Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 72 (2023) 1296–1302

Transportation Research Procedia

www.elsevier.com/locate/procedia

Transport Research Arena (TRA) Conference

Battling the large car boom: How to increase the adoption of small battery electric vehicles

Raphael Hoerler[a1], Thomas Stoiber[b], Andrea Del Duce[a]

[a]Institute for Sustainable Development, Zurich University of Applied Sciences (ZHAW), Technikumstrasse 9, 8401 Winterthur, Switzerland
[b]Department of Social Sciences, University of Basel, Vesalgasse, 4051 Basel, Switzerland

Abstract

The transport sector needs to be decarbonized drastically to meet the goal of the Paris Agreement. Yet, we see a trend towards heavier and larger cars in new car registrations, leading to higher greenhouse gas emissions. By conducting a choice experiment with 859 Swiss households, we estimate the probability of conventional car owners to switch to owning a small BEV for everyday trips in combination with either public transport or carsharing/car-rental for the occasional long-range trips. Through binary logistic regression, we test several variables related to socio-demographics, mobility characteristics, attitudes and values in increasing the odds to switch to one of the alternatives. We provide relevant guidance to policy makers and transport planners in increasing the uptake of small BEVs in combination with mobility services in order to counter the trend towards large cars.

Keywords: Sustainable mobility; battery electric vehicle; carsharing; car size; choice experiment; attitudes and values

1. Introduction

There is common agreement amongst policy makers, mobility planners and scientists that private car mobility, which still mostly depends on fossil fuels, is one of the main contributors to CO_2 emissions, noise, air pollution, accidents and congestion. Technological advances are among the various possibilities to increase sustainability. In particular, electrified cars fuelled with renewable electricity can lead to considerable CO_2 emission reductions (Bauer et al., 2015; Franzò & Nasca, 2021). In this context, battery electric vehicles (BEVs) are gaining in share of total new car registrations around the globe. Norway, for example, has reported a share of BEV on new car registrations of over 80% in 2022 so far, fortifying their lead in BEV market share of new car registrations (European Alternative Fuels Observatory, 2022). But there is also significant growth in BEV sales in other countries such as China and USA (IEA, 2022). In view of these developments, it is expected that a substantial share of BEVs will be bought in the future. In

[1]* Corresponding author. Tel.: +41 58 934 47 10.
E-mail address: raphael.hoerler@zhaw.ch

10.1016/j.trpro.2023.11.590

line with the United Nations Sustainable Development Goals and the Paris Agreement, it is undoubtedly imperative to continue fostering a substantial uptake of electric vehicles in private car mobility, in order to move towards a more sustainable, decarbonized transport system. However, the trend towards large cars and sportive-utility-vehicles (SUVs) is increasing (JATO, 2021). Simply replacing current fossil fuel cars with a large and high range BEV bears several risks: Firstly, large cars increase fatal pedestrian crashes (Tyndall, 2021). Secondly, facing the characteristics of electric cars, considerable CO_2 and other pollutant emissions result from car production and strongly depend on the battery capacity, which usually increases with larger BEVs (Franzò & Nasca, 2021). Thirdly, through the extensive success of SUVs, the average size of cars has been increasing considerably during the last decades, leading to higher consumption of raw materials in vehicle production and higher fuel consumption in the use phase of vehicles (Craglia, 2020). Finally, in view of the expected population growth, road infrastructure will increasingly face capacity limits with negative effects on quality of life in cities. Competition with alternative utilizations of public space, as well as increasing congestion and car presence are among the impacts if the stock of vehicles (and particularly large vehicles) continues to increase (Henderson, 2020). With regards to private car utilization, small BEVs with smaller batteries (i.e., smaller car, shorter range) are sufficient for most of the daily, routinary mobility needs (Melliger et al., 2018). In conjunction with other mobility solutions (e.g., carsharing, car-rental, public transport) for more uncommon purposes (e.g., long-range trips, transport with luggage), a small BEV would lead to lower environmental impacts from vehicle production and less energy demand from travelling. Such an alternative multimodal mobility lifestyle combining the ownership of a small BEV for everyday trips and using mobility services for more occasional long-range trips has, to the best of the authors knowledge, only been considered by qualitative research so far (e.g., Sprei and Ginnebaugh (2018)). A study specifically investigating this relationship of small BEV in combination with mobility servicers through a stated preference study is missing.

Hence, our research focused on whether conventional car owners are open to switch to a small BEV for shorter everyday trips (daily distance less than 200km) in combination with one of the following alternatives for long-range trips (daily distance more than 200km) undertaken less frequently: Firstly, a combination with public transport and secondly, a combination with carsharing/car-rental. We further investigated what factors the preference for either a conventional vehicle or a combination of small BEV with one of the mobility service options depend on. In this respect, we formulated the following research question:

What socio-demographic factors, mobility characteristics, attitudes and values could increase the probability of consumers owning conventional cars to switch to a small BEV in combination with either public transport or carsharing/car-rental?

2. Methodology

2.1. Survey

In order to answer the research question, we created a choice experiment within the Swiss Household Energy Demand Survey 2020 (SHEDS). SHEDS is representative for age, gender and tenancy status for the German- and French speaking population of Switzerland. For more information about SHEDS, refer to Weber et al. (2017). In total, 1175 respondents took part in the survey, from which 859 possess at least one household car. SHEDS contains a large set of socio-demographic variables (e.g., gender, income, household size), mobility characteristics (e.g., number of cars in households, car size, public transport passes, mode choice), attitudes and values (e.g., importance of owning a car, biospheric values).

The survey is structured in 4 parts:

1. Questions on mobility behaviour
2. Introduction to the choice experiment
3. Choice experiment
4. Follow-up questions

The first part includes questions about the respondents' car and car use characteristics like the yearly kilometres driven, fuel type, and price of the car. In the second part of the survey, respondents are told to imagine a hypothetical scenario: The main household car breaks down and cannot be repaired any more. In the third part, the respondents are offered two options to choose from: Firstly, whether to buy a similar car again (same size and engine) and secondly, to switch to an alternative mobility lifestyle replacing their current car and all car trips conducted with that car. In total, we tested two alternative mobility lifestyles. Table 1 provides an overview of these alternatives.

Table 1. Overview of alternative mobility lifestyles.

Options in the binary choice task	Description
Conventional car	A car similar to the respondents' current main household car
Alternative 1: BEV + PT	Small BEV for everyday trips (until 200 km a day) and public transport for long-distance trips
Alternative 2: BEV + CS	Small BEV for everyday trips (until 200 km a day) and carsharing/car rental for long-distance trips

In the fourth part of the survey, the respondents had the opportunity to reflect on the decisions in the choice experiment, stating the likelihood that they would really switch to the alternatives proposed under real-life conditions.

The threshold of 200 km per day (see section 1), ensures that a currently commercially available small BEV (e.g., Renault Zoe or BMW i3) would be capable to cover this distance even in bad weather conditions that would reduce the range of the car (e.g. during winter) (Hao et al., 2020). The Renault Zoe is characterized with a range of 342 km according to the worldwide harmonized light vehicles test procedure (WLTP), while the BMW i3 has a range of 310 km according to WLTP.

2.2. Choice experiment

The choice experiment was structured as a binary choice task in the form shown in Fig. 1. Option 1 corresponds to the respondents' current car and relates to preliminary answers in the survey (e.g. purchase prize, fuel cost). Option 2 is either alternative 1 or alternative 2. For both options, we provide a short description, the car price, and the variable cost according to the individual mobility behaviour of the respondent. Furthermore, we provided information on gas stations available, charging stations, or carsharing availability (depending on the alternative proposed). This information varied with the assignment of the respondents to one of four treatment groups. These treatment groups were implemented to study measures for increasing the attractiveness of the proposed alternatives. The analysis of these treatment group effects is not within the research objective of this conference paper, and therefore not mentioned in the following.

Fig. 1. Example choice task for the control group regarding alternative 1 as shown to the survey respondents.

2.3. Statistical analysis

In order to study the influence of user characteristics on the choices conducted within the experiment, we included 26 independent variables related to socio-demographics, mobility characteristics, attitudes and values. The full list of variables and can be received upon request.

We used binary logistic regression to estimate the effect of the independent variables on the probability to choose the proposed alternative over the conventional car. The full 26 variables were initially included in the regression and were subsequently removed if they didn't increase the model fit (Nagelkerke R-squared). We further conducted a Hosmer-Lemeshow test to see whether the observed event rates match the expected event rates in the population subgroups. Last, we ensured to have at least 10 cases per degree of freedom to minimize overfitting and checked for any multicollinearity between the 26 variables finding no correlation above $r = 0.6$.

3. Results

The omnibus chi-square test of the binary logistic regression is strongly significant for both dependent variables: $\chi 2$ (df = 24) = 138.36, $p < 0.001$ (switch to alternative 1), $\chi 2$ (df = 24) = 111.79, $p < 0.001$ (switch to alternative 2). The Nagelkerke R-Squared is 0.22 for alternative 1 and 0.18 for alternative 2, explaining 22% and 18% of the variance in switching to alternative 1 and alternative 2, respectively. Last the Hosmer-Lemeshow test is non-significant for both alternatives suggesting that the model is a good fit.

Fig. 2 provides the results of the binary logistic regression in the form of odds ratios and a 95% confidence interval for alternative 1 (BEV + PT) and alternative 2 (BEV + CS). Only variables are depicted that have at least one significant effect with regard to one of the two variables. A positive odds ratio states that the variable leads to an increase in the probability to choose the alternative. The reference category is shown in parentheses. As an example, female participants are significantly less likely to switch to alternative 1 compared to men.

Regarding socio-demographic variables, the most influential variables are income and age. Generally, people with a lower income are less likely to switch to the alternatives. Older individuals (35-54 years and 55+ years) are less likely to switch than their younger counterparts (18-34 years old). This is especially relevant regarding the switch to alternative 1. People aged 55+ are slightly less likely to indicate a switch to alternative 2 as well, yet this is only significant on the $p < 0.1$ level. People living in the countryside are more likely to indicate a switch to alternative 1 and alternative 2 compared to people living in the city.

We find some mobility characteristics to influence the probability to switch to either one of the alternatives. People dominantly choosing soft modes (e.g., bicycle, walking) for leisure trips are significantly more likely to switch to both alternatives. Also, owning a public transport pass significantly increases the odds to switch to alternative 1 and 2. Further, having experience with carsharing (through companies or friends) increases the odds to switch to both alternatives. Instead, people having more than 6 trips per year exceeding a cumulative daily distance of 200 km are less likely to switch. Regarding overnight trips exceeding 200 km (one-way), we find a trend that respondents are less open to switch when having more than 2 overnight trips per year exceeding the 200 km threshold, yet this is only significant on $p < 0.1$ level.

Attitudes and values also influence the probability to switch to the alternatives. Importance of having nice possessions and importance of having a private car reduce the odds to switch to both alternatives, with stronger negative effects regarding alternative 2 (BEV + CS). Contrary, altruistic and biospheric values increase the odds to switch to the alternatives.

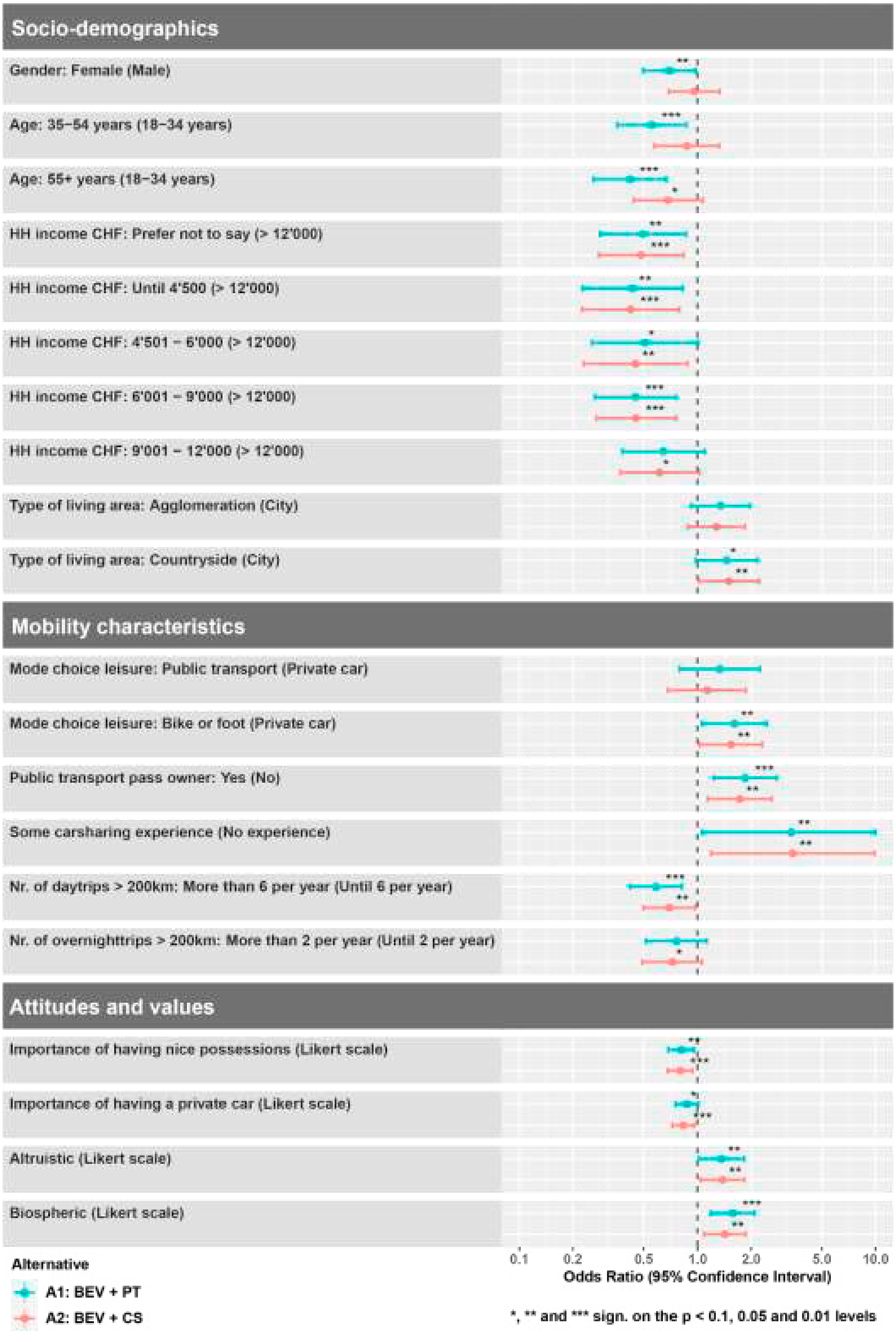

Fig. 2. Summary of the binary logistic regression results in switching to alternative 1 and alternative 2.

4. Discussion and conclusion

The results suggest that experience with mobility services like public transport and carsharing might increase the probability to switch from previously owning a conventional car to owning a small BEV in combination with either public transport or carsharing/car-rental. This result underlines the finding from Hoerler et al. (2021) that carsharing experience could increase the probability to buy a small to mid-sized BEV when replacing the next car. In order to reduce the uptake of large cars in the future, providing experience with high quality long distance public transport, as well as carsharing and other car-rental services - and thereby guaranteeing the availability of long-range alternatives for the unusual long trips - thus seems to be one possible strategy to counter the ongoing trend towards heavier and larger cars. This could be further supported by targeted communication campaigns to the younger, middle-income households living in the countryside. Especially since younger generations start to see less value in the car as a means of status symbol (Delbosc & Currie, 2014; Zhang & Jiang, 2020), we see a mutual relationship with our results regarding the importance of having nice possessions and the importance of having an own car. Low importance of having nice possessions and importance of having an own car both increase the odds to switch to either a combination of a small BEV with public transport and a small BEV with carsharing/car-rental.

Our results further provide insights into the importance of values in increasing the openness to the alternative mobility lifestyles. Especially altruistic and biospheric values significantly increase the openness to switch to one of the alternatives. The accelerating warming of the planet, the new publications from the IPCC (IPCC, 2022) and the climate-strike movements around the globe (Cologna et al., 2021) create a social, cultural and political environment in which biospheric values are getting more important. Such a trend seems to be crucial in accelerating a transformation in the mobility sector where the traditional mindset of owning a car that is capable of satisfying all trip needs (e.g., holidays, large luggage) is still prevalent (Noel et al., 2019).

Our results might be used by policy makers and mobility planners to spur the adoption of both, small BEVs and mobility services like public transport, carsharing and car-rental, in an integrated manner. It also widens the discussion about the potential benefits of new mobility services like Mobility as a Service (MaaS), which could serve as a complement to a small BEV. Our results together with the results of Hoerler et al. (2020) show that experience is key in accelerating the uptake of new mobility services creating a mutualistic relationship between small BEVs and mobility services.

With respect to the limitations of the study, a main aspect is in the design of the choice experiment, where we fixed the alternative to a small BEV. People might not stick to their current car but prefer a mid-sized or large BEV. As such, we don't know whether people who chose their current car instead of the alternative, would be open to switch to a BEV. We will address this limitation with an additional survey focusing on the car size and electric vehicle range preferences of Swiss residents. Further, our survey was conducted in the midst of the corona pandemic, which also might have affected preferences with regard to mobility. Finally, the electric car boom that is currently observable, had not yet begun during data collection. This might have resulted in an under-estimation of the e-car-preference compared to nowadays.

Acknowledgements

We would like to acknowledge the access to the SHEDS database provided by the University of Neuchatel. This research was supported by the Swiss Competence Center for Energy Research (SCCER) Efficient Technologies and Systems for Mobility and SCCER CREST, funded by Innosuisse.

References

Bauer, C., Hofer, J., Althaus, H.-J., Del Duce, A., & Simons, A. (2015). The environmental performance of current and future passenger vehicles: Life cycle assessment based on a novel scenario analysis framework. *Applied Energy*, *157*, 871–883. https://doi.org/10.1016/j.apenergy.2015.01.019

Cologna, V., Hoogendoorn, G., & Brick, C. (2021). To strike or not to strike? An investigation of the determinants of strike participation at the Fridays for Future climate strikes in Switzerland. *PLOS ONE*, *16*(10), e0257296. https://doi.org/10.1371/journal.pone.0257296

Craglia, M. A. M. (2020). *The role of technical improvements in decarbonising passenger transport* [Thesis, University of Cambridge]. https://doi.org/10.17863/CAM.59355

Delbosc, A., & Currie, G. (2014). Using discussion forums to explore attitudes toward cars and licensing among young Australians. *Transport Policy*, *31*, 27–34. https://doi.org/10.1016/j.tranpol.2013.11.005

European Alternative Fuels Observatory. (2022). *Vehicles and fleet | European Alternative Fuels Observatory*. https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road/norway/vehicles-and-fleet

Franzò, S., & Nasca, A. (2021). The environmental impact of electric vehicles: A novel life cycle-based evaluation framework and its applications to multi-country scenarios. *Journal of Cleaner Production*, *315*, 128005. https://doi.org/10.1016/j.jclepro.2021.128005

Hao, X., Wang, H., Lin, Z., & Ouyang, M. (2020). Seasonal effects on electric vehicle energy consumption and driving range: A case study on personal, taxi, and ridesharing vehicles. *Journal of Cleaner Production*, *249*, 119403. https://doi.org/10.1016/j.jclepro.2019.119403

Henderson, J. (2020). EVs Are Not the Answer: A Mobility Justice Critique of Electric Vehicle Transitions. *Annals of the American Association of Geographers*, *110*(6), 1993–2010. https://doi.org/10.1080/24694452.2020.1744422

Hoerler, R., Stünzi, A., Patt, A., & Del Duce, A. (2020). What are the factors and needs promoting mobility-as-a-service? Findings from the Swiss Household Energy Demand Survey (SHEDS). *European Transport Research Review*, *12*(1), 27. https://doi.org/10.1186/s12544-020-00412-y

Hoerler, R., van Dijk, J., Patt, A., & Del Duce, A. (2021). Carsharing experience fostering sustainable car purchasing? Investigating car size and powertrain choice. *Transportation Research Part D: Transport and Environment*, *96*, 102861. https://doi.org/10.1016/j.trd.2021.102861

IEA. (2022). *Electric cars fend off supply challenges to more than double global sales – Analysis*. IEA. https://www.iea.org/commentaries/electric-cars-fend-off-supply-challenges-to-more-than-double-global-sales

JATO. (2021). *European new car market starts 2021 with record market share for SUVs*. https://www.jato.com/european-new-car-market-starts-2021-with-record-market-share-for-suvs/

Melliger, M. A., van Vliet, O. P. R., & Liimatainen, H. (2018). Anxiety vs reality – Sufficiency of battery electric vehicle range in Switzerland and Finland. *Transportation Research Part D: Transport and Environment*, *65*, 101–115. https://doi.org/10.1016/j.trd.2018.08.011

Noel, L., Zarazua de Rubens, G., Sovacool, B. K., & Kester, J. (2019). Fear and loathing of electric vehicles: The reactionary rhetoric of range anxiety. *Energy Research & Social Science*, *48*, 96–107. https://doi.org/10.1016/j.erss.2018.10.001

Sprei, F., & Ginnebaugh, D. (2018). Unbundling cars to daily use and infrequent use vehicles—The potential role of car sharing. *Energy Efficiency*, *11*(6), 1433–1447. https://doi.org/10.1007/s12053-018-9636-6

Tyndall, J. (2021). Pedestrian deaths and large vehicles. *Economics of Transportation*, *26–27*, 100219. https://doi.org/10.1016/j.ecotra.2021.100219

Weber, S., Burger, P., Farsi, M., Martinez-Cruz, A. L., Puntiroli, M., Schubert, I., & Volland, B. (2017). *Swiss Household Energy Demand Survey (SHEDS): Objectives, design, and implementation* (Working Paper Nr. 17–14). IRENE Working Paper. https://www.econstor.eu/handle/10419/191509

Zhang, J., & Jiang, Y. (2020). An introduction to the special issue of young people's life choices and travel behavior. *Transportation Research Part D: Transport and Environment*, *85*, 102477. https://doi.org/10.1016/j.trd.2020.102477