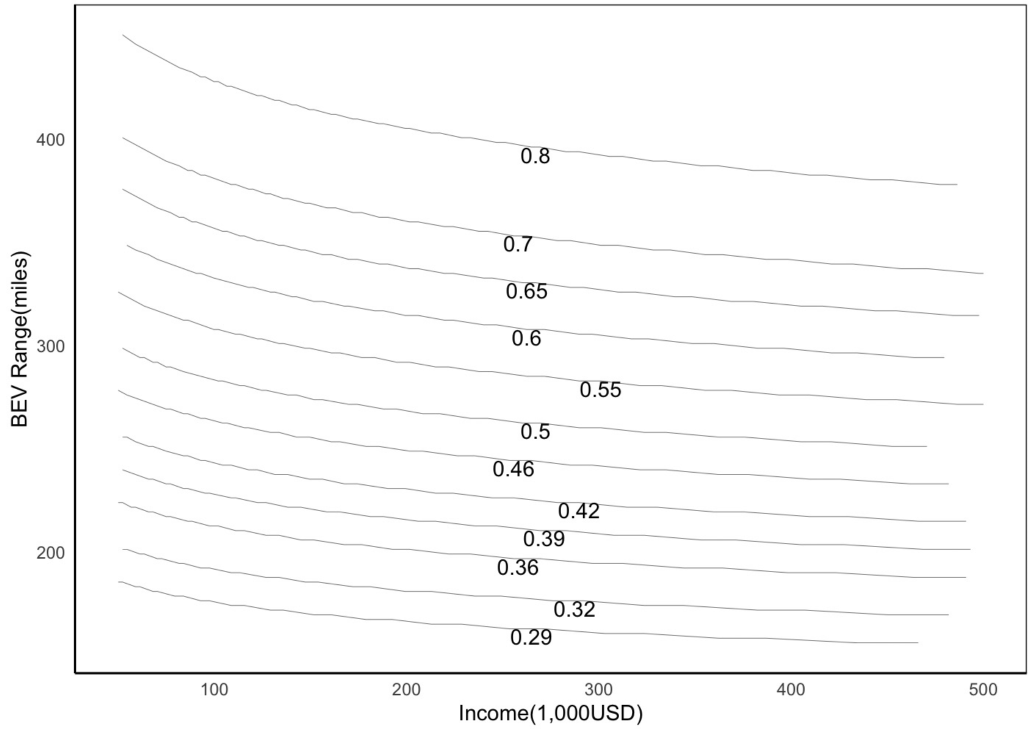

Figure 6. Willingness to pay (in $) for a 1-minute reduction in charging time, as a function of BEV range and income

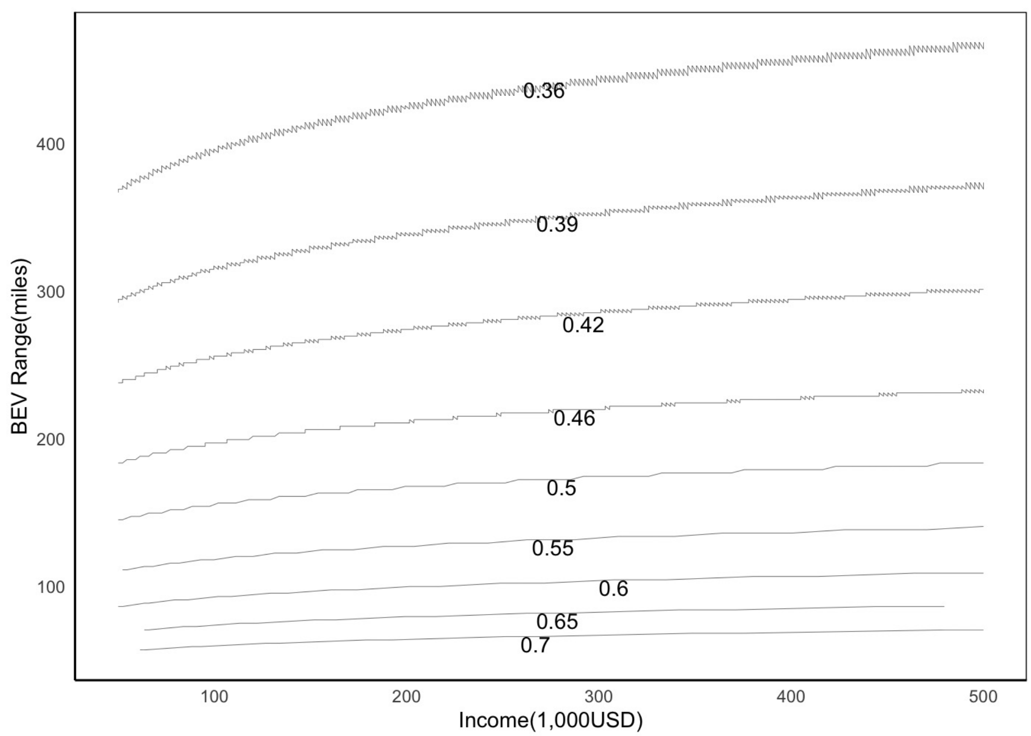

Figure 7. Willingness to pay (in $) for a 1-minute reduction in detour time as a function of BEV range and income

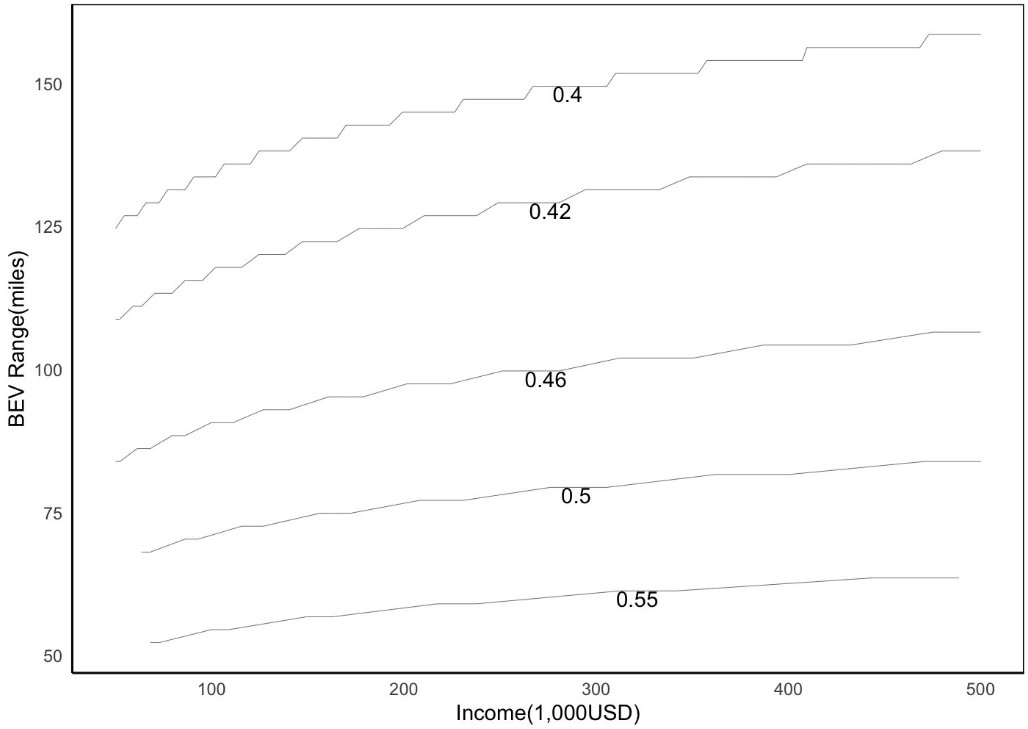

Figure 8. willingness to pay for a 1-minute reduction in wait time as a function of BEV range and income

Conclusion

The descriptive analysis reveals a high dependence on home charging among respondents, with more than 80% of charging occurring at or near home. Respondents also reported that a lack of home charging access would impact their BEV ownership experiences: about 35% reported they would switch their BEVs for traditional vehicles without home charging, and 34% of respondents would consider replacing their BEV with PHEV. The primary concerns are the high costs (66%), and inconvenience (84%) associated with non-home charging options. We further explored the preferences of BEV owners for DCFC on long-distance trips using stated choice data, with each respondent completing four choice tasks featuring two unlabeled choice alternatives each (choice a and choice b). We employed a logit model with non-linear parameters to better understand the attributes influencing DCFC decisions and examined the impact of range and income elasticity on the utility function. Our findings indicate that the availability of restrooms, coffee shops/restaurants, and play areas/green outdoor spaces significantly influences BEV drivers' selection of charging locations, demonstrating a strong preference for amenities at these sites. These facilities not only enhance the charging experience but could also generate additional revenue for charging infrastructure providers and attract more BEV drivers to stations, thereby improving the economic feasibility of installing and maintaining charging stations. Consumers also show a preference for faster chargers, locations with minimal detour from their travel route, and shorter waiting times. BEV drivers are willing to pay additional for reductions in charging time, detour distance, and wait times. To increase utilization and to encourage investment in infrastructure that drivers value, providers should focus on installing faster chargers, strategically locating chargers to minimize travel deviations, expanding charging capacity to reduce wait times, and enhancing charging locations with amenities that enhance the user experience. For interaction with BEV range and income, the results show that people are willing to pay a higher value for short charge time with higher recharge range and higher income.

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Data Summary

Products of Research

A questionnaire survey was conducted in February and March 2024, targeting existing plug-in electric vehicle (PEV) owners. The respondents were sampled from respondents to prior UC Davis EV Center Surveys. Recruitment for those surveys was from Clean Vehicle Rebate Recipients, specifically targeting PEVs of model year 2015 and later. The survey was distributed to 4,120 PEV owners, of whom 1,265 began the survey. A total of 1,102 respondents completed the choice experiment, and 1,086 completed the entire questionnaire. This survey aims to quantitatively evaluate the factors influencing charging preferences for long-distance trips using stated preference (SP) data.

Data Format and Content

We summarized our survey data in Excel format, including demographic variables, Electric Vehicle profiles, choice tasks, etc. The data can be downloaded from the link under Data Access and Sharing.

Data Access and Sharing

The data can be accessed via the Dryad data repository:
https://doi.org/10.5061/dryad.vt4b8gv1t

Reuse and Redistribution

The data can be used for charging station design or incentive design for the operation of charging stations. The dataset should be cited as follows:

> Dong, Lu; Hardman, Scott; Bunch, David (2024). Data from: Consumer evaluations of charging infrastructure and preferences for fast charging infrastructure [Dataset]. Dryad. https://doi.org/10.5061/dryad.vt4b8gv1t