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Perceived Uncertainty in the Demand for Electric Vehicles: A Qualitative Assessment

Working Paper

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Abstract

The transition to Electric Vehicles (EVs) is considered to represent a primary means by which significant reductions in greenhouse gas emissions and improvements to energy security will be achieved in the transport sector of the United Kingdom. EVs are now available for purchase in the mainstream automotive market though sales rates, whilst growing annually, remain markedly low. This paper investigates the prevalence of uncertainty in the emerging market for EVs in an effort to consider its likely implications. A conceptual framework is applied which illustrates the locations of uncertainty in the EV market. A series of qualitative interviews with thirteen stakeholders form the basis of the research with thematic analysis being employed in order to identify common themes and to contemplate the location of these themes.

Specific attention is paid to how uncertainty is a *perceived* concept, with the perceptions of different stakeholders often being in conflict with each other and objective reality. Moreover, these perceived uncertainties are compared to an assessment of UK and EU government policy to evaluate the degree to which policy has so far approached perceived uncertainty. Results of the analysis suggest that uncertainty is present in a number of different locations inclusive of [1] consumer, [2] policy, [3] infrastructure, [4] technical, [5] economic and [6] social uncertainties. In places, UK and EU government policy provides a partial match to the perceived uncertainties, indicating that policy makers are responding to developments in the EV market. Some notable divergences between perceived uncertainty and government policy have also been identified.

Contents

1 Introduction

Transport in the United Kingdom (UK) represents the largest sector of energy demand, accounting for 53 million tonnes of oil equivalent in 2012 which amounts to 37.9% of final energy consumption (DECC, 2013). Of the energy demanded by the transport sector, 96.9% is provided by oil based fuels (ibid.). This situation generates two prominent concerns regarding the sustainability of the current transport system. Firstly, significant quantities of greenhouse gas (GHG) emissions originate from the transport sector, accounting for 21% of UK territorial emissions in 2012 (DECC, 2014). Of particular concern is the entrenched nature of transport GHG emissions, with transport being the only sector not to achieve significant reductions in emissions since 1990 (ibid.). Secondly, with transport being highly dependent on a single fuel source, the sector is vulnerable to changes in the price and availability of oil. The UK Government has expressed a commitment to addressing these two issues by establishing a legally binding GHG reduction target of 80% by 2050 compared to 1990 levels (Climate Change Act, Great Britain, 2008) and achieving improvements in the energy security of the transport sector (DfT, 2009a).

The introduction of Electric Vehicles (EVs) into the national fleet offers a strategy whereby the issues of GHG emissions and energy security can be partially addressed. The widespread diffusion of EVs is an objective of the UK Government, with significant political and fiscal investment having been made to realise this goal (OLEV, 2013). The Committee on Climate Change conducted a back-casting analysis to estimate the number of EV[1] sales required in order to meet the GHG emission targets, with EVs obliged to account for 9% of new car sales by 2020 (CCC, 2013) to put the UK on course for 60% of new car sales to be EVs by 2030. Examining sales rates in the current UK market, there were 1, 742 new registrations of EVs in 2012, which accounts for 0.08% of total new car registrations (DfT, 2013). In order to reach the sales requirements estimated by the Committee of Climate Change, registration rates of EVs will have to double every year to 2020. To provide some perspective to the scale of this challenge, the average annual growth in registrations of Hybrid Electric Vehicles in the UK between 2005 and 2012 was 17.5% (ibid.).

Understanding the potential factors which are limiting the demand for EVs has the potential to offer guidance in the development of strategies to reduce and remove any identified barriers. Research on this issue has been extensive, with functional considerations relating to EVs (Mannering and Train, 1985), awareness of EVs with consumers (Axsen and Kurani, 2008), effectiveness of incentive policies (Brand et al.,

[1] Inclusive of plug-in hybrid electric vehicles and pure battery electric vehicles

2013; Harrison and Shepherd, 2013) and the provision of charging infrastructure (Trümper, 2014) having been assessed for their impact on EV adoption. In this paper, a more abstract perspective is taken through an assessment of the role of uncertainty in the emerging market for EVs. Specifically, this paper explores the opinions of stakeholders in reference to perceived uncertainties which are limiting EV demand. This is achieved through a series of qualitative semi-structured interviews with a sample of 13 participants comprising EV adopters, academics, consultants, NGOs and market implementers. The interview transcripts were coded using a two-stage thematic analysis to identify the prominent discussion points. The research presented in this paper compliments an earlier output (Morton et al., 2014) which involved an extensive assessment of UK and EU Government literature in order to produce a conceptual framework of the locations of uncertainty in reference to EV demand. To structure the analysis of the paper, three research objectives have been established:

1. Identify the prominent perceived uncertainties detailed by stakeholders
2. Determine if these perceived uncertainties match up with UK and EU Government policy
3. Consider what insights and recommendations for policy emerge from the analysis

Results indicate that UK government policy provides a partial fit to the perceived uncertainties of stakeholders. There are a number of notable divergences between the perceived uncertainties and policy position, such as the issues of changes to vehicle taxation, enforcement of charging infrastructure and the resilience of government commitment. The findings of this research may assist in informing forthcoming government policy in this area to mitigate the identified perceived uncertainties and improve the probability of meeting the EV registration targets implied by the Committee on Climate Change's analysis.

In the next section, a brief overview of the existing literature in the field of EV demand is offered followed by an outline of the methodology used in this paper. Following this, the results of the thematic analysis are presented and discussed. To conclude, a summary of the key findings of the research is provided alongside suggestions for future research.

2 Literature Review

Understanding the barriers which are limiting the demand for EVs has been an active area of research since the 1980s. Initial research in this field tended to use quantitative approaches based on econometric methodologies (Mannering and Train, 1985), and was successful at identifying the prominent adoption barriers relating to the limited range of EVs, aversion to price premiums and high levels of discount rate associated with operation costs (Beggs et al., 1981; Calfee, 1985). Research of this variety is of significant value due to its ability to guide researchers working to improve the technical performance of EVs by allowing them to concentrate on the attributes which are likely to have the most significant affect over demand. Research activity has subsequently progressed by a broadening of the methodologies utilised in the assessment of EV demand. The application of psychometric models assisted in demonstrating the importance of attitudes such as environmental concerns (Sangkapicha and Saphores, 2009) and evaluations of relative advantage (Peters et al., 2011) whilst assessments of social networks and communication behaviours demonstrated the importance of communicated experience and opinion (Axsen and Kurani, 2011) over EV demand.

More closely aligned to the approach taken in this paper, Kurani et al. (1994) applied a life-preference interview to examine purchase intentions and explore how households would fit an EV into their fleet. Results indicate that previous research has inappropriately framed EVs as a second car as opposed to a new component in a household's fleet and that households tended to consider home recharging to be the most valuable EV attribute. More recently, the growing prevalence of EV trials has allowed researchers to gain access to individuals who have had extended practical experiences with EVs. Caperello and Kurani (2012) examined the stories of households who participated in a trial for plug-in hybrid EVs through a thematic analysis of narratives with the results suggesting that the topics of technology confusion, charging habits, changes to driving behaviour and financial payback are salient. In a similar piece of research, Graham-Rowe et al. (2012) conducted a qualitative appraisal of user response to hybrid and pure battery EVs through a grounded theory analysis (Willig, 2008) with response categories of cost minimisation, vehicle confidence, vehicle adaption demands, environmental beliefs and impression management being identified.

The past application of qualitative methods by researchers in this field has demonstrated the value of open ended approaches. The research presented in this paper further contributes to this growing body of qualitative knowledge by exploring the implications that perceived uncertainties in this market have over demand for EVs.

3 Methodology

The method section is partitioned into three parts. The first of these parts defines how uncertainty is considered in this paper alongside a description of the conceptual framework whilst the second part provides details on the format and conduct of the interviews. The final part outlines the type of analysis conducted on the interview transcripts and how the results were generated.

3.1 Conceptualising uncertainty

Offering guidance on this topic, Walker et al. (2003) developed a conceptual basis for uncertainty, which is defined as any deviation from the unachievable ideal of deterministic knowledge of the relevant system. Drawing on this guidance and the wider literature, Meijer et al. (2006) outlined a typology which categorises uncertainties in socio-technical transitions by their source of origin. These sources are inclusive of technological, resource, consumer, competitive, supplier and political uncertainties. Specific attention is given to how uncertainty is a perceived concept, with perceptions of uncertainty likely to vary between different actors in the system. For instance, the perception of uncertainties faced by the manufacturer of a new innovation is likely to be different to the uncertainties which are apparent to a consumer considering adopting the innovation. This framework was then subsequently applied to the transition to micro combined heat and power in the Netherlands (Meijer et al., 2007) with the results demonstrating that perceived uncertainties play a prominent role in the innovation and transition process.

In the research presented in this paper, Meijer et al.'s approach is utilised to provide a basis on which uncertainty in the demand for EVs is evaluated (Meijer et al, 2006). A conceptual framework of uncertainty in EV demand is detailed in a complimentary paper (Morton et al., 2014), which conducted an extensive assessment of UK and EU Government literature in order to determine the relevant 'locations of uncertainty'[2] in the field of EV demand. This conceptual framework is reproduced in Figure 1 with the locations which were identified being inclusive of [1] consumer, [2] policy, [3] infrastructure and [4] technical uncertainties which are internal components of the framework alongside [5] economic and [6] social uncertainties which are external to the system yet hold influence over it.

[2] Walker et al. (2003) define three dimensions of uncertainty: 'location', 'level' and 'nature' of uncertainty. They define location of uncertainty as "where the uncertainty manifests itself within the model complex"; level of uncertainty as "where the uncertainty manifests itself along the spectrum between deterministic knowledge and total ignorance"; and nature of uncertainty as "whether the uncertainty is due to the imperfection of our knowledge or is due to the inherent variability of the phenomena being described".

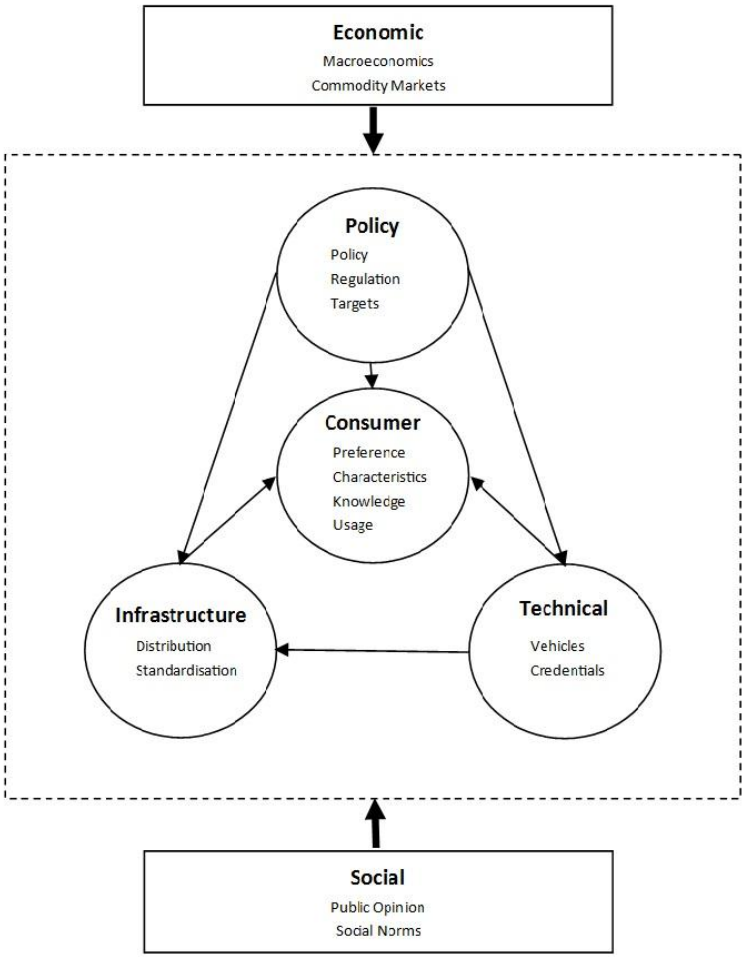

Figure 1: Conceptual framework of the locations of uncertainty in the demand for Electric Vehicles (detailed in Morton et al., (2014)

3.2 Interview Procedure

As uncertainty is a perceived concept, this research project attempted to attain a sample of participants from a selection of the different categorises of actors who are operating in this field. In total, 34 different organisations were approached covering government agencies, private consultancies, non-governmental organisations (NGOs), driver associations, vehicle manufactures and market implementers. Of this sampling frame, 8 organisations agreed to participate totalling 13 individual interviews inclusive of 4 EV adopters, 2 market implementers, 4 NGOs, 2 consultants and 1 academic. Interviews lasted between 50 and 90 minutes with a total of 933 minutes of narrative transcribed. Interviews took place between November of 2013 and January of 2014 either via Skype or telephone. An overview of the participants is presented in Table 1, which provides details of the type and position of each stakeholder alongside the length of their narrative, the number of items coded in their narrative and the label used to refer to them.

Table 1: Overview of the stakeholders who participated in the semi-structured interviews

Label	Type	Position	Length of Narrative	Number of Codes
SH1	Consultant	Independent researcher	56 minutes	63
SH2	Market Implementer	Strategy manager	81 minutes	66
SH3	EV Adopter	Consumer	70 minutes	36
SH4	EV Adopter	Consumer	83 minutes	56
SH5	NGO	Director of clean vehicles	82 minutes	47
SH6	Market Implementer	Infrastructure manager	65 minutes	44
SH7	NGO	Policy director	59 minutes	25
SH8	Consultant	Spatial planner	70 minutes	33
SH9	Academic	Researcher	92 minutes	50
SH10	EV Adopter	Consumer	54 minutes	37
SH11	EV Adopter	Consumer	69 minutes	49
SH12	NGO	Senior analyst	60 minutes	30
SH13	NGO	Research manager	92 minutes	28

The interviews were partitioned into two parts. In the first part, a semi-structured question and answer format was used which began with introductory questions regarding EVs in general and concluded with more focused questions relating to uncertainty in EV demand in particular. This was followed by an uncertainties exercise, which utilised the 'uncertainties matrix' initially defined by Walker et al. (2003), to provide a more focused discussion regarding uncertainties that are limiting the demand for EVs. An example of the output produced through this uncertainties exercise is provided in Table 2.

Table 2: Example of an Uncertainty Matrix Completed by Participant SH6

Location	Level				Nature	
	Statistical	Scenario	Recognised Ignorance	Total Ignorance	Epistemic Uncertainty	Variability Uncertainty
Technical: state of heath of battery	✓				✓	
advancements	✓				✓	
Consumer: resale value			✓		✓	
insurance		✓				✓
lifestyle choice			✓			✓
Policy: government change				✓		✓
Economic: new market continuation			✓			✓
Social: not present		✓			✓	

3.3 Analysis

To assess the interview transcripts, thematic analysis was selected due to its suitability in interpreting qualitative data in order to identify key themes (Guest et al., 2012). The coding procedure detailed by Braun and Clarke (2006) formed the basis of the analysis with a two stage deductive format followed. In the first stage of coding, transcripts were initially divided into the six locations of uncertainty detailed in the conceptual framework. Following this, a second stage of coding was employed to identify the relevant themes which are present in each of these uncertainty locations and further refine the output.

4 Results

This section of the paper presents the findings of the thematic analysis conducted on the interview transcripts. The main themes are presented in accordance with their associated location of uncertainty in reference to EV demand. Table 3 provides an overview of the main themes which were identified in the analysis and their associated uncertainty locations. To begin, the internal locations of uncertainty are considered before moving on to the external locations.

Table 3: Coding hierarchy of the thematic analysis relating to uncertainties in the demand of EVs

Themes	Description
Internal Uncertainties	
1. Consumer	
Market Size	Rate of uptake and likely demand for EVs
Information	Awareness of EVs and communication strategies
Experience	Communicated and practical experience with EVs
2. Policy	
Commitment	Government support of EV technology
Fiscal	Financial incentives and rates of taxation for EVs
Management	Political oversight and coordination of EV market
3. Infrastructure	
Management	Government administration of infrastructure
Standards	Payment and technical standardisation of infrastructure
4. Technical	
Development	Battery improvement and powertrain competition
Credibility	Trustworthiness of claims made concerning EV attributes
External Uncertainties	
5. Economic	
Macroeconomics	Variability of economic environment
Resources	Availability and price of commodities
6. Social	
Public Opinion	Current level and method of influence
Social Norms	Image and meaning of EVs

4.1 Consumer Uncertainty

Representing the location of uncertainty which is perhaps closest to demand, the understanding of consumers in this emerging market is often raised as an issue of significant importance. Topics of interest include the quantification of likely demand for EVs (Eggers and Eggers, 2011; Lieven et al., 2011) and identifying the motivators of adoption (Sangkapichai and Saphores, 2009; Ozaki and Sevastyanova, 2011). The results of the thematic analysis indicated that three themes were salient with participants in relation to consumer uncertainty: market size, information and commitment.

Market Size

Perhaps unsurprisingly, a significant proportion of the dialogues in consumer uncertainty were focused on the likely size of the market and how the rate of adoption will change in the future. The opinions of stakeholders tended to be split between optimistic and pessimistic outlooks, with one participant considering EV demand to have ability to widely diffuse analogous with the contagion of a pathogen "*once it gets past the tipping point, I think it will be like contagious, very much a sort of viral thing*" (SH11), whilst another participant was more reserved in their projection stating "*I don't think we're going to see any dramatic increase in EV sales*" (SH9). The attainment of a critical mass was viewed as an important issue by a number of stakeholders. The realization of cost and range parities with conventional vehicles was seen as representing a significant milestone that, once past, would create an exponential jump in demand with supply having to "*struggle to keep up*" (SH2). In this sense, the demand for EVs was viewed by some participants as representing a non-linear function.

Information

The provision of information surrounding EVs was viewed as an issue of concern. Participants considered the availability of information to represent an area which could be improved to reduce the uncertainty perceived by "*making things simple … for people to go out and understand these vehicles and what they can and cannot do*" (SH2). At a more general level, a lack of awareness concerning EVs and the wider topic of transport sustainability were issues of common discussion. One participant noted that the general populace were unlikely to be able to identify EVs they might come across:

> *"Joe Bloggs on the street doesn't see many EVs and I suppose if they did see them they might not even recognise it was an electric vehicle"* (SH10)

Providing guidance on this issue, one participant stated that a potential strategy would be to raise knowledge concerning the impacts of transport with children in order to embed sustainable behaviours from an early age:

> "*how we convince toddlers, juniors and the rest of the school population that moving towards a sustainable transport system is not an option, it's an absolute necessity*" (SH2)

Communication strategies can also be organised through government and manufacturer engagement with the general market. One participant advised that public information campaigns could prove beneficial to raising awareness of the topic. A similar suggestion was provided by another participant, who extolled the virtues of outreach programmes which seek to "*inform and also, most importantly, to complete the loop and receive the feedback*" (SH4).

Experience

With EVs having only recently entered the mainstream automotive market, consumer understanding of these vehicles remains limited. The importance of ensuring that initial experiences are positive was generally identified as an important issue by participants, in order to address the "*natural scepticism. People are afraid of things they don't understand*" (SH10). Participants tended to express a view that once individuals had the opportunity to acquire practical experiences with EVs, their opinions would improve as a consequence:

> "*People will start to drive them, find that they are rather nice … There are genuine upsides, they will only emerge as people become more accustomed to them*" (SH1)

Whilst the virtues of practical experience of EVs are generally held in high regard, it is not always feasible to achieve this at a large scale. An alternative strategy is to encourage indirect experience through communicated opinions with the market being "*very dependent on early adopters to carry this forward and it will be slow but people need to see that plug-in vehicles work*" (SH13). Related to this is the topic of usage and how the experience of owning an EV will affect mobility patterns. A lack of knowledge relating to usage is potentially affecting decisions in related areas with "*that uncertainty is something which is creating a risk in investing in an infrastructure*" (SH6).

4.2 Policy Uncertainty

EVs have been prominently discussed in policy literature by both UK (DfT, 2009a; OLEV, 2013) and EU (EC, 2012a; EC, 2012b) Governments, often in reference to their ability to contribute to improving energy efficiency, reducing carbon intensity and improving energy diversity. With EVs representing a developing technology, political support tends to be viewed as a necessity in order to create a protected space to facilitate maturation (Lane, 2002). In reference to the policy uncertainty surrounding the demand for EVs,

three themes were identified in the narratives of participant: commitment, fiscal and management.

Commitment

Whilst a significant degree of financial backing has been allocated to support the emerging market for EVs, participants were still uncertain regarding how committed the UK Government is to the technology. This scepticism in political commitment appears to originate from the understanding of participants that "*politics is more of a short-term game, that's quite difficult to achieve that longer-term vision*" (SH13). An appreciation for the dynamics of politics led one participant to comment that "*I think it would be reasonably easy for them to pull the plug*" (SH2), perhaps under the condition that uptake is "*not happening fast enough for the political types*" (SH11) helping to exacerbate the opinion that "*politicians tend to like a subject for a period of time then they get bored with it*" (SH6).

This doubt concerning the commitment of politicians to supporting the demand for EVs was felt to stem from two possible sources. Firstly, the challenge of facilitating a transition to EVs was perhaps not well understood at the outset leading to the "*expectations that were built up around electrification were completely unrealistic*" (SH5) with another participant expressing the opinion that:

> "*asking someone to do something which is difficult and extremely uncertain that they might end up falling flat on their faces is a big ask, not many politicians will do that*" (SH1)

An alternative perspective was put forward by two other participants, who expressed larger concerns regarding "*are we actually committed to decarbonising our economy by 2050? If we are then a lot of things flow from that and EVs would be one of them*" (SH1). The attainment of a global deal on climate change was seen as an important issue due to the opinion that "*If everyone stopped caring about climate change then maybe EVs become slightly less of an imperative*" (SH12). An additional wider issue relating to the UK's potential departure from the EU was a significant concern due to "*all of the regulations and standards [being] set by the European Union*" (SH13) leading to uncertainty over market regulation in a post-EU UK. With these comments in mind, reinforcing political commitment to supporting the market for EVs is likely to generate significant benefit through "*having a kind of stable policy framework with a long-term commitment to EVs and potentially having targets and so on would help give confidence to manufacturers and investors*" (SH12).

Fiscal

In an attempt to incentivize EV adoption, the UK Government introduced a number of policies to promote the purchase of less polluting cars. These policies included a £5,000

grant to assist in reducing the upfront purchase price of an EV (DfT, 2009b), alterations to the circulation tax regime and the exemption of electricity from transport fuel duty (HoC, 2008). EV adopters held mixed views regarding the fiscal policies, with one participant expressing "*stress about the prospects of being charged for electricity or paying tax on it*" (SH10), which highlights the uncertainty of calculating reliable cost projections. Conversely, another participant was more accepting, expressing the view that "*the government needs the money to run the country, and if more people take on EVs they are going to change the taxation*" (SH11). Participants raised questions regarding "*what would the sale of EVs be today if there hadn't been a subsidy?*" (SH6), demonstrating a lack of understanding regarding the impact of these policies. This point was taken further by other participants, who expressed concerns that "*no one has, in my view, created a brave new world for electrical motoring*" (SH4) and that "*if we want to see massive cultural shift, we need to actually change the environment*" (SH7). Perhaps to alleviate the considered ineffectiveness of the current fiscal policies, one participant advised the government "*needs to think about new ways to influence hearts and minds*" (SH4), perhaps indicating that a combination between functional and emotive messages is required to generate momentum (Sheller, 2004).

Management

One possible medium available to address the issues of policy uncertainty in this market is through improved political management of the EV transition. The lack of coordinated action was a specific topic of interest for participants, with elements of the UK Government felt to be "*running the show in a detached way*" (SH4) resulting in a "*very disparate mix of actions*" (SH5) with a "*lack of adaptive policies*" (SH4) having the potential to lead to path dependencies. However, the scale of the challenge was not taken lightly, with one participant stating that "*there are so many different decision makers which need to come together to make the market work*" (SH5). The internal dynamics of government departments was viewed as being somewhat problematic, creating a situation where "*there isn't a single person that deals with us … who hasn't changed jobs at least twice*" (SH2). Indeed, this staff movement might be contributing to the perceived situation that the *"government is writing a strategy and allowing it to stand for years*" (SH4).

At a more general level, there was a lack of clarity concerning the degree of government management required and the nature of this management. Some participants described the virtues of a laissez faire approach, expressing opinions that "*it's not the government's role to pick winners, it's the market's role*" (SH8). However, some level of government intervention was desired by the majority of participants ranging from the role of "*nudg[ing] certain technologies in a certain direction*" (SH13) potentially through the application of "*soft solutions*" (SH4) to the opinion that "*I think you do need to, if not pick winners, but at least give a leg up to emerging solutions*" (SH5). Thus, the level of

governmental intervention required is not clearly defined, with participants holding different opinions on the issue.

4.3 Infrastructure Uncertainty

One of the distinct benefits related to a transition to EVs is that the fuelling infrastructure is already partly established (Struben and Sterman, 2008). However, some additional hardware is required to facilitate charging in public spaces and to enable longer distance journeys. Embedded in the participant's narratives appear to be two distinct themes orientated around uncertainty in the required infrastructure: management and standards.

Management

The UK Government has embarked on a scheme (Plugged in Places) to install a significant quantity of charging points to provide a basic infrastructure provision for EVs (OLEV, 2011). The manner in which this scheme has been conducted represents a topic of concern for a number of the participants. Local governments, who are generally tasked with implementing the roll out of infrastructure, were felt not to have "*the expertise to deal with this themselves …. It's not that they are necessarily incompetent, it's just that they don't' necessarily have the appropriate skills*" (SH9). This point was echoed by another participant, who felt local governments "*are not appraised of the situation, of technology advances and what have you. They are making key decisions that are affecting the uptake*" (SH11). This perceived deficiency led one participant to state that "*it's like blowing on a dandelion and watching the seeds go out. Ten land in one spot of the garden, the rest of the garden get none*" (SH4).

One of the consequences of this for EV adopters is that the charging infrastructure is perceived as being "*isolated individual charge-points they are actually increasing the risk of failure significantly*" (SH4). This has the potential to lead to a situation where "*who would drive into central London on the off-chance that they could find a charging point to charge them up to go back? I mean, you wouldn't!*" (SH1). The problem of the perceived ineffective distribution of infrastructure seems to be exacerbated for EV adopters by a lack of confidence regarding the availability of charging. One participant described the occurrence of "*temporary road works … that would make the whole, the system, inaccessible*" (SH10). A similar situation occurs when bays reserved for EV charging are occupied by conventional vehicles, with a lack of enforcement leading to bays "*which frequently get abused by everyone else*" (SH10). This issue of misuse of EV charging infrastructure is comparable to the experiences observed in an extensive EV trial in Germany (Trümper, 2014), indicating that the policing of EV charging infrastructure is not an isolated problem.

Standards

Whilst a significant quantity of charge points have been installed through the Plugged in Places scheme, consortiums tasked with implementing the initiatives have been given the freedom to select their desired approach. This has led to a partial fragmentation of the installed infrastructure, with different types of charge point and payment mechanism having been selected. This has generated a situation whereby EV adopters "*carry in the car a whole cluster of cards*" (SH3) and experience frustration with one participant stating "*you shouldn't have to be sort of looking up on the internet in advance to find out that a charging point that your car is compatible with*" (SH11)

This lack of standardisation of the EV infrastructure is heightened by the perceived absence of infrastructure integration throughout Europe:

> "*we're in a situation where there is a number of manufacturers, there is a number of charging standards … what's the right way forward?"* (SH10)

One of the participants discussed their experience with attempting to take their EV to Europe, stating that when "*I go to Renault in France and say "Can I use your chargers?" and they shrug their shoulders*" (SH4). This uncertainty concerning the ability to utilise EV infrastructure in different countries leads to a situation where "*there is no hope whatsoever of using these things for trans-European travel*" (SH4).

4.4 Technical Uncertainty

One of the significant challenges facing the promotion of EVs is that the "*internal combustion engine coupled with petrol or diesel fuel, it is a mighty powerful combination refined over a very long time*" (SH1). EVs have to advance to the stage where they have the capacity to displace the incumbent technology if they are to attain widespread appeal. However, participants perceived uncertainty as being present in terms of the future technical developments of EVs and the credentials assigned to these vehicles.

Development

Perhaps the most important technical feature of EVs relates to their on-board battery packs, which hold significant influence over the range and cost of the vehicle (Axsen et al., 2010; Cluzel and Douglas, 2012). Participants tended to consider technical improvements in battery technology to be well defined, seeing it to be "*something that is going to improve. The only uncertainty is the rate of improvement*" (SH11) with "*broadly, the direction of travel is known*" (SH1). One participant expressed concern over the uncertain rate of battery degradation resulting from rapid charging, stating that it "*hasn't quite been long enough that people really know what is going to happen with batteries*" (SH12).

Conversely, opinion regarding the future prospects of the EV powertrain was less certain. Government support for alternative fuels seems to fluctuate through a series of hype cycles (Bakker, 2010), progressing through liquefied petroleum gas, hydrogen and biofuels to the current point where "*we've been on an EV kick for quite some time*" (SH5). This variability in support has led some participants to question "*are EVs the answer, should we be waiting for fuel cells, are biofuels any good, those debates are still completely open and raging*" (SH1). The consequences of supporting an unsuccessful technology can prove significant, with the feeling that "*you don't want to end up with the one car that no-one supports and really, truly no-one cares about*" (SH10). Moreover, if the level of investment in alternative propulsion systems does not produce a viable product, it has the potential to lead to a situation where questions may be raised concerning the "*dominant myth of unfettered mobility being a societal good* "(SH7).

Credibility

In terms of certain technical attributes, EVs represent significant divergences compared to conventional internal combustion engine (ICE) vehicles. The manner in which these technical attributes are benchmarked to allow consumers to compare vehicles using different powertrains was a prominent issue with participants. Doubts emerged concerning the credibility of some of the stated attributes, such as in terms of range with "*most vehicles it's quoted as a hundred miles. The reality is you don't get a hundred miles, you know, you're talking about seventy miles*" (SH2). Concerns over the credibility of EV attributes was replicated in other areas, with one participant expressing doubt regarding whether EVs are as "*environmentally friendly as they're painted, because … you can read five reports in the press and they'll all be different*" (SH2). Similarly, clarity on the costs of ownership was lacking for another participant who stated "*the actual economic costs and whether it costs what people say it costs to charge the car and run the car*" (SH2). The uncertainty regarding the credibility of stated EV attributes leads to a situation where "*the unaware consumers, considering alternatives, get misled* "(SH10) and "*having to accept and have a high degree of probability that the data they are using in the calculation is in fact [un]certain*" (SH3).

4.5 Economic Uncertainty

Whilst the modern automotive market represents a highly integrated globalised industry, the sector still relies on supplies from other industries in order to function. With the EV market currently only representing a niche part of the large automotive sector, it is likely to be susceptible to fluctuations in external economic conditions. Two specific themes emerged from the dialogue of participants related to the issue of economic uncertainty around macroeconomics and resource availability.

Macroeconomics

The recent global financial recession has provided an apt example of the responsiveness of output in the automotive industry to changes in macroeconomic conditions. One participant commented "*if you look at the recession the car industry is one of the first things that collapsed*" (SH13) with the implication being if "*we had another recession, then … everything shrinks … that's got to have an impact on the uptake of the EV*" (SH2). A number of participants raised questions regarding if the automotive market in the UK will ever reach its pre-recession levels "*we're faced with fundamental questions about the cake not getting bigger anymore, that's a really big deal and that's when we clutch onto our sticking plasters, desperately*" (SH7). However, this uncertainty may provide an opportunity to alternative models of car ownership to break the "*obsession in this country of buying houses and buying cars. Nowhere else in the world does what we do*" (SH6).

Resource Availability

The viability of EVs is likely to be contingent on the future prospects of conventional ICE vehicles. These future prospects are likely to be significantly affected by changes to the price and availability of oil. Participants tended to express the opinion that oil is likely to increase in scarcity "*I'm pretty sure it's not going to get cheaper or at the very least, it's going to be very volatile, something that government will want to wean itself off*" (SH13). This forecasting might be underpinned by the recent dynamics of the oil market, with another participant stating "*it's impossible to say really how much the price of fuel is going to rise over the coming years but it's certainly increased a lot in the last ten years*" (SH9). However, this perspective depends on no alternative fuels entering the market such is if "*shale gas was found to be able to secure our energy needs for the next fifty years*" (SH2) leading to a situation whereby "*the state then took their foot off the gas*" (SH2).

Additionally, the manufacturing mix for EVs needs to be somewhat different compared to a conventional vehicle. Rare earth metals are currently required to create EV battery packs, leading to the industry being vulnerable to "*things like China[3] putting a cap on rare earth metals in a move to protect its own industries … that brings about economic limitation*" (SH13). Relating to this is the wider issue of production capacity and the length of time required to bring EV manufacturing capability online. Specifically, "*the culpable outlay to produce a battery plant at the moment is prohibitive*" (SH6) with one participant raising the question of "*where are the batteries coming from*?" (SH2) in response to the expected scaling up of demand.

[3] The People's Republic of China currently supplies over 90% of the rare earth metals on the world market.

4.6 Social Uncertainty

Cars, whilst having a significant degree of functional value, are not only interpreted as instrumental objects but also carry social meanings (Dittmar, 1992) and symbolic expressions (Steg, 2005). This generally leads to a situation in which individuals who are considering the purchase of a new car evaluate the functional capabilities which it offers alongside the image which it represents. The role symbolic features play in the adoption of EVs has been examined by Schuitema et al. (2013), who found that individuals who consider EVs to possess symbolic value tend to hold positive opinions of EV instrumental attributes. The narratives of participants made specific comment on two aspects of social uncertainty: public opinion and social norms.

Public Opinion

How society interprets EVs can be indirectly assessed through the public opinion regarding these vehicles. Understanding the "*perceptions, for the average consumer, is very important*" (SH10). With EVs having only recently been released into the mainstream market, public opinion is likely to be the formation stage and "*we don't know how far or how fast [public opinion] will turn into demanding a perfectly quiet, perfectly clean city*" (SH1). A number of participants discussed the importance of opinion leaders in this market, with "*EVs have been hindered by the so-called Clarkson[4] effect*" (SH12), potentially leading to an initial negative social understanding of EVs. Individuals who are forming opinions of EVs tend to "*trust who or what they regard as an authority in a certain field*" (SH13). With this in mind, the role of opinion leaders could be significant with one participant stating the hope that "*inspiration will come from or some sort of leader will … change and lead public opinion*" (SH4).

Related to the topic of opinion leaders is the importance of the media in raising awareness of EVs. Participants tended to hold negative evaluations of the actions so far conducted by the media, with there being "*opinion informers out there and those opinion informers are often mis-informers*" (SH1) characterised by "*all of the reports are always so sensationalised*" (SH9). The power of traditional media is substantial, leading to a situation where "*if you've got the media slating [EVs] people have got nothing to contradict that with*" (SH12). However, the increasing prominence of social media has the potential to allow the public to directly observe the opinions of EV adopters:

> "*when EVs enter the Twittersphere and everybody is telling all their friends on social media how great EVs are*" (SH1)

[4] Reference to Jeremy Clarkson, a prominent individual in the UK automotive media, presenter on BBC Top Gear and critic of EVs.

Moreover, one participant suggested the potential benefits of "*almost like an old-fashioned public information film*" (SH1) to provide a balanced perspective on the implications and benefits of adopting an EV.

Social Norms

The symbolic interpretations of cars are perhaps most apparent in the social norms which surround car ownership. One participant noted that "*everyone has their own special perception of the sort of car they should be driving*" (SH4), demonstrating that individuals have the propensity to match the car they drive to their position in society. With EVs represented a new feature of the social system, questions remains regarding "*when people are looking at buying one … are they seen as being with it and taking things forward or seen as being a bit odd and geeky*?" (SH11). A lack of appreciation for the role that social norms play in steering the demand for EVs could lead to a situation where "*there is a strong aversion to EVs because they are perceived as being a little bit off beat … you are not going to earn any respect*" (SH4).

5 Discussion

The first and second objectives of this research were to identify the prominent perceived uncertainties in EV demand and to assess whether or not these perceived uncertainties were well matched to government policy in this market. This was achieved by evaluating the effectiveness of the conceptual framework in providing a lens through which to assess the narratives of the qualitative interviews. Stakeholders who participated in the interviews did not have a-priori knowledge of the locations of uncertainty which have been identified from a review of the policy literature (Morton et al., 2014) and detailed in the related conceptual framework. Generally, the results of the thematic analysis provide partial support to the locations of uncertainty specified in the conceptual framework. Participants discussed topics inclusive of consumer, policy, technical, infrastructure, economic and social uncertainties. In places, the identified themes which sit within the locations of uncertainty differ from those identified in the policy analysis. Of particular note, the role of government in managing the demand for EVs was considered to be introducing policy and infrastructure uncertainty into the market. Moreover, the rate of adoption of EVs by the mainstream market was repeatedly described as being an unknown issue, despite the large degree of research on the topic (Eggers and Eggers, 2011; Lieven et al., 2011; Musti and Kockelman, 2011). Conversely, other parts of the framework are distinctly similar to the stakeholder narratives, with the external locations of economic and social uncertainties alongside the internal location of technical uncertainty being well represented. These results demonstrate that the uncertainties detailed in UK and EU policy documents concerning the demand for EVs provide a moderately successful fit to the perceptions of uncertainty described by the participants in this research.

The third objective of this paper was to determine what policy insights could be offered from the results of the analysis. Three recommendations appear to arise from the interpretation of the narratives. Firstly, policy makers may want to consider the provision of more long term fiscal support for EV adoption by expressing a guarantee over rates of registration and circulation taxes alongside a time specific moratorium on the introduction of fuel duty to electricity used in EVs. This will provide consumers considering the purchase of an EV more confidence in making cost projections over the lifetime of the vehicle. The lessons learned from the introduction of feed-in tariff policies might provide advice on this issue (Coututre and Gagnon, 2010). More generally, increasing the perceived government commitment to EVs is likely to reduce uncertainty in this market. Policy makers may want to assess alternative options to achieve this as, whilst the publication of policy documents on this issue has been extensive (Morton et al., 2014), perceptions regarding the credibility and stability of these stated commitments appears to be insufficient. A possible strategy could involve

improving the interaction with stakeholders by reducing the turnover of staff working in this area and making direct communication easier.

Secondly, whilst the work so far commissioned by the UK Government regarding the installation of an EV charging infrastructure is commendable, a number of improvements could be suggested from this analysis. Facilitating the provision of an integrated payment mechanism which is easily accessible and widely advertised to EV users would likely reduce the uncertainty in EV adoption. Developments in this area can be further supported through the establishment and communication of technical standards to improve user confidence in travelling across national borders. Moreover, considering the basis and provision for an enforcement of EV charging infrastructure would further assist in providing assurance to EV users in their ability to refuel their vehicles. Thirdly, uncertainty in the demand for EVs could be reduced by improving the credibility of their unique characteristics such as range limitations, cost projections and carbon dioxide emissions. Policy makers are in a position to call for more robust estimation methodologies to be adopted to ensure potential consumers are not misled by the information they receive.

Whilst these policy recommendations emerge from the narratives of the stakeholders, it would be advisable to further test their implications before implementation. With the analysis presented in this paper concentrating on the concept of perceived uncertainty, it may transpire that mechanisms are already established to account for the identified issues. In cases of this variety, a potential solution is to improve information provision and dissemination to reduce the possibility of individuals operating in this market from being unaware of relevant policies. In this sense, perceived uncertainties may only be reduced if the visibility of legislation in this area is improved. Whilst being of specific relevance to UK and EU policy, the results of this analysis may assist in directing the formation of policy in foreign governments who are considering how to structure their approach to EVs.

6 Summary

Electric Vehicles (EVs) are being positioned as a primary means by which the UK will achieve significant reductions in the greenhouse gases emitted from the transport sector (DfT, 2009a). With EVs having only recently been released into the mainstream market, sales rates remain low (DfT, 2013). A significant increase in the rate of EV adoption will be necessary up to 2020 if the transport sector is to achieve a trajectory necessary to reach the carbon dioxide reductions commitments detailed in the climate change act (CCC, 2013). With the increasing clarity concerning the science and risks of anthropogenic climate change (IPCC, 2007; IPCC, 2013), the successful transition to EVs may represent a fundamental necessity.

The research presented in this paper examined demand in the emerging market for EVs through the lens of uncertainty. A conceptual framework, which is developed from a review of policy documents in this field and described in detail in a related paper (Morton et al., 2014), was applied through a qualitative assessment of semi-structured interviews with stakeholders. Results of the analysis demonstrate that the locations of uncertainty which are defined in the conceptual framework provide an effective means by which to consider participant narratives. Moreover, the results appear to indicate that the uncertainties which are perceived by participants provide a partial fit to the policy expressed by the UK Government. In places, there are clear convergences such as in the case of participant concern over the credibility of EV attributes linked to the UK Government's expressed desire to ensure the claims made regarding vehicle environmental impact are reliable and robust (HoC, 2009). Conversely, there are instances where the perceived uncertainties of the participants do not appear to be covered in the policy documents. Instances include the perceived uncertainties surrounding enforcement of EV charging infrastructure, changes to taxation system and the potential size of the EV market. With these points in mind, policy makers may want to consider how the perceived uncertainties detailed in this paper can be accounted for in future policy.

Having said this, the complete removal of all controllable uncertainties in this market may not be entirely desirable. Participants noted that uncertainty can indeed bring a number of benefits to the market such as through the promotion of entrepreneurial activity. With this final reflection in mind, understanding in this field could benefit from future research focused on what uncertainties actually bring positive effects.

"Uncertainty and expectation are the joys of life. Security is an insipid thing."
William Congreve

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