
# FINAL REPORT

# Environmental Attributes of Electric Vehicle Ownership and Commuting Behavior in Maryland: Public Policy and Equity Considerations

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**16. Abstract**

This research investigated the socio-demographic attributes that contribute to electric vehicle (EV) ownership and EV owners' commuting behavior based on different types of developed human settlements such as city, suburb, and rural area. EVs still are pricier than comparable internal combustion engine vehicles (ICEVs). The objective of this study was to suggest public policies and recommendations to decision makers to prompt EV ownership equitably by identifying socio-demographic factors that influence the purchasing/leasing decision. The State of Maryland promotes EV ownership by subsidizing EV purchases and deploying charging facilities at transit rail stations. The other objective was to determine mode choice by EV owner commuters. An online survey of EV (non-fleets) owners registered in Maryland was conducted from July 1, 2016, to August 19, 2016. In total, 1,257 EV owners completed the survey. After assessing data quality, the survey data were tabulated and visualized to observe general trends that helped construct appropriate hypotheses and statistical models. Multinomial logistic regression models (MNL) were constructed to examine the associations between EV owner characteristics and their reasons for purchasing/leasing the EV. The findings revealed five key points. First, socioeconomic attributes such as age, education, income, household size, marital status, number of vehicles in a household, and political affiliation significantly affected EV owners' preference when making purchasing/leasing decisions. Second, environmental concerns were the main reason for purchasing and driving an EV; vehicle price was the third most important factor. Third, very few EV owners used rail transit for the commute to work prior to EV purchase, and even fewer after purchase. Fourth, EV owners who had longer commuting trips were more concerned about price and operating costs and efficiency and performance of the EV than those with shorter commuting trips. Fifth, some significant similarities and differences are found in the travel patterns of both EV and ICEV owners.

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## Abstract

This research investigated the socio-demographic attributes that contribute to electric vehicle (EV) ownership and EV owners' commuting behavior based on different types of developed human settlements such as city, suburb, and rural area. EVs still are pricier than internal combustion engine vehicles (ICEVs). The objective of this study was to suggest public policies and recommendations to decision makers to prompt EV ownership equitably by identifying socio-demographic factors that influence the purchasing/leasing decision. The State of Maryland promotes EV ownership by subsidizing EV purchases and deploying charging facilities at transit rail stations. The other objective was to determine mode choice by EV owner commuters. An online survey of EV (non-fleets) owners registered in Maryland was conducted from July 1, 2016, to August 19, 2016. In total, 1,257 EV owners completed the survey. After assessing data quality, the survey data were tabulated and visualized to observe general trends that helped construct appropriate hypotheses and statistical models. Multinomial logistic regression models (MNL) were constructed to examine the associations between EV owner characteristics and their reasons for purchasing/leasing the EV. The findings revealed five key points. First, socioeconomic attributes such as age, education, income, household size, marital status, number of vehicles in a household, and political affiliation significantly affected EV owners' preference when making purchasing/leasing decisions. Second, environmental concerns were the main reason for purchasing and driving an EV; vehicle price was the third most important factor. Third, very few EV owners used rail transit for the commute to work prior to EV purchase, and even fewer after purchase. Fourth, EV owners who had longer commuting trips were more concerned about price and operating costs and efficiency and performance of the EV than those with shorter commuting trips. Fifth, some significant similarities and differences are found in the travel patterns of both EV and ICEV owners.



*Keywords: Electric vehicle, EV incentive programs, Equity, Willingness-to-adopt, Maryland*

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## INTRODUCTION

Central Maryland has been designated as an ozone nonattainment area for many years. Because of concerns over climate-changing greenhouse gas emissions and ground-level ozone experienced during summers, the State of Maryland has developed strategies to reach a goal of 300,000 electric vehicles (EVs) by 2025 through subsidizing the purchase of EVs and the installation of private sector charging facilities, and investing in public charging stations (Maryland Electric Vehicle Infrastructure Council, 2017). According to the Maryland Motor Vehicle Administration (MVA), the total number of EVs registered in Maryland increased from 609 in FY 2012 to 6,788 in FY 2016 (See Table 1); battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) accounted for approximately 39% and 61%, respectively (Maryland Electric Vehicle Infrastructure Council, 2017).[1]

In addition to a federal subsidy program (a tax credit of $7,500), Maryland EV owners[2] are eligible for state excise titling tax credits of up to $3,000 depending on battery capacity and funding availability[3], a rebate of up to $700 for individuals, $4,000 for businesses, and $5,000 for retail service stations, and access to high occupancy vehicle (HOV) lanes (Maryland Department of the Environment, 2017). Because of significant monetary incentives toward EV purchase provided to higher-income households, equity issues result. Another equity issue is that non-EV owners shoulder the burden of supporting various transportation services and infrastructure needs. When refueling the vehicle, EV owners pay little or no motor fuel tax to the state's transportation trust fund. These equity issues need to be addressed for more equitable access to EV markets and faster EV adoption. Public outreach detailing EV purchasing incentive programs should be effectively designed and administered. A state-sponsored survey of 2,000 Maryland residents revealed that they are generally unaware of the financial incentives for EV purchase and the existence of charging stations. Even so, most respondents (65%) who expect to purchase a vehicle in the next few years would consider an EV for cost and environmental reasons (Maryland Electric Vehicle Infrastructure Council, 2017). With that said, understanding potential owners' characteristics, their needs, and travel behavior—geospatial trip patterns (e.g., home-to-work trips) and mode choice—should be investigated in detail to justify potential demand locations and an efficient and prioritized resource association for providing EV infrastructure.

Most EV charging will take place at owners' residences, but the state has committed to adding charging facilities in areas with marginal demand. One major initiative places charging facilities at Maryland Transit Administration (MTA) rail transit stations near the center of Baltimore City and in the vicinity. The first installations took place at selected Baltimore and Central Maryland commuter rail and light rail stations with parking spaces. Additional charging facilities at other commuter and light rail stations are planned. Interestingly, no charging stations were planned for Washington Metropolitan Area Transit Authority (WMATA)—e.g., METRO rail stations in Montgomery and Prince George's counties—even though there is a high concentration of EV

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[1] BEVs and PHEVs differ according to power sources. While BEVs are powered only by electricity stored in a battery pack, PHEVs have smaller battery capacity than BEVs, and a conventional engine takes over when batteries are discharged.

[2] For the sake of brevity references to EV ownership and owners will include those who lease the vehicles long-term. Purchase incentives typically include incentives for leasing.

[3] There is a cap of $60,000 on vehicle purchase price for tax credit eligibility.

owners (44.2%) in those counties (**Table 1**) (Maryland Electric Vehicle Infrasturcture Council, 2012). Moreover, most workers in the two counties commute to Washington, D.C., or its suburbs in Virginia, not Baltimore City. The original intent was to fund charging facilities at MTA sites and METRO sites in suburban Maryland. WMATA's existing contracts for parking operations did not allow for design and construction within the required time frame, so the funding was allocated to additional MTA sites instead (Maryland Electric Vehicle Infrasturcture Council, 2012). There are now nearly 200 outlets for charging EVs installed at state-owned or leased facilities (Maryland Electric Vehicle Infrastructure Council, 2017).

**Table 1. Number and Percentage of Registered EVs by MD County in February 2015**

| County | Number of Registered EVs | Percent |
|---|---|---|
| Montgomery | 1,997 | 33.6 |
| Prince George's | 631 | 10.6 |
| Anne Arundel | 551 | 9.3 |
| Baltimore | 527 | 8.9 |
| Howard | 433 | 7.3 |
| Baltimore City | 379 | 6.4 |
| Frederick | 300 | 5.0 |
| The rest of Maryland counties | 1,127 | 19.0 |
| Total | 5,945 | 100 |

Note: Percentage may not add up to 100% due to rounding.
Source: Maryland Motor Vehicle Administration

The underlying assumption behind the state's investment in charging facilities at rail transit stations is that some EV owners are also transit riders when commuting to work, perhaps because EV owners are thought to be more environmentally conscious. According to the Census Bureau's last Journey to Work Profile for the Washington-Baltimore Consolidated Metropolitan Statistical Area (CMSA), 82% of trips were by private vehicle; only 9% of commute trips were by transit (U.S. Census Bureau, 2017). Nationwide only 10% of transit trips are by riders who have incomes of $100,000 or more (Neff & Pham, 2007).

In January 19, 2018, public utilities, environmental groups and charging station companies proposed to the Maryland Public Service Commission the installation of 24,000 chargers across Maryland, including a variety of charging station ownership models for various housing types in multiple locations. "*The utilities have also included plans for whole-house time-of-use rates to encourage off-peak charging. Moving forward, utilities said they hope to develop standards for EV-only time-of-use rates"* (Foehringer Merchant, 2018). However, kilowatt-hours data from existing public charging facilities at rail stations, particularly at commuter rail stations, show some modest charging of EVs; the highest monthly charging (kWh) in 22 MTA PEV charging sites at 11 rail stations peaked at around 1,600 kWh in October 2014 (*Interim report presented to Governor Martin O'Malley and the Maryland General Assembly*, 2015). On average approximately 73 kWh were used per month per charger. This translates into 214 miles of vehicle travel from each charger in October 2014.[4]

[4] This estimate was made by using the Alternative Fuels Data Center's estimate: An EV consumes 34 kWh to travel 100 miles (https://www.afdc.energy.gov/fuels/electricity_charging_home.html).

Several research questions arise from the state's policies to spur EV ownership through subsidizing purchase price and deploying public charging facilities. Who drives EVs and what are EV owners' socioeconomic characteristics? Have mostly affluent EV owners been subsidized by incentive programs? What are the primary reasons for EV purchase decisions and how are they related to owners' attitude toward and preferences for purchasing reasons, such as environmental concerns, gas prices, and vehicle performance? Is EV purchase associated with owners' political, economic and social philosophies (political affiliation as a proxy for liberal/conservative outlook)? Have EV owners' purchasing and commuting behaviors been influenced by incentive programs and affected mode choice? How has commuting behavior been distributed geographically and why? How can EVs be promoted in a more equitable manner?

**Hypotheses and Objectives**

The hypotheses of this research are that in addition to the net price of EVs, EV owners' sociodemographic characteristics, political affiliation, and attitudes toward various factors—such as environmental concerns, gas prices, safety, technology and innovation— influence their purchase and commuting behavior, and EV owners are less likely to choose rail transit for commute trips. This research posits that some striking similarities and differences are found between commuters with internal combustion engine vehicles (ICEVs) and those with plug-in hybrid electric (PHEV) or battery electric (BEV) vehicles. Even with charging facilities at rail stations, owners of EVs are hypothesized to use rail transit less than owners of ICEVs because fuel cost savings over lengthy commute distances and preferential treatment of EVs by governments and employers would discourage modal transfers and rail transit use. Analyses of commuting mode choice and home-to-work travel patterns and purchasing reasons are modeled by constructing multinomial logit models, correlation analysis, and analysis of variance (ANOVA) in order to determine statistically significant EV owners' characteristics.

This research will discern who has purchased/leased EVs and which factors have influenced that purchase, and whether charging facilities at rail transit stations enhance market penetration of EVs in Maryland and affect commuting behavior and mode choice. The objectives of the research are to reveal from surveys the factors that contribute to EV ownership and owners' commuting behavior and present recommendations for addressing the equity issues resulting from government subsidy of EV ownership.

**LITERATURE REVIEW**

EV purchasing decisions, as with other products in the marketplace, are influenced by many consumer attributes—e.g., age, sex, income, price, understanding of technology, attitudes toward environmental issues, and many others. "Early adopters are generally wealthier, more educated, more comfortable with technology, and have a stronger environmental attitude … (than) the rest of society" (The U.S. Department of Energy's Vehicle Technologies Office, 2018). Indeed, other societal status variables—such as educational attainment, living in a detached home, and high household income (over $100,000)—have been associated with EV purchases in California (Lane, Sherman, Sperl, Krause, & Graham, 2014). In addition, environmental stewardship affects EV purchasing decision. Individuals who feel strongly about reducing energy consumption and greenhouse gas emissions are more likely to consider purchasing an EV than those who do not (Powers, 2014). Vergis and Chen (2013), using data from all 50 states, found that the number of public charging facilities, concern for the environment, gasoline and electricity prices, education level, vehicle miles travelled, HOV lane access and the presence of purchase incentives were associated with EV market share in 2013 (Vergis & Chen, 2015).

According to a study of gender differences in automobile ownership choices in Toronto, women preferred practicality, safety and roominess in vehicles, while men preferred engine power and performance (Carley S. , Krause, Lane, & Graham, 2013). Women were also more sensitive to the price of automobiles than men were. A survey of PHEV acceptance in the U.S. indicated that women had different vehicle preferences, but had similar willingness-to-pay (WTP) for these advanced vehicles (Vergis & Chen, 2015). Shin et al. (2015) also found that men and women had similar WTP for safety technologies in connected vehicles, but women's budgets for vehicle purchase were less (Shin, Callow, Dadvar, Lee, & Farkas, 2015). Among Japanese early adopters of EVs, women were more excited about purchasing new technologies and more environmentally conscious than were men, and they were willing to sacrifice some comfort for the sake of the environment (Curtin et al., 2009). On the other hand, Caperello et al. (2014) found women more likely to frame their PHEV ownership in practical terms, while men were more likely to frame their PHEV in terms of a research project. Women spoke of their PHEV as a tool to use in their everyday lives. Men elaborated on their explorations of what PHEVs are, how they work, and how they would like them to improve in range, decrease in price, and increase in style options (Caperello, Hageman, & Kurani, 2014).

While research has shown strong associations between socioeconomic and demographic characteristics and EV ownership, causality, i.e., the characteristics that cause or predict EV ownership, is still unclear (Radtke, et al., 2012). There is some evidence that EV promotion should target social networks, because they may be more important than individual purchaser characteristics. Likewise, an association between the number of charging facilities and EV market share does not reveal causality.

Research has revealed geographic and mode choice patterns to EV ownership. Plötz et al. (2014) found that EV buyers in Germany are middle-aged men living in rural or suburban multi-person households, while urban dwellers are less likely to purchase EVs because of their low vehicle-miles of travel and resulting small fuel cost savings (Plötz, Schneider, Globisch, & Dütschke, 2014). Another recent study reviewed the literature on EV use and attitudes in Europe and the U.S. and found that early adopters of EVs are middle aged, mostly men, have high education and income, live near cities and own more than one car (Hjorthol, 2013).The review also found that EV owners are often former public transportation commuters. Some reasons for this mode change are: availability of employer charging facilities, preferential parking, and access to HOV lanes, which make the EV trip more convenient than using transit.

Overall, very little knowledge is available about the geographic and spatial attributes of EV users' travel patterns and commuting trip behavior. The authors did not find many studies that were able to determine the spatial analysis of travel behaviors and patterns of EV users not only in the U.S. but internationally. Tal & Nicholas (2013) have found that in the California Bay Area the inner ring of the metropolitan area has a higher ratio of BEVs to PHEVs, while on the outer ring PHEVs have a higher ratio. This geographic pattern can be correlated with commute distance and income levels (Modarres, 2013). BEVs in general have a smaller commuting range than do PHEVs.

High income has characterized EV ownership, and public subsidization of affluent purchasers necessitates a more equitable approach to EV promotion. Regarding the equity consideration of EV adoption, most incentive programs are not accessible to low- and middle-income people, who are disproportionately minority, impacted by air pollution, limited in their transportation choices, and experiencing long commutes to work (Coffman, Bernstein, & Wee, 2017). Rather, these programs are enjoyed by high-income individuals. (Espino, Joel.; Vien, Truong.; and Environmental Equity Director, 2015) suggested an EV car-sharing service as a means to improve socially equitable EV access. Alternatively, (DeShazo, Sheldon, & Carson, 2015) suggest that programs that increase rebates to low-income groups result in additional cost-effective EV purchases. This policy maximizes the number of EVs "sold per rebate dollar given."

The California Air Resources Board is initiating a pilot program in the Los Angeles area and San Joaquin Valley to help low-income vehicle owners replace old, polluting cars with cleaner, more fuel-efficient hybrid and electric vehicles (Green Car Congress, 2015). The program is available for three income levels: low, moderate and above moderate. The program provides financial incentives with larger cash payments for the lowest-income families moving up to the cleanest cars. Eligible vehicle buyers would receive between $2,500 and $12,000, depending on their income and the type of replacement vehicle purchased.

## METHODOLOGY

### Survey of EV Owners

This research surveyed registered PHEV and BEV owners in Maryland in 2015 regarding attitudes toward EV purchasing and travel behavior, environmental considerations, and mode choice for work trips before and after purchase. The online survey was designed in Google Forms. Participants were asked about socioeconomic characteristics, vehicle features, current technology use, travel attributes, and preferences (see Appendix A).

The survey was divided into four sections. The first section asked participants' socioeconomic characteristics such as age, gender, marital status, household characteristics, and political affiliation. The next section consisted of questions about mode choice (i.e., rail transit use), trip purposes, travel patterns, and usage of charging facilities at rail stations, and the ZIP codes of residence and work locations. The third section asked about EV purchase decision variables such as environmental issues and concerns, fuel costs (e.g., gas price vs. electricity), driving range concerns, vehicle efficiency and performance, current use of in-vehicle technology, and their preferences for in-vehicle equipment when they purchased an EV. Lastly, the survey wrapped up with additional socioeconomic questions: household income, educational attainment, and race/ethnicity.

The MVA identified 4,282 EV (non-fleet) owners by county and notified them by letter of the survey objectives and a web link that would take owners to the respective online survey. The survey questionnaires informed participants about giving consent and that they could end participation at any time. The EV survey was administered from July 1, 2016, through August 19, 2016, and 1,323 responses were received (30.9% response rate). All information regarding participation in this survey was confidential. Only researchers at Morgan State University collected the survey responses, aggregated the data and conducted analyses. The individual survey responses were not shared with state agencies, insurance companies or other private organizations. The research team used descriptive analyses, cross tabs, ANOVA tests, and factor analysis to analyze the data. Data has been archived and preserved electronically.

**Spatial classifications**

Survey participants provided ZIP codes of their home and work locations so that researchers could understand EV owners' travel patterns, identify locations of high charging demand—i.e., trip generators—and determine associations between EV driver attributes and travel patterns and home and work locations. Since socioeconomic characteristics and travel behavior of EV owners would differ by residential and work locations, the areas were classified into three categories, using the U.S. Census Geography's definition of urban and rural areas. According to the U.S. Census Bureau, the urban area has two subcategories depending on population size: areas with a population of 50,000 or more known as "urbanized areas (UAs)," and areas with at least 2,500 but less than 50,000 known as "urban clusters (UCs)." The rest of the areas is rural All other areas that are not included in the two subcategories are considered rural (The U.S. Census Bureau).

It should be noted that the census geography was delineated for administrative purposes that may not be a relevant base spatial unit for the current study. In this study, spatial areas were classified at three levels: city, suburb and rural. The city area represents highly built-up areas with high population density and a set of closely related urban infrastructures. This area is a continuously built-up area with a population of 50,000 or more or some areas associated with these areas that have multiple central places and densely settled areas. Baltimore City, Towson, and Washington, D.C., are examples of city areas in this classification. The suburban area represents urbanized areas that have lower population density than city areas and are not as highly built-up as cities, like Pikesville in Baltimore County. The rural area represents areas with low population and density within the outskirts of a metropolitan statistical area (MSA); rural areas are much nearer to natural environments. Figure 1 represents the classification of areas in Maryland in this study.

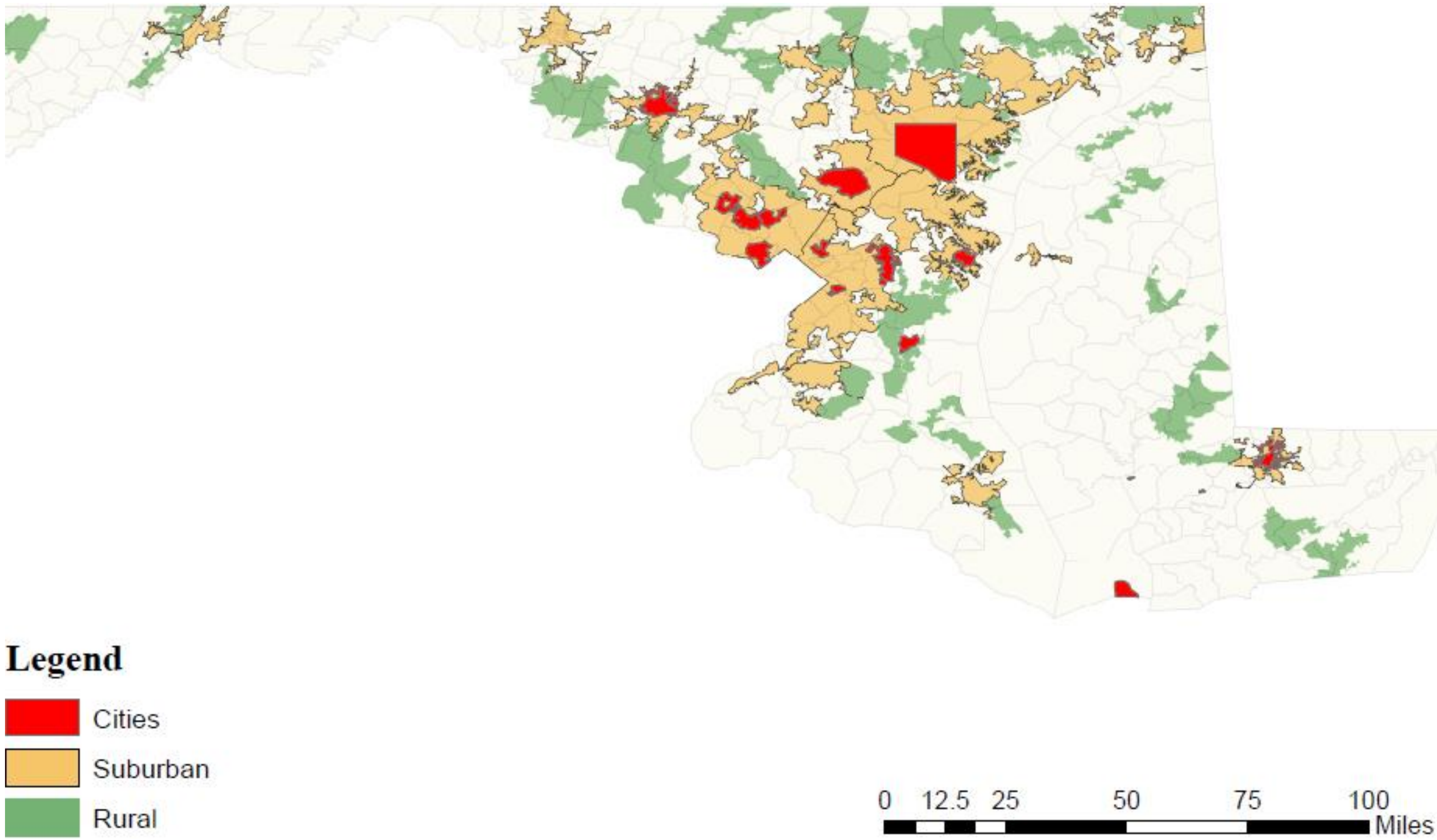



**Figure 1. Classification of areas in Maryland**

**Multivariate statistical analysis and models**

Two statistical methods were employed in this study. Multinomial logit models (MNL)—in addition to a set of statistical techniques such as analysis of variance (ANOVA), crosstabs and correlation tests—were constructed to estimate relationships among EV owners' primary reasons for EV purchase, the current use of in-vehicle driving assistance equipment, socioeconomic characteristics, travel patterns, and political affiliation. These questions can be answered by employing MNL models that are the most widely used among various discrete choice models in similar studies (Liao, Molin, & van Wee, 2017). The MNL as a maximum likelihood estimator is appropriate to use when the dependent variable has multiple discrete outcomes and these outcomes are not ordered (Espino & Truong, 2015). The dependent variable is assumed to follow a multinomial distribution, and a generalization of the binomial distribution (McFadden, 1978):

- If $p_{ij}$ is the probability of $y_i$ falling in category $j$: $(j = 1, 2, 3, \cdots, J)$, then:

$$\ln\left(\frac{p_{ij}}{p_{iJ}}\right) = \alpha_j + \beta_j X_i, \qquad j = 1, 2, ...., J-1$$

leading to

$$p_{ij} = \frac{e^{\alpha_j + \beta_j X_i}}{1 + \sum_{k=1}^{J-1} e^{\alpha_k + \beta_k X_i}}, \qquad j = 1, ...., J-1$$

and

$$p_{iJ} = \frac{1}{1 + \sum_{k=1}^{J-1} e^{\alpha_k + \beta_k X_i}}$$

where αj is a constant and βj is a vector of regression coefficients. ANOVA is a useful statistical test for assessing the influence of two (or more) categorical independent variables on a continuous outcome variable. It was used in this study to find out possible relationships between ordinal and continues variables including family size, number of children in the house, number of vehicles in the house, age, income, education and driving distance. All statistical analyses were conducted using SPSS Version 24 and evaluated at 90%, 95% and 99% confidence levels.

## ANALYSES

### Who drive EVs?

A summary of selected socioeconomic characteristics is presented in Table 2. It reveals that most collected socioeconomic variables were not balanced—i.e., not representative of the population. This was expected for two reasons. First, the survey samples were not randomly drawn. Second, EV owners' socioeconomic characteristics are probably different from non-EV owners. Since there were about 5,000 registered EVs in Maryland at the time of this study, current EV owners are considered early adopters. Many studies, as discussed earlier, found that early adopters' socioeconomic characteristics are different from later adopters. Indeed, the survey revealed that EV owners are socially and economically more established than non-EV owners. EV owners generally have higher household income, better educational attainment and are older than the rest of society. This observation conforms to past research (DeShazo, Sheldon, & Carson, 2015). For example, approximately two-thirds of the respondents were over 50, which is roughly 20% higher than the national average; individuals over 50 accounted for roughly 45% of the total population over 20 years in 2015 (U.S. Census Bureau, 2016). More than 80% of the respondents earned a household income of more than $100,000. Nearly 90% of the respondents earned at least a bachelor's degree. Other attributes —such as race/ethnicity, marital status and household size —also implied the more comfortable socioeconomic status of EV owners. Also, males accounted for nearly 75% of the participants. Several reasons for male dominance could be speculated. It is possible that most households registered their EVs under male householders, and males were likely to be primary EV drivers. Another interesting observation is that nearly 52% of the respondents identified themselves as Democrats, whose attitudes toward environmental issues are generally perceived as liberal compared to people with other political beliefs.

### EV vs. ICEV drivers: Are their socioeconomic characteristics different?

One of the research questions was "*Who drives EVs and what are EV owners' socioeconomic characteristics?*" To answer the question, the EV owners' socioeconomic attributes were compared with those of ICEV drivers. An ICEV driver data set was collected from an earlier ICEV driver preference survey administered by the authors (Farkas, Shin, Dadvar, & Molina, 2017). The following comparisons showed remarkable differences in socioeconomic characteristics between EV and ICEV drivers. First, the gender difference between EV and ICEV ownership is significant (Figure 2). The male dominance in EV ownership (85%) was significant; however, the gender difference in ICEV ownership was only about 10%. Even though potential sampling errors are considered, the gender difference by vehicle type is considerable. Second, EV owners tend to be older than ICEV owners, and not vice versa (Figure 3). Particularly, EV owners ages 40-69 comprised a majority proportion in EV ownership (77%), compared with the same age cohort of ICEV owners (57%). On the other hand, a proportion of EV owners under 39 was more than twice that of ICEV owners (12% vs. 27%). Third, a considerably higher proportion of EV owners (77%) had at least a bachelor's degree than did ICEV owners (60%) (Figure 4). Lastly, the owners had higher income; approximately 81% of EV owners earned over $100,000, compared to only about 28% of ICEV owners (Figure 5).

**Table 2. EV Owners' Demographic Characteristics**

| Demographic Characteristic | | Count | Percent |
|---|---|---|---|
| Gender (*N* = 1,257) | Male | 941 | 74.9 |
| | Female | 316 | 25.1 |
| Age (*N* = 1,257) | Under 20 | 2 | 0.2 |
| | 20 to 24 years old | 3 | 0.2 |
| | 25 to 29 years old | 19 | 1.5 |
| | 30 to 39 years old | 125 | 9.9 |
| | 40 to 49 years old | 274 | 21.8 |
| | 50 to 59 years old | 386 | 30.7 |
| | 60 to 69 years old | 329 | 26.2 |
| | 70 and older | 119 | 9.5 |
| Race/Ethnicity (*N* = 1,160) | White (non-Hispanic) | 989 | 85.3 |
| | Hispanic | 27 | 2.3 |
| | Black or African-American | 47 | 4.1 |
| | Asian | 76 | 6.6 |
| | American Indian or Alaska Native | 6 | 0.5 |
| | Other | 15 | 1.3 |
| Education (*N* = 1,252) | Some high school | 3 | 0.2 |
| | High school diploma or GED | 83 | 6.6 |
| | Associate degree | 78 | 6.2 |
| | Bachelor's degree | 350 | 28.0 |
| | Master's degree | 381 | 30.4 |
| | Doctoral or professional degree | 357 | 28.5 |
| Household Income (*N* = 1,071) | Less than $50,000 | 21 | 2.0 |
| | $50,000 – $75,000 | 47 | 4.4 |
| | $75,000 – $100,000 | 137 | 12.8 |
| | $100,000 – $200,000 | 426 | 39.8 |
| | More than $200,000 | 440 | 41.1 |
| Marital status (*N* = 1,247) | Single | 186 | 14.9 |
| | Married or in domestic partnership | 1,061 | 85.1 |
| Household size (*N* = 1,254) | One | 122 | 9.7 |
| | Two | 563 | 44.9 |
| | Three or more | 569 | 45.4 |
| Children in household (*N* = 1,254) | One | 829 | 66.1 |
| | Two | 359 | 28.6 |
| | Three or more | 66 | 5.3 |
| Vehicles in household (*N* = 1,257) | One | 112 | 8.9 |
| | Two | 575 | 45.7 |
| | Three or more | 570 | 47.1 |
| Political Affiliation (*N* = 1,210) | Democrat | 649 | 51.6 |
| | Republican | 175 | 13.9 |
| | Independent | 269 | 21.4 |
| | Not interested in politics | 117 | 9.3 |

*Note: Percentages may not total 100 due to rounding*

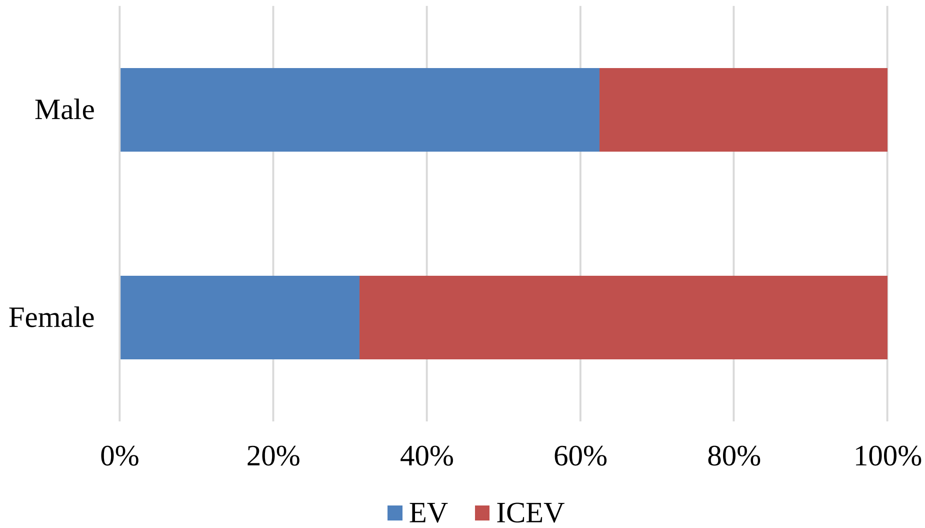



**Figure 2. Percent differences in gender between EV and ICEV owners**

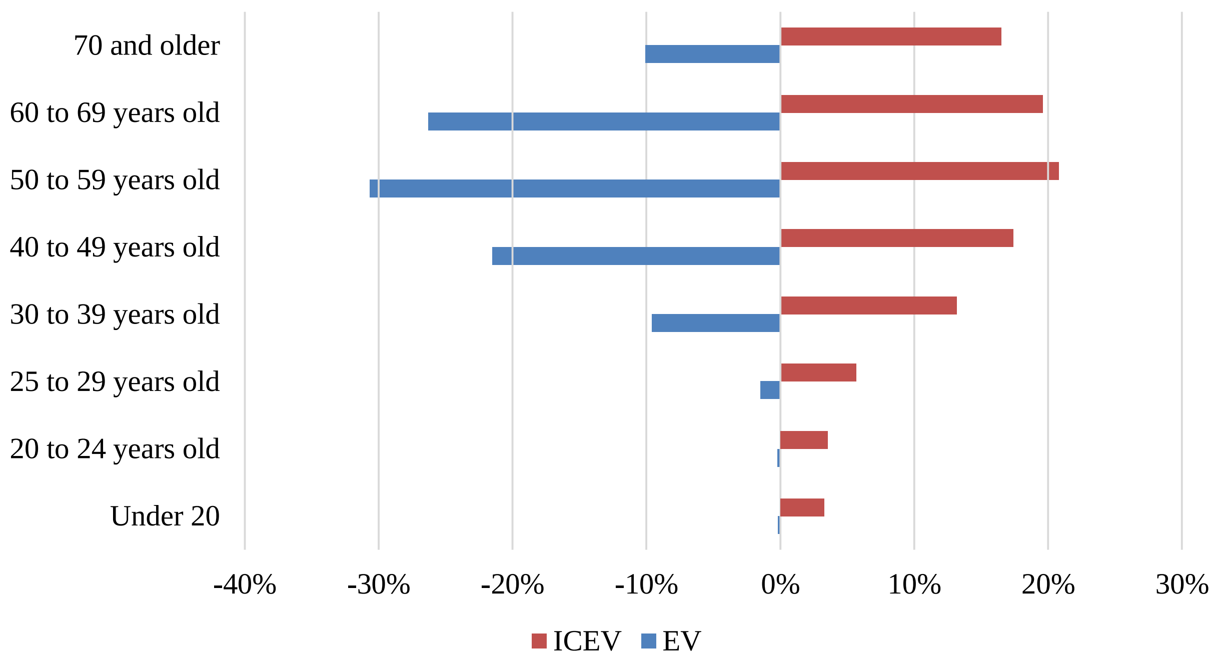



**Figure 3. Age distribution of EV and ICEV owners**

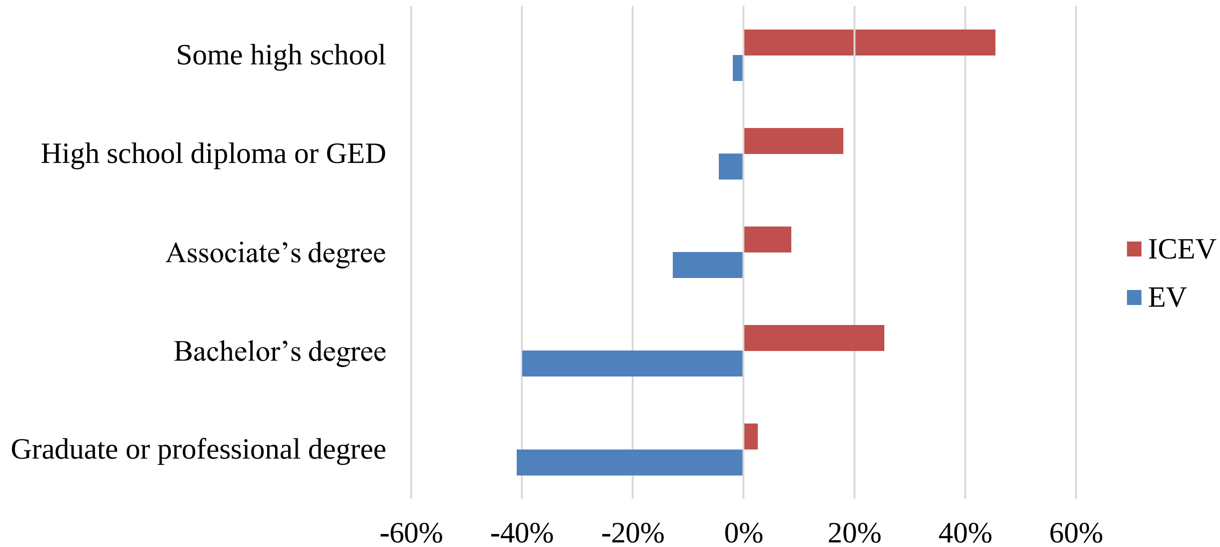



**Figure 4. Educational attainment of EV and ICEV owners**

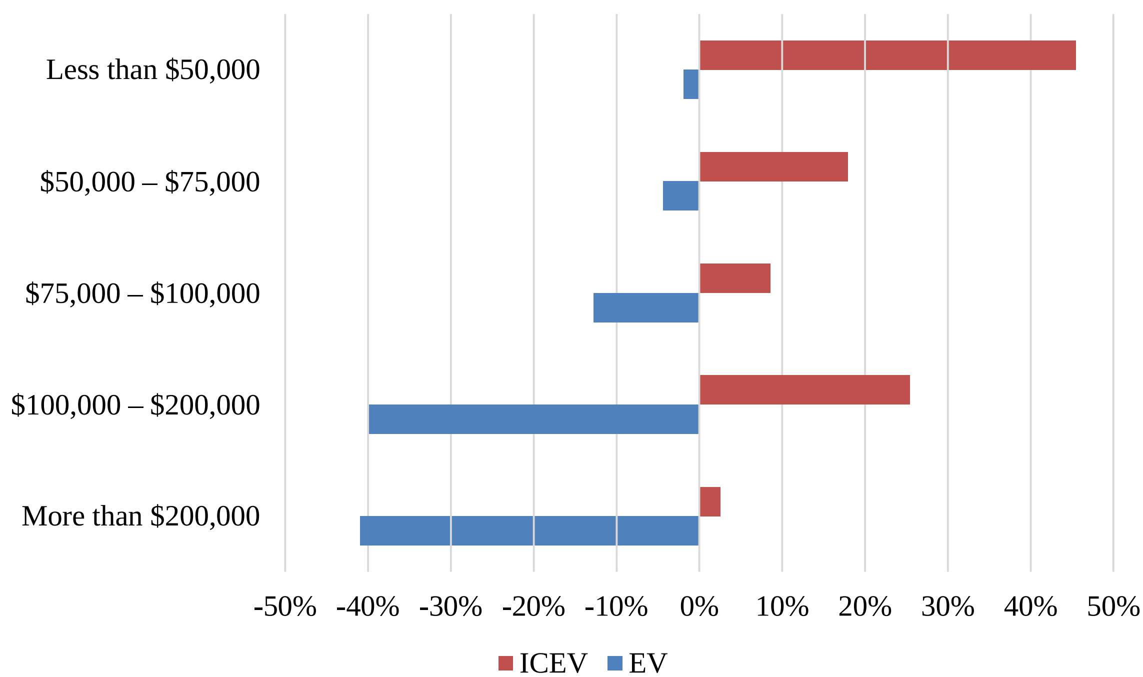



**Figure 5. Household income of EV and ICEV owners**

**Summary of EV owners’ trip patterns**

Table 3 summarized the EV owners’ home-to-work trips by combinations of three spatial classifications defined earlier: city, suburb and rural areas. As one may expect, most common trip patterns were between suburb and city areas: *suburb-to-suburb* (32%) and *suburb-to-city*

(24.9%). Only about 4.2% of trips originated in or were destined for rural areas. According to the 2010 Decennial Census, just over 87% of Marylanders live in urban areas.

EVs' driving range limitation is no longer a concern. EV owners drive to work on average between 11.3 and 33.6 miles. Due to a rapid advancement of battery technology, driving range is less of a problem when purchasing EVs. According to (Winegarden, 2018), the average driving distance of 10 popular EVs is about 160.3 miles at a full charge, ranging from 84 miles (2017 Fiat 500e) to 335 miles (2017 Tesla Model S).

These findings hinted at the priority locations for installing charging stations. First, an absolute majority of trips started and ended in suburb and city locations, implying that highly traveled corridors should be considered for the installation of EV charging stations. Second, the fact that 58% of trips started in suburban locations suggests that the identification of major trip generators in suburban areas would help allocate charging locations more effectively with given resource limits. Indeed, nearly 60% of the EV owners lived in suburbs, and about 50% worked in suburban areas.

**Table 3. Trip status by spatial classifications and average driving distance**

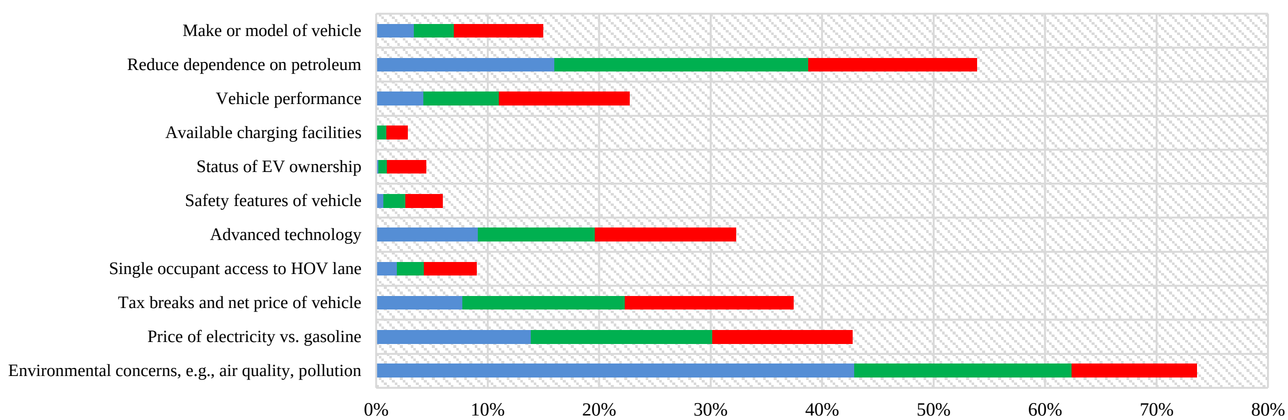
| Home-to-Work Trip Pair | Number of Trips | Percent (%) | Average Trip Distance (miles) |
|---|---|---|---|
| Suburb to Suburb | 261 | 32.0 | 13.8 |
| Suburb to City | 203 | 24.9 | 18.8 |
| Suburb to Rural | 8 | 1.0 | 30.8 |
| City to City | 142 | 17.4 | 11.3 |
| City to Suburb | 88 | 10.8 | 18.6 |
| City to Rural | 3 | 0.4 | 14.0 |
| Rural to City | 41 | 5.0 | 33.6 |
| Rural to Suburb | 47 | 5.8 | 26.8 |
| Rural to Rural | 23 | 2.8 | 12.4 |
| Total | 816 | 100 | |

*Note: Percentage may not add up to 100% due to rounding.*

**Reasons for EV purchase and owner characteristics**

The participants were asked to choose the three most important reasons that encouraged them to buy or lease an EV from among 11 reasons: (*a*) Environmental concerns, e.g., air quality, pollution, (*b*) Price of electricity vs. gasoline, (*c*) Tax breaks and net price of vehicle, (*d*) Single occupant access to HOV lane, (*e*) Advanced technology, (*f*) Safety features of vehicle, (*g*) Status of EV ownership, (*h*) Available charging facilities, (*i*) Vehicle performance, (*j*) Reduce dependence on petroleum, and (*k*) Make or model of vehicle. A summary was presented in Figure 6. The blue bar in the figure indicates the percentage of participants who chose the corresponding reason as the most important reason, and green and red bars represent second and third purchasing reasons, respectively. Most participants purchased an EV due to concerns about *Environment* and *Oil dependence*, choosing them as either the first, second or third key decision factor. Approximately 75% of EV drivers chose *Environmental concerns*, and *Dependence on* *petroleum* accounted for roughly 45%. The next important purchasing reasons were *Price of electricity vs. gasoline* (43%), *Tax breaks and net price of vehicle* (38%), and others such as, in order, *Advanced technology* (32%), *Vehicle performance* (21%), *Make or model of vehicle* (15%), *Single occupant access to HOV lane* (9%), *Safety features* (6%), *Status of EV ownership* (4%), *and Available charging facilities* (3%).

These observations provided several important insights for estimating statistical significance among the purchasing reasons. First, the top two reasons (*Environmental concerns* and *Oil dependence*) may be correlated to some degree. However, it is not clear yet whether their associations are statistically significant or whether adding additional variables—such as socioeconomic variables, political affiliation, and trip patterns—yields mixed-results. Second, quite a few participants (43%) chose monetary benefits (*Price of electricity vs. gasoline*) as a critical purchasing reason. It can be inferred that EV owners probably value a long-term benefit as a difference between EV charging and gasoline prices. Indeed, the U.S. Environmental Protection Agency (EPA) has emphasized cost savings as a public outreach strategy. The EPA has released "*fuel economy label*" to the public as a strategy to promoting EV adoption (Farkas, Shin, Dadvar, & Molina, 2017). A study conducted by Idaho National Laboratory (INL)—part of the U.S. Department of Energy's complex of national laboratories—showed that driving an EV is much cheaper than driving an ICEV (Maryland Electric Vehicle Infrastructure Council, 2017). For example, when one gallon of gasoline is $2, the energy costs of EVs ranged from roughly $0.01 to $0.04 per mile, while those of ICEV's were between $0.09 to $0.11 per mile. To put it into perspective, the average gas price in Maryland, as of May 31, 2018, is nearly $3/gallon. At this price level, energy costs of EVs are between $0.03/mile and $0.07/mile and the corresponding energy costs of ICEVs ranged from $0.13/mile to $0.17/mile (Maryland Electric Vehicle Infrastructure Council, 2015).




| | Environmental concerns, e.g., air quality, pollution | Price of electricity vs. gasoline | Tax breaks and net price of vehicle | Single occupant access to HOV lane | Advanced technology | Safety features of vehicle | Status of EV ownership | Available charging facilities | Vehicle performance | Reduce dependence on petroleum | Make or model of vehicle |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1st Reason | 43% | 14% | 8% | 2% | 9% | 1% | 0% | 0% | 4% | 16% | 3% |
| 2nd Reason | 20% | 16% | 15% | 2% | 10% | 2% | 1% | 1% | 7% | 23% | 4% |
| 3rd Reason | 11% | 13% | 15% | 5% | 13% | 3% | 3% | 2% | 12% | 15% | 8% |

**Figure 6. Summary of participants' reasons for purchasing/leasing an EV**

**Top Three Reasons for EV Purchase and Political Affiliation**

Little if any research has assessed reasons for EV adoption and political beliefs, which may be a factor in EV adoption. Closing such a research gap is a substantial contribution of this study. In addition to choosing the top three reasons for EV purchase, participants provided their political affiliation.

Scrutinizing the survey data enabled the authors to gain great insights into EV drivers' concerns and their differences by political belief.

**Table 4** presents comparisons of political beliefs and EV purchase reasons. Several observations are provided. Table 4(a) reveals clearly concerns about environmental issues played a critical role in EV purchase decisions in relation to political beliefs. First, political affiliation is—indeed, like people's general perception— related to EV purchase reasons. First, *Environmental concern* was the most important EV purchasing reason for Democrats, compared with the average of the surveyed owners. Approximately 54.2% of Democrats considered environment as the first purchase reason, about 10% higher than the average (43.3%). That is over three times as high as Republicans (14.5%). Second, *Price of electricity vs. gasoline* is the moderately important factor. On average, 15.8% of participants indicated that they bought the EV due to concerns about potential fuel cost savings. Again, the difference by political affiliation is clear. *Price of electricity vs. gasoline* was chosen by 27.8% of Republicans, as opposed to just 9.4% of Democrats and 14.6% of Independents. Third, *Tax breaks and net price of vehicle* did matter more to Republicans than the others. Nearly 14% of Republicans said they made a purchasing decision because of monetary benefits that relieved their worries over the upfront costs. On the other hand, less than 8% of Democrats and Independents were concerned about tax breaks and net price of vehicle.

Findings from Table 4(b)—which shows "the second most important EV purchasing reasons"—revealed EV owners' attitudes about EV purchase in relation to political affiliation and confirmed findings from Table 4(a). First, Democrats were more concerned about environment-related reasons than were other population groups. While 23% of Democrats and 26.9% of Independents said that oil dependence was the second most important decision factor, only 10.6% of Republicans did so. Second, not all Republicans disregarded environmental matters; 23.5% of Republicans viewed it as the second most important reason. However, it should be noted that more than 55% of Democrats contemplated *Environmental concerns* as the most critical decision factor. Third, again, monetary incentives were more important to Republicans (21.2%) than Democrats (17.9%) and Independents (14.6%). In terms of the third reason (Table 4(c)), all three groups shared similar attitudes toward EV purchase reasons.

**Table 4. Top Three Reasons for EV Purchase and Political Affiliation**

(a) First reason for EV purchase (%)

| | Average | Democrat | Republican | Independent |
|---|---|---|---|---|
| Environmental concerns, e.g., air quality, pollution | 43.3 | 54.2 | 14.5 | 39.6 |
| Reduce dependence on petroleum | 15.8 | 15.6 | 15.6 | 17.2 |
| Price of electricity vs. gasoline | 13.5 | 9.4 | 27.8 | 14.6 |
| Advanced technology | 9.2 | 7.1 | 9.8 | 13.4 |
| Tax breaks and net price of vehicle | 7.6 | 5.6 | 13.9 | 6.7 |
| Vehicle performance | 4.3 | 2.8 | 10.4 | 3.7 |
| Make or model of vehicle | 3.3 | 3.1 | 3.5 | 3.0 |
| Single occupant access to HOV lane | 1.9 | 1.4 | 3.5 | 0.8 |
| Safety features of vehicle | 0.7 | 0.6 | 1.2 | 0.4 |
| Status of EV ownership | 0.3 | 0.3 | 0.0 | 0.4 |
| Available charging facilities | 0.1 | 0.0 | 0.0 | 0.4 |

(b) Second reason for EV purchase (%)

| | Average | Democrat | Republican | Independent |
|---|---|---|---|---|
| Reduce dependence on petroleum | 23.0 | 26.9 | 10.6 | 22.8 |
| Environmental concerns, e.g., air quality, pollution | 19.5 | 20.8 | 23.5 | 14.6 |
| Price of electricity vs. gasoline | 16.7 | 17.9 | 17.1 | 13.8 |
| Tax breaks and net price of vehicle | 14.5 | 12.6 | 21.2 | 15.7 |
| Advanced technology | 10.3 | 9.6 | 6.5 | 11.6 |
| Vehicle performance | 6.4 | 4.0 | 7.1 | 10.8 |
| Make or model of vehicle | 3.6 | 3.0 | 6.5 | 4.1 |
| Single occupant access to HOV lane | 2.3 | 1.9 | 3.5 | 1.5 |
| Safety features of vehicle | 2.1 | 1.1 | 2.4 | 4.5 |
| Status of EV ownership | 0.8 | 1.2 | 0.0 | 0.8 |
| Available charging facilities | 0.8 | 0.9 | 1.8 | 0.0 |

(c) Third reason for EV purchase (%)

| | Average | Democrat | Republican | Independent |
|---|---|---|---|---|
| Reduce dependence on petroleum | 15.3 | 16.8 | 14.9 | 11.7 |
| Tax breaks and net price of vehicle | 15.2 | 16.8 | 10.1 | 15.2 |
| Advanced technology | 12.9 | 12.7 | 12.5 | 14.0 |
| Price of electricity vs. gasoline | 12.2 | 13.0 | 14.3 | 11.4 |
| Vehicle performance | 11.9 | 11.3 | 11.3 | 12.9 |
| Environmental concerns, e.g., air quality, pollution | 11.2 | 10.1 | 12.5 | 12.9 |
| Make or model of vehicle | 7.9 | 6.8 | 11.3 | 8.3 |
| Single occupant access to HOV lane | 4.6 | 4.3 | 4.2 | 4.2 |
| Status of EV ownership | 3.6 | 3.8 | 3.0 | 2.7 |
| Safety features of vehicle | 3.2 | 2.5 | 3.6 | 4.2 |
| Available charging facilities | 2.0 | 1.9 | 2.4 | 2.7 |

*Note: Percentages may not total 100 due to rounding*

**Top Three Reasons for EV Purchase and Educational Attainment**

It is widely accepted that higher educational attainment is positively associated with innovative technology adoption, which may be related to higher income with higher educational attainment. With that said, it would be of interest to find out whether the important EV purchase reasons are related to educational attainment, and whether some hints of income effect can be deduced. Below, the top three reasons for EV purchase were summarized by educational attainment (Table 5). It should be noted that the tables do not include EV owners with educational attainment lower than a high school diploma or GED due to a small sample size, 3 responses. Table 5(a) summarized the first reason by educational attainment. First, the proportion of EV owners who chose *Environmental concerns* as the most important reason among other reasons is the highest by a wide margin. Roughly 43.1% of participants bought an EV due to environmental issues. Second, people with higher education tend to care more about environmental issues. The second row of Table 5 (a) shows that the proportion for environmental issues increases in order of educational attainment. Third, respondents can be divided into two distinct groups: owners with bachelor's degrees or less, and those with post-graduate degrees; the two groups' share of choosing *Environmental concerns* was different. The former group's share of choosing *Environmental concerns* was lower than the average (43.1%). At least 43.2% of the latter group, by contrast, was concerned about the environment as the most critical EV purchase decision reason. Fourth, the proportions of respondents choosing *Price of electricity vs. gasoline* is higher for those with an associate degree or lower than EV owners with at least a bachelor's degree. In Table 5 (b) and 5(c), the reasons for purchasing an EV are evenly distributed regardless of educational level.

**Table 5. Top Three Reasons for EV Purchase and Educational Attainment**

(a) First reason for EV purchase (%)

| | All | High school diploma or GED | Associate degree | Bachelor's degree | Master's degree | Doctoral or professional degree |
|---|---|---|---|---|---|---|
| Environmental concerns, e.g., air quality, pollution | 43.1 | 32.5 | 34.6 | 35.2 | 43.2 | 54.8 |
| Reduce dependence on petroleum | 15.8 | 19.3 | 21.8 | 16.3 | 16.6 | 12.4 |
| Price of electricity vs. gasoline | 13.7 | 22.9 | 24.4 | 14.0 | 13.4 | 9.3 |
| Advanced technology | 9.2 | 7.2 | 9.0 | 10.0 | 8.4 | 9.9 |
| Tax breaks and net price of vehicle | 7.8 | 7.2 | 3.9 | 11.5 | 7.6 | 5.4 |
| Vehicle performance | 4.3 | 3.6 | 2.6 | 6.0 | 5.0 | 2.3 |
| Make or model of vehicle | 3.3 | 2.4 | 3.9 | 3.4 | 2.4 | 4.2 |
| Single occupant access to HOV lane | 1.8 | 4.8 | 0.0 | 2.3 | 2.4 | 0.6 |
| Safety features of vehicle | 0.6 | 0.0 | 0.0 | 0.6 | 0.8 | 0.9 |
| Status of EV ownership | 0.2 | 0.0 | 0.0 | 0.3 | 0.3 | 0.3 |
| Available charging facilities | 0.1 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 |

*Note: Percentages may not total 100 due to rounding*

(b) Second reason for EV purchase (%)

| | All | High school diploma or GED | Associate degree | Bachelor's degree | Master's degree | Doctoral or professional degree |
|---|---|---|---|---|---|---|
| Reduce dependence on petroleum | 23.0 | 17.1 | 18.0 | 21.4 | 22.4 | 27.7 |
| Environmental concerns, e.g., air quality, pollution | 19.5 | 12.2 | 20.5 | 21.7 | 19.3 | 19.1 |
| Price of electricity vs. gasoline | 16.3 | 23.2 | 18.0 | 18.8 | 16.9 | 10.9 |
| Tax breaks and net price of vehicle | 14.5 | 13.4 | 15.4 | 13.0 | 16.9 | 13.4 |
| Advanced technology | 10.3 | 12.2 | 7.7 | 11.3 | 10.0 | 9.7 |
| Vehicle performance | 6.6 | 7.3 | 9.0 | 6.1 | 4.8 | 8.6 |
| Make or model of vehicle | 3.7 | 4.9 | 5.1 | 3.5 | 2.9 | 4.3 |
| Single occupant access to HOV lane | 2.4 | 4.9 | 1.3 | 2.0 | 2.6 | 2.3 |
| Safety features of vehicle | 2.0 | 3.7 | 5.1 | 1.5 | 1.6 | 2.0 |
| Available charging facilities | 0.9 | 1.2 | 0.0 | 0.6 | 1.3 | 0.9 |
| Status of EV ownership | 0.8 | 0.0 | 0.0 | 0.3 | 1.3 | 1.1 |

*Note: Percentages may not total 100 due to rounding*

(c) Third reason for EV purchase (%)

| | All | High school diploma or GED | Associate degree | Bachelor's degree | Master's degree | Doctoral or professional degree |
|---|---|---|---|---|---|---|
| Reduce dependence on petroleum | 15.3 | 16.1 | 10.5 | 15.1 | 16.6 | 15.3 |
| Tax breaks and net price of vehicle | 15.3 | 12.4 | 11.8 | 12.4 | 14.4 | 19.9 |
| Advanced technology | 13.0 | 13.6 | 21.1 | 11.8 | 11.8 | 13.5 |
| Price of electricity vs. gasoline | 12.3 | 13.6 | 13.2 | 10.7 | 14.2 | 11.4 |
| Vehicle performance | 11.7 | 11.1 | 13.2 | 13.3 | 9.6 | 12.3 |
| Environmental concerns, e.g., air quality, pollution | 11.0 | 11.1 | 9.2 | 13.6 | 13.1 | 6.5 |
| Make or model of vehicle | 8.0 | 7.4 | 9.2 | 8.0 | 8.6 | 7.3 |
| Single occupant access to HOV lane | 4.9 | 6.2 | 2.6 | 5.0 | 4.3 | 5.6 |
| Status of EV ownership | 3.5 | 3.7 | 4.0 | 4.4 | 3.5 | 2.4 |
| Safety features of vehicle | 3.1 | 2.5 | 2.6 | 3.6 | 2.4 | 3.8 |
| Available charging facilities | 2.0 | 2.5 | 2.6 | 2.1 | 1.6 | 2.1 |

*Note: Percentages may not total 100 due to rounding*

**Associations among individual and household attributes, and driving distance**
A correlation test has been performed to measure the strength of the relationship between different variables of study. As shown in Table 6, there is a positive, direct relationship between driving distance and the three variables of household size, number of children in the house, and number of vehicles in the house, but this variable has a negative, direct relationship with age and education level of EV owners.

**Table 6. Correlation of sociodemographic variables and driving mileage**

| | | Age | People in Household | Children in Household | Vehicles in Household | Education | Income |
|---|---|---|---|---|---|---|---|
| People in Household | Correlation Coefficient | -.319** | | | | | |
| | *p* | 0.000 | | | | | |
| Children in Household | Correlation Coefficient | -.449** | .707** | | | | |
| | *p* | 0.000 | 0.000 | | | | |
| Vehicles in Household | Correlation Coefficient | 0.068 | .333** | 0.061 | | | |
| | *p* | 0.052 | 0.000 | 0.081 | | | |
| Education | Correlation Coefficient | .115** | 0.001 | 0.044 | -0.052 | | |
| | *p* | 0.001 | 0.974 | 0.208 | 0.141 | | |
| Income | Correlation Coefficient | -0.025 | .177** | .146** | .176** | .342** | |
| | *p* | 0.509 | 0.000 | 0.000 | 0.000 | 0.000 | |
| Driving Distance (Miles) | Correlation Coefficient | -.144** | .081* | .086* | .084* | -.133** | 0.021 |
| | *p* | 0.000 | 0.021 | 0.014 | 0.017 | 0.000 | 0.576 |

**p<0.05; **p<0.001*

The results of correlation testing show that the driving distance of EV owners has a strong statistical correlation with most of the socio-demographic characteristics of EV owners. In this regard, older EV drivers tended to drive less and shorter distances than younger ones did, and EV owners with higher education levels also tended to drive less than EV owners with lower education levels. However, EV owners with bigger families, more children, and more vehicles in the house tended to drive longer distances by EV. There was no correlation between the driving distance of EV owners and their income levels.

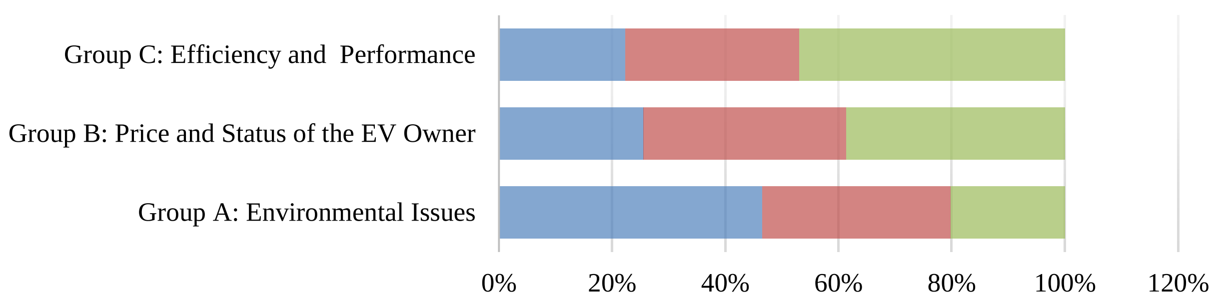
This result also shows some correlations between socio-demographic characteristics of EV owners. The income level has a direct positive correlation with education level, household size, number of children, and number of vehicles in the house. Correlation of education and income among EV owners has been seen in past studies as well. Age has a positive direct correlation with education, which means older EV owners have had more education; however, this factor has a negative direct correlation with household size and number of children in the house, meaning older EV owners have fewer people and less number of children in the house.

Moreover, the number of vehicles in the house and family household size have a positive direct correlation.

**Reclassification of purchasing reasons**
To simplify statistical models, the 11 EV purchasing reasons were classified into three main categories (Table 7). Each category was renamed as Group A-*Environmental Issues*, Group B-*Price and Status of the EV Owner*, and Group C-*Efficiency and Performance*. The summary by new categories is presented in Figure 7. Summary of classified participants' reasons for purchasing/leasing an EV. As expected, *Environmental Issues* was the first reason for EV purchase (46 %), followed by *Efficiency and Performance* (47%) and *Price and Status of the EV Owner* (36%).

**Table 7. Reclassification of EV purchasing reasons**

| 11 Purchasing reasons | New reclassified reasons |
|---|---|
| Environmental concerns<br>Reduce dependence on petroleum | Group A : Environmental Issues |
| Make or model of vehicle<br>Price of electricity vs. gasoline<br>Status of EV ownership<br>Tax breaks and net price of vehicle | Group B: Price and Status of the EV Owner |
| Advanced technology<br>Available charging facilities<br>Safety features of vehicle<br>Single occupant access to HOV lane<br>Vehicle performance | Group C: Efficiency and Performance |




| | Group A: Environmental Issues | Group B: Price and Status of the EV Owner | Group C: Efficiency and Performance |
|---|---|---|---|
| 1st Reason | 46% | 26% | 22% |
| 2nd Reason | 33% | 36% | 31% |
| 3rd Reason | 20% | 39% | 47% |

**Figure 7. Summary of classified participants' reasons for purchasing/leasing an EV**
*Note: Percentages may not total 100 due to rounding*

**The Multinomial Logit Regression Modeling**

***Models for EV owners' socioeconomic attributes and purchasing reasons***

Three multinomial logit regression models were constructed to determine influential socioeconomic characteristics of the respondents on their EV purchasing decisions. The dependent variables were three reclassified purchasing reasons: Group A-*Environmental Issues*, Group B-*Price and Status of the EV Owner*, and Group C-*Efficiency and Performance*. Three models were built—one model for each group. Each model was built to identify statistically significant socioeconomic characteristics of EV owners in choosing one of the dependent variables—Group A, Group B or Group C. For example, Model 1 estimated the likelihood of choosing Group A-*Environmental Issues* as the most important EV purchasing reason.

Table 8 presents Chi-square and statistical significance of variables derived from likelihood ratio tests. Model 1 estimated that EV owners' *income* and *political affiliation* ($p < 0.001$); *race* and *age* ($p < 0.05$); and *marital status* ($p < 0.1$) were statistically significant variables for those EV owners belongs to Group A-*Environmental Issues*. In Model 2, for those EV owners in Group B-*Price and Status of the EV Owner*, political affiliation ($p < 0.05$), household size and higher income (both $p < 0.1$) were statistically significant socioeconomic characteristics affecting their decision to purchase an EV. Lastly, for those EV owners in Group C-*Efficiency and Performance*, gender ($p < 0.05$), income ($p < 0.05$) and education ($p < 0.05$) influenced their intent to purchase an EV (Model 3).

## Table 8. Results of Likelihood Ratio Tests for EV purchasing reasons logit model

| EV owners' socioeconomic characteristics | Model 1: Group A-Environmental Issues | | | Model 2: Group B-Price & status of the EV owners | | | Model 3: Group C-Efficiency & performance | | |
|---|---|---|---|---|---|---|---|---|---|
| | -2 Log Likelihood of Reduced Model | Chi-Square | Sig. | -2 Log Likelihood of Reduced Model | Chi-Square | Sig. | -2 Log Likelihood of Reduced Model | Chi-Square | Sig. |
| Intercept | 959.261[a] | | | 1157.253[a] | | | 1153.202[a] | | |
| Gender | 963.156 | 3.895 | 0.143 | 1158.58 | 1.327 | 0.515 | 1159.335 | 6.133 | 0.047** |
| Age | 972.672 | 13.411 | 0.037** | 1164.85 | 7.597 | 0.269 | 1167.492 | 14.29 | 0.027** |
| Household Size | 964.27 | 5.009 | 0.286 | 1165.554 | 8.301 | 0.081* | 1155.824 | 2.622 | 0.623 |
| Children in Household | 961.351 | 2.09 | 0.719 | 1163.017 | 5.764 | 0.218 | 1155.229 | 2.027 | 0.731 |
| Vehicles in Household | 961.046 | 1.785 | 0.775 | 1163.973 | 6.721 | 0.151 | 1160.372 | 7.17 | 0.127 |
| Education | 970.696 | 11.435 | 0.076* | 1162.025 | 4.772 | 0.573 | 1173.15 | 19.948 | 0.003** |
| Income | 977.95 | 18.689 | 0.001*** | 1165.511 | 8.259 | 0.083* | 1163.956 | 10.754 | 0.029** |
| Marital status | 964.962 | 5.701 | 0.058* | 1157.814 | 0.561 | 0.755 | 1156.883 | 3.681 | 0.159 |
| Race/Ethnicity | 968.257 | 8.996 | 0.011** | 1157.375 | 0.122 | 0.941 | 1154.67 | 1.468 | 0.48 |
| Political affiliation | 1016.863 | 57.602 | 0.000*** | 1176.392 | 19.139 | 0.004** | 1156.196 | 2.994 | 0.81 |

* $p \le .1$ , ** $p \le .05$ , *** $p \le .001$

Additionally, three more models were tested: Models 4, 5, and 6 (Tables 9, 10 and 11). These models estimated the probability of choosing one top reason over another reason and related statistically significant owner characteristics—for example, choosing Group A-*Environmental Issues* over Group B-*Price and Status of the EV Owner*. The three tables provided adjusted relative odds ratios and 95% confidence intervals. The threshold value of odds ratio is 1.0: positive relationship when the ratio is greater than 1.0. Each model's results are presented below.

Model 4 estimated the probability of choosing Group A-*Environmental Issues* over either Group B-*Price and Status of the EV Owner* or Group C-*Efficiency and Performance* (Table 9). The first sub-model (Model 4(a) vs. Group B) revealed that Republican EV owners with ssociate or bachelor's degrees are more likely to choose Group B-*Price and Status of the EV Owner* as the top purchasing reason than Group A-*Environmental Issues.* In Model 4(b), those younger than 39 and with Republican affiliation were statistically significantly associated with choosing Group C-*Efficiency and Performance.* On the other hand, unmarried EV owners with lower than $200,000 income were concerned about Group A-*Environmental Issues.*

Model 5 identified population groups that are statistically significantly related to choosing or not choosing Group B-*Price and Status of the EV Owner* over the other two purchase reasons (Table 10). First, in Model 5(a), no statistically significant variables were found. On the other hand, in Model 5(b), younger EV owners with less than two household members favored Group C-*Efficiency and Performance* over Group B-*Price and Status of the EV Owner.* By contrast, Group B was considered important by households with fewer than two cars and income of less than $100,000. Like earlier models, political affiliation was a statistically significant variable: Republicans chose Group B-*Price and Status of the EV Owner* compared with Group C-*Efficiency and Performance.*

The probability of choosing Group C-*Efficiency and Performance* over Groups A and B was estimated and summarized in Table 11. Model 6(a) found that lower education (college degree or lower) is associated with choosing Group C-*Efficiency and Performance* over Group A-*Environmental Issues*, while respondents with lower household income were more likely to purchase an EV due to Group A-*Environmental Issues.* Model 6(b) estimated the odds of choosing Group C-*Efficiency and Performance* over Group B-*Price and Status of the EV Owner*. The model suggested that single males younger than 30 who earned more than $200,000 and had lower than doctoral/professional degrees are more likely to buy an EV for the expectation of better vehicle efficiency and performance.

**Table 9. Model 4 - Choosing Group A vs. Group B or C**

| | (a) vs. Group B | | (b) vs. Group C | |
|---|---|---|---|---|
| | Adj. rel. odds | 95% CI for odds | Adj. rel. odds | 95% CI for odds |
| Gender | | | | |
| male vs. female | 0.86 | 0.54-1.38 | 1.71 | 0.89-3.28 |
| Age | | | | |
| < 30 vs. 60 + | 1.52 | 0.42-5.56 | **6.84**** | 1.44-25.63 |
| 30-39 vs. 60 + | 0.98 | 0.52-1.82 | **1.87*** | 0.90-3.86 |
| 50-59 vs. 60 + | 0.91 | 0.52-1.61 | 0.8 | 0.39-1.65 |
| Household size | | | | |
| 1 vs.3 + | 0.48 | 0.14-1.64 | 4.02 | 0.64-5.47 |
| 2 vs.3 + | 0.71 | 0.39-1.32 | 1 | 0.45-2.22 |
| Children in household | | | | |
| 0 vs. 3 + | 0.51 | 0.20-1.33 | 0.71 | 0.22-2.35 |
| 1-2 vs. 3 + | 0.71 | 0.31-1.61 | 0.92 | 0.34-2.51 |
| Vehicles in household | | | | |
| 1 vs. 3 + | 0.7 | 0.26-1.82 | 0.92 | 0.27-3.15 |
| 2 vs. 3 + | 1.1 | 0.70-1.72 | 0.82 | 0.49-1.40 |
| Education | | | | |
| College vs. Doc. or profession. | **2.16**** | 1.05-4.41 | 1.77 | 0.76-4.12 |
| Bachelor’s vs. Doc. or profession. | **2.50**** | 1.41-4.44 | 1.6 | 0.83-3.09 |
| Master’s vs. Doc. or profession. | 1.56 | 0.89-2.75 | 1.17 | 0.62-2.21 |
| Income | | | | |
| < $100,000 vs. $200,000 + | 1.36 | 0.72-2.58 | **0.16**** | 0.05-0.54 |
| $100,000–$200,000 vs.$200,000 + | 0.82 | 0.52-1.30 | **0.53**** | 0.31-0.90 |
| Marital status | | | | |
| Single vs. Married | 1.45 | 0.64-3.27 | **0.27*** | 0.06-1.17 |
| Race/Ethnicity | | | | |
| White vs. Others | 0.46 | 0.27-0.76 | 0.8 | 0.41-1.53 |
| Political affiliation | | | | |
| Democrat vs. No interest in politics | 0.8 | 0.40-1.63 | 0.56 | 0.25-1.24 |
| Republican vs. No interest in politics | **5.97***** | 2.63-13.57 | **3.16**** | 1.25-7.96 |
| Independent vs. No interest in politics | 1.35 | 0.63-2.87 | 0.91 | 0.39-2.12 |

Note: Group A – Environmental issues; Group B – Price and status of EV owners; and Group C – Efficiency and performance

* $p \leq .1$ , ** $p \leq .05$ , *** $p \leq .001$

**Table 10. Model 5 - Choosing Group B vs. Group A or C**

| | (a) vs. Group A | | (b) vs. Group C | |
|---|---|---|---|---|
| | Adj. rel. odds | 95% CI for odds | Adj. rel. odds | 95% CI for odds |
| Gender | | | | |
| male vs. female | 1.25 | 0.82-1.90 | 1.27 | 0.74-2.18 |
| Age | | | | |
| < 30 vs. 60 + | 2.98 | 0.70-12.63 | **5.59**** | 1.15-27.30 |
| 30-39 vs. 60 + | 1.12 | 0.65-1.92 | 1.61 | 0.83-3.12 |
| 50-59 vs. 60 + | 1.28 | 0.78-2.08 | 1.23 | 0.65-2.32 |
| Household size | | | | |
| 1 vs.3 + | 1.33 | 0.41-4.25 | **5.29**** | 1.32-21.3 |
| 2 vs.3 + | 0.97 | 0.56-1.69 | **2.16**** | 1.03-4.54 |
| Children in household | | | | |
| 0 vs. 3 + | 1.85 | 0.74-4.58 | 0.9 | 0.30-2.71 |
| 1-2 vs. 3 + | 1.71 | 0.77-3.83 | 1.71 | 0.67-4.36 |
| Vehicles in household | | | | |
| 1 vs. 3 + | 0.94 | 0.40-2.21 | 0.55 | 0.20-1.54 |
| 2 vs. 3 + | 1.12 | 0.75-1.67 | **0.61**** | 0.37-1.00 |
| Education | | | | |
| College vs. Doc. or profession. | 0.67 | 0.34-1.29 | 1.19 | 0.55-2.56 |
| Bachelor's vs. Doc. or profession. | 0.84 | 0.51-1.39 | 0.97 | 0.52-1.78 |
| Master's vs. Doc. or profession. | 0.74 | 0.46-1.19 | 0.73 | 0.40-1.32 |
| Income | | | | |
| < $100,000 vs. $200,000 + | 1.03 | 0.56-1.89 | **0.37**** | 0.17-.084 |
| $100,000–$200,000 vs.$200,000 + | 1.13 | 0.75-1.70 | 0.72 | 0.44-1.19 |
| Marital status | | | | |
| Single vs. Married | 0.78 | 0.35-1.76 | 1.07 | 0.41-2.79 |
| Race/Ethnicity | | | | |
| White vs. Others | 0.99 | 0.61-1.61 | 1.1 | 0.60-2.00 |
| Political affiliation | | | | |
| Democrat vs. No interest in politics | 1.11 | 0.55-2.21 | 0.39 | 0.19-0.82 |
| Republican vs. No interest in politics | 0.72 | 0.32-1.60 | **0.50**** | 0.21-1.16 |
| Independent vs. No interest in politics | 0.77 | 0.36-1.64 | 0.71 | 0.33-1.53 |

Note: Group A – Environmental Issues; Group B – Price and Status of the EV Owner; and Group C – Efficiency and Performance

* $p \leq .1$ , ** $p \leq .05$ , *** $p \leq .001$

**Table 11. Model 6 - Choosing Group C vs. Group A or B**

| | (a) vs. Group A | | (b) vs. Group B | |
|---|---|---|---|---|
| | Adj. rel. odds | 95% CI for odds | Adj. rel. odds | 95% CI for odds |
| Gender | | | | |
| male vs. female | 0.69 | 0.41-1.15 | **0.56**** | 0.36-0.89 |
| Age | | | | |
| < 30 vs. 60 + | 10.8 | 1.83-63.62 | **0.29**** | 0.12-42.70 |
| 30-39 vs. 60 + | 1.85 | 0.97-1.73 | 1.73 | 0.89-3.06 |
| 50-59 vs. 60 + | 1.18 | 0.66-2.14 | 1.03 | 0.62-1.72 |
| Household size | | | | |
| 1 vs.3 + | 2.39 | 0.62-9.16 | 2.48 | 0.72-8.61 |
| 2 vs.3 + | 1.06 | 0.54-2.07 | 1.1 | 0.61-1.89 |
| Children in household | | | | |
| 0 vs. 3 + | 0.78 | 0.29-2.09 | 1.61 | 0.59-4.40 |
| 1-2 vs. 3 + | 0.87 | 0.38-1.99 | 1.34 | 0.55-3.30 |
| Vehicles in household | | | | |
| 1 vs. 3 + | 0.5 | 0.18-1.40 | 0.82 | 0.34-1.98 |
| 2 vs. 3 + | 0.65* | 0.41-1.04 | **0.61**** | 0.40-0.93 |
| Education | | | | |
| College vs. Doc. or profession. | **0.38**** | 0.17-0.86 | **0.49**** | 0.25-0.94 |
| Bachelor’s vs. Doc. or profession. | 1.22 | 0.69-2.17 | **0.58**** | 0.34-0.99 |
| Master’s vs. Doc. or profession. | 1.36 | 0.78-2.37 | 0.8 | 0.48-1.33 |
| Income | | | | |
| < $100,000 vs. $200,000 + | **2.17**** | 1.06-4.46 | **2.24**** | 1.14-4.40 |
| $100,000–$200,000 vs.$200,000 + | 1.13 | 0.71-1.81 | **1.68**** | 1.09-2.60 |
| Marital status | | | | |
| Single vs. Married | 0.66 | 0.26-1.67 | **0.42*** | 0.17-1.03 |
| Race/Ethnicity | | | | |
| White vs. Others | 0.94 | 0.54-1.61 | 1.28 | 0.76-2.15 |
| Political affiliation | | | | |
| Democrat vs. No interest in politics | 1.2 | 0.57-2.51 | 1.33 | 0.67-2.66 |
| Republican vs. No interest in politics | 1.64 | 0.70-3.84 | 1.26 | 0.56-2.84 |
| Independent vs. No interest in politics | 1.19 | 0.54-2.63 | 1.07 | 0.51-2.28 |

Note: Group A – Environmental Issues; Group B – Price and Status of the EV Owner; and Group C – Efficiency and Performance

* $p \leq .1$ , ** $p \leq .05$ , *** $p \leq .001$

**Home-to-work travel patterns and EV owner characteristics**

This study also assumed that the geographical distribution of home-to-work commuting trips would be related to EV owner characteristics. In order to identify statistically significant variables for building logit models, statistically significant variables from likelihood ratio tests were reported in Table 12.

**Table 12. Likelihood Ratio Tests for Building EV commuting trip logit model**

| Effect | Model Fitting Criteria | Likelihood Ratio Tests | | |
|---|---|---|---|---|
| | -2 Log Likelihood of Reduced Model | Chi-Square | df | Sig. |
| Intercept | 1584.201[a] | 0 | 0 | |
| Age | 1612.476 | 28.274 | 24 | 0.249 |
| Vehicles in Household | 1612.008 | 27.807 | 16 | 0.033** |
| People in Household | 1599.494 | 15.293 | 16 | 0.503 |
| Education | 1616.297 | 32.096 | 24 | 0.125 |
| Income | 1605.069 | 20.868 | 16 | 0.184 |
| Political Affiliation | 1641.034 | 56.833 | 24 | 0.000*** |

* $p \leq .1$ , ** $p \leq .05$ , *** $p \leq .001$

Six variables identified above were tested by building logit models. Of 11 commuting trip pairs, six trip pairs produced statistically significant results (Table 13). It should be noted that each model was compared to *suburb-to-suburb* trips. In other words, socioeconomic characteristics of EV owners commuting *suburb-to-suburb* were the reference variables. This is because suburb-to-suburb commuting trips were the most common trip pairs—32% of the total trip pairs (Table 3). In terms of the income level, EV owners earning $200,000 or lower were less likely to have s*uburb-to-city* or *city-to-city* commuting trips than *suburb-to-suburb* commuting trips. In the case of EV owners with Less than $100,000, the results also showed lower *city-to-suburb* and *rural-to-city* trips. From these observations, we may infer that EV owners living and working in suburban areas are more affluent than the rest of the EV-owning population. Political affiliation seemed to be associated with EV owners' residential and employment locations. The models showed that EV owners who were Democrats or Independents were less likely to have a *suburb-to-rural* commuting trip than *suburb-to-suburb* trips. In addition, Democrats were less likely to have a *rural-to-rural* commuting trip than *suburb-to-suburb*. EV owners with Republican political affiliation, on the other hand, were more likely to commute between suburb and rural. Other variables were also showing distinctive relationships between commuting patterns and owner characteristics. If an EV is the only vehicle in the household, they tended to travel within the same city or from one city to the other.

**Table 13. Home-to-work trip geographic pairs and EV owner characteristics**

| | Home-to-work commuting trip geographic pairs [1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Suburb-to-city | Suburb-to-rural | City-to-city | City-to-suburb | City-to-rural | Rural-to-city | Rural-to-suburb | Rural-to-rural |
| Intercept | -0.226 | -3.549* | -0.74 | 1.197** | -4.203 | -2.436** | -1.493** | -4.533** |
| Age | | | | | | | | |
| < 30 vs. 60 + | -0.744 | -15.888 | -1.213 | 0.765 | 10.303 | -0.328 | -16.553 | 2.021 |
| 30-39 vs. 60 + | 0.145 | -0.008 | -0.192 | 0.307 | -14.615 | -0.402 | 0.234 | 0.138 |
| 50-59 vs. 60 + | -0.161 | -1.623 | -0.52 | 0.181 | -13.885 | -1.47** | 0.264 | 1.539* |
| Vehicles in household | | | | | | | | |
| 1 vs. 3 + | 0.855 | 2.964 | 1.359** | 1.287** | 14.11 | -16.023 | -0.437 | -15.454 |
| 2 vs. 3 + | 0.299 | 2.373 | 0.363 | 0.601** | 13.88 | 0.247 | -0.274 | -0.432 |
| Household size | | | | | | | | |
| 1 vs.3 + | -0.642 | 1.923 | -0.651 | -0.28 | -0. 41 | -0.065 | 0.073 | -15.822 |
| 2 vs.3 + | -0.06 | 0.429 | 0.044 | 0.198 | 0.55 | -1.157** | -0.369 | 0.44 |
| Education | | | | | | | | |
| College vs. Doc. or profession. | 0.318 | 1.282 | -0.429 | -0.303 | -12.918 | 1.068 | 0.777 | 1.381 |
| Bachelor's vs. Doc. or profession. | 0.366 | -16.911 | 0.09 | -0.12 | -27.109 | 1.782** | 0.439 | 1.358 |
| Master's vs. Doc. or profession. | 0.266 | -0.036 | 0.049 | 0.389 | 2.338 | 1.199* | 0.633 | 1.384 |
| Income | | | | | | | | |
| < $100,000 vs. $200,000 + | -0.678* | 0.745 | -0.919** | -1.058** | 14.276 | -1.624* | -0.802 | 0.783 |
| $100,000–$200,000 vs.$200,000 + | -0.563** | -0.206 | -0.816** | -0.453 | -2.225 | -0.574 | -0.338 | 0.052 |
| Political affiliation | | | | | | | | |
| Democrat vs. No interest in politics | -0.551 | -2.932** | 0.164 | -0.065 | 15.424 | 0.61 | -0.649 | -1.973* |
| Republican vs. No interest in politics | -0.231 | -18.255 | 0.484 | -0.412 | 12.416 | 1.572* | 0.436 | 1.253 |
| Independent vs. No interest in politics | -0.543 | -2.321* | 0.269 | -0.32 | 2.933 | -1.035 | -0.424 | -1.075 |

* $p \leq 0.1$, ** $p \leq 0.05$ , *** $p \leq 0.001$

[1] *The estimated multinomial logistic regression coefficient*

**Trip Origin and EV Owner Characteristics**

To test the relationship between trip origin and owner characteristics, likelihood ratio tests were conducted in order to identify potentially significant variables for detailed logit models. Seven variables were identified. Each variable's test statistics were summarized in Table 14.

**Table 14. Likelihood Ratio Tests for EV owner travel origin logit model**

| Effect | Model Fitting Criteria | Likelihood Ratio Tests | | |
|---|---|---|---|---|
| | -2 Log Likelihood of Reduced Model | Chi-Square | df | Sig. |
| Intercept | 911.343[a] | 0 | 0 | |
| Age | 912.757 | 1.414 | 6 | 0.965 |
| People in Household | 915.7 | 4.357 | 4 | 0.36 |
| Children in Household | 920.533 | 9.19 | 4 | 0.057 |
| Vehicles in Household | 922.648 | 11.305 | 4 | 0.023 |
| Education | 923.62 | 12.277 | 6 | 0.056 |
| Income | 919.61 | 8.267 | 4 | 0.082 |
| Political affiliation | 932.875 | 21.532 | 6 | 0.001 |

* $p \leq .1$ , ** $p \leq .05$ , *** $p \leq .001$

Using the seven selected variables, two logit regression models were constructed by which the relationships between owner characteristics and each trip origin—city and suburb—were estimated using rural origin as a reference trip origin (Table 15). In terms of educational attainment, EV owners with less education levels were less likely to start their commuting trip from city and suburban areas than rural areas. Similarly, EV owners with Republican political affiliations were less likely to start their commuting trip from city and suburban areas than rural areas. In terms of the number of vehicles in the house, EV owners for whom the EV is the only vehicle in the household were more likely to have started their commute from city areas than rural areas. EV owners with fewer children in the house were more likely start their trip from suburban areas than rural areas.

**Table 15. Trip origin and EV owner characteristics**

| | Trip Origin | |
|---|---|---|
| | City | Suburban |
| Intercept | 0.487 | |
| Age | | |
| < 30 vs. 60 + | 0.719 | 0.425 |
| 30-39 vs. 60 + | 0.599 | 0.5 |
| 50-59 vs. 60 + | 0.439 | 0.561 |
| Household size | | |
| 1 vs.3 + | 0.566 | 0.949 |
| 2 vs.3 + | 0.146 | 0.148 |
| Number of children | | |
| 1 vs.3 + | 0.411 | 0.16 |
| 2 vs.3 + | 0.095 | **0.004**** |
| Vehicles in household | | |
| 1 vs. 3 + | **0.016**** | 0.32 |
| 2 vs. 3 + | **0.059*** | 0.578 |
| Education | | |
| College vs. Doc. or profession. | **0.013**** | 0.108 |
| Bachelor's vs. Doc. or profession. | **0.014**** | **0.023**** |
| Master's vs. Doc. or profession. | **0.086*** | **0.023**** |
| Income | | |
| < $100,000 vs. $200,000 + | 0.745 | 0.18 |
| $100,000–$200,000 vs.$200,000 + | 0.17 | 0.977 |
| Political affiliation | | |
| Democrat vs. No interest in politics | 0.432 | 0.87 |
| Republican vs. No interest in politics | 0.107 | **0.013**** |
| Independent vs. No interest in politics | 0.277 | 0.438 |

* $p \leq .1$ , ** $p \leq .05$ , *** $p \leq .001$

**Trip Origin and ICEV Owner Characteristics**

To compare the travel pattern of ICEVs with EVs, an analysis has been performed of travel patterns of ICEVs. For the database of ICEVs, the results of the most recent National Household Travel Survey (NHTS) data have been used to analyze travel patterns of ICEV drivers in Maryland. The initial dataset contained 923,572 records of which 3,911 were used for this section of the study (U.S. Department of Transportation, 2018). A multinomial logit regression model was constructed to determine the predictive factors for EV owners' traveling patterns and behavioral attributes. The dependent variable in the model is the geographic area where drivers of the ICEVs started their commuting trips: three levels of city, suburban, and rural areas. Chi-Square and their statistical significance derived from likelihood ratio tests of the logit regression model were reported in Table 16.

**Table 16. Likelihood Ratio Tests for ICEV owner travel origin logit model**

| Likelihood Ratio Tests | | | | |
|---|---|---|---|---|
| | Model Fitting Criteria | Likelihood Ratio Tests | | |
| Effect | -2 Log Likelihood of Reduced Model | Chi-Square | *df* | Sig. |
| Intercept | 2721.587[a] | 0.000 | 0 | |
| Age | 2755.705 | 34.118 | 6 | 0.000*** |
| Income | 2817.349 | 95.762 | 8 | 0.000*** |
| Education | 2818.636 | 97.049 | 8 | 0.000*** |
| Race | 2790.155 | 68.568 | 2 | 0.000*** |
| People in Household | 2768.673 | 47.086 | 4 | 0.000*** |
| Vehicle in Household | 2846.230 | 124.643 | 4 | 0.000*** |

* $p \leq .1$ , ** $p \leq .05$ , *** $p \leq .001$

The results of the models of trip origins and ICEV owner characteristics were presented in Table 17. Trips originating in rural areas were the reference category. As shown in Table 19, ICEV drivers with less education levels were less likely to start their commute from city than rural areas. Similarly, ICEV drivers with lower income were less likely to commute from city or suburban areas. In terms of age, younger drivers were more likely to start their commuting trip from urbanized areas (population of 50,000 or more) and urban clusters (population of at least 2,500 but less than 50,000) areas than rural areas. Likewise, drivers with fewer vehicles in the house were more likely to start their commutes from urbanized areas and urban clusters than rural areas. Household size was also related to trip origin locations. ICEV drivers with fewer people in the household were less likely to commute from city or suburban areas. In terms of race, white ICEV drivers were less likely to commute from cities.

**Table 17. Trip origin and ICEV owner characteristics**

| Trip Status | | | B | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) Lower Bound | 95% Confidence Interval for Exp(B) Upper Bound |
|---|---|---|---|---|---|---|---|
| Urban | | Intercept | 2.463 | 0.000 | | | |
| | Age | younger than 30 vs. 60 and older | 0.508 | 0.004** | 1.662 | 1.173 | 2.355 |
| | | 30 to 49 years vs. 60 and older | 0.419 | 0.003** | 1.521 | 1.154 | 2.004 |
| | | 50 to 59 years vs. 60 and older | -0.278 | 0.026* | 0.757 | 0.593 | 0.967 |
| | Income | less than $50,000 vs. More than $200,000 | -0.740 | 0.000*** | 0.477 | 0.321 | 0.710 |
| | | $50,000 to $100,000 vs. More than $200,000 | -0.821 | 0.000*** | 0.440 | 0.320 | 0.605 |
| | | $100,000 to $150,000 vs. More than $200,000 | -0.483 | 0.004** | 0.617 | 0.445 | 0.855 |
| | | $150,000 to $200,000 vs. More than $200,000 | 0.734 | 0.002** | 2.084 | 1.314 | 3.306 |
| | Education | Less than a high school graduate vs. Advanced degree | -0.922 | 0.001** | 0.398 | 0.227 | 0.699 |
| | | High school graduate or GED vs. Advanced degree | -0.823 | 0.000*** | 0.439 | 0.331 | 0.582 |
| | | Some college or associate degree vs. Advanced degree | -0.526 | 0.000*** | 0.591 | 0.456 | 0.767 |
| | | Bachelor's degree vs. Advanced degree | 0.297 | 0.029* | 1.346 | 1.031 | 1.758 |
| | Race | White vs. other | -1.077 | 0.000*** | 0.340 | 0.253 | 0.458 |
| | People in Household | One vs. three and more | -0.364 | 0.073 | 0.695 | 0.467 | 1.034 |
| | | Two vs. three and more | -0.021 | 0.861 | 0.979 | 0.771 | 1.243 |
| | Vehicle in Household | One vs. three and more | 1.785 | 0.000*** | 5.957 | 4.134 | 8.583 |
| | | Two vs. three and more | 0.633 | 0.000*** | 1.883 | 1.524 | 2.327 |
| Urban Cluster | | Intercept | -1.128 | 0.006 | | | |
| | Age | younger than 30 vs. 60 and older | 0.691 | 0.021* | 1.996 | 1.110 | 3.587 |
| | | 30 to 49 years ago vs. 60 and older | 0.299 | 0.220 | 1.349 | 0.836 | 2.174 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 50 to 59 years ago vs. 60 and older | -0.235 | 0.313 | 0.791 | 0.501 | 1.248 |
| Income | less than $50,000 vs. More than $200,000 | -1.213 | 0.001** | 0.297 | 0.141 | 0.627 |
| | $50,000 to $100,000 vs. More than $200,000 | -0.497 | 0.085 | 0.608 | 0.345 | 1.071 |
| | $100,000 to $150,000 vs. More than $200,000 | -0.799 | 0.010** | 0.450 | 0.245 | 0.824 |
| | $150,000 to $200,000 vs. More than $200,000 | 0.925 | 0.011** | 2.522 | 1.241 | 5.126 |
| Education | Less than a high school graduate vs. Advanced degree | -0.889 | 0.144 | 0.411 | 0.125 | 1.356 |
| | High school graduate or GED vs. Advanced degree | -0.094 | 0.726 | 0.910 | 0.537 | 1.541 |
| | Some college or associate degree vs. Advanced degree | 0.307 | 0.183 | 1.360 | 0.865 | 2.138 |
| | Bachelor's degree vs. Advanced degree | 0.409 | 0.084 | 1.506 | 0.947 | 2.395 |
| Race | White vs. Others | -0.376 | 0.134 | 0.687 | 0.420 | 1.123 |
| People in Household | One vs. three and more | 0.230 | 0.467 | 1.259 | 0.677 | 2.341 |
| | Two vs. three and more | -0.935 | 0.000*** | 0.392 | 0.250 | 0.616 |
| Vehicle in Household | One vs. three and more | 1.597 | 0.000*** | 4.938 | 2.613 | 9.331 |
| | Two vs. three and more | 1.169 | 0.000*** | 3.220 | 2.145 | 4.834 |

* $p \leq .1$ , ** $p \leq .05$ , *** $p \leq .001$

**Trip purpose and mode choice**

Participants were asked to provide information on their primary vehicle uses (work vs. non-work), commuting distances, experience with congestion during commuting trips, and rail transit use. The reasons for asking about rail transit use were to determine whether EV owners utilized the state-funded public charging facilities at rail stations and whether owners' exhibited environmental sensitivity translated into using transit for a portion of the commute trip. Table 18 shows vehicle use behavior and trip characteristics. An absolute majority of the respondents (97 %) drive the EV more than three days a week and most EV owners' trip purpose (70%) was to commute to work.

One of the interesting findings of the survey is that the rail transit mode has not affected EV owners' travel patterns or mode choice behavior. Most EV owners (94%) did not use transit rail to commute before the EV purchase/lease; likewise, buying the EV did not influence them to choose rail transit for part of the commute. However, most of them (77%) do not have a rail transit station located on the way to work. This finding reveals why EV owners are not interested in charging the vehicle at rail stations, and most EV owners (80%) charge their EV at home.

**Table 18. Vehicle Use and Trip Characteristics**

| Item | | Responses | Percent |
|---|---|---|---|
| Purpose of using EV (*N*=1255) | Trip to work destination | 878 | 70 |
| | Trip to non-work destination | 377 | 30 |
| Number of days in a week to travel to work by EV(*N*=878) | One | 4 | 1 |
| | Two | 18 | 2 |
| | Three or more | 856 | 97 |
| Primary work trip driver (*N*=875) | Myself | 793 | 91 |
| | Other household members | 82 | 9 |
| Using public rail transit before purchasing EV(*N*=923) | Yes | 59 | 6 |
| | No | 864 | 94 |
| Using public rail transit now to commute as a part of trip (*N*=923) | Yes | 38 | 4 |
| | No | 885 | 96 |
| Main Charging Location (*N*=873) | Home | 694 | 79 |
| | Work | 49 | 6 |
| | Both | 130 | 15 |
| Nearby rail station (*N*=884) | Yes | 182 | 21 |
| | No | 682 | 77 |
| | Don't know (Not sure) | 20 | 2 |
| Charging at Rail Station (*N*=1257) | Yes | 8 | 1 |
| | No | 28 | 2 |
| | Don't know (Not sure) | 3 | 1 |
| | No response / Not Applicable | 1218 | 94 |
| Charging facility at rail station | Yes | 49 | 4 |

| | | | |
|---|---|---|---|
| influence on using rail (*N*=1257) | No | 134 | 10 |
| | No response / Not Applicable | 1074 | 83 |
| Commuting Distance (miles) (*N*=876) | Minimum | 1 | |
| | Maximum | 160 | |
| | Average | 20.1 | |
| Concerns over the EV's battery range (*N*=877) | Yes | 236 | 27 |
| | No | 641 | 73 |

*Note: Percentages may not total 100 due to rounding*

**Origin/destination and length of trip-making**

According to the results of the survey, approximately 60% of all trips in Maryland were out of cities or counties, and that includes all trips between two different cities or counties. Nearly 19% of all trips belonged to inter city/county trips, those within a city or a county, and about 21% of all trips were out of state. The out of state trips include those by Maryland vehicle owners who work out of state; the top destinations were the District of Columbia with 12% and Virginia with 9%. Table 19 represents the top 10 cities where the origin and destination of trips by EV are in Maryland.

**Table 19. The top urban areas in Maryland as the origin and destination for EV trips**

| Origin | | | Destination | | |
|---|---|---|---|---|---|
| Areas | Number of trips | Percent from all of trips | Area | Number of trips | Percent from all of trips |
| Bethesda | 50 | 6 | Baltimore | 96 | 12 |
| Silver Spring | 44 | 5 | Washington DC | 94 | 12 |
| Gaithersburg | 43 | 5 | Bethesda | 50 | 6 |
| Baltimore | 41 | 5 | Rockville | 39 | 5 |
| Rockville | 30 | 4 | Silver Spring | 34 | 4 |
| Frederick | 27 | 3 | Columbia | 28 | 3 |
| Ellicott City | 26 | 3 | Greenbelt | 28 | 3 |
| Columbia | 24 | 3 | Gaithersburg | 25 | 3 |
| Potomac | 23 | 3 | College Park | 21 | 3 |
| Annapolis | 22 | 3 | Frederick | 17 | 2 |

*Note: Percentages may not total 100 due to rounding*

There are interesting outcomes when analyzing the mean of driving distance of the EV owners based on their first reason for purchasing/leasing EV (see Table 20). First, in the level of inter-suburban or intercity trips, the owners who selected environmental issues and price and the status of the EV owner as the first reason for purchasing an EV have approximately the same average driving distance. Meanwhile— for trips to the adjacent suburban, city, and rural areas —the owners who selected environmental issues and efficiency and performance have approximately the same average driving distance. Second, for trips beyond the adjacent suburban or city areas, the owners who selected efficiency and performance as the first reason for purchasing an EV have a greater commuting distance than others do. These results show that EV drivers with a higher average driving distance are more concerned about the price and the status of the EV owner, while drivers with lower average driving distance are more concerned about the environmental issues. Moreover, generally, when both the home and workplace are located in a city or suburban area, most of the EV owners (62%) are more concerned about Group A: *Environmental Issues*, and when they use the EV for commuting trips to the adjacent city or suburban area, concern about environmental issues goes down (58%). Those EV owners whose commuting trips were beyond their adjacent city or suburban area, with longer average distances, had the least concern (54%) about Group A: *Environmental Issues*.

As verified with software, the commute of EV owners is on average 17 miles, but respondents reported in the survey that their commute was nearly 20 miles. Also, the graphs of the post-hoc analysis with average driving distance for the 1st reason (Figure 8), 2nd reason (Figure 9), and 3rd reason (Figure 10) are exhibited in Table 20. These figures show that EV owners' most important purchasing reasons are statistically significantly correlated to their average travel distance.

**Table 20. Comparing driving distance means between different trip status by reason**

| Trip Status | | Mean (miles) | N | Std. Deviation |
|---|---|---|---|---|
| Intercity or intersuburban trips | Group A: Environmental Issues | 1.41 | 96 | 2.61 |
| | Group B: Price and the Status of the EV Owner | 1.74 | 29 | 3.04 |
| | Group C: Efficiency and Performance | 0.5513 | 29 | 1.42 |
| | Total | 1.31 | 154 | 2.54 |
| Trips to adjacent city, suburban, or rural area | Group A: Environmental Issues | 16.95 | 287 | 9.84 |
| | Group B: Price and Status of the EV Owner | 21.51 | 128 | 20.99 |
| | Group C: Efficiency and Performance | 20.16 | 72 | 13.71 |
| | Total | 18.63 | 487 | 14.27 |
| Trips not to adjacent city, suburban, or rural area | Group A: Environmental Issues | 24.17 | 94 | 15.37 |
| | Group B: Price and Status of the EV Owner | 28.78 | 47 | 19.66 |
| | Group C: Efficiency and Performance | 30.29 | 30 | 14.985 |
| | Total | 26.51 | 171 | 16.70 |
| Total | Group A: Environmental Issues | 15.25 | 477 | 12.72 |
| | Group B: Price and Status of the EV Owner | 20.38 | 204 | 20.77 |
| | Group C: Efficiency and Performance | 18.14 | 131 | 16.08 |
| | Total | 17.0030 | 812 | 15.79 |

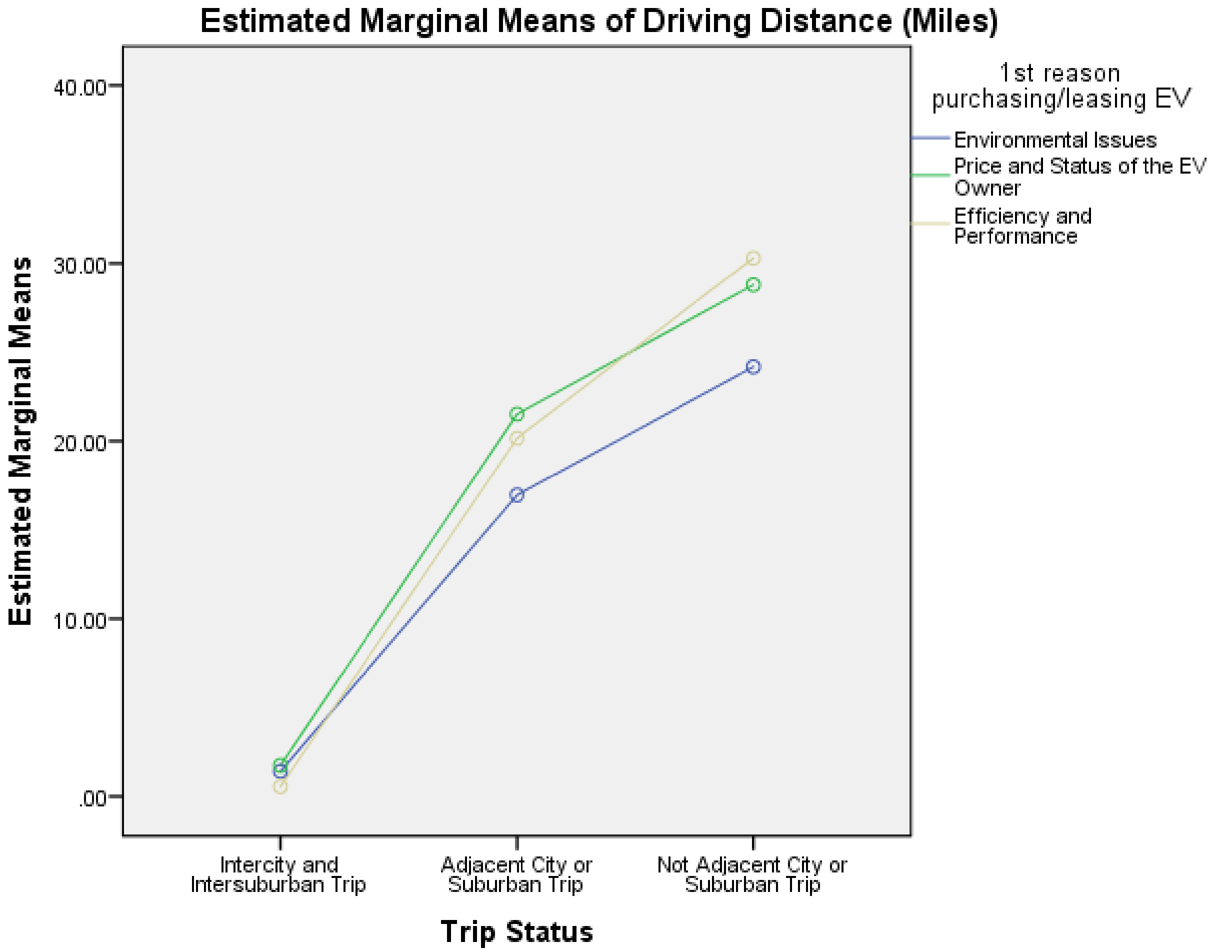



**Figure 8. Average driving distance by trip types and the 1st purchasing reason**

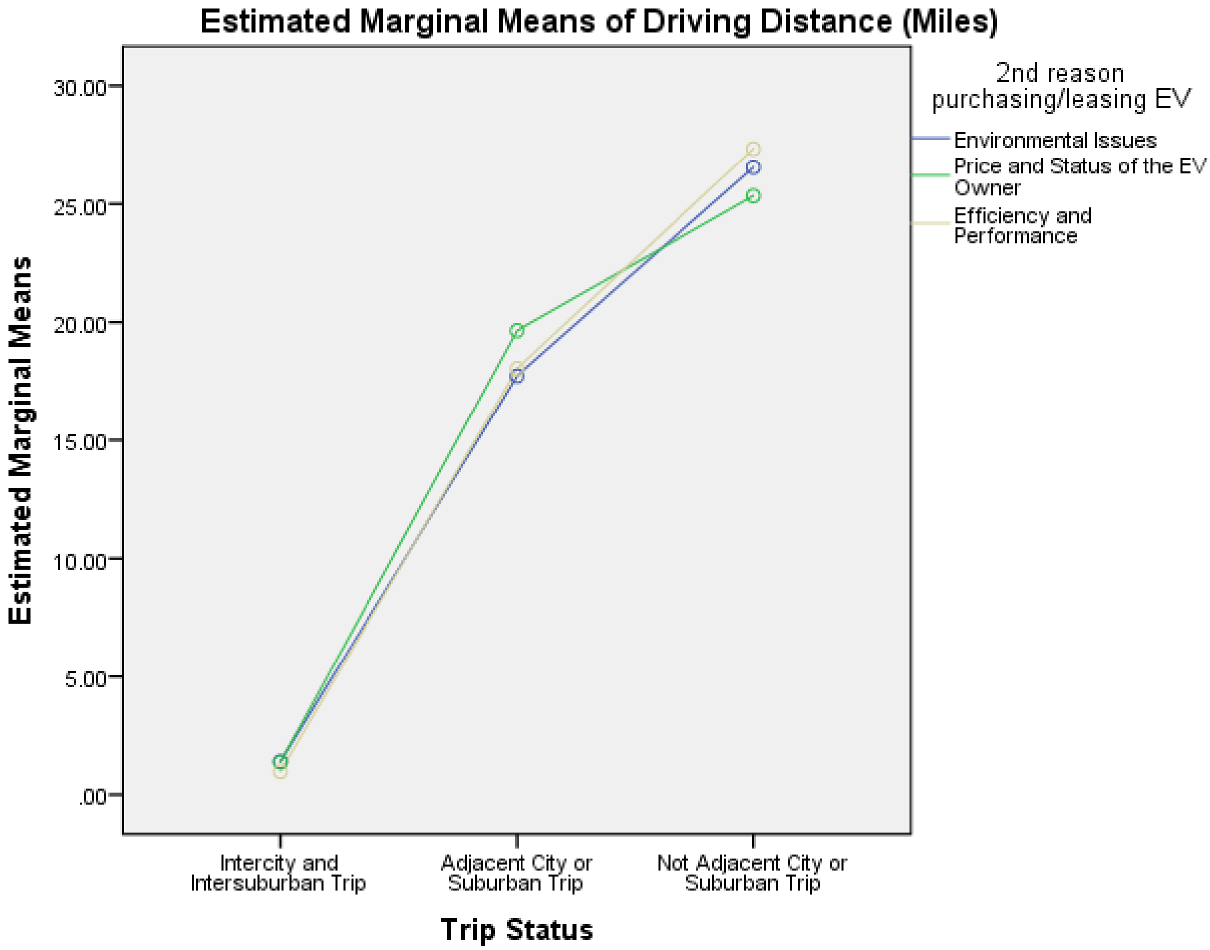



**Figure 9. Average driving distance by trip types and the 2nd purchasing reason**

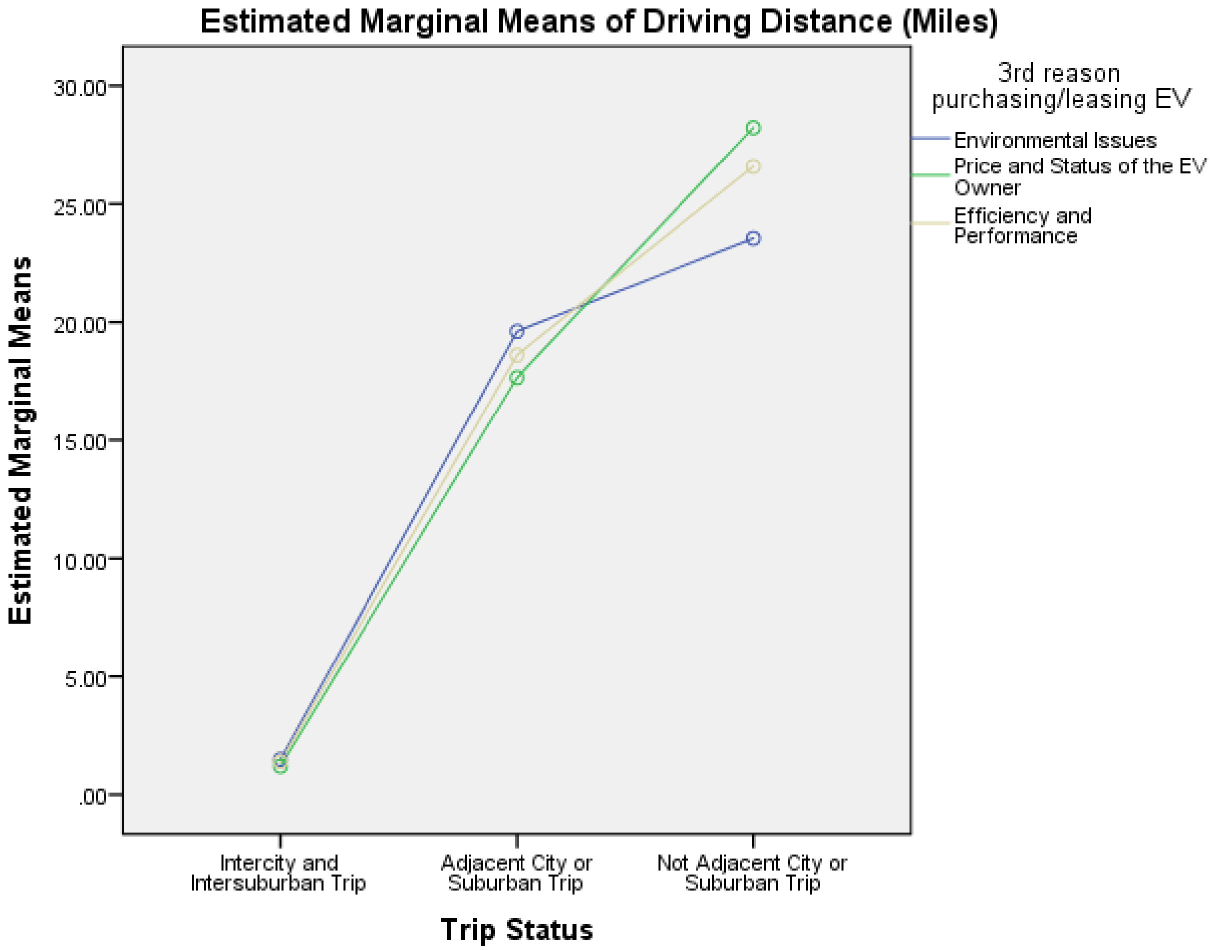



**Figure 10. Average driving distance by trip types and the 3rd purchasing reason**

**Commute trip patterns and ownership characteristics**

It is hypothesized that there is a relationship between EV owners' commuting trip distance and their sociodemographic characteristics; therefore, in this section, a set of one-way analyses of variance was conducted to examine possible relationships between socio-demographic characteristics of EV owners and their driving distance by EV. The trip length was calculated as the average driving distance between stated living place and working place zip codes using the Microsoft MapPoint 2013 and CDXZipStream Excel Zip Code Add-in software. Values of F and their significance levels in ANOVA are summarized in Table 21.

**Table 21. ANOVA on driving distance mileage among socio-demographic variables**

| Variable | Driving distance (miles) | |
|---|---|---|
| | F | Sig. |
| Gender | 0.006 | 0.938 |
| Age | 1.734 | 0.059* |
| Household size | 0.099 | 0.753 |
| Children in household | 0.984 | 0.322 |
| Vehicles in household | 0.837 | 0.361 |
| Education | 3.015 | 0.050** |
| Income | 1.859 | 0.157 |
| Marital | 0.096 | 0.757 |
| Race/Ethnicity | 0.047 | 0.828 |
| Political affiliation | 2.799 | 0. 390 |
| Household size * Vehicles in household | 2.082 | 0.082* |
| Age * Education | 2.812 | 0.025** |
| Household size * Education * Income | 3.108 | 0.002** |

* $p \leq .1$ , ** $p \leq .05$

According to the values in Table 21, the driving distance by EV significantly changes based on age groups, education levels, and three combined variables of household size and vehicles in household; age and education; and household size, education and income. Driving distance varied on the basis of age and education with a negative association. Older EV owners or those with higher education levels drive less than other groups; likewise, the interaction of these two variables is statistically significant at the 0.05 significance level. Although income did not seem statistically significant with regard to driving distance, this variable in conjunction with education and number of people in family showed a negative association, revealing that more educated EV owners with higher income levels and bigger family size drive less than other groups. However, household size has played a different role in conjunction with number of vehicles in a household because this interacted variable has a positive association with driving distance, which means EV owners with more people and vehicles in their family drive more than other groups.

## DISCUSSION AND CONCLUSIONS

This study focused on the identification of sociodemographic attributes that may contribute to EV ownership and owners' commuting behavior in Maryland. This study included two innovations compared to past studies: first, considering a new socio-demographic factor of political affiliation as an element of EV ownership and EV drivers' travel patterns, and, second, conducting a spatial analysis of commuting behavior and travel patterns of EV owners. To the authors' best knowledge, this is the first study that comprehensively analyzed EV owners' travel behavior by geographic classifications as city, suburban, and rural areas and compared the results with travel behavior of ICEV drivers.

Comparison between the travel pattern of EV and ICEV drivers in Maryland shows some significant similarities and differences. It seems income and education have a correlated relationship in the travel behavior of both EV and ICEV drivers because EV drivers with higher education and income levels were more likely to have city to city, suburban to city, and city to suburban commuting trips. Similarly, ICEV drivers were more likely to start their commuting trips from urban and suburban areas than from rural areas. In addition, household size and number of vehicles in the house showed a correlation in both EV and ICEV travel pattern analysis which found families with bigger household size and more vehicles in the house were more likely to start their trip from urban areas than from rural areas. However, age and race were not statistically meaningful variables for travel patterns of EV owners while these variables were meaningful for ICEV drivers—younger drivers and drivers who were Caucasian (white) were more likely to start their commuting trips from urban areas than from rural areas.

According to the results of this study, socio-demographic attributes of age, household size, number of vehicles in the house, education, income and political affiliation have been identified as influential factors on EV ownership. EV owners are white males who are more educated, affluent, older, and more environmentally focused than are owners of ICEVs. EVs were most popular among Democrats and least among those not interested in politics. Generally, for younger EV owners, efficiency and performance of the EV was the main reason for purchasing an EV rather than environmental issues and price and status of the EV.

In terms of household size and number of vehicles in the house, EV owners with fewer people and vehicles in the house were more likely to consider efficiency and performance of the EV than other reasons for purchasing the EV. With respect to education attainment, EV owners with lower education levels were more concerned about the price and status of the EV rather than environmental issues and efficiency and performance of the EV. Also, EV owners with lower income levels were more concerned about the price and status of the EV. This result is concordant with the study by (Hidrue, Parsons, Kempton, & Gardner, 2011) which showed that EV owners with higher income and education levels consider environmental concerns more than other groups.

Finally, EV owners with Republican political affiliation were more likely to consider price and status than other reasons for purchasing an EV. This finding is not unexpected because (Costa & Kahn, 2015) indicated that the effectiveness of energy conservation nudges depends significantly on an individual's political ideology. In the context of American politics, Democrat, Peace and Freedom, and Green party members (liberals) are more likely to vote for environmental causes than Republican, American Party, or Libertarian party members (conservatives) are. In a sample study of sending out Home Energy Reports (HERs) from utility companies with tips for energy savings to random households, households identifying with liberal politics were more likely to be responsive to reducing their residential energy consumption. The fraction of liberals and the fraction of college-educated in a target census block group positively affect treatment response, independent of other characteristics (Costa & Kahn, 2015). In terms of political impediments, while there was an inflated expectation of the boom of renewables following the energy crisis of the 1970s, the political atmosphere and priorities of the 1980s (Reagan administration, low fossil fuel costs, etc.) depleted the social and political capital of renewables at that time. Into the Carter administration and beyond, there have been some improvements but also other setbacks. Some states with higher proportions of industrial output (e.g., Iowa) have mandated renewable power use to increase overall output. Simultaneously, public and private funding for R&D into renewables has fallen short of creating systemic change. Additionally, because so many Americans are removed from energy production (including fossil fuel resource extraction), large-scale renewables are not at the forefront of American thought, and sudden, radical changes are likely to be met with public reluctance and political obstruction. While this does not directly relate to consumer behavior patterns regarding electric vehicles, it does demonstrate that the political zeitgeist can be a strong tool or a strong obstruction in large-scale R&D and implementation strategies. Moreover, state-level deployment that is not dependent on national funding impetuses might be more practical to encourage adoption of new technology (Sovacool, 2009). It is postulated that future research should examine what might be effective conservation messages with political conservatives for environmental nudges.

Analyses of travel types and home-to-work commuting raised questions about the effectiveness of current incentive programs and charging station deployment strategies. Owners use EVs for commuting to work, but transit was not at all a significant mode choice either before or after EV purchase. This result calls into question the state's emphasis on placing public charging units at rail transit stations. While placing a few units at those locations may have made sense, policy and programs to place units prior to assessing demand (as this study did) were probably not wise use of resources. Not being able to involve WMATA METRO stations in this effort was a major weakness, as many EV owners live in Montgomery County, Maryland, a suburb of Washington, D.C.

EV owners are statistically significantly associated with average driving distance by geographic trip patterns— intercity/suburban, travel to adjacent city/suburban, and not to adjacent city/suburban. Drivers with environmental concerns drove the shortest distances when traveling between counties and cities, as well as out-of-state. However, for the intercity or intersuburban trips, EV owners considering *Efficiency and Performance* the most important drove the least, 0.6 miles or 0.996 km, nearly a 70% shorter travel distance than environmentally concerned EV owners. On the other hand, the same driver group drove the longest distance, 30.3 miles or 48.8 km, when it came to travel beyond the adjacent city or suburban area, which is roughly 20% longer than EV owners with *Environmental Issues*. Therefore, it can be concluded that for EV owners whose commuting trips were limited to their own city or suburban areas, *Environmental Issues* was their main influencing factor in purchasing the EV. But if their commuting distance is longer, EV owners become more concerned about *Price and the Status of the EV Owner* and *Efficiency and Performance* of the EV.

**POLICY RECOMMENDATIONS**

The research results provide a foundation for public policy going forward. It is clear from the research that environmental concerns were the major reason for purchasing EVs by registered owners. Most such owners were in highly educated, affluent households and received significant financial incentives toward purchasing EVs. Yet, within these generalities one can discern market segments or broad social networks. Political affiliation of EV owners, a proxy for political, economic and cultural philosophy within a social network, was significant in the purchasing decision. Those owners who were Republican with more modest incomes and rural orientation purchased an EV for cost and fuel independence considerations. Environmental concerns influenced those who were Democrat or Independent with higher incomes and urban orientation, the large majority of owners. These findings still involve some generalities as there are, of course, exceptions to them, but they do suggest that public information and marketing should be targeted to socioeconomic-political networks.

Marketing of EVs in Maryland should distinguish between older, high-income households and younger, lower-income households; the former likely to purchase an EV for environmental reasons, reside in urban suburban locations and commute relatively short distances, while the latter may have a more rural orientation and purchase for price, value and/or performance and sometimes commute longer distances. It can be inferred that those who primarily travel short distances may have less incentive to purchase an EV, because travel time and cost saving differences between EVs and gasoline would be negligible. It suggests that an increase in accessibility to charging facilities in suburban areas would result in a faster EV adoption. New charging units placed in suburban and rural locations should be concentrated in employment clusters. Because price and value may be more important to EV ownership in those settings emphasis should be placed on level one charging (house current), the most ubiquitous and cheapest form of EV charging.

An increase in EV purchase affordability can be accomplished by mitigating equity issues of the current incentive programs. Approximately, 74% of the participants earned at least $100,000 annually, which means, of course, that a quarter of EV owner households earn more modest incomes. This research suggests providing financial incentives proportionally aimed more toward low- and medium-income households, and for previously owned vehicles, may increase EV market share. In addition, the state could craft incentives for fleet vehicles, such as for taxis, car and ride-sharing, which should broaden society's access to EV ownership and/or use. Research shows that for owners of high-end luxury EVs financial incentives are not important to the purchasing decision (Idaho National Laboratory, 2016).

The Maryland Clean Cars Act of 2017 capped financial incentives for EV purchases at $60,000 per vehicle. Thus, more of the incentive goes to owners for whom incentives are more important to the purchasing decision. For high-income households that can easily afford a Tesla Model S, financial incentives are not important. For households with low incomes (from our survey, below $100,000), financial incentives are even more critical to owning an EV. There is still a price differential between purchasing an EV or the sibling ICEV. The differential becomes smaller with depreciation, but may still persist. Public policy that delivers incentives for purchasing previously owned EVs would further EV market penetration and result in more equitable policy.

Incentives for amassing fleets of EVs for taxis, car and ride sharing would also be a more equitable subsidization of EV penetration.

There are still misconceptions regarding EV environmental benefit, price, cost of operation and battery range (see (Farkas, Shin, Dadvar, & Molina, 2017)). The one major weakness of EVs in terms of air quality and greenhouse gasses benefits is that much electric power in Maryland is still generated with fossil fuels. There are options for "cleaner energy" supply, so EV charging should utilize such energy to attract more environmentally conscious buyers. The literature shows that those households that use solar generated power are prime candidates for EV ownership. Public utilities should incorporate at-home time of day pricing with cleaner sources of electricity and treat EV charging more favorably in terms of cost per kwh. The public utilities in Maryland, charging network suppliers and other stakeholders have worked together through the Maryland Public Service Commission to offer preferential off-peak charging for EVs through various business models and locations of charging units.

Among those who are motivated by cost or energy independence considerations, promotion of EVs should focus on EV life cycle costs. The up-front price differential between EV and ICEV can be overcome with reduced fuel and maintenance costs over time. In addition, vehicle purchasers motivated by cost or energy independence may be attracted to opportunities for vehicle-to-grid return of power from the EV to the electric grid, as needed. The possible inconvenience of V2G to EV owners during peak times would have to be overcome.

While a large majority of EV owners charge their vehicles at home, many potential owners cannot, because they may live in multi-family or attached units without garages and a source of electricity for charging. Because of Home-Owner Association (HOA) opposition, the state legislature has failed repeatedly to pass bills that would override or coordinate with HOA rules that prohibit installing charging units, even at an EV owner's cost. A law that would accommodate both HOAs and EV owners would result in, again, more equitable policy to promote EV market penetration.

In any case, while all EV owners benefit from financial incentives and public charging units, particularly those EV owners of modest income, all vehicle owners would benefit from a more concerted effort by state government, public utilities and vehicle manufacturers to educate the public on the benefits of EV ownership and increase the supply of charging units. However, the state's early priority to place charging units at rail transit stations appears to have been misplaced, as very few EV owners utilize transit after vehicle purchase. It would be more advantageous for the public sector to supplement the charging units installed by employers at major employment agglomerations. Employers could also utilize preferential parking and charging at work to favorably treat EV owners.

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## REFERENCES


*AAA*. (May 31, 2018). Retrieved from AAA Gas Prices: https://gasprices.aaa.com/

Caperello, N., Hageman, J. T., & Kurani, K. S. (2014). *Engendering the future of electric vehicles: Conversations with men and women.* Institute of Transportation Studies. Davis: University of California.

Carley, S., Krause, R. M., Lane, B. W., & Graham, J. D. (2013). Intent to purchase a plug-in electric vehicle: A survey of early impressions in large US cities. *Transportation Research Part D: Transport and Environment, 18*, 39-45.

Clark, H. M. (2017). *Who rides public transit.* Washington, D.C.: American Public Transportation Association. Retrieved May 3, 2018, from https://www.apta.com/resources/reportsandpublications/Documents/APTA-Who-Rides-Public-Transportation-2017.pdf

Coffman, M., Bernstein, P., & Wee, S. (2017). Electric vehicles revisited: A review of factors that affect adoption. *Transport Reviews, 37*(1), 79-93.

Costa, D., & Kahn, M. (2015). Energy Conservation "Nudges" and Environmentalist Ideology: Evidence from a Randomized Residential Electricity Field Experiment. *Journal of the European Economic Association, European Economic Association, 11*(3), 680-702.

Curtin, R., Shrago, Y., & Mikkelsen, J. (2009). *Plug-in hybrid electric vehicles.* Ann Arbor: University of Michigan.

DeShazo, J., Sheldon, T., & Carson, R. (2015). Designing Efficient and Equitable Policy Incentives for Cleaner Technologies: Lessons from California's Plug-in Electric Vehicle Rebate Program. *Transportation Research Board 94th Annual Meeting.* Washington, D.C.

Dumortier, J., Siddiki, S., Carley, S., Cisney, J., Krause, R. M., Lane, B. W., Graham, J. D. (2015). Effects of providing total cost of ownership information on consumers' intent to purchase a hybrid or plug-in electric vehicle. *Transportation Research Part A: Policy and Practice, 72*, 71-86.

*Environmental Protection Agency*. (n.d.). Retrieved May 31, 2018, from Basic Information on Fuel Economy Labeling: https://www.epa.gov/fueleconomy/basic-information-fuel-economy-labeling

Farkas, Z., Shin, H., Dadvar, S., & Molina, J. (2017). *Electric vehicle ownership factors, preferred safety technologies and commuting behavior in the United States.* Charlottesville, VA: Mid-Atlantic Transportation Sustainability University Transportation Center, University of Virginia.

Franke, T., & Krems, J. F. (2013). What drives range preferences in electric vehicle users? *Transport Policy, 30*, 56-62.

Green Car Congress. (2015). *Green Car Congress*. Retrieved from http://www.greencarcongress.com/2015/01/index.html

Hardman, S., & Tal, G. (2016). Exploring the decision to adopt a high-end battery electric vehicle: Role of financial and nonfinancial motivations. *Transportation Research Record, Journal of the Transportation Research Board*(2572), 20-27.

Hidrue, M. K., Parsons, G. R., Kempton, W., & Gardner, M. P. (2011). Willingness to pay for electric vehicles and their attributes. *Resource and Energy Economics, 33*(3), 686-705.

Hjorthol, R. (2013). *Attitudes, ownership and use of Electric Vehicles–a review of literature.* National Academy of Sciences.

Idaho National Laboratory. (2016). *Comparing energy costs per mile for electric and gasoline-fueled vehicles.* Idaho Falls: Idaho National Laboratory, U.S. Department of Energy. Retrieved May 31, 2018, from Idaho National Laboratory: https://avt.inl.gov/sites/default/files/pdf/fsev/costs.pdf

Lane, B., Sherman, C., Sperl, J., Krause, R. C., & Graham, J. (2014). Beyond early adopters of plug-in electric vehicles? Evidence from fleet and household users in Indianapolis. *Transportation Research Board 2014 Annual*.

Liao, F., Molin, E., & van Wee, B. (2017). Consumer preferences for electric vehicles: a literature review. Transport Reviews. *37*(3), 252-275.

Maryland Department of the Environment. (2017, December). *Electric vehicle incentives.* Retrieved from http://mde.maryland.gov/marylandgreen/Documents/EV_dealershipflyer_online.pdf

Maryland Electric Vehicle Infrastructure Council. (2015). *Interim report presented to Governor Martin O'Malley and the Maryland General Assembly.* Hanover: Maryland Department of Transportation.

Maryland Electric Vehicle Infrastructure Council. (2017). *Interim report to the governor and Maryland General Assembly.* Hanover: Maryland Department of Transportation.

Maryland Electric Vehicle Infrasturcture Council. (2012). *Final report to the governor and Maryland General Assembly.* Hanover: Maryland Department of Transportation.

Maryland Transit Administration. (n.d.). *MTA and MEA partner to provide new electric vehicle charging stations*. Retrieved May 3, 2018, from Maryland Transit Administration: https://mta.maryland.gov/news/mta-and-mea-partner-provide-new-electric-vehicle-charging-stations

McFadden, D. (1978). Modeling the choice of residential location. *Transportation Research Record, 673*.

Merchant, E. F. (2018, January 26). Maryland could soon have the second-largest EV charging network in the US. Retrieved from https://www.greentechmedia.com/articles/read/maryland-second-largest-ev-charging-network#gs.yzVHFzc

Modarres, A. (2013). Commuting and energy consumption: toward an equitable transportation policy. *Journal of Transport Geography, 33*, 240-249.

Mohammadian, A. (2005). Gender differences in automobile choice behavior. *Research on Women's Issues in Transportation: Report of a Conference, 2*, pp. 41-48.

Momtazpour, M., Bazchalui, M., Ramakrishnan, N., & Sharma, R. (2016). Installing electric vehicle charging stations city-scale: How many and where? *Computational Sustainability, 645*, pp. 149-170.

Neff, J., & Pham, L. (2007). *A profile of public transportation passenger demographics and travel characteristics reported in on-board surveys.* Washington, D.C., United States: American Public Transportation Association.

Plötz, P., Schneider, U., Globisch, J., & Dütschke, E. (2014). Who will buy electric vehicles? Identifying early adopters in Germany. *Transportation Research Part A: Policy and Practice, 67*, 96-109.

Power, C. (2014). *Supporting the Plug-In Electric Vehicle Market Best Practices from State Programs.* Georgetown Climate Center.

Powers, C. (2014). *Supporting the plug in electric vehicle market: Best practices from state programs.* Washington, D.C.: Georgetown Climate Center.

Radtke, P., Krieger, A., Kirov, S., Maekawa, A., Kato, A., Yamakawa, N., & Henderson, D. (2012). *Profiling Japan's early EV adopters: A survey of the attitudes and behaviors of early electric vehicle buyers in Japan.* New York City: McKinsey & Company.

Rauh, N., Franke, T., & Krems, J. F. (2015). Understanding the impact of electric vehicle driving experience on range anxiety. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 57*(1), 177-187.

Shin, H., Callow, M., Dadvar, S., Lee, Y., & Farkas, Z. (2015). User acceptance and willingness to pay for connected vehicle technologies: Adaptive choice-based conjoint analysis. *Transportation Research Board: Journal of the Transportation Research Board*(2531), 54-62.

Sovacool, B. ( 2009). Rejecting renewables: The socio-technical impediments to renewable electricity in the United States. *Energy Policy, 37*(11), 4500-4513.

Tal, G., & Nicholas, M. (2013). Studying the PEV market in California: Comparing the PEV, PHEV and hybrid markets. *EVS27 International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium*, (pp. 1-10). Barcelona, Spain.

The U.S. Department of Energy's Vehicle Technologies Office. (2018). *Alternative Fuels Data Center*. Retrieved from AFDC: https://www.afdc.energy.gov/fuels/electricity_charging_home.htm

U.S. Census Bureau. (2000). Census Transportation Planning Products. Washington, D.C.

U.S. Census Bureau. (n.d.). *2010 Geographic Terms and Concepts*. Retrieved May 22 https://www.census.gov/geo/reference/terms.html, 2018, from U.S. Census.

U.S. Census Bureau. (2016). *2011-2015 ACS 5-Year Estimates.* Washington, D.C.: U.S. Census Bureau.

U.S. Census Bureau. (2017). 2012-2016 American Community Survey 5-Year Estimates. Washington, D.C.

U.S. Department of Energy. (n.d.). *Charging Plug-in Electric Vehicles at Home*. Retrieved May 3, 2018, from Alternative Fuel Data Center: https://www.afdc.energy.gov/fuels/electricity_charging_home.html

U.S. Department of Transportation. (2018). *Federal Highway Administration.* Retrieved from National Household Travel Survey: http://nhts.ornl.gov

United States Census. (2010). *Geographic Terms and Concepts.* Retrieved from https://www.census.gov/geo/reference/terms.html

Vergis, S., & Chen, B. (2015). Understanding variations in U.S. plug-in electric vehicle markets. *Transportation Research Board Annual Meeting.* Washington, D.C.

Winegarden, W. (2018). *Costly subsidies for the rich: Quantifying the subsidies offered to battery electric powered cars.* San Francisco: Pacific Research Institute.

**Appendix A:**

**Electric Vehicle Owners' Survey**

Morgan State University's National Transportation Center (www.morgan.edu/soe/ntc) would like to learn, through this five-minute online survey, about EV owners' purchasing decisions, commuting and preferred vehicle safety technologies.

Survey participants must be at least 18 years old and own/lease a plug-in hybrid or plug-in battery electric vehicle registered in the State of Maryland. The electric vehicle should be equipped with: a steering wheel and pedals, bucket or bench seats, and carry 2 or more people. Participation in this survey is voluntary, and there is no risk associated with participation. You are free to discontinue the online survey at any time.

All information submitted in the survey will be anonymous and confidential. Only the National Transportation Center will collect the survey responses, aggregate the data and analyze results. The individual survey responses will not be shared with the MVA, other state agencies, insurance companies or other private organizations.

What is your gender?

- ☐ Male
- ☐ Female

What is your age?

- ☐ Under 20
- ☐ 20 to 24 years old
- ☐ 25 to 29 years old
- ☐ 30 to 39 years old
- ☐ 40 to 49 years old
- ☐ 50 to 59 years old
- ☐ 60 to 69 years old
- ☐ 70 and older

How many people are in your household (including you)?

- ☐ One
- ☐ Two
- ☐ Three or more

How many children (under 18) currently live with you in your household?

- ☐ None
- ☐ One or Two
- ☐ Three or More

How many vehicles does your household have?

- ☐ One
- ☐ Two
- ☐ Three or more

Which zip code do you live in?

What were the top three reasons for your household purchasing or leasing an electric vehicle (EV)?

- ☐ Environmental concerns, e.g., air quality, pollution
- ☐ Price of electricity vs. gasoline
- ☐ Tax breaks and net price of vehicle
- ☐ Single occupant access to HOV lane
- ☐ Advanced technology
- ☐ Safety features of vehicle
- ☐ Status of EV ownership
- ☐ Available charging facilities
- ☐ Vehicle performance
- ☐ Reduce dependence on petroleum

Did your household purchase or lease the EV?

- ☐ Purchased the EV
- ☐ Leased the EV

What kind of EV does your household own/lease?

- ☐ Plug-in hybrid electric, such as a Chevy Volt
- ☐ Plug-in battery electric, such as a Nissan Leaf

Is EV charged at home?

- ☐ Yes
- ☐ No

Do you have a level 2 charger (240 volts)?

- ☐ Yes
- ☐ No

Why don't you charge at home?

What is the primary purpose for using the EV?

- ☐ Trip to work destination
- ☐ Trip to non-work destination

Who drives the EV to work primarily?

- ☐ I do
- ☐ Other household member does

How many days per week is the EV usually driven to work?

- ☐ 1 day
- ☐ 2 days
- ☐ 3 days or more

Does the primary driver have any concerns over the EV's battery range?

- ☐ Yes
- ☐ No

Does the primary driver have access to a charging facility at the work location?

- ☐ Yes
- ☐ No
- ☐ Don't know (Not sure)

Does the primary driver charge the EV mostly at home or at work?

- ☐ Home
- ☐ Work
- ☐ Don't know (Not sure)

Which zip code does the primary driver work in?

How far is the primary driver's one-way commute to work with the EV?
(in miles)

Does the primary driver frequently encounter severe congestion or run late when commuting to work?

- ☐ Yes
- ☐ No
- ☐ Don't know

Before you purchased/leased the EV did the primary driver use public rail transit at least once or twice a week to commute to work?

- ☐ Yes
- ☐ No

Does the primary driver use rail transit now for part of the commute trip with the EV?

- ☐ Yes
- ☐ No

Is a charging facility available at the rail station?

- ☐ Yes
- ☐ No
- ☐ Don't know

Does the primary driver use the facility to charge the EV?

- ☐ Yes
- ☐ No

What are the reasons for not using the charging facility at the rail station?

- ☐ Concerned about vandalism of vehicle
- ☐ Concerned about other crime in the parking lot
- ☐ Concerned about not finding an available charging facility
- ☐ Concerned about taking too long to hook up to charging facility
- ☐ Concerned about cost for charging vehicle
- ☐ Concerned about EV being hooked up to charging facility for too long
- ☐ Other

Is there a rail transit station located on the way to work that the primary driver could use to get to work?

- ☐ Yes
- ☐ No
- ☐ Don't know

Would access to a charging facility influence the driver to use rail transit?

- ☐ Yes
- ☐ No

What are the reasons for not using a charging facility and taking rail transit for the rest of the commute?

- ☐ Concerned about vandalism of vehicle
- ☐ Concerned about other crime in the parking lot
- ☐ Concerned about not finding an available charging facility
- ☐ Concerned about taking too long to hook up to charging facility
- ☐ Concerned about cost for charging vehicle
- ☐ Concerned about EV being hooked up to charging facility for too long
- ☐ Transit service is inconvenient
- ☐ Driving is faster
- ☐ Other

Please indicate whether you have any of the following technologies in your current EV.
(Select all that apply)

- ☐ Navigation

- Hands-free calling (e.g., Bluetooth)
- Parking assistance
- Back-up warning
- Back-up camera
- Lane departure warning
- Video entertainment
- Satellite or HD radio

What types of safety technologies would you like to have in your next vehicle? (Select all that apply)

- Front collision warning
- Side collision warning
- All around collision warning
- Do not pass warning
- Pedestrian and cyclist alert
- Control loss warning
- Other

What is your highest level of formal education?

- Some high school
- High school diploma or GED
- Associate's degree
- Bachelor's degree
- Master's degree
- Doctoral or professional degree

What is your annual household income?

- Less than $50,000
- $50,000 – $75,000
- $75,000 – $100,000
- $100,000 – $200,000
- More than $200,000
- Prefer not to answer

What is your marital status?

- Single
- Married or in domestic partnership

What is your race/ethnicity?

- White (non-Hispanic)
- Hispanic
- Black or African-American
- Asian

- ☐ American Indian or Alaska Native
- ☐ Native Hawaiian or other Pacific Islander
- ☐ Other
- ☐ Prefer not to answer

What is your political affiliation?

- ☐ Democrat
- ☐ Republican
- ☐ Independent
- ☐ Not interested in politics

Are you satisfied with your EV? Why or why not?

Other comments

If you have any questions or if you are interested in knowing the study results, please contact:

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Thank you! Your response has been recorded.