Center for Teaching Old Models New Tricks (TOMNET)

A USDOT Tier 1 University Transportation Center

PROJECT PROPOSAL 2021-2022

Title: Valuation of Free Electric Vehicle Charging Bundles

Principal Investigator: Michael Maness, Assistant Professor, Department of Civil and Environmental Engineering, University of South Florida

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1. Introduction

A knowledge gap has been identified in the areas of free public charging behavior and infrastructure. Inferential analysis is needed to determine if offering free charging causes different vehicle purchasing behavior. The bundling of a free item or service in a purchase can result in additional perceived valuation over the consumers valuation of the item in isolation. This additional valuation can cause a product bundle to become significantly more desirable when the bundled item is offered for free versus a marginally higher price. As policymakers and businesses consider expanding electric vehicle (EV) infrastructure and creating pricing structures to increase EV demand, there is limited guidance on the value that consumers place on free charging. Langbroek and colleagues (2016) found a significant willingness-to-pay for EVs under a free public charging policy. They also found that free public charging had a significantly greater effect on the individuals who wanted to purchase a new EV.

In this research, we will establish an early estimate of the value of free charging bundles in the United States. To solve this, this research program will analyze consumers' responses to a vehicle choice task through a stated preference approach. Under this approach, different valuation behaviors would be explored through varying experimental scenarios. In these scenarios, the respondent would need to be presented with a vehicle choice where one or more electric vehicles are presented with the EVs varying in bundled years of free charging. Using a nationally-representative stated preference dataset from a previous TOMNET project, the choice experiment involves three alternatives – two EVs and one conventional vehicle – that vary across four attributes: vehicle price, refueling range, annual fuel cost, and years of free charging.

The acquired dataset will be analyzed in a discrete choice approach. Determining the value of free charging bundles will entail adding at least a dummy variable to the model for when a free charging bundle is offered. Discrete choice models are versatile enough to determine the valuation through a ratio of coefficients and to determine if there is systematic taste variation in the value of free. Additionally, it is expected that this valuation will vary across the population. To account for this variation, we will use a mixture choice model – including continuous mixtures using mixed logit and discrete mixtures using latent class logit models – to obtain population distributions of the value of free.

The project will conclude with an analysis and distributional estimate of the value of free charging bundles through a discrete choice approach. Research results will be disseminated through a journal article style working paper and a technical report detailing the project analysis.

2. Project Objectives

This project will have the following objectives:

1. Process, review and manage a stated preference survey dataset involving vehicle ownership choices involving electric vehicles and including free charging bundles.
2. Provide the electric vehicle modeling and policy community with a nationally-representative dataset to assist in research and analysis of electric vehicle ownership involving free EV charging bundles
3. Conduct modeling and inference to provide distributional estimates of the value of free charging bundles

3. Proposed Methodology and Data

To determine the value of free vehicle charging bundles in a household vehicle purchase decision, a stated choice experiment on vehicle choice will be analyzed. This survey data was collected during July and August 2020 using a probability-based internet panel. Respondents were first asked about their preferred vehicle price range, vehicle size, and annual mileage. An adaptive choice experiment is then presented to respondents. Thirty-six choice scenarios were generated with 9 scenarios received per respondent. Individuals chose between three vehicles (two EVs and a comparable gasoline vehicle) with varying vehicle attributes: purchase price, driving range, annual fuel cost, and years of free charging. For EVs, free charging bundle times were offered at four levels: zero, one, two, and three years. The attribute levels are presented below:

Attribute	Levels	
Purchase price (relative to your future vehicle choice)	Same, 10% higher, 20% higher	
Driving range	100 miles, 200 miles, 300 miles	
Annual fuel cost (The levels:1,2,3 were accommodated according to the previous selection of the respondent)	EV	Gasoline
	1, 2, 3	1, 2, 3
Years of free charging	0 year, 1 year, 2 years , 3 years	

The modeling approach used in this study is based on random utility models. In a preference space, each individual n is assumed to have a deterministic utility of each vehicle ($y \in \{A, B, C\}$) that takes the following general form:

$$V_{ni} = \alpha_i + \beta_p P_i + \beta_f F_i + \beta_r r_i + \beta_c C_i$$

Where:

- α_i is an alternative-specific constant for the vehicle type of alternative i (EV or conventional)

- P denotes the charge price ($),
- F is a categorical indicator vector for years of free charging bundled with the vehicle purchase (for EVs only),
- R denotes the refueling range (for EVs only),
- C denotes the annual fueling cost ($),
- $\beta_p, \beta_f, \beta_r, \beta_c$ are model parameters which are generic parameters.

The willingness-to-pay for a free charging bundle may be derived by obtaining the money value of the bundle. With units of $/bundle, the willingness-to-pay can be derived in preference space as follows:

$$WTP_f = \frac{\frac{\partial F_i}{\partial V_i}}{\frac{\partial P_i}{\partial V_i}} = \frac{\beta_f}{\beta_p}$$

As the free charging bundle is a categorical variable (by years of free charging), this would need to be calculated for each year of free charging (one through three years). Estimating the value of refueling range can be done similarly.

To arrive at the most accurate estimation of the willingness-to-pay, each independent variable will be systematically tested and the final parameter values obtained from estimations of latent class models. Latent class models are capable of capturing unobserved heterogeneity in the data and have been widely used to model similar datasets (for discussion see Greene and Hensher, 2003). As noted by Wolbertus and Gerzon (2018), models that assume continuous distribution of the preference parameters (e.g. mixed logit) are not capable of connecting the heterogeneity to discretely defined group of users. They also argued that latent class models were best suited for studying such preferences since they can provide richer insights for policy by enabling easier interpretation of the heterogeneity among respondents.

Estimation of the zero-price effect and other willingness-to-pay measured are derived from estimating latent class models. The individuals in the sample are divided into C distinct classes with preferences varying across the classes. Allocating observations to specific classes allows to capture class-specific unobserved heterogeneity (Xiong and Mannering, 2013) without making distributional assumptions (as is required in traditional random parameter models). Latent class models are also readily estimated with maximum likelihood procedures (see Greene and Hensher (2003) and Hensher et al. (2015) for details) and the log-likelihood function is formulated as:

$$\ln L = \sum_{i=1}^{N} \ln P_i = \sum_{i=1}^{N} \ln \left[\sum_{q=1}^{Q} H_{iq} \left(\prod_{t=1}^{T_i} P_{it|q} \right) \right]$$

Where H_{iq} denotes the prior probability for a class q for individual i and $P_{it|q}$ is the probability for the specific choice made by an individual i in choice situation t conditional on being in class q.

The initial analysis will serve to derive these preference classes and describe the national population distributed between these classes. Additional analysis will be conducted incorporating sociodemographics into class membership models, thus providing some clues as to the likely demographic makeup of the different preference classes. This can serve to assist in targeted policy interventions with preferrable and vulnerable groups.

4. Work Plan

Task 1: Process and clean vehicle choice dataset

We propose to start the analysis by preparing the vehicle choice dataset for choice modeling and willingness-to-pay analysis. Additionally, this task will serve as a step to providing the community with a publicly available dataset. The components of this task are as follows:

1.1 Clean the vehicle choice experiment data: The data will need to be refactored according to experiment/scenario. The dataset was collected by respondent but will need to be separated by scenario and then by alternative. This format will allow for analysis using NLOGIT and/or LatentGold software packages.

1.2 Produce a data dictionary for the vehicle choice dataset: To allow the dataset to become publicly usable, a data dictionary will be produced explaining the survey collection procedure, choice experiment design, and variable identification.

Task 2: Conduct analysis to estimate valuations of free charging using the acquired dataset

This study establishes an early estimate of the value of free charging bundles for EV purchases in the United States. This will serve to assist policy analysts in understanding and calculating the economic benefits of such a program for designing EV incentive program. To study the possibility, the following subtasks will be undertaken:

2.1 Conduct willingness-to-pay analysis with nationally-representative preference classes: The researchers will estimate latent class discrete choice models of vehicle choice preferences using the cleaned dataset. A weighted estimate of the average willingness-to-pay for free charging bundles will be obtained as well as a distributional estimate that accounts for preference heterogeneity among the national population.

2.2 Conduct demographically-sensitive willingness-to-pay analysis: The researchers will account for demographic differences in the preference classes by estimating latent class discrete choice models of vehicle choice preferences with demographic-based class membership. Descriptions of the preferences classes will be provided by likelihood of membership by demographics.

Task 3: Produce free charging bundle analysis working paper and technical report

Changing travel patterns during the pandemic could potentially impact the proportion of injury severities occurring in crashes (reported in crash reports as no injury, possible injury, evident injury, disabling injury, fatality). To study this possibility, the following subtasks will be performed:

3.1 Write a working paper and submit to journal: A journal style working paper will be developed, proofed, and revised for submission to a peer-reviewed transportation or energy journal.

3.2 Write a technical report: A technical report will be written that describes the survey and the willingness-to-pay analysis and includes the data dictionary.

5. Project Schedule

The proposed project schedule is shown in the table below. It is expected that milestones will be accomplished after each subtask (at the end of that subtask's final month). These are denoted in parentheses below the task labels.

Subtasks	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Task 1: Process and clean vehicle choice dataset												
1.1 Clean the vehicle choice experiment data (Anonymized dataset developed)												
1.2 Produce a data dictionary for the vehicle choice dataset (Data dictionary developed)												
Task 2: Conduct analysis to estimate valuations of free charging using the acquired dataset												
2.1 Conduct willingness-to-pay analysis with nationally-representative preference classes (Model results documented)												
2.2. Conduct demographically-sensitive willingness-to-pay analysis (Model results documented)												
Task 3: Produce free charging bundle analysis working paper and technical report												
3.1 Write a working paper and submit to journal (Journal article submission)												
3.2 Write a technical report (Technical report completed and publicly posted)												

6. Relevance to the Center Theme/Mission

This project's application area in electric vehicle ownership and infrastructure directly addresses FAST Act Research Priorities in (1) strengthening transportation planning and environmental decision-making and (2) improving infrastructure integrity. This project will contribute to TOMNET's mission to address barriers related to inclusion of alternative behavioral theories in travel models. This will be done through data collection and analysis of attitudinal data. In producing a valuation for free charging bundles, this project will provide policymakers and businesses with a nationally representative valuation which can be used in cost-benefit analysis and for revenue maximization.

7. Anticipated Outcomes and Deliverables

The project will result in the following deliverables:

1. A working paper prepared for future submission to peer-reviewed journals
2. A technical report detailing the two major phases of the project
3. Publicly available version of the vehicle choice dataset

8. Research Team and Management Plan

Michael Maness is an Assistant Professor in the Department of Civil and Environmental Engineering at the University of South Florida. His research interests are in the methodology and application of behavioral modeling in urban and regional systems. His dissertation, which was awarded the 2015 Eric Pas Dissertation Prize, involved incorporating social interactions into activity and travel behavior models. Maness is experienced in advanced choice models with applications to car ownership, electric vehicles, managed lanes, cycling, activity behavior, and communication behavior. His professional experience has included a postdoc at Oak Ridge National Laboratory and a graduate research fellowship at Turner-

Fairbank Highway Research Center. He has published articles in top transportation journals including Transportation Research Part B, Transportation Research Part A, and Journal of Transport Geography. Michael Maness will be involved in statistical model development and interpretation of findings. A research assistant will be involved with data cleaning and documentation as well as model development and report writing. The PI will supervise the student researcher with the student directly reporting to the PI weekly. Fred Mannering, a professor of Civil and Environmental Engineering at the University of South Florida, will provide some additional modeling guidance and support of the student research (about one-tenth month in cost-share).

9. Technology Transfer Plan

The technology transfer component of the project involves: (1) dissemination of project findings and outcomes in the form of conference presentations (such as the Transportation Research Board Annual Meeting) and peer-reviewed journal publications and (2) making the dataset available for public use through TOMNET's website.

10. Workforce Development and Outreach Plan

The project will directly provide career development opportunities for one doctoral student. The research effort will allow the doctoral student to expand their technical skills into new areas of discrete choice modeling and willingness-to-pay analysis. The supported doctoral student is expected to gain experience in conducting a research project and technical writing.

The project will include an educational component where data and information from the project will be provided to students to aid in their development. The PI will teach a graduate-level course on econometric methods and data science. A project module component involving the analysis of transportation data will be produced. Data from the general EV survey and stated choice experiments will be provided and students will estimate willingness-to-pay using a statistical programming language. This will serve to expose students to data cleaning, data analysis, and computational methods.

11. References

Greene, W., Hensher, D. (2003). A latent class model for discrete choice analysis: Contrasts with mixed logit. Transportation Research Part B 37, 681– 698.

Hensher, D. A., Rose, J. M., & Greene, W. H. (2015). Applied choice analysis: a primer (2nd ed.). Cambridge university press.

Langbroek, J. H., Franklin, J. P., & Susilo, Y. O. (2016). The effect of policy incentives on electric vehicle adoption. *Energy Policy*, *94*, 94-103.

Wolbertus, R., Kroesen, M., van den Hoed, R., & Chorus, C. (2018) Fully charged: An empirical study into the factors that influence connection times at EV-charging stations. Energy Policy 123, (1-7). https://doi.org/10.1016/j.enpol.2018.08.030

Xiong, Y., & Mannering, F. (2013). The heterogeneous effects of guardian supervision on adolescent driver-injury severities: A finite-mixture random-parameters approach. Transportation Research Part B 49, 39 -54.

12. Qualifications of Investigators

13.Budget Including Non-Federal Matching Funds

Institution: University of South Florida
Project Title: Valuation of Free Electric Vehicle Charging Bundles
Principal Investigator: Michael Maness

Budget Period: 8/1/2020 - 07/31/2021

CATEGORY	Budgeted Amount from Federal Share	Budgeted Amount from Matching Funds	Explanatory Notes; Identify Source of Matching Funds
Faculty Salaries	$5,278	$8,587	Salary for Michael Maness with assistance from Fred Mannering
Other Staff Salaries	$0	$0	
Student Salaries	$22,000	$0	One 12-month GA
Fringe Benefits	$3,501	$2,481	Faculty and Student Benefits
Total Salaries & Benefits	$30,779	$11,068	
Student Tuition Remission	$0	$7,993	Tuition waivers for GA (24/24/15 credits)
Operating Services and Supplies	$0	$0	Estimation and Analysis Software
Domestic Travel	$0	$0	
Other Direct Costs	$2,050	$0	Virtual Conference Registration
Total Direct Costs	$32,829	$19,061	
F&A (Indirect) Costs	$16,250	$5,479	
TOTAL COSTS	$49,079	$24,540	

Grant Deliverables and Reporting Requirements for UTC Grants (November 2022)
Exhibit F

UTC Project Information	
Project Title	Valuation of Free Electric Vehicle Charging Bundles
University	University of South Florida
Principal Investigator	Michael Maness
PI Contact Information	Address: 4202 E. Fowler Ave, ENB 118 Tampa, FL 33620 Email: manessm@usf.edu
Funding Source(s) and Amounts Provided (by each agency or organization)	US Department of Transportation (Federal UTC): $49,079 University of South Florida (Cost Share): $24,540
Total Project Cost	$73,619
Agency ID or Contract Number	
Start and End Dates	09/01/2021 – 08/31/2022
Brief Description of Research Project	
Describe Implementation of Research Outcomes (or why not implemented) Place Any Photos Here	
Impacts/Benefits of Implementation (actual, not anticipated)	The eventual impact of this research will be to improve the accuracy of cost-benefit analyses of free charging incentive programs and product development for revenue maximization in electric vehicle sales.
Web Links • Reports • Project Website	Reports and data will be made available on the TOMNET website.

MICHAEL MANESS

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University of South Florida (USF), Tampa, FL 33620 Email: manessm@usf.edu

Education

Ph.D., Civil Engineering, University of Maryland, May 2015.

M.S., Civil Engineering, University of Maryland, December 2010.

B.S., Civil Engineering, University of Maryland, May 2009

B.S., Computer Science, University of Maryland, May 2009

Selected Employment and Professional Experience

Postdoctoral Scholar, Department of Civil and Environmental Engineering, USF, 2017-present.

Postdoctoral Research Associate, Center for Transportation Analysis, Oak Ridge National Laboratory, 2015-2016.

Graduate Research Fellow, Office of Operations Research and Development, Federal Highway Administration, 2013-2014.

Fields of Interest and Expertise

1. Advanced discrete choice modeling
2. Agent-based modeling of people and freight
3. The role of social networks and social interactions in decision making
4. Forecasting emerging technologies in transportation
5. Data collection and experimentation in transportation

Recent Relevant Publications

1. M. Maness and Z. Lin (2019). Free Charging: Exploratory Study of Its Impact on Electric Vehicle Sales and Energy. Transportation Research Record: Journal of the Transportation Research Board, 2673(9), 590-601.
2. M. Maness and C. Cirillo (2012). Measuring Future Vehicle Preferences: Stated Preference Survey Approach with Dynamic Attributes and Multiyear Time Frame. *Transportation Research Record: Journal of the Transportation Research Board*, 2285, 100-109.
3. C. Cirillo, Y. Liu, and M. Maness (2017). A Time-dependent Stated Preference Approach to Measuring Vehicle Type Preferences and Market Elasticity of Conventional and Green Vehicles. Transportation Research Part A: Policy and Practice, 100, 294-310.
4. M. Maness and C. Cirillo (2016). An Indirect Informational Conformity Social Influence Choice Model: Formulation and Case Study. *Transportation Research Part B: Methodological*, 93, 75-101.
5. C. Cirillo, M. Maness, and N. Serulle (2014), Measuring Value of Travel Time in the Presence of Managed Lanes: Results from a Pilot Stated Preference Survey on the Capital Beltway. Transportation Letters, 6(1), 23-35.

Recent Honors and Awards

Appointed as a Member of the Traveler Behavior and Values Committee (ADB10), Transportation Research Board, 2017-Present

2015 Eric Pas Dissertation Prize, International Association for Travel Behaviour Research, 2017

Outstanding Student of the Year, University Transportation Centers Program, 2015

Eisenhower Transportation Fellowship, Federal Highway Administration, 2010-2012, 2013-2014