Impact of Public Charging Infrastructure on the Adoption of Electric Vehicles in London

Shaherah Jordan[1], Darryl Newport, Stephanie Sandland, Paula Vandergert

[1] University of East London, Sustainability Research Institute, Knowledge Dock, 4-6 University Way, London E16 2RD

Keywords: Behaviour Change, Public Charging Infrastructure, Electric Vehicles.

Abstract *The discussion on the importance of public charging infrastructure is usually framed around the 'chicken-egg' challenge of consumers feeling reluctant to purchase without the necessary infrastructure and policy makers reluctant to invest in the infrastructure without the demand. However, public charging infrastructure may be more crucial to EV adoption than previously thought.*

Historically, access to residential charging was thought to be a major factor in potential for growth in the EV market as it offered a guaranteed place for a vehicle to be charged. However, these conclusions were reached through studies conducted in regions with a high percentage of homes that have access to residential parking.

The purpose of this study is to understand how the built environment may encourage uptake of EVs by seeking a correlation between EV ownership and public charging points in an urban and densely populated city such as London.

Using a statistical approach with data from the Department for Transport and Zap Map, a statistically significant correlation was found between the total (slow, fast and rapid) number of public charging points and number of EV registrations per borough – with the strongest correlation found between EV registrations and rapid chargers.

This research does not explicitly prove that there is a cause and effect relationship between public charging points EVs but challenges some of the previous literature which indicates that public charging infrastructure is not as important as home charging. The study also supports the notion that the built environment can influence human behaviour.

Introduction

As part of the London Mayor's drive to make London a zero-emission city by 2050, the London Mayor has pledged to have 150 rapid charging points installed in the capital by the end of 2018. Understanding how public charging infrastructure impacts consumer behaviour and ultimately the adoption of plug-in electric vehicles (PEVs) in London is important due to the high cost of installation.

Public charging forms part of the built environment, and the built environment has been found to influence changes in travel behaviour across studies on different continents after accounting for attitude-induced self-selection (Milakis, Efthymiou and Antoniou, 2017). Behaviours researched across the studies covered modes such as driving, walking and cycling;

and related to behaviours like a switch in transport mode such as driving to walking, or the reduction of the use of transport which considerably contributes to high emissions such as driving (Milakis, Efthymiou and Antoniou, 2017).

As charging time, range anxiety and purchase price are the most commonly cited barriers to EV adoption (Hidrue *et al.*, 2011; Egbue and Long, 2012; Carley *et al.*, 2013), addressing the role of public charging infrastructure in the equation could be advantageous in the efforts to encourage uptake. According to Carly et al (2013, p. 45) 'range anxiety could be addressed by increasing the number and visibility of public charging stations'.

Although self-efficacy is key to behaviour change, 'capability, opportunity and motivation must exist for any behaviour to occur' (Michie, Atkins and West, 2014, p. 59) and an adequate public charging network addresses capability and opportunity where the operation of an electric vehicle is concerned. While there has been some discussion regarding the importance of access to residential charging as a factor for PEV adoption in the UK, analysis of London PEV registration data shows that prevalence of public charging points could be a greater factor in the adoption of PEVs. Furthermore, as residential parking is less prevalent in urban areas, understanding how and where the public charging infrastructure should be installed is important in ensuring that it allays range anxiety.

Literature Review

The current body of work regarding charging type and PEV adoption is arguably divided with some studies indicating that access to residential charging is a key factor in PEV adoption and other studies indicating that public charging infrastructure is the key factor.

Stated preference studies (Hidrue *et al.*, 2011; Hackbarth and Madlener, 2013) indicate that having a place to charge a PEV increased the likelihood of respondents to consider purchasing a PEV. In addition to the limitations associated with stated preferences, much of the research exploring access to charging as a driver of PEV uptake, were conducted in the United States where at least half of the homes have access to residential charging.

In their study amongst new car buying households (Axsen and Kurani, 2012), more than three quarters of the respondents who expressed an interest in making their next vehicle an EV, had the ability to install a charge point.

In addition to academic literature, a report from the London Environmental Committee (2018) states that residents with off street parking tended to be the early adopters of PEVs due to the accessibility of charging.

The literature focused on public charging infrastructure points towards it being a positive factor, however, the conditions under which it has the most impact varies, as do the potential reasons why.

Charge infrastructure has been shown to reduce the impact of range anxiety (Neubauer and Wood, 2014, p. 20) and it has been argued that it will be crucial to the early stages of PEV diffusion due to its practical and psychological function (Bakker, 2011).

A study by the Tokyo Electric Power Company exploring the driving and charging habits of PEV drivers before and after the installation of a charging point found that there was little use of the public charging point but that the distance drivers travelled increased considerably after installation and they returned with less stored battery power than before (Bakker, 2011).

The real potential for impact on EV growth may be found in the combination of access to both public and residential charging, with public charging seeing as the supplement to residential charging (Lin and Greene, 2011)

However, it has also been posited that awareness of public chargers was not deemed to be 'the most significant determinant of PEV interest' (Bailey, Miele and Axsen, 2015, p. 9). One of the limitations flagged in the study by Bailey was that 'consumer interest, perception and technology acceptance were not tested'.

Finally Bonges and Lusk (2016) looked into various factors associated with public charging points such as how the design of parking spaces and chargers for PEVs could limit access to the charging point. The social side of public charging points such as etiquette, best practice and the current limits to the enforcement of best practice was also explored in Bonges' study.

Due to the disparity in literature pertaining to charging, the relationship between EV registrations and housing type was explored statistically, with the results indicating that access to residential charging may not be as strong of a factor as previously believed.

Using data from the Department for Transport (DfT) and Nomis, a correlation was sought between the number of PEV registrations per borough and the number of detached and semi-detached houses per borough. Housing stock was chosen as the variable as detached and semi-detached properties are the property types most likely to have the potential for off street parking and ultimately home charging installation. Furthermore, analysing the data in this way was reflective of how the data was analysed in the study by Axsen and Kurani (2012).

Using this approach, the correlation between detached and semi-detached houses in was found to be weak (0.1311589 and 0.00920882 respectively). In fact, the strongest correlation was found between flats and EV registrations in 2011/2012 (0.529) when PEV registrations were first being recorded. This correlation was statistically significant.

The results of this analysis led to questions as to whether using the same methodology would illustrate a similar trend with public charging points.

This paper seeks to understand the impact of public charging infrastructure on EV adoption in London using existing data. For the purpose of this study, public charging refers to charging points that are installed in public.

Hypotheses

The total number of public charging points per borough is a factor in PEV adoption.

There is no difference between the type of charging point (speed) and the adoption of PEVs per borough.

Charging points in combination with housing type have a positive effect on PEV registrations.

Research Method

Secondary analysis of existing data was selected as a research method as the data was readily available and could be analysed quickly. Given the nature of the research question, using existing data was able to more quickly answer the research question than primary research involving respondents. Furthermore, previous studies that suggest that public charging is a factor in PEV adoption are based on stated preference choice models (Batley, Toner and Knight, 2004; Achtnicht, Buhler and Hermeling, 2012; Hackbarth and Madlener, 2013).

Statistical analysis was conducted on 1) the number of public charging points per borough, 2) percentages of housing stock type per borough and the 3) number of registered PEVs per borough.

Charging point data for Q2 of 2018 was sourced from Zap Map who hold the data on the charging points in the UK – both publicly and privately funded. The data was segmented into rapid chargers (43kw), fast chargers (7 – 22kw) and slow chargers (3kw) and the total number of connectors.

Housing stock data was sourced from the Office of National Statistics and was segmented into five categories: detached, semi-detached, combined detached and semi-detached, terraced and flats. Detached and semi-detached properties were combined as a segment because percentages of each type of housing stock were relatively low across London.

The data on EV registrations per borough in Q2 2018 was sourced from the Department for Transport.

Correlation and chi tests were performed on the charging point and PEV registration data to understand if there was a relationship between the number of public charging points available per borough and the number of PEV registrations per borough, and how strong the correlation was.

The same tests were performed on the housing type and PEV registration data, after which a pcor test was performed, where the PEV registration was x, housing type was y and the number of charging points was z. Each of the different types of charging points were analysed in this way.

After this a correlation test was run to ascertain the strength of the correlation between connector types and PEV registrations per borough.

The main limitation to this approach is the sample size. There were 2.665m cars on London roads in Q1 of 2018 and of which 14,466 were plug-in cars, LGVs and quadricycles (VEH0131). The ideal sample size of for this type of analysis would be 19,800 based on a confidence level of 95 per cent and a confidence interval of 4.

In addition to this, this data contains details of cars registered to car clubs in London. In many instances cars in car clubs would be registered to one address in a borough which may slightly skew the data, particularly as the sample size is already small.

Lastly, although the car registration data was available at borough level, a more accurate correlation may have been able to be drawn had the data been available at ward level.

Results

Hypothesis: The total number of public charging points per borough is a factor in PEV adoption.

A positive high degree of correlation was found between the number of PEVs registered per borough and the number of total connectors (0.530).

Hypothesis: There is no difference between the type of charging point (speed) and the adoption of PEVs per borough.

When testing the correlation between PEV registrations per borough and the different types of connectors (slow, fast and rapid) the strength of the correlation between rapid chargers was the strongest 0.61. The strength of the correlations between slow chargers and fast chargers was relatively similar with correlations of 0.466 and 0.437 respectively.

Hypothesis: Charging points in combination with housing type have a positive effect on PEV registrations.

The introduction of housing type as a variable had only a slight impact on the correlation between PEV registrations and total connectors per borough.

There was a positive high degree of correlation between total connectors and PEV registrations per borough (0.530). This level of correlation remains the same when detached properties (0.576), semi-detached properties (0.551) a combination of detached and semi-detached properties (0.560) and flats (0.529) were introduced as factors.

This drops slightly to a moderate degree of correlation when terraced properties (0.490) are introduced as a factor.

Discussion

These results are promising in as much that they support the case for investment into public charging infrastructure, however, factors such as location are thought to be critical in the efforts to increase EV adoption (Azadfar et al). Commercial locations and areas where people linger, such as restaurants, hotels, shopping malls, churches and entertainment venues - are considered more promising locations for installation of EVSE (Bakker, 2011, p. 50).

The strong correlation between rapid chargers and PEVs is another positive result, however, due to the potential for accelerated battery degradation with overuse of rapid chargers, it would be advantageous to educate drivers accordingly. Furthermore, although access to rapid chargers is likely to encourage longer journeys and ultimately appeal to the public to adopt EVs more rapidly (Azadfar, Sreeram, & Harries, 2015) usage patterns remain very low (Bakker, 2011, p. 56)

Industry insight indicates that fuelling behaviour differs from ICE to EV driver in that EV drivers are more opportunistic in the way that they charge, and are more likely to charge because of convenience as opposed to battery depletion (Azadfar, Sreeram and Harries, 2015).

Conclusion

Although the role of the built environment on transport has been explored from various angles and looks at various modes, PEV ownership is at a unique cross-section of greener travel, technology adoption and a change in fuelling behaviour as opposed to travel behaviour. This makes identifying the factors for behaviour change more challenging.

Built environment characteristics related to perceived outdoor spaciousness such as off-street parking have been found to influence automobile ownership after accounting for attitudes (Cao, Mokhtarian and Handy, 2007). Therefore, it is plausible that the presence of a PEV charger could influence the type of automobile someone chooses to purchase.

This study only looks at whether the number of public charging points is a factor in PEV adoption and does not explore the location, visibility, price or aesthetics of the charging points. However, given the level of investment required to roll out public charging infrastructure, this study indicates that more research needs to be done to determine the factors that make the installation of public charging more impactful in the efforts to drive PEV growth.

Yet still, evidence from this analysis shows that there is a significant enough correlation between the number of charging points per borough and the number of PEV registrations per borough to put more effort into the public charging infrastructure in a holistic way involving, quantity, location, design and visibility. Ultimately, access to charging adds to the capability that potential PEV drivers need in order to change their vehicle. This study supports existing research that identifies public charging infrastructure as an adequate response to the real and perceived barriers to PEV adoption.

Acknowledgment

Special thank you to Zap Map for providing the charging point data for this study.

References

Achtnicht, M., Buhler, G. and Hermeling, C. (2012) ‘The impact of fuel availability on demand for alternative-fuel vehicles’, *Transportation Research Part D: Transport and Environment*, 17(3), pp. 262–269. doi: https://doi.org/10.1016/j.trd.2011.12.005.

Axsen, J. and Kurani, K. (2012) ‘Who can recharge a plug-in electric vehicle?’, *Transportation Research Part D: Transport and Environment*, 17, pp. 349–353. Available at: https://pdfs.semanticscholar.org/928a/cd77c7e0eb3b49f6878ee16b7f4c1a17282d.pdf.

Azadfar, E., Sreeram, V. and Harries, D. (2015) ‘The investigation of the major factors influencing plug-in electric vehicle driving patterns and charging behaviour’, *Renewable and Sustainable Energy Reviews*. Elsevier, 42, pp. 1065–1076. doi: 10.1016/j.rser.2014.10.058.

Bailey, J., Miele, A. and Axsen, J. (2015) ‘Is awareness of public charging associated with consumer interest in plug-in electric vehicles?’, *Transportation Research Part D: Transport and Environment*. Elsevier Ltd, 36, pp. 1–9. doi: 10.1016/j.trd.2015.02.001.

Bakker, J. (2011) ‘Contesting range anxiety: The role of electric vehicle charging infrastructure in the transportation transition’, *Eindhoven University of Technology*, 18(May).

Batley, R. P., Toner, J. P. and Knight, M. J. (2004) ‘A MIXED LOGIT MODEL OF U.K. HOUSEHOLD DEMAND FOR ALTERNATIVE-FUEL VEHICLES’, *International Journal of Transport Economics*, 31(1), pp. 55–77.

Bonges, H. A. and Lusk, A. C. (2016) ‘Addressing electric vehicle (EV) sales and range anxiety through parking layout, policy and regulation’, *Transportation Research Part A: Policy and Practice*. Elsevier Ltd, 83, pp. 63–73. doi: 10.1016/j.tra.2015.09.011.

Cao, X., Mokhtarian, P. L. and Handy, S. L. (2007) ‘Cross-sectional and quasi-panel explorations of the connection between the built environment and auto ownership’, *Environment and Planning A*, 39(4), pp. 830–847. doi: 10.1068/a37437.

Carley, S. *et al.* (2013) ‘Intent to purchase a plug-in electric vehicle: A survey of early impressions in large US cites’, *Transportation Research Part D: Transport and Environment*. Elsevier Ltd, 18(1), pp. 39–45. doi: 10.1016/j.trd.2012.09.007.

Egbue, O. and Long, S. (2012) ‘Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions’, *Energy Policy*. Elsevier, 48(2012), pp. 717–729. doi: 10.1016/j.enpol.2012.06.009.

Environmental Committee (2018) *Electric Vehicles*. London. Available at: https://www.london.gov.uk/moderngov/documents/s67614/xx EVs Appendix - scoping document.pdf.

Hackbarth, A. and Madlener, R. (2013) ‘Consumer preferences for alternative fuel vehicles: A discrete choice analysis’, *Transportation Research Part D: Transport and Environment*, 25, pp. 5–17. doi: 10.1016/j.trd.2013.07.002.

Hidrue, M. K. *et al.* (2011) ‘Willingness to pay for electric vehicles and their attributes’, *Resource and Energy Economics*. Elsevier B.V., 33(3), pp. 686–705. doi: 10.1016/j.reseneeco.2011.02.002.

Lin, Z. and Greene, D. (2011) ‘Promoting the Market for Plug-In Hybrid and Battery Electric Vehicles’, *Transportation Research Record: Journal of the Transportation Research Board*, 2252, pp. 49–56. doi: 10.3141/2252-07.

Michie, S., Atkins, L. and West, R. (2014) *The Behaviour Change Wheel. A Guide to Designing Interventions*. London: Silverback Publishing.

Milakis, D., Efthymiou, D. and Antoniou, C. (2017) ‘Built environment, travel attitudes and travel behaviour: Quasi-Longitudinal analysis of links in the case of Greeks relocating from US to Greece’, *Sustainability (Switzerland)*, 9(10). doi: 10.3390/su9101774.

Neubauer, J. and Wood, E. (2014) ‘The impact of range anxiety and home, workplace, and public charging infrastructure on simulated battery electric vehicle lifetime utility’, *Journal of Power Sources*. Elsevier B.V, 257, pp. 12–20. doi: 10.1016/j.jpowsour.2014.01.075.

Table VEH0131, Plug-in cars and vans licensed at the end of quarter by location of registered keeper: United Kingdom in Ultra Low Emission Vehicles, Department for Transport, 2018, Available at: https://www.gov.uk/government/statistical-data-sets/all-vehicles-veh01, accessed 10 Feb, 2019