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Topical issues

What drives range preferences in electric vehicle users?

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ABSTRACT

While research has shown that limited-range electric vehicles (EVs) satisfy the range needs of a sizeable share of the driving population, car buyers seem to prefer vehicles with high available range. The objective of the present research was to advance understanding of the factors that influence the range preferences of potential EV customers who had the opportunity to test an EV. Data from 79 participants who had driven an EV for 3 months was assessed in a field study setting. Range preferences of those users were found to be substantially higher than their average range needs. Regression analyses indicated that higher average range needs, higher range of the driver's familiar combustion vehicle (CV), and greater experienced range anxiety were related to higher range preferences. Furthermore, we found that range preferences decreased over the first 3 months of EV use. Finally, indicators of average range needs were more strongly associated with range preferences as EV experience increased. Thus, only customers with EV experience seem to rely on accurate estimates of their range needs when constructing their range preferences. Implications for strategies aimed at enhancing customer appraisal of limited range mobility and determining optimal EV range are discussed.

1. Introduction

What is the optimal range of an electric vehicle (EV)? This question is consistently raised in conjunction with efforts to develop sustainable and marketable EVs, and has yielded substantially disparate answers: evidence suggests that range needs of a sizeable share of the current car fleet could be covered with 100-mile range per charge (Pearre et al., 2011). However, potential customers have repeatedly been found to prefer vehicles with considerably higher available range (Dimitropoulos et al., 2011).

This paradoxical disparity has been noted frequently in the literature (e.g., Giffi et al., 2011; Kurani et al., 1994) and various explanations for high range preferences have been suggested, such as inaccurate conceptions of usual mobility needs (Kurani et al., 1994), high anchors for estimating required range stemming from experience with combustion vehicles (CVs; Kurani et al., 1994), range anxiety (Nilsson, 2011), and lack of experience with limited range mobility (Kurani et al., 1994). However, research that examines these assumptions is lacking. Moreover, it has been argued that examining the range preferences of respondents without EV experience, as most previous studies did, may not be a useful approach for determining truly marketable EV range in more mature markets. Accordingly, researchers have recommended that studies of range preferences should include samples of drivers with EV experience (Kurani et al., 1994).

The objective of the present research was to increase understanding of range preferences of potential EV customers with practical EV experience and of the factors driving those preferences. To this end, a field trial approach was applied in which 79 EV users drove an EV for 3 months and provided extensive objective and subjective data. We studied the disparity between range needs and range preferences and examined potential explanatory variables for range preferences. This research aims to provide data needed to guide the development of measures for reducing the gap between range needs and range preferences, and to support customers in selecting more sustainable EV setups.

2. Background

2.1. The EV range paradox

The battery of a fully electric vehicle is a precious resource. Its efficient layout is critical for environmental utility, as it uses a sizeable amount of energy and rare mineral resources for production and, consequently, has a substantial impact on the ecological footprint of an EV (McManus, 2012). Moreover, more battery capacity results in a higher purchase price and, thus, lower affordability and cost-effectiveness (Neubauer et al., 2012). Hence, from a sustainability perspective, the optimal EV range is the smallest sufficient range.

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Determining sufficient EV range has been the focus of numerous studies examining data on travel behavior. For example, findings based on representative data of everyday automobile usage in Germany show that on a typical day, 95% of cars on the road travel less than 100 km (Öko-Institut, 2011). Similar figures have been reported for other European countries (Bunzeck et al., 2011). However, this criterion has been criticized for underestimating range needs, because a vehicle that can cover an average, or typical, day will not satisfy user needs on many days (Greene, 1985). Consequently, other indicators have been studied, for instance, the longest daily travel distance per year (Greene, 1985; Pearre et al., 2011), per week (Chlond et al., 2012) or on a certain energy critical day (Sammer et al., 2011). Still, these studies show that the currently common 100-mile range of EVs is sufficient for a sizeable share of the car driving population (see overview in Table 1).

However, since acceptance and marketability are fundamental factors of sustainability of EVs, optimal range depends not only on range needs (objectively sufficient range), but also on customer preferences. In previous EV range preference studies, two major methodological approaches have been used (see also Table 2). First, numerous studies used the direct stated preference approach, which requires respondents to indicate a numerical range value that matches a certain utility level (e.g., minimum required range for purchase or minimum acceptable range). For instance, stated preference data for Germany indicate that the average customer wants a range of approximately 340 km (Bunzeck et al., 2011 [328 km]; VDE, 2010 [353 km]). Studies on the European (Bunzeck et al., 2011 [308 km]) and world-wide level (Bronchard et al., 2011 [437 km]) report similar or higher figures.

Second, numerous studies have employed the indirect hypothetical approach with choice-based conjoint analyses (i.e., discrete choice experiments) or contingent ranking tasks. A recent meta-analysis of 31 studies examining customer valuation of driving range (Dimitropoulos et al., 2011) reveals that the compensating variation for increasing range from 100 to 350 miles would be 16,200 US$. The authors conclude that EVs with a 100-mile range would have to be priced 50% cheaper than comparable CVs to be competitive. A similar pattern of results is revealed by Daziano (2013) analysis of choice experiment data. Using the

Table 1
Results from previous studies on range needs.

Study	Sample	Results
infas and DLR (2010)	$N=60{,}713$; representative for German population (MiD).	On average, people in Germany travel 39 km per day (one-day travel diary).
Öko-Institut (2011)	Analysis of data collected in MiD 2008 (infas and DLR, 2010).	80% of vehicles travel less than 50 km per day, 95% less than 100 km. On average, 12 trips per year exceed a driving range of 160 km.
Zumkeller et al. (2011)	$N=1800$; representative for German population (MOP).	On average, people in Germany travel 41 km per day (7-day travel diary).
TÜV Rheinland (2011)	$N=1000$; considered representative for Germany.	On average, 91% of German respondents drive less than 100 km per day, 61% of them less than 50 km.
Bunzeck et al. (2011)	$N=1899$ respondents from 7 EU countries.	61% of European participants drive less than 100 km per day, 24% even less than 20 km. 15% drive more than 150 km per day.
Giffi et al. (2010)	$N>13{,}000$ respondents from 17 countries worldwide.	78% of German respondents drive less than 80 km on a typical weekday.
Pearre et al. (2011)	$N=484$ cars in Atlanta, Georgia greater metropolitan area.	The mean daily driving distance is 45 miles (median: 30 miles). On average, the daily driving range exceeds 100 miles on 23 days per year and 150 miles on 9 days per year. An EV with 100 miles driving range could fully satisfy 9% of the drivers.
Krumm (2012)	$N=150{,}147$ US households (representative).	The mean daily distance of US drivers on a random weekday is 38.4 miles. An EV with 60 miles driving range would satisfy 83%, while 80 miles would be suitable for 90% and 120 miles for 95% of the US drivers.

Table 2
Results from previous range preference studies.

Method	Study	Sample	Results
Direct approach	VDE (2010)	$N=1000$; German residents >14 years of age (representative).	The average German resident considers 353 km driving range to be acceptable.
	ADAC (2013)	$N=803$ (2011) vs. 507 (2013) ADAC members.	In 2011 74% of ADAC (German automobile club) members desired an EV range of more than 200 km. In 2013, this decreased to 50%.
	Bunzeck et al. (2011)	$N=1899$ respondents from 7 EU countries.	European respondents require 308 km driving range on average; for German consumers, this figure is somewhat higher (328 km).
	Giffi et al., 2011	$N>13{,}000$ respondents from 17 countries worldwide.	60% of German respondents want an EV to have more than 320 km driving range before they would consider a purchase.
	Bronchard et al. (2011)	$N=7003$; representative for the general population of 12 countries worldwide.	In order to consider purchasing an EV, people worldwide would prefer to have a range of at least 437 km.
	Zpryme (2010)	$N=1046$; representative for US drivers.	On average, US drivers consider 294 miles driving range to be acceptable.
Indirect approach	Dimitropoulos et al. (2011)	Meta-analysis of 31 discrete choice and contingent ranking studies.	Compensating variation to extend driving range from 100 to 150 miles is 3500 US$ (16,200 US$ from 100 up to 350 miles). Willingness to pay for one-mile increase in driving range between 47 and 64 US$.
	Daziano (2013)	$N=500$ California residents.	An EV is perceived as attractive as a gasoline vehicle if its driving range reaches 330 miles. However, if operating costs are integrated into the analysis, the estimate decreases to 180 miles (assuming comparable prices of EV and gasoline vehicle).
	Hoen and Koetse (2012)	$N=1802$ Dutch drivers.	Willingness to pay for an increase of driving range reaches its maximum in lower range areas, i.e., consumers are highly motivated to avoid low EV driving ranges.