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Electric Vehicle Acceptance: A Household Study

Fakhra Jabeen [+]
University of Western Australia

Abstract. The increased demand for cars on the road along with the environmental need to reduce emissions, create a need to use alternative fuels. The Electric Vehicle (EV) is a zero-emission vehicle, and with the latest technologies it can reduce travel cost. The challenges associated with the EV include the driving range, and the recharging times. This vehicle requires charging the EV battery instead of re-fuelling the car, and it has to be recharged each 140-160km. EV is useful and cost effective for short drives within the city and for chores such as grocery, picking up children from school, or going to work at shorter distances. In the long term considering purchase and running costs together, EV is very cost-efficient, making it attractive particularly as a second car in the multicar household. The acceptance of EV requires a change in people's behaviour. This paper presents an overview of the experimental design to study the household's response to the Electric Vehicle in Australia. The results will be presented in a later study.

Keywords: Choice modelling, Electric Vehicle, Stated preferences, Zero tailpipe emissions

1. Introduction

The electric vehicle (EV) competed with conventional cars until about 1920, *"...electric automobiles were competitive with petroleum-fuelled cars particularly as luxury cars for urban use and as trucks for deliveries at closely related points,..."* [1]. Subsequently there were intermittent attempts to win acceptance for EV [2]. Wakefield in his book *The Consumer's Electric Car* [5], mentions the "*re-birth of interest*" in EV with then modern technology, i.e. EV again emerged with slight enhancements in the 1960s. Rajashekara [4] summarises the EV history of General Motors, presenting a review of a number of electric and hybrid vehicles developed by GM in the previous three decades. GM focused EV development efforts on environmental concerns, and began the development in 1916, then gradually slowed down but resurrected the research on EV and propulsion systems in 1960. In the late 1970's the interest declined due to a reduction in gasoline prices but GM continued research in EV technology. Despite the development initiatives by GM, one of its EV models was withdrawn and destroyed as shown in a documentary film [6]. This case may seem to indicate some kind of conspiracy but throughout this period other models continued to be available in the market [7].

People's acceptance of new fuels and vehicles are determinants of the EV's place in the ensemble of vehicle technologies. This study aims to explore the purchase behaviour by analysing buying cost, maintenance types, and the pattern of usage. With the low travel cost EV can be fully utilised for short trips within the city, but the charging requires good trip planning. The location of charging stations is therefore crucial to ensure that the destination is reached, when unexpected detours in a trip may be necessary. These elements will be investigated through stated choice experiments where households will be asked to compare a set of optimally designed scenarios with various vehicle and fuel alternatives (including the EV) and choose the preferred alternative.

Next section discusses literature review of EV, the green impact of EV, followed by a discussion about discrete choice modelling, and the experimental design to study EV.

[+] Fakhra. Tel.: + (61-411694924)
E-mail address: *fakhra2005@gmail.com*.

2. Literature Review

2.1. Electric Vehicle – Zero Tailpipe Emissions

The concept of the EV has existed for over a century. The differentiating characteristic of EV is the battery charging. Instead of going to a petrol station for re-fuelling at the bowser, EV needs to be re-charged from an electric power source. This operation can be done at home or at a specialised station. The driving range is a barrier for EV acceptance falling far short of the Hess et al. [10] criterion of 353 miles for EV adoption. A full charge currently allows EV a range of only 100-130km.

Another frequently stated inconvenient aspect of EV use is the long time required for re-charging – compared to the few minutes a consumer needs to fill their tank with liquid fuel. However, given the push for more efficient and environmentally friendly vehicles, major automobile manufacturers, such as Ford, GM, and Tesla have now announced plans to bring electric vehicle technology into the mainstream [8].

While there is widespread public awareness of hybrid vehicle technology, EV technology is not well understood. In 2008, the Renewable Energy Vehicle (REV) project at the University of Western Australia converted a petrol engine Hyundai Getz to a full electric vehicle as a proof of concept using available technologies. The infrastructure for EV being developed at UWA [11] is associated with the conversion of EV from an internal combustion engine (ICE) car.

The benefits associated with EV include the energy conservation and green impact on the environment. The cost per km of travel using an EV is less as compared to petrol: for a small economy car it costs only \$1.40/100km whereas a petrol car costs \$10/100km. From an environmental perspective, the use of conventional motor vehicles in Australia remains a major source of carbon dioxide (CO_2e) and noxious pollutant emissions. Adoption of EV will result in substantial reduction in transport pollutant emissions although the use of coal fired power stations to generate electricity will leave GHG emissions little changed [12], [13].

2.2. EV Acceptance Studies

The low travel cost, and the green impact of EV are factors now leading to explore how people can adopt the EV as their future car? It will be taken positively by young people or by people having low income living in metropolitan life. Many studies in literature explore the EV acceptance in different regions of the world for example USA [3],[10], [14], [15]; Canada [15], Norway [17], South Korea [18]. A recently concluded SP study at UWA [19] has found a variety of factors driving the choice of new technology fuels and vehicles (other than EV) with *fuel cost* and *efficiency* being the most important.

Applying the multinomial probit model (MPM), Ziegler [20] found that younger potential car buyers have higher preference for natural gas vehicles as compared to petrol for the journey to work; they usually purchase environmentally friendly products and own more than one vehicle, which runs on biofuel. Younger males prefer environmentally friendly products and hence show a higher preference for hydrogen vehicles or EVs. Recently Zhang *et al*. [21] have demonstrated the usefulness of an agent-based model in studying the diffusion of alternative fuel vehicles.

2.3. Discrete Choice Modelling

Every human is exposed to a set of choices each day. One has to make a set of decisions or choose an option among a set of alternatives. An example can be choosing a mode of transport from home to work; one must choose keeping few factors in mind that may include the travel cost, time to travel, and comfort level. The cost and time are important factors in making a choice. In a basic choice model [22], *"... the choice probability of alternative i is equal to the probability that the utility of alternative i, U_{in}, is greater than or equal to the utilities of all other alternatives in the choice set (C). This can be written as follows ..."* According to this random utility theory following equation [22] is given:

$$P_{in} = P\left(U_{in} \geq U_{jn}, \forall j \neq i\right) \tag{1}$$

These utility levels are estimated from the choice model. The analyst has to collect information as to which choice is preferred. Discrete Choice Modelling (DCM) is used to understand and forecast consumer preferences [23]; the analysts have widely applied discrete choice models to analyse individual choice

behaviours in different fields such as health, environmental or transport economics. DCM is used to explore product purchase decisions, which in transport may correspond to choice of automobiles for travel. DCM is based on random utility theory [23]; according to this theory, each individual has a utility function that is dependent on the set of alternatives and their characteristics. This individual function can be divided into a systematic part by Ben-Akiva, and Lerman, [23] as shown below:

$$U_{in} = X_{in}\beta + \upsilon_{in}$$
$$y_{in} = \begin{cases} 1 & if \quad U_{in} \geq U_{jn} \\ 0 & otherwise \end{cases} \tag{2}$$

where X_{in} is the row vector of attributes of alternative i and socioeconomic characteristics of the individual n,

β is the column vector of unknown parameters,

υ_{in} is the error term, with certain properties (Gumbel distributed, IIA and IID).

To estimate the choice models, the analysts have to collect information on both chosen and not chosen alternatives. Two approaches are adopted in the literature: revealed preference (RP), and stated preference (SP) data collection.

2.4. Revealed Preference vs. Stated Preference

The revealed preference data reflects the data collected based on choices in the actual market [22]. According to Louviere *et al.* [24], RP data depicts the current market equilibrium, and has high reliability and face validity. The limitation on RP data collection is that it relies on existing alternatives that are available in the market; one may not experimentally test an attribute that does not exist in the market. The stated preference (SP) data, on the other hand, reflects choice mechanisms in hypothetical or virtual situations. Here the analyst has to generate realistic/plausible scenarios by manipulating the levels of the attributes considered to affect the choice. The benefit of SP data is that it allows the analyst to efficiently create scenarios that combine existing attributes with novel attributes, testing for characteristics that are not currently available. SP data are rich in attribute trade-off but the contextual realism may get low, therefore SP may be more useful in forecasting changes in behaviour. For the purpose of this EV study a combination of RP/SP will be used as already used by few of the strategies in literature to model a choice that is not currently available in market.

3. Household Car – Discrete Choice Survey

In order to conduct the household survey multiple choice-sets for different cars will be created, respondents being asked to choose their preferred car alternative. Again the literature review and a focus group will inform the design of the experiment. The vehicle and propulsion options will range over conventional petrol, hybrid petrol, diesel, LPG, and EV. The cost attribute will be expressed as weekly cost for average urban running. Availability of fuel and battery charging will be important attributes. To be as realistic as possible, the initial background information provided by respondents will be used to condition the scenarios. For example, if they drive a small car then SUV will be excluded from scenarios. The final experimental design used in data collection will be optimised, taking into account important interactions and relying on prior parameter estimates from the pilot survey.

Sample households will be sent an introductory letter, with a preliminary short questionnaire, and given the option of completing the survey online or on paper. Those preferring paper surveys will be asked to return the completed preliminary questionnaire. The answers to the preliminary questionnaire will condition the printed scenarios, which we will send back for completion. The resulting data will be analysed using various, more or less sophisticated types of discrete choice models (multinomial, nested, mixed logit models[*]).

4. Experimental Design

[*] The eager reader is recommended Louviere *et al*. [24]

In the experiment, households will be asked to assess combinations of vehicle technologies and fuels, in a labelled experiment with five alternatives (petrol, diesel, LPG, hybrid petrol, and EV). Performance of the vehicles (speed, range, and emissions, noise levels), efficiency, comfort, and total costs (purchase, running, and maintenance) are attributes included in the scenarios for the type/size of vehicle the household owns/needs for its travel. An example of a hypothetical scenario with only three fuel options is given in Table 1.

Table 1: Stated Preference Preliminary Hypothetical Example

Vehicle Type	**SMALL ECONOMY CAR**		
Engine Size (litres)	**1.6L**		
Fuel type/ technology	**Electric Vehicle**	**Petrol Car**	**Hybrid LPG**
Purchase Price *	**30000$ includes home-charging**	**21000$**	**30500$**
Top Speed	**120 km/hr.**	**140 -160 km/hr.**	**140 -160 km/hr.**
Energy (Travel Cost)	**$1.4/100 km**	**$10/100 km**	**$3.2/100 km**
Driving Range	**180 km**	**400 km**	**400 km**
Maintenance Cost †	**1100$ per year**	**1200$ per year**	**1200$ per year**
Noise Level ‡	★★★★★	★★	★★
Temperature inside the vehicle	**Cooling mechanisms require additional cost**	**Cooling mechanism is part of the travel cost**	**Cooling mechanism is part of the travel cost**
Pollutant emissions §	★★★★★	★★	★★★★
My vehicle choice (CHOOSE ONE)	○	○	○

5. Conclusion

The objective of this research work is to explore the individual behaviour with respect to Electric Vehicles. People's acceptance of new fuels and vehicles are determinants of the EV's place in the ensemble of vehicle technologies. The brief literature review has presented the findings of different analysis methodologies in the same field. A plausible experimental design is also discussed. The presentation of research method in this paper is general but will become more specialised as the detailed study progresses.

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† These values are assumed; later on they will be verified from the actual information.

‡ More stars means less noise.

§ More starts means less emissions.

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