Capturing the Effect Range of Anxiety on Electric Vehicle Charging Behaviour: An Integrated Choice and Latent Variable Approach

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Extended Abstract

Their limited driving range in combination with the lack of a widespread rapid charging infrastructure makes electric vehicles (EV) a limited mobility resource when compared to vehicles that can rely on conventional fuels. This characteristic affects vehicle adoption choices and EV drivers, mobility and charging choices. Moreover, the available EV range corresponding to an amount of energy stored in the EV battery is often perceived as uncertain, i.e. difficult to predict by inexperienced users and arguably also by experienced users when operating it under unfamiliar conditions. This perception of range affects EV adoption choices as well as usage patterns and charging patterns, requiring range resource management strategies. The aversion towards uncertainty in EV range and the way it affects consumer behaviour in EV markets has been popularised with the term "range anxiety". Apart from minor nuances, the most frequent definition of range anxiety in popular and scientific press is fear (or concern) of not reaching a destination when driving an EV (Nilsson 2011).

The effect of range anxiety on EV use (and indeed charging) choices can then be framed as the effect of source of uncertainty. The utilisation of expected utility (EU) models and non–EU models would assume a certain degree of awareness of the probability of the event "not reaching the destination", which non-EU theories transform into a weight, to account for the well documented biases in the human processing of chances.

An alternative approach is to view range anxiety a latent characteristic of the individual EV driver that can be more or less affected by the concern of remaining stranded. The advantage of this approach with respect to the traditional approaches in modelling choice under uncertainty is that no assumptions regarding the subjective distribution of the uncertain quantity has to be made. It can be hypothesised that individuals more prone to range anxiety tend to adopt a more precautionary approach when appraising an available energy stored in the EV battery obtained by adopting a charging option or another, in response to variable electricity prices. We therefore propose that range anxiety will have the effect of increasing the marginal utility for the available energy.

In the present paper we adopt the second view and use the integrated choice and latent variable (ICLV) modelling framework represented in Figure 1 to model EV charging choices.

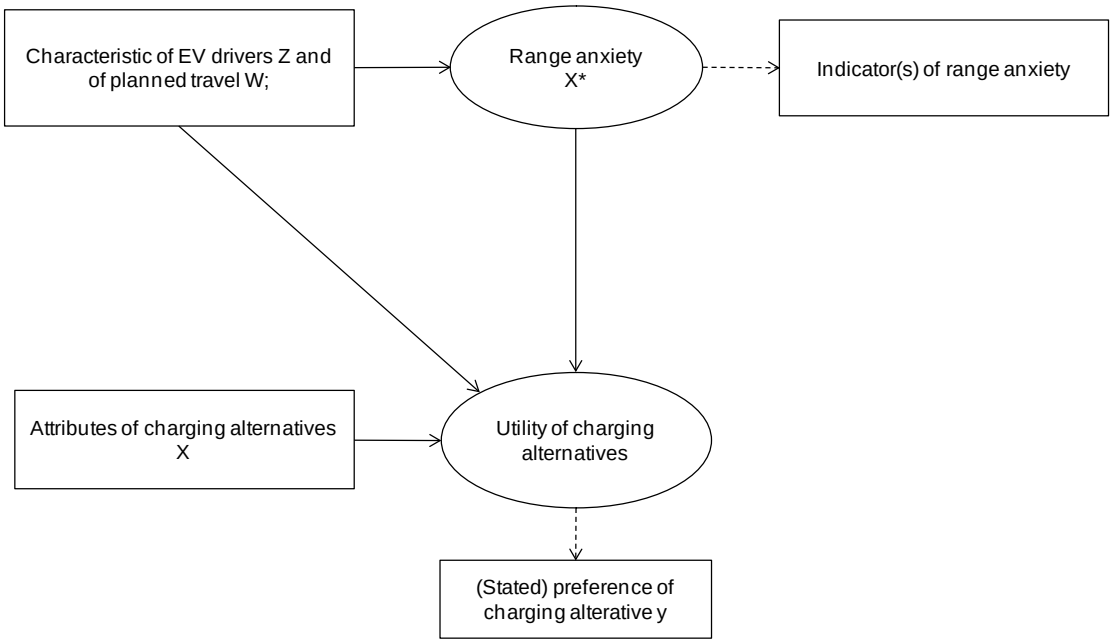

Figure 1: ICLV modelling framework for accommodating the effect of range anxiety on charging choices

The choice model is estimated using state preference data from charging choice experiments in variable electricity pricing contexts form a survey administered to private car drivers (Daina, 2014). The ICLV's measurement model is based on set of perceptual indicators of range anxiety that were collected alongside the choice experiment data from the survey respondents.

Amongst indicators for use in the measurement model we consider the answer to a question aimed at gauging the expectation of what range could be achieved on the next full charge, knowing that typically this would oscillate between two extremes: "*Suppose that on a full battery you usually get between 60 and 100 miles before it runs out. How far would you expect to be able to drive after the next full charge?"* Respondents could choose within a range between 0 and 100 miles. It can be assumed that people who are more concerned about not having enough range would adopt a more conservative (risk averse) approach to range appraisal, and would therefore tend to have lower range expectations than others. The inverse of the answer to such a question is adopted as an indicator for range anxiety. Other indicators for the measurement models are related to the perceived flexibility of the journeys observed from the respondents that were used to construct the hypothetical choice situations for the charging choice experiments (the charging choice was to hypothetically take place before a home-based tour typically undertaken by the respondents). The underlying hypothesis is that a dimension of range anxiety could be related to the perception of the necessity of being able to drive a specific distance to undertake the activities constituting the purpose of the journey. We also consider indicators of the perceived predictability of respondents travel patterns. In this case, the underlying hypothesis is that the more one perceives one's travel patterns difficult to predict the more one might be concerned about remaining stranded due to EV battery depletion.

Preliminary results obtained using only the (inverse) range expectation indicator show that this is positively correlated with the latent variable range anxiety. Moreover these results show that the hypothesis that the range anxiety positively affects the marginal utility for available energy at the end of the charging operation is not rejected. Further analyses to be presented at the hAERT Conference 2015 will include results obtained estimating measurement models using the full set of indicators of range anxiety.

In addition to results based on the proposed ICLV approach, the final paper will include a discussion and results from alternative approaches to modelling the range anxiety effect on charging choices as the result of a choice under uncertainty.

The paper concludes discussing the implications of the gauged range anxiety effects on deployment of demand response measures to smartly shape electric vehicle charging demand. At the current stage, based on the preliminary results we have obtained, the following observation can be made. Individuals showing higher tendencies to range anxiety will be less responsive to demand side management policies intended to mitigate the impact of the EV load on the electric grid, if these policies imply a reduction in the range available at the end of the charging operation. This implication will be further discussed in the final paper.

References

Daina, N. 2014. *Modelling electric vehicle use and charging behaviour*. PhD thesis, Imperial College London.

Nilsson , M. 2011. Electric vehicle: the phenomenon of range anxiety. ELVIRE Consortium. Available: http://www.elvire.eu/IMG/pdf/The_phenomenon_of_range_anxiety_ELVIRE.pdf.