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University of Southampton

Faculty of Engineering and Physical Sciences

Eng Ed – Central; Transportation Research Group

The role of digital media in the electromobility transition

by

Andrea Farah Alkhalisi

Thesis for the degree of PhD Engineering and the Environment

August 2020

University of Southampton

Abstract

Faculty of Engineering and Physical Sciences

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The role of digital media in the electromobility transition
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Road transport is a major contributor to air pollution in the UK (DEFRA, 2019) with serious effects on public health (DEFRA and DfT, 2017), and a significant source of greenhouse gas emissions (DECC, 2016). Measures to mitigate this environmental – and social – impact must be taken for the UK to achieve its targets for decarbonising transport and to reduce harmful emissions. Introducing electric vehicles (EVs) is key to tackling air quality (BEISC, 2018); and these offer heightened advantages in combination with renewable energy management and storage (Hall and Lutsey, 2017), and deployment in networked multi-modal transport systems or vehicle-sharing services (Urry and Dennis, 2009).

Digital connectivity and communications systems are an enabling factor in such hypothetical smart transportation futures. However, while digital media tools and technologies such as smartphone apps and social media platforms are believed to prompt new practices and behaviours among users of other transport modes (i.e. Pawlak et al., 2015), more knowledge of their influence or effects is needed with specific reference to EV driving.

Quantitative and qualitative data collected in this research have provided insight into demographic, attitudinal and behavioural characteristics of the early-innovator EV community. A typology has been created to chronologically itemise and delineate the EV-specific journey-making process, including digitally-mediated interventions. Drivers' engagement with digital media has been correlated against reported behaviour changes or certain adaptations in household routines, habits and practices since driving an EV. User segmentation and archetypal EV driver personas have been developed, informing models mapping driver behaviour and digital engagement to appropriate implementation of new and upcoming technologies; and recommendations have been made relevant to stakeholders including vehicle and user experience designers; service and infrastructure providers; and developers of mobility or transportation systems.

Considered in the theoretical context of the Multi-Level Perspective (MLP) on socio-technical transitions (Geels, 2002), the conclusion finds that while niche-level activity has encouraged and supported early-innovators and initial experimentation, technologies from established regime-level companies and service providers are crucial for more mainstream EV adoption; but digital media alone cannot accelerate the transition to electromobility.

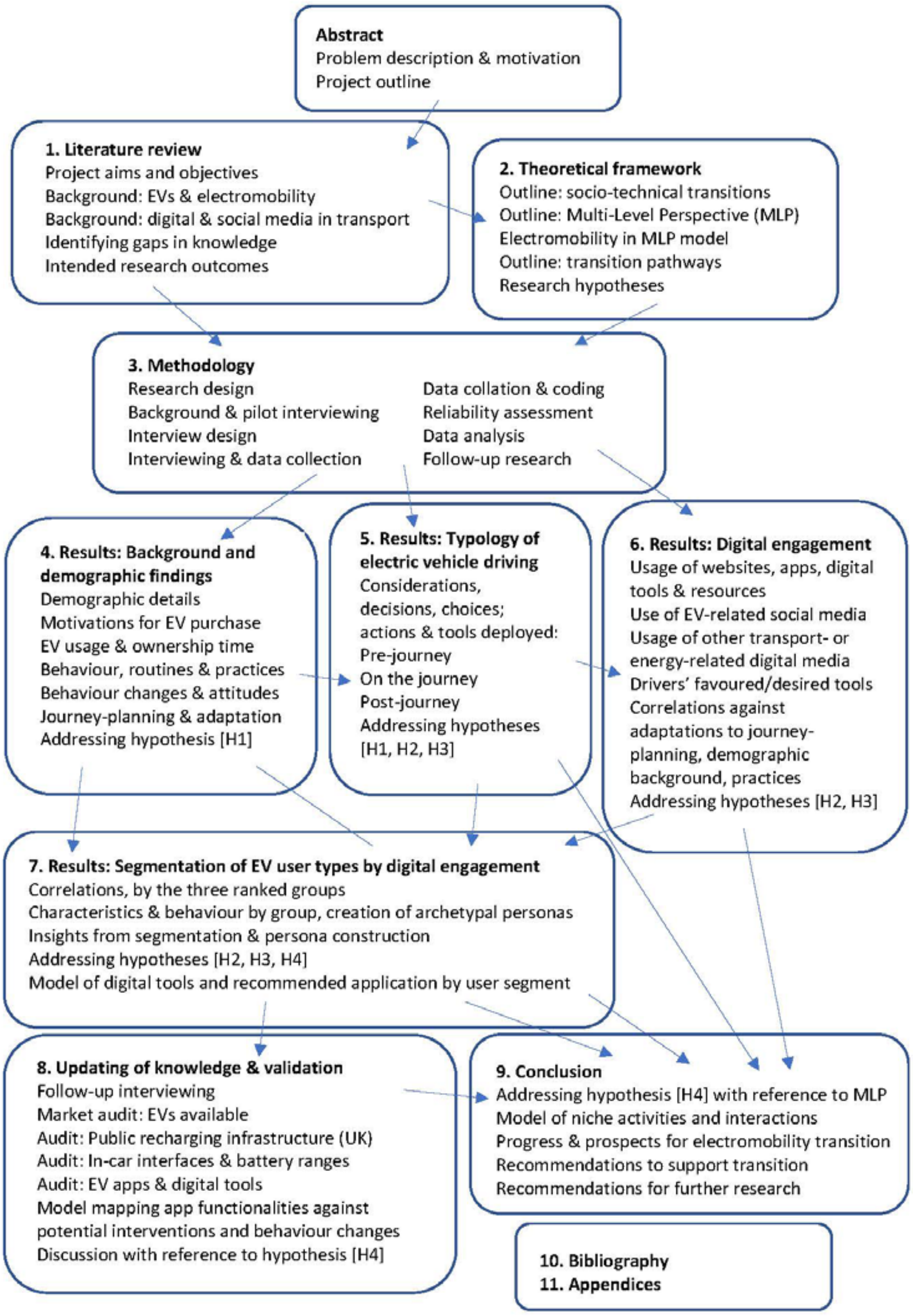

fig 0.i: Chapter structure schematic

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Research Thesis: Declaration of Authorship

Print name: Andrea Farah Alkhalisi

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I declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

I confirm that:

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2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
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6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
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Glossary of terms and abbreviations

ACEA	European Automobile Manufacturers' Association
AI	Artificial intelligence
BEISC	Business, Energy and Industrial Strategy Committee (UK government)
CANbus	Controller Area Network (interconnects vehicle components)
CCS	DC rapid-charging protocol/standard (compatible with, i.e. BMW i3, VW e-Golf)
CHAdeMO	DC rapid-charging protocol/standard (compatible with, i.e. Nissan Leaf)
CYC	ChargeYourCar (service provider)
DECC	Department of Energy & Climate Change (UK)
DEFRA	Department for Environment, Food & Rural Affairs (UK)
DfT	Department for Transport (UK)
DVLA	Driver and Vehicle Licensing Agency (UK)
EV	Electric vehicle (used here to represent 'pure' battery-electric models)
GHG	Greenhouse gas, i.e. CO_2 (carbon dioxide)
GitHub	Platform hosting collaborative software development/open-source projects
Hive, Nest	'Smart' thermostats for home energy monitoring
HTAoD	Hierarchical Task Analysis of Driving (Walker et al., 2015)
Hybrid	Vehicle with (minimal) degree of electrical motive assistance, i.e. Toyota Prius
ICE	Internal combustion engine (i.e. petrol or diesel)
ICT, ICTs	Information and communications technology/technologies
IoT	Internet of Things (connected devices/objects)
MLP	Multi-Level Perspective (theoretical framework)
NOx	Nitrous oxides
OCPP	Open Charge Point Protocol
OEM	Original Equipment Manufacturer (i.e. a car manufacturer)
Ofgem	Office of Gas and Electricity Markets (regulator, UK)
OLEV	Office for Low Emission Vehicles (UK)
OVMS	Open Vehicle Monitoring System
NCR	National Chargepoint Registry (UK)
PAYG	pay-as-you-go (i.e. for EV charging)
PCP	Personal Contract Purchase (finance plan)
PHEV	Plug-in hybrid electric vehicle
PM	Particulate matter (i.e. PM_{10}, $PM_{2.5}$, indicating particle size in micrometers)
PV	Photovoltaic (i.e. solar panels)
RE-EV	Range-extended electric vehicle, i.e. Vauxhall Ampera, BMW i3 REx
SMMT	Society of Motor Manufacturers and Traders (UK)
SNM, TM	Strategic Niche Management, Transitions Management (extrapolations of MLP)
UX, UI	User Experience, User Interface (design)
V2I, V2G, V2X	Vehicle-to-infrastructure, vehicle-to-grid, vehicle-to-vehicle communications
WTO	World Trade Organisation

Chapter 1 Introductory literature review

1.1 Overview

The aims and objectives of this research are to explore the role of digital media in supporting electric vehicle usage and operation, including how it may influence or prompt any adaptive practices or behaviour changes involved in electric vehicle adoption; and ultimately, to gain a wider understanding of the role of digital strategies both within the system of electromobility and in the broader theoretical context of a socio-technical transition [discussed, Chapter 2].

In this review, the background to the research is investigated as an introduction to the project, starting with an overview [1.2] of why electrification of vehicles is necessary. The concept of 'electromobility' is outlined; its potential role in future smart transport and energy systems and pathways to realise this are discussed; but it is concluded that a transition to electromobility is still at a very early stage. The literature on barriers to electric vehicle take-up is then discussed [1.3], followed by existing knowledge on driver strategies and adaptations; and then on potential interventions, including the role of information systems. It is suggested that there is a less detailed understanding of how drivers engage with information sources and data external to their vehicle, including with reference to different spatio-temporal elements involved in operating an electric vehicle. The role of digital media is proposed [1.4] with discussion of its known usage with other modes of transport and in other sectors, and further gaps in the knowledge of electric vehicle drivers' practices and behaviours are identified [1.5] with reference to their usage of digital communication tools such as smartphone apps and social media platforms.

1.2 Why are electric vehicles necessary?

1.2.1 The case for electrification of vehicles

Despite a strong long-term downward trend, road transport accounts for 32% of the UK's total nitrogen oxide (NOx) emissions, 11% of PM10 and 12% of PM2.5 particulate matter (PM) emissions (DEFRA, 2019); 80% of NOx emissions at the roadside (DEFRA and DfT, 2017); and is the most significant source of the transport sector's 29% contribution to total CO_2 emissions (DECC, 2016) in the UK, the focus for this research. Diesel vehicles are the most harmful (Brand and Hunt, 2018). Both NOx and PMs have serious effects on public health (DEFRA and DfT, 2017), and road transport-related pollutants are implicated in a variety of specific serious health conditions, including asthma (i.e. Anenberg et al., 2018), increased cardiovascular morbidity and mortality

(Aung et al., 2018); adverse effects on fetal growth (Smith et al., 2017); decreased lung function and lung volumes in children (Griffiths et al., 2016); reduced lung volume and growth in children and adolescents (Milanzi et al., 2018); decline in lung function, especially in older adults and in people with chronic obstructive pulmonary disease (COPD); plus excess deaths from ischaemic heart disease and COPD (Sinharay et al., 2018) and diagnoses of dementia (Carey et al., 2018).

Electrification of vehicles – including the application of hybrid, plug-in hybrid (PHEV) and range-extended (RE-EV) technologies – has for some time been seen as crucial for the UK to meet targets for decarbonisation of transport and improvements in air quality, to satisfy the 2008 Climate Change Act objectives (Committee on Climate Change, 2013) and net zero carbon targets. These represent reducing net emissions of greenhouse gases by 100% compared to their levels in 1990, as of a legislation amendment in June 2019 upping that target from 80% (legislation.gov.uk, 2019), and achieving a balance between reduction and production of greenhouse gas emissions, effectively cancelling out emissions (Shepheard, 2020).

Large-scale deployment of electrified vehicles could cut the UK's oil imports by 40% and carbon emissions by 47% by 2030, and near-eliminate transport NOx and particulate emissions by 2050 (Cambridge Econometrics, 2015). It represents the best potential pathway for a combined cutting of CO_2, NOx and PM emissions (Brand, 2016) with associated benefits for public health (Brand et al., 2017). EVs also have an industrial and economic role in positioning the UK as a centre for low-carbon vehicle research, design, development and manufacturing (SMMT, 2013).

All-electric vehicles in particular are seen as a key measure to tackle air quality (BEISC, 2018) and the Modern Transport Bill (DfT and OLEV, 2017) called for detailed policy measures to support uptake in a strategy for most cars and vans on the UK's roads to be zero-emissions by 2050. There is an aim to end the sale of new petrol and diesel cars and vans by 2040 (DEFRA and DfT, 2017); and a subsequent aspiration for 50-70% of new car sales, and up to 40% of new van sales, to be of 'ultra-low emission' models by 2030 (DfT, 2018). There have, however, been concerns about the clarity of these goals, as well as a call to bring the sales deadlines forward to meet the 2050 goal (BEISC, 2018).

Yet while electrification is a key EU policy approach to decarbonisation of land passenger transport, this is alongside vehicle-sharing and other adaptations, and in parallel with reducing travel need and trip length, and encouraging modal shift (Köhler et al., 2017); importantly, quicker reductions in air pollution and GHG (greenhouse gas) emissions could be achieved in synergy with lifestyle changes such as modal shift and changes in travel behaviour than by electrification of vehicles alone (Brand et al., 2018).

Nonetheless, although structural changes in demand for car travel have been observed, notably the ‘peak car’ indications of a reversal in upward trends of motor vehicle usage (i.e. Goodwin, 2012a, 2012b; Melia, 2012; Metz, 2012; Stokes, 2012; Kuhnimhof et al., 2013), these may be confined only to certain demographics, settings and groups of road-users (Hobbs and Harriss, 2013), with very different trends in urban and rural areas (Ellerton and Bray, 2018) and trends offsetting each other (Le Vine et al., 2013). There is no consensus that a saturation point for car travel has been reached (Lyons and Goodwin, 2014) and “little evidence to confirm that car ownership levels or distance travelled per person have reached saturation” (DfT, 2016, p.11). Indeed, while overall travel demand appears to be falling in the UK (Marsden et al., 2018), both motor vehicle traffic as a whole and car traffic have reached record levels in Great Britain (DfT, 2017), and across all modelled scenarios, traffic is forecast to continue to grow through to 2050 (DfT, 2018a).

Personal ‘automobility’ – the system of vehicle use (Urry, 2004), considered against a broader backdrop (Böhm et al., 2006) – is consistently preferred by individuals over public or active transport modes, the car taking on new, appealing roles such as acting as a ‘cocooning’ personal space (Wells and Xenias, 2015); and car-dependent practices, such as cargo-carrying functions, endure (Mattioli et al., 2016). It appears that “car-based mobility is our default option, well embedded into our routines. It is our normalcy. It is a cultural cornerstone that we cannot simply remove” (Hajer et al., 2012, p.152); there is a resistance to change, and entrenched car-dependency (Nieuwenhuis and Wells, 2012). Against this backdrop, the environmental impact of road transport and automobility must be mitigated: if people cannot easily, or quickly, be persuaded to give up their cars and driving on any grand scale, then cleaner vehicles must be deployed alongside measures to reduce their use.

Electric vehicles are both more economically-attractive and promise better carbon-saving across a community than hydrogen fuel cell cars (Felgenhauer et al., 2016), as well as lower well-to-wheel emissions and energy demand (Wolfram and Lutsey, 2016). There have been concerns over the source of electricity used to charge EVs, materials used in their batteries, and how batteries are both manufactured and recycled at end-of-life (Gbegbaje-Das and Smith, 2013); and over the persistence of non-exhaust particulate emissions, i.e. from brakes and tyres (Timmers and Achten, 2016). However, over the course of a typical vehicle lifecycle, in-use benefits counter the higher energy consumption and emissions involved in EV production, offering significant overall reductions in carbon and GHG emissions compared to petrol and diesel vehicles (i.e. Eastlake, 2013; Hall and Lutsey, 2018).

Benefits of EVs are greatest in the EU countries with the cleanest, lowest-emissions electricity supplies (Buekers et al., 2014), in suburban and rural areas where energy efficiencies can be maximised (Newman et al., 2014), and are multi-dimensional with co-benefits for adoption of other sustainable technologies and climate change mitigation policies (Sovacool et al., 2020), further aiding progress towards net zero targets – although the UK will only meet its 2050 target if EV adoption is combined with intense decarbonisation of the electricity grid (Hill et al., 2019). This underlines not just the potential role of EVs in the decarbonisation of the energy sector, but the need to consider the broader concept of electromobility as a system rather than just focusing on vehicles alone.

1.2.2 The case for the electromobility system

Electromobility is generally defined as "a road transport system based on vehicles that are propelled by electricity," (Grauers et al., 2014), with a focus on systemic aspects (*ibid*.). Two distinct pathways have been identified for vehicle electrification by Dijk et al. (2013): firstly, as a straightforward technology-for-technology substitution, but alternatively, as part of the development of a new mobility configuration in a longer-term transition process. These pathways are not mutually exclusive – the first could be an incremental step towards the second – but only achieving like-for-like 'technical fix' solutions may simply perpetuate unsustainable practices (Spurling and Welch, 2014); fail to challenge automobile dominance and related issues (Cohen, 2006); or have undesirable outcomes such as vehicles powered by fossil fuel-derived electricity (Whitmarsh, 2012).

As such, EVs have been conceptualised within a convergence of technologies. Even in the most imaginative or ambitious 'post car' models for the mid-21st century (i.e. Urry, 2007) cars still have a place – albeit electrified, networked, shared, accessed on-demand or even autonomously-guided – alongside other modes of transport including cycling and walking (Moss and O'Neill, 2012); and in a multi-modal, digitally-connected network (Urry and Dennis, 2009). Combining electric powertrains with autonomous driving and connectivity innovations could result in disruptive products and services (Sprei, 2018) more than the 'sum of their parts' (Watt, 2014); and tackle environmental, economic and social issues (Davies, 2018), with benefits in multiple usage scenarios, i.e. in on-demand one-way shared and inter-modal services (Mounce and Nelson, 2019), maximised further in systems integrating public transport and electric bicycles as well (Hoekstra, 2019). Sperling (2018) describes the 'three revolutions' of electrification, pooling or sharing, and autonomy; how the inter-relations between these elements open up opportunities for new services, reductions in vehicle numbers and traffic congestion, and improvements in vehicle usage efficiency; and the potential combined impact upon factors such as equity of transport access, public health and city livability, as well as benefits for sustainability – if the right policy interventions are made (*ibid*). To achieve such benefits from this convergence, technological, social and political changes must be aligned and steered (Lang & Mohnen, 2019).

In the nearer-term, EVs are well-suited to car clubs and car-sharing scenarios (Shaheen, 2012a; Dijk et al., 2013), where they could have greater overall transformative potential (Bergman et al., 2017) than in private usage. It is recognised and must be emphasised that while offering an important contribution to decarbonisation of the transport sector (Hill et al., 2019) they are not a sole solution: other strategies such as demand management, car sharing and modal shift are also necessary (*ibid*.) with focus on the whole mix including active transport (Hobbs, 2018) and reducing both car ownership and travel demand full stop (Anable and Goodwin, 2019). As Steinhilber et al. (2013) note, EVs offer a chance to redefine how we think about mobility as a whole, but their full environmental potential will only be realised if they are viewed as components of an integrated multi-modal network – and as tools for electricity grid-balancing.

Particular synergy has been suggested between deployment of EVs and decarbonisation of the power system (i.e. Thiel et al., 2016; Grauers et al., 2014), in a co-evolving, symbiotic development with the renewable energy sector. This could go beyond specific case-study applications such as the Quebec hydroelectricity system (Haley, 2015) in a wider complementing and supporting of decentralised microgrid electricity generation (Vidal, 2014); smart-grid, smart-building and energy storage applications (Lombardi et al., 2018); contributing to grid-balancing and transient stability including prevention of 'brown-outs' (Gajduk et al., 2014); and even potentially negating the need for static storage systems (Forrest et al., 2016), with extensive and novel cross-system co-benefits from vehicle-to-grid technologies (Noel et al., 2018).

Vehicle-to-grid (V2G) technology and controlled smart-charging to even out demand peaks and troughs will enable vehicle owners and fleet operators to sell power back to the grid, thus aiding integration of renewable-source electricity and increasing system-wide benefits in both the energy and transportation sectors (Coignard et al., 2018), including more efficient grid operation and a potential future lowering of electricity prices (Wolinetz et al., 2018; Hall and Lutsey, 2017b). Public charging facilities could become hubs for other smart-city services and operations (Lombardi et al., 2018) – or attractive green-planted 'parklet' public spaces also housing facilities such as seating, cycle stands, phone charging and wi-fi (Arup.com, 2018).

Dismissing EVs as like-for-like substitutions – "the answer to the wrong question" (Spurling, 2014) or no real challenge to the system (Sheller, 2012) – therefore misses an opportunity to lessen the ongoing environmental and social impacts of road traffic; presumes that a transition in vehicle technology is mutually-exclusive from wider contextual transitions in the way vehicles are accessed, used or integrated with other modes of transport; and also fails to look beyond the near term to consider the roles electric vehicles could play in longer-term future transport and energy generation/distribution systems. These scenarios are, however, a long way from the contemporary status of electromobility.

1.2.3 Electromobility: where are we now?

Plotted on the classic bell or 'S' curves (Rogers, 1983) depicting the typically non-linear uptake of innovations and technologies, electric vehicles are still firmly at the innovation stage, delineated by Rogers as adoption by fewer than 2.5% of the user population. Data from the UK's Society of Motor Manufacturers and Traders (SMMT, 2019a) show that just 15,474 new all-electric vehicles were registered in the UK in 2018, around 0.7% of the 2.5million-plus new car market, a figure rising to a 0.9% market share in the first six months of 2019 (SMMT, 2019b). At the end of 2018, there were a total of around 55,300 battery-electric vehicles and 9,500 range-extended EVs of all ages registered in the UK, accounting for just 0.2% of the total car parc (Department for Transport (DfT), 2019), marking a 0.1% rise in the EV population on the previous year (DfT, 2018a).

With the exception of Norway, where EVs reached a 39% market share in 2017 thanks to exemption from import tax, VAT, annual road tax; reduced company car tax; additional taxes for petrol and diesel vehicles; and incentives such as reduced parking, tolls and ferry transport (BEISC, 2018), internationally most governmental goals for EV uptake have not been reached (Coffman et al., 2017); their sales proportion Western Europe-wide averages 1.5% (ACEA, 2017), a figure skewed by Norway's contribution. No potential 'tipping point' (Gladwell, 2000) – whereby a critical threshold is achieved for the rapid spread of a trend or adoption of a product in the mass market (*ibid*.) – has yet been reached, and testing a hypothesis of disruptive innovation, Dijk et al. (2016) conclude that the niche of electromobility is currently insufficient to displace the ICE (internal combustion engine) regime [the 'niche' and 'regime' concepts are discussed further, Chapter 2]. After an initial low-level impact largely driven by incentives, tax breaks and subsidies (Bakker and Farla, 2015), there is a danger that momentum may be lost, and modelling studies suggest that transformative measures must be taken to achieve the Committee on Climate Change's targets (Brand et al., 2017). As Coffman et al. (2017) point out, more understanding is needed of the attitude-action gap in EV purchases, and of the relationship between uptake, supporting infrastructure and driving patterns – as well as the barriers to EV purchase and take-up. These may be social, affective and cultural, as well as technical, and are now considered in more detail.

1.3 Consumer concerns, adaptations and interventions

1.3.1 Barriers to EV adoption: 'range anxiety' and other consumer concerns

The now considerable and rapidly-expanding body of literature on barriers to EV adoption shows repeated themes, though the most recent studies more closely represent current market conditions, product availability and vehicle characteristics. A major focus of interest has been so-called 'range anxiety', or fear of exhausting battery power on a journey, given the typical early EV's sub-100-mile range between recharges, thought to be a continued major barrier to market acceptance (Noel et al., 2019). This may have contributed to poor confidence or concerns that EVs may require impossible lifestyle changes (Campbell et al., 2014), and earlier studies identified negative perceptions over price, range, charging time and operating costs (Bunce et al., 2014; Rolim et al., 2014) as well as image (Burgess et al., 2013) or negative stereotypes (King et al., 2019); the immaturity of technologies (Steinhilber et al., 2013); and the lack of common standards for charging equipment (Bakker and Trip, 2013) – still unresolved (Hall and Lutsey, 2017b).

Access to a viable, reliable network of public facilities, and fast- or rapid-chargers in particular (Yap, 2017), is crucial to dispel range anxiety and enable drivers to venture longer-distance or take more trips (Rowney and Straw, 2013; Hutchins et al., 2013; Dong et al., 2014); 'blackspots' remain, with the inability to 'roam' between charging network providers a remaining challenge (Ricardo, 2019). Europe's shortage of dedicated residential or domestic parking with access to power supply (Pasaoglu et al., 2014) also continues to be a significant barrier (Traut et al., 2013), also inhibiting take-up by fleets whose users take their vehicles home (Skippon and Chappell, 2019). Availability and proximity of charging infrastructure, both public and private, has been thought to be the single most important indicator of European EV take-up (Sierzchula et al., 2014) and infrastructural development the leading factor to accelerate EV market penetration (Santos and Davies, 2019); local provision is positively associated with EV demand (Morton et al., 2018); and better public car park design and enforcement of parking regulations to ensure access to charging equipment, along with establishing an etiquette to guard against 'charger-hogging', is also considered an important element (Bonges III and Lusk, 2016).

Recharging concerns and purchase prices or costs have all persisted as leading off-putting factors (DfT, 2015a; ACEA, 2018; Höfling and Römer, 2018), along with unpredictable taxation policy (Ricardo, 2019) – with limited model availability, poor industry-level promotion, and unhelpful, dismissive and even misleading car dealers as further issues (de Rubens et al., 2018a and 2018b). The UK government also acknowledges inadequate vehicle supply and infrastructure (DfT, 2018c), despite the continuing growth of the charging network. Berkeley et al. (2018) synthesised concerns into two key areas: 'economic uncertainty', including purchase price and worries about car resale values, as the leading factor, but also 'socio-technical concerns', around charging infrastructure, charging time, driving range, durability, and driving behaviour. In all, across Europe, a lack of suitable infrastructure, cost concerns and technical or operational restrictions outweigh motivating factors in EV take-up (Biresselioglu et al., 2018).

Yet for all that prospective car-buyers are thought to worry about battery range, existing privately-owned EVs are being driven for mileages comparable to ICE cars and even typically used as a main car in a household (Knight et al., 2015), albeit in two-car households doing only short, well-planned peak-time trips (Jensen and Mabit, 2017). Research has consistently found that just a range of around 100 miles would be sufficient for a majority of drivers, most of the time, with little compromise or adaptation (i.e. Cocron et al., 2011; Technology Strategy Board, 2013; Pearre et al., 2011; Weiss et al., 2014), the parking habits of most Europeans make charging EVs feasible (Pasaoglu et al., 2014), and up to 90% of trips could be done by EV (Melliger et al., 2018).

And although EV drivers will choose to charge at public points if this gives them free city-centre parking and free electricity (Robinson et al., 2013), it has consistently been found that the majority of vehicle charging – up to 95%, in Europe (Transport & Environment, 2018) – is done at home, usually overnight, whether in the UK (i.e. Knight et al., 2015), Europe, North America or China (Hardman et al., 2018). It has been argued that public infrastructure is actually more necessary for psychological reassurance, since few drivers venture out of range (i.e. Bunce et al., 2014); that provision of infrastructure within or around a local authority is not actually related to EV uptake anyway (Morton, 2016); and that access when necessary to an ICE vehicle or willingness to use alternative transport modes are arguably more meaningful indicators of EV adoption potential than range (Tamor et al., 2013). Nonetheless, existing EV owners consistently report a desire for more extensive and fast public charging to enable them to undertake longer journeys (Knight et al., 2015); and research for infrastructure-provider Source London found that over half of owners do not use their EV as much as they would like, with a lack of charging points more of an issue than range itself (Lilly, 2016). Needs could also change as battery ranges increase (Hardman et al., 2018), i.e. as vehicles are capable of travelling further on a single charge.

This all suggests perhaps not so much a disconnect between perceptions of EV ownership and the actual experience, as 'range anxiety' being part of a more complex concern which involves perceived – rather than actual – operational limitations; and deeper affective or emotional responses (Noel et al., 2019). As Whittle et al. (2019) argue with reference to a transition to not just electrified but autonomous, shared and even reduced mobility, sociological and psychological decision-making needs to be considered at a user level (*ibid*.).

1.3.2 Driver strategies and adaptations

Drivers' attitudes towards EVs change over time and experience too, in an evolving dynamic between driver and vehicle. After three months, they adapt to charging routines and become more confident (Bunce et al., 2014), although range itself may actually become a heightened concern as limitations for their needs are identified (Jensen et al., 2013). Few EV drivers have been left stranded, because they avoid situations when they might run out of power (Nilsson, 2013), and most early trial participants maintained a safe 'buffer' by not letting charge levels dip below 50% (Technology Strategy Board, 2013).

Adaptations and behavioural changes have been observed as drivers establish a routine for charging (Bunce et al., 2014), with self-reported behaviour modifications on three levels: strategic, tactical and operational (Labeye et al., 2016). Drivers explore optimisation of regenerative braking (*ibid*.); learn how heating and air conditioning affect range (Burgess and Harris, 2011); and adapt their driving style to maximise range (Gjøen and Hård, 2002; Rolim et al., 2012; Anfinsen et al., 2019). Preferences for longer-range vehicles decrease as drivers gain experience and learn how to plan journeys (Franke and Krems, 2013a), though some show greater awareness of energy levels and range dynamics than others (Franke and Krems, 2013b).

It is less-explored, however, how drivers engage with and adapt to their electric vehicles and associated infrastructure in spatio-temporal terms – with reference to time and place. If recharging at home, at a workplace, on-street or at an unconventional location, plugging in overnight on a standard domestic socket or planning a journey around availability of a public-access rapid-charger, there appears to be different spatio-temporal or even psycho-geographical elements to owning or operating an EV – psychogeography here being a loose reference to Debord (1955) and the relationship between location, environment and emotions or affective behaviour. This represents an area worthy of further investigation when considering how to overcome the barriers to EV uptake and operation, and how to support the existing population of EV drivers.

1.3.3 The role of interventions and information

Supplementing the experiential learning, there are interventions which could be made to increase driver confidence. Both experience and driver training are beneficial (Günther et al., 2019) and training interventions and information could help overcome some psychological barriers about range (Franke and Krems, 2013c; Franke et al., 2012) – and accurate information about remaining range may actually be more important to drivers than the maximum range itself (*ibid*.), making critical situations less stressful (Eisel et al., 2016). Predictions on traffic flow, more accurate range calculations, routing and easier-to-understand feedback on energy consumption are all thought to mitigate against range anxiety – although new forms of display and communication of information to the driver may be needed (i.e. Lundström, 2014; Neumann and Krems, 2016; Strömberg et al., 2011; Neaimeh et al., 2013; Franke et al., 2016; Eisel and Schmidt, 2014). However, similarly to findings on eco-driving in ICE or hybrid vehicles (i.e. Franke et al., 2016), EV drivers do not necessarily calculate their energy-saving through regenerative braking (Burgess, 2014), nor do they understand how much energy is regenerated and how this supplements or enhances range (Carroll et al., 2013).

There further appears to be less detailed insight into how drivers engage with information sources and data *external* to their vehicle and with reference to their spatio-temporal position in the wider transport and energy networks – at least, that involving 'mainstream' drivers rather than trial volunteers and employees of energy firms (Schmalfuß et al., 2015). In general, the relationships between ICTs or digital media and the spatio-temporal (re)organisation of travel is not well-understood (Ben-Elia et al., 2014), nor the impact of digital tools such as smartphone apps on mobility and travel behaviour, which is diverse and very app-specific (Ettema, 2018).

Much research in this area has also so far centred around incentives to participate in grid-optimising controlled smart-charging, i.e. finding willingness to engage in gamification of the charging process (i.e. Fetene et al., 2017), and that competitive elements and motivational rewards could incentivise charging behaviour (Franke and Krems, 2013b; Schmalfuß et al., 2015), and knowledge of this so far is largely confined to hypothetical scenarios. Vehicle owner behaviour and practices need to be understood within a broader context (Sovacool, 2018), including their social dimensions and implications (Sovacool et al., 2018a) and cultural contexts (Anfinsen et al., 2019) – and not just with reference to vehicle-to-grid (V2G) integration, but with a view to overall support of EV drivers and uptake of electric vehicles.

1.4 The case for digital media

In general, innovation – "an idea, practice, or object perceived as new" (Rogers, 1983, p.11) – can be an agent for behaviour change (*ibid*.). Digital communications and new media are changing pace, scale and organisation at personal, local and global levels (Sutko, 2010); transforming spatio-temporal structures, the co-ordination of practices and social representations, and the geography of social relationships with reference to mobilities (Mondoux, 2010); and are implicated in the fragmentation or spatio-temporal reorganisation of activities with reference to travel behaviour (Ben-Elia et al., 2014) and mobility (Ben-Elia and Zhen, 2018).

1.4.1 App use in other transport modes

Apps launched by transport providers, service operators or local authorities are very much a part of the digital transport offering, and public transport users, cyclists and pedestrians have for some time shared travel information, complained about delays, and accessed timetables, maps and route plans via social media and smartphone apps (Lyons, 2012a). Users innovate if their needs are not adequately met by existing products and services, adding new elements specific to their context (Lyons et al., 2012); platforms and apps such as CycleStreets, JustPark (formerly ParkatmyHouse), Waze, Strava and OpenStreetMap show how peer-to-peer and community platforms using open-source and user-generated data have since become increasingly commercialised and globalised.

Smartphone-enabled trip-specific transport information, including data on carbon emissions, influences modal choice (Brazil and Caulfield, 2013); apps using crowd-sourced data can enable innovations such as real-time cycle routing, freight efficiency improvements and lobbying on local transport issues (Ross, 2012); and Twitter is a particularly rich source of information-sharing at times of travel disruption (Barber, 2013). In general, digital media can encourage and play a role in intermodal transport (Parkhurst et al., 2012), with a growing part in future urban transport (Shaheen and Christensen, 2014), and enable increasing flexibility and personalised strategies (Götzenbrucker et al., 2010; Pawlak et al., 2015). Indeed, it is already transforming urban mobility (Aguilera and Boutueil, 2018).

1.4.2 Digitalised driving

A range of digital communications technologies, including smartphone apps and in-car internet connectivity, is now becoming widely available to drivers, again representing an opportunity for original research on their impact upon electromobility. Independent start-ups, third-party developers and major OEMs alike are creating digital products for drivers, and with the advent of smartwatches and other 'wearables' as additional communications devices, this is a rapidly-growing market and opportunities in the digitisation of electromobility have long been discussed. An 'internet of cars' has implications for connecting people, artifacts, services and places (Speed and Shingleton, 2012) and could enable more flexible, opportunistic multi-modal and shared travel-planning (Davies et al., 2012), while smartphone apps are already widely-used in car-sharing (Shaheen, 2012b). As more EV drivers need to access the public infrastructure, real-time data on queue length and waiting times for chargers will be increasingly important both for individual user and the electricity supply network (Johnson et al., 2013). Although at the moment there are issues with data reliability, a lack of standardisation, and fragmented offerings in niches, such apps could provide important direct benefits as well as ancillary services for EV drivers (Stillwater et al., 2013).

EV-related digital resources and technologies, enabling location of public charging points, remote scheduling and monitoring of charging, and monitoring energy consumption, are already available in variety. Platforms and apps range from the model-specific such as Nissan's Connect EV and earlier Carwings for the Leaf, the third-party Leaf Control, Leaflink or Leafspy, to charging point locators with routing, real-time information on availability and network access such as Zap-Map and Plugsurfing, or peer-to-peer 'sharing' apps such as Zap-Home and Zap-Work. In-car interfaces incorporating navigation and routing to chargers, and even vehicle-to-infrastructure (V2I) communications, topographical data, real-time traffic information and hazard alerts to optimise range – and even recommend public transport connections for onward travel – have also come to market, i.e. the ConnectedDrive system for the BMW i3 and i8. However, there is little feedback as yet as to whether drivers have been finding apps and digitised services of use so far, or indeed, whether they engage with them to any degree at all. As has been seen with digital applications in other everyday contexts such as health self-tracking or cycling (Pink et al., 2017), there is little understanding of how people actually produce, experience or engage with their data.

As research with other transport users implies [1.4.1], social media with user-generated or crowd-sourced content could also be influential. With specific reference to electric vehicle ownership, virtual user communities are thought to support drivers in establishing their charging and driving routines (Meelen et al., 2019), with added effects of developing wider and public knowledge; empowering drivers; and even contributing to upscaling EV uptake (*ibid.*). As noted of participants in a Dutch Tesla owners' forum (*ibid.*), British EV drivers can be observed to enthusiastically interact on platforms such as Twitter and Facebook, or in forums and online discussion groups such as Speak EV (speakev.com), sharing content such as screengrabs of their cars' data on battery capacity and charging rates – much as an intersection between self-tracking of health or fitness data and social media has been observed (i.e., by Lupton, 2015).

On Twitter, for example, drivers are observed to inform each other about out-of-order or new facilities, to ask about charging options in an area, or even arrange 'emergency' charges at each other's houses, as described later by participants in this research. Social media is used to lobby service providers over charging point unreliability; to seek or share technical information; or lobby manufacturers over perceived issues with vehicles, as well as to complain about 'ICE-ing' (when an internal combustion engined vehicle is parked in a reserved EV bay, blocking access to charging equipment; hashtags for this have included #IveBeenICED and #ICEtard) and 'charger-hogging' by PHEV owners with a less-critical need, or by other EVs parked at a point but not actually charging

(#DimWatt, amongst others). Some drivers also contribute to resources such as OpenChargeMap.org, a database of charging point locations, and social media may also involve advocacy and membership groups as well as the formation of supportive virtual communities.

1.4.3 Digital technologies and consumer engagement

Literature and ongoing research projects in other non-transportation contexts also suggest that apps and digital technologies may engage users and potential consumers in a wider range of pro-environmental behaviours (i.e. Nilsson, 2017); calculating personal CO2 or energy savings, for example, can encourage and reinforce more energy-efficient and sustainable transport choices as well as raise environmental awareness (Gabrielli and Maimone, 2013) and could in general be linked to more sustainable and lower-carbon mobility (Schwanen, 2015).

A 'technology fix' solution may not be suitable in every scenario, nonetheless. Domestic energy monitors become absorbed into normal routines and practices and do not necessarily lead to lower household energy consumption (Hargreaves et al., 2013); the impact of interactive smart metering depends on the motivations, prior attitudes towards energy-saving and degree of involvement with the monitoring system (Oltra et al., 2013); and too much focus on technology can be a barrier (Verbong et al., 2013).

Care must be taken, therefore, not to assume that apps and digital tools will be quantifiably beneficial, or effective beyond an initial novelty period; this also underlines the importance of understanding how they are used in the first instance. "Interactions between apps and physical mobility are only partially understood, in both empirical and conceptual terms," concludes Schwanen (2015, p.675). How – or indeed, if – this applies to the specific case of electric vehicle operation is even less clear: but as the above literature reviews expresses, it warrants investigation.

1.5 Gaps in the knowledge and intended research outcomes

The above literature review highlights that, while some topics related to electric vehicle uptake and usage are reasonably well-understood with consistent findings, other aspects are less well-covered. These include:

- identification and study of any different spatio-temporal or psycho-geographical elements to owning or operating an EV, and how these may be negotiated
- how electric vehicle drivers engage with information sources and data external to their vehicle, i.e. with reference to wider transport and energy systems

- electric vehicle drivers' engagement with digital communications technologies, such as smartphone apps, and digital media-enabled practices and behaviours
- social media engagement related to EV ownership or use, including involvement in crowdsourced data and peer-to-peer platforms
- how engagement with digital or social media may be implicated in wider behaviour change inherent in EV operation, such as new transport- or energy-related practices, routines and habits.

As research on non-car modes of transport and from other sectors such as domestic energy consumption implies, gaining an insight into these points could inform the development of relevant services and products and facilitate the uptake and operation of EVs in the near-to-medium term – and contribute to a better understanding of how electric vehicles could be deployed within the desired smarter, cleaner, convergent and more sustainable transportation systems of the longer-term future.

Chapter 2 Theoretical framework

2.1 Overview

Conceptualising the adoption of electric vehicles as a socio-technical transition (Rip and Kemp, 1998) gives a theoretical model with sufficient breadth, scope and long-term contextual perspective, and also positions the research within the wider field of sustainability transitions. This cross-disciplinary framework accommodates a consideration of agency, human behaviour, social and psychological factors. As a sub-strand of the socio-technical transitions approach, the Multi-Level Perspective (MLP) can then be applied to explore activities on three levels – niche, regime and landscape – and explore technological trajectories and pathways to adoption. The concept of co-evolution of technologies and innovations is presented as a key element of a socio-technical transition, and a simple model is constructed to suggest the potential role (or roles) of digital media as a co-evolving technology in the transition to electromobility. Examples of prior application of the MLP in studies of electromobility are given, and shortcomings of the framework discussed – with reference to the opportunities for elaborating upon it and adding new knowledge or understanding, and how complementary approaches can be applied to supplement its insight. The MLP is shown to provide a suitable framework to explore the research objectives and to build and test the theory; and to provide the vocabulary to generate a set of hypotheses [2.8.2].

2.2 The Multi-Level Perspective (MLP) on socio-technical transitions

2.2.1 Introducing the MLP

> "Electromobility is a complex phenomenon that will involve technological development, policymaking, innovation, new business models, new driving behaviour and new linkages between industries. The systemic aspects of electromobility thus reach far beyond mere technical aspects and a transition to electric propulsion must be understood as a process of socio-technical transformation" (Grauers et al., 2014, p.11).

> "Understanding large-scale transitions to new transport systems requires analytical frameworks that encompass multiple approaches in ways that address interactions between them. The multi-level perspective (MLP)... is one such framework" (Geels, 2012, p.472).

The roots of socio-technical study are in the conceptualising of industrial work systems (Trist, 1980) and hold that interdependency of the social and the technical is paramount in the success of the introduction of new technologies (Clegg, 2000); and that joint consideration must be given to infrastructure and buildings, people, processes, procedures and culture as well as technology

(Challenger and Clegg, 2011); “human needs must not be forgotten when technical systems are introduced” (Mumford, 2006); and if the technical takes precedence over the ‘socio’, unpredictable events and non-linear outcomes occur (G. H. Walker et al., 2008).

Rip and Kemp (1998) further conceptualised shifts to a new technology as socio-technical transitions: transformation processes shaped by social, economic and political forces in turn leading to the technology and its associated systems shaping human relations and societies, in an ongoing dynamic. Drawing upon sources including the evolutionary economics of Nelson and Winter (1982), the ‘megamachine’ concept (Mumford, 1967) and long-term Kondratiev waves or 50-year cycles of socio-technical landscape changes (Freeman and Perez, 1988), the transitions model has technology as part of the process of societal transformations rather than as an external driver, and describes a selection environment for technologies, subject to but also influencing market forces and institutional structures. A socio-technical hierarchy is outlined which can be used to illustrate and analyse a technology’s design, operations and use within a system or ‘regime’.

From Rip and Kemp’s insights, a socio-technical transition is defined as a long-term and large-scale evolutionary, heuristic process (Rotmans et al., 2001), demanding “alignments between multiple developments” (Kemp et al., 2012, p.4); and a co-evolving configuration of elements encompassing cultural meanings and consumer practices as well as technical infrastructures, scientific knowledge, governmental policies and economic markets (Berkhout et al., 2004). Scrase & Smith (2009) claim that technological development and social change are inseparable in the transition process. In this rapidly-broadening and multi-disciplinary field (Markard et al., 2012), in which research has expanded rapidly in the last ten years (Köhler et al., 2019), the term ‘transition’ is often deployed with specific reference to sustainability, and it gives perspective on developments in a long-term context (Voß et al., 2009).

A distinct strand of the socio-technical transitions approach has been developed, notably by Geels (2002), into the Multi-Level Perspective (MLP). Now established in the literature (Tyfield, 2014), this ‘middle-range’ bridge between grand theory and empirical research (Geels, 2011) situates and relates structure and agency (Smith, 2009) and provides “a ‘heuristic’ for thinking through socio-technical transitions” (Tyfield, 2014, p.586). In this model, non-linear processes of transition and technological trajectories happen as a result of heuristic (learning) interplay, discourses and conflicts between three distinct levels – and “enable a co-evolutionary analysis of transport systems that overcomes the dichotomy in transport studies between technology solutions and behaviour change” (Geels and Kemp, 2012, p.75).

The MLP “does away with simple causality”, exploring “processes on multiple dimensions at different levels which link up and reinforce each other” and “encompasses both stability and change” (*ibid*., p.58). It gives us “a language, a shorthand for evoking complex processes” (Smith, 2013); a tool “to conceptualise these very messy, very ambivalent, very complex processes of change” (*ibid*.); a way to explain trajectories from the micro to macro level (Berkhout et al., 2004); and “an integrated and systemic perspective on socio-technical change” (Whitmarsh, 2012, p.486), as well as a valuable analytic tool for identifying and engaging with diverse stakeholders (*ibid.*), for predictive modelling (Köhler et al., 2009; Whitmarsh and Nykvist, 2008), and to discuss the roles of industry or policy-makers (Whitmarsh and Köhler, 2010).

Though criticised for functionalism (Genus and Coles, 2008), “it does not assume that all actors work towards shared system goals” and has “no bias towards stability” (Geels, 2010, p.506); having common ground with conflict theory and actor-network theory, it can “assume creative and heterogenous actors, but also acknowledge the embeddedness of actors in regimes”, allowing it to combine “evolutionary interest in long-term patterns” with “interpretive interest in social enactment, sense making and cognitive learning” (*ibid*., p.504-5), making it an appropriate framework in which to pursue research involving both quantitative and qualitative analysis.

Effectively, the MLP is a coherent and clearly-defined approach to bring together the technological and the social in an ongoing dynamic analysis. In the structure of its three levels – which echo the original three levels of socio-technical analysis: primary, whole organisation and macrosocial (Trist, 1980) – it gives a vocabulary to describe processes and relationships at all scales. These levels, outlined below, correlate neatly with the micro-, meso- and macro-level activities considered in this research project.

2.2.2 Micro-level niche

The micro-level niche is defined as the locus for radical innovations (Geels, 2002) and radical activities (Köhler et al., 2009), from where novelties evolve and emerge (Rip and Kemp, 1998); where new routines, rules and user practices can be tried and tested (Smith, 2013); and where learning processes take place and experiments and demonstration projects are carried out (Geels and Kemp, 2012). Context-specific innovations – such as practices, interventions and trials, as well as technologies – occur and are developed by actors; importantly, these actors include consumers and end-users (Geels et al., 2018).

Discursive properties within the niche enable the nurturing of an innovation and its shielding from market or political forces in its nascent stages (Smith and Raven, 2012) although expectations, learning and problem agendas may be shared on a wider level (Geels and Kemp, 2012).

There are challenges for wider diffusion (Seyfang and Smith, 2007), but an emphasis on knowledge production and engagement at grassroots and community level (Smith et al., 2013; Leach et al., 2012; Ockwell et al., 2009). It is these bottom-up activities which lead to 'cracks' in an incumbent regime such as automobility (Geels et al., 2012; Kemp et al., 2012; Dudley and Chatterjee, 2012), ultimately opening up to form a new paradigm.

Mapping electromobility onto the MLP framework to construct a theoretical model of EV adoption as a socio-technical transition, therefore, individual electric vehicle drivers could thus be conceptualised as niche-level actors, employing and experimenting with technologies and novel practices. Examples of niche-level actors and innovators, and niche-level activities, are suggested and summarised below:

table 2.i: Electromobility: Niche-level actors and activities (examples)

Niche actors	Individual EV drivers Fleets running EV trials Local/grassroots social enterprises or business initiatives, i.e. EV hire for tourism Local councils running small-scale initiatives, i.e. free parking for EV charging, toll-free access etc. Start-up vehicle manufacturers Start-up vehicle converters (aftermarket) Start-up service providers, i.e. infrastructure, charging networks Mobility service providers, i.e. EV car clubs, car-shares, on-demand services Digital developers, i.e. of charging network access apps Regime-level incumbents running small-scale experiments and trials
Niche activities	'Refuelling' at home or at non-commercial locations i.e. workplaces, private businesses 'Refuelling' at unconventional locations, i.e. public car parks, on-street, leisure centres Recharging using renewable electricity generated by domestic PV array or similar Establishing new business practices and routines, i.e. to support EV deliveries, electric car-pooling Establishing new social protocols, i.e. when acceptable to unplug another car at a public point Establishing new practices, i.e. driving to a park-and-ride to leave car charging Using apps and digital tools for journey-planning with reference to vehicle range and charging Contributing to open- and crowd-sourced data and resources, i.e. information on charging points Participation in online EV communities, i.e. web forums, discussion groups Participation in offline activities i.e. environmental lobby groups, EV enthusiast clubs

2.2.3 Meso-level regime

Meanwhile, social groups, habits, cultural associations plus industrial, political and economic interests sustain the meso-level 'regimes', defined as the loci of established practices and associated rules (Geels and Kemp, 2012), embedded in institutions and infrastructures (Rip and Kemp, 1997), typically on a national or organisational level. Socio-technical regimes are less rigid and tangible than systems (Geels, 2012), with multiple causalities, alignments and linkages between levels. They are a coalition and meta-coordination of many different elements in the socio-technical system, including institutions, companies, policy-makers, special-interest groups and civil society actors, and they come in and out of alignment (Geels, 2004); and they are often multiple in a scenario and hierarchical, i.e. subaltern and dominant regimes (Geels and Kemp, 2012). A dominant regime actor might be national government itself, i.e. the British government backing incentives such as the Plug-In Car and Plug-In Van grants, zero-rate Vehicle Excise Duty and 0% benefit-in-kind company car tax. Smith et al. (2005) further differentiate between 'nesting' and 'spanning' regimes, giving the example of how the electricity regime is nested within a global energy regime which is organised around fossil fuel trade and consumption.

As elements of the regime come under pressure from niche or landscape activities, alignments shift or tensions appear; these 'cracks' open up possibilities for transition to take place. However, the relationship between niche and regime often has blurred boundaries and inequalities of power (Smith, 2007), and the interplay between protective niches and selection pressures from the dominant regime has led to cycles of hype, path-dependencies and technological trajectories in earlier unsuccessful attempts to produce and market EVs (Geels et al., 2012).

Regime incumbents (existing, established actors or institutions) have become increasingly involved in electromobility: household-name service providers such as British Gas and Siemens are supplying recharging equipment, for example, and both BP and Shell are rolling out EV charging points on their forecourts. More major carmakers and manufacturers are beginning to offer mainstream-sector, purpose-engineered electric models which have now largely superceded retro-fit conversions of vehicles originally designed to accommodate an ICE powertrain. 'Outsider' niche players such as renewable-energy firm Ecotricity (installer and operator of the Electric Highway motorway service charger network) have become increasingly incorporated into the regime, i.e. through installation and operation of their chargers at pre-existing service station locations, and incumbents in other regimes, such as in the solar energy industry, are interlinked with electromobility and appear to be shaping the emerging technological field from an earlier stage than previously thought (Apajalahti et al., 2017). Some of this activity is again underpinned by both central and local government funding, grants and other investment incentives.

table 2.ii: Electromobility: Multiple regimes and regime-level incumbents (examples)

Implicated and inter-related regimes	**Regime-level actors in incumbent regimes**
Automotive regime	Automotive OEMs and suppliers; car dealers, maintenance/service providers
Oil industry and fuel supply regimes	Fuel suppliers now offering EV charging (i.e. via new divisions or takeovers), i.e. BP, Shell; established standalone providers, i.e. Ecotricity
Electricity generation, distribution, supply regime	Energy firms, providers; i.e. National Grid, Ofgem
Transport regime	Established and large-scale fleet operators

Implicated and inter-related regimes	Regime-level actors in incumbent regimes
Planning and policy regimes	Central government, local councils/authorities
Industrial and infrastructural regimes	Established manufacturers and installers
Media, advertising and marketing regimes	Automotive media and events; influencers in car culture; advertising and marketing agencies
Business regime	Organisational-level initiatives at firms and corporations, i.e. for CSR (corporate and social responsibility), PR (public relations)
Taxation regime	Organisational accountants and auditors; cost-cutting initiatives

Examples of regime-level actors, institutions and the multiple regimes implicated in electromobility are given in *table 2.ii*. Most (if not all) of these are, of course, also implicit within the existing internal combustion engine-driven regime, with vested interests and established operational models; the newcomers without a background in ICE mobility must interact and cooperate with these incumbents.

2.2.4 Macro-level landscape

The wider-context macro-level ‘landscape’ is more abstract: it exercises exogenous influence in terms of, for example, the broader political and macro-economic backdrop, social values, and belief systems or ideologies. ‘Landscape’ is seen in a literal sense – the built environment and physical infrastructure, houses and cities (Geels and Kemp, 2012) – as well as metaphorical and again, as with the regime-level actors and institutions, many elements are shared with, or developed with reference to, the existing automobility regime.

table 2.iii: Electromobility: Landscape-level influences, actors or institutions (examples)

Landscape influences	Landscape-level actors and institutions
Economic and financial climate	International trade bodies i.e. WTO; industry-specific trade bodies, i.e. ACEA
Public concerns over sustainability, climate change, pollution, health	International campaigning organisations, non-profits, charities (i.e. Greenpeace)
Political opinions and campaigns	EU, international-level legislators
Societal values and beliefs, cultural norms	Social, cultural and even religious leadership
Consumer trends and fashions, behavioural and demographic trends	Economists and forecasters

Top-down pressure can stimulate activity and open up windows of opportunity at regime and niche levels, such as legislation on vehicle emissions impelling development of cleaner technologies, or macro-economic recession having an effect on mileage driven. For example, electromobility in the UK has benefited from a certain level of support from landscape-level actors such as the EU, behind much funding of research and development programmes as well as driving legislation on air quality and GHG emissions. Yet in turn, new niche activities and regimes emerging as a result of niche activity influence the landscape, such as new consumer behaviours growing to wider trends then incorporated into future planning and informing economic modelling. Large multi-national and multi-sectoral corporations offering products and services on a global scale – in infrastructure, energy, technology and manufacturing, for example – could also be seen as landscape-level operators, having influence on legislation and policy. Examples of landscape-level influences and actors are suggested in *table 2.iii* above.

Actors, whether individuals, organisations or institutions, can move between levels over time, across different regions or operate at different levels simultaneously: for example, Tesla began as a niche US electric car and energy products start-up, but with its cars now among the best-selling models in Europe (Bolduc, 2020) it has effectively become an established automotive regime player in some countries – and as a globally-known and sometimes controversial public figure even intervening and speaking out on governmental policies, its co-founder and figurehead Elon Musk has landscape-level influence across multiple industries. Meanwhile, established regime incumbents have funded or operated niche experiments, such as BMW's DriveNow carsharing service which included the option of EVs. Such a dynamic can sometimes blur the boundaries between niche, regime and landscape, but the discursive, reflexive nature of the interplay, and subsequent interpretative flexibility, is stressed at length as a benefit (i.e. Smith and Kern, 2009; Smith and Stirling, 2007; Walker and Shove, 2007).

2.3 Transition pathways

Different pathways to the transition result from different alignments between the three levels, and their timings or synchronisation. Geels and Schot (2007) describe four main types of pathway, not necessarily mutually exclusive:

- transformation, when the regime modifies its activities (such as research and development into innovations) as a result of landscape pressure. This could be manifested as, for example, a change in focus for a vehicle manufacturer, or infrastructure- or service-provider

- de-alignment and re-alignment, when regimes disintegrate under major landscape pressure, opening up cracks for niche innovations; new alignments between the regime actors and the niche are then formed, creating a new regime. In electromobility, this could be a legislative or economic backlash against an existing technology, such as more punitive taxation or banning of diesel cars

- technological substitution, when well-developed niche innovations replace the existing regime: i.e. when electric vehicles displace ICE in a manufacturer's range and charging points supersede petrol pumps

- and reconfiguration, when niche innovations are adopted within a regime on a small level, triggering more major changes in the regime itself. This encompasses 'add-ons' and hybridisation – new technologies supplementing or complementing those in the existing regime – as well as competing or disruptive elements; i.e. the combination of EVs with vehicle automation, vehicle-to-grid and vehicle-to-infrastructure connectivity, integration into shared fleets or multi-modal transport systems.

Electromobility in Germany so far has been conceptualised as a process of transformation and adaptation, for example (Mazur et al., 2015), but a more radical reconfiguration may be possible in the UK due to a lesser incumbent regime – automotive manufacturing – to protect (*ibid*.). Pathways to future mobility emerge as a result of coalitions and competition between innovative actors (Marletto, 2014) though Steinhilber et al. (2013) warn of the risks of 'lock-ins' to unsustainable technologies.

Further descriptive elements in the MLP framework include the concept of 'innovation cascades': the knock-on effects and developments from an innovation's impact or the coming-together of multiple innovations (Geels and Kemp, 2012), such as the advent of improved batteries for EVs as a result of advances in nanotechnology (*ibid.*), and 'fit-stretch patterns', whereby incremental introductions are made which have a good 'fit' with the existing regime but then 'stretch' its parameters or applications. Hybrid vehicles, for example, are not a desirable end-product in themselves, still dependent upon fossil fuels, but have served as a short-term platform for 'stretching' technology innovation and public awareness of vehicle electrification in general; Geels and Kemp (2012) give the example of electrified vehicles as 'fitting' with the regime in terms of their potential usage, but 'stretching' their potential as energy storage devices in vehicle-to-grid configurations. The MLP can also describe discontinuities and cultural misalignments associated with the emergence of new paradigms in a transition (Dosi, 1982), whereby messages from regime and landscape contradict the activity in and perceptions from the niche, or vice versa.

Accommodating the potential to describe a diverse and dynamic set of narratives in different domains over the process of a transition, the MLP therefore provides a broader overview on human engagement with technologies, especially at the landscape or macro level, than, for example, the context-specific cognitive work analysis framework (Rasmussen et al., 1994) –

although this takes a similar view on siting individuals as actors with agency in human-information interactions – or methodologies such as AcciMaps (Rasmussen, 1997; Rasmussen and Svedung, 2000), usually applied in retrospective system analyses of very specific incidents or accidents. It has parallels with the systems and complexity theory-based new mobilities paradigm (i.e. Urry, 2007), but is considerably less abstract in its formalising of an analytical framework. It also has some common ground with practice theory – as derived from Bourdieu (1977) to explore social habits and their contextual background – and which can be applied for an analysis with reference to behaviour and social change (Spaargaren et al, 2016), but has more emphasis on individual actors and is more hierarchical (Shove and Walker, 2010). As well as giving greater long-term perspective, it describes a more clearly delineated relationship between individuals and structures – taking a greater emphasis on structural influences – than, for example, the energy cultures or mobilities cultures frameworks (i.e. Hopkins and Stephenson, 2014), or theories focusing on affect and embodiment, or production and consumption. However, approaches sharper-focused on a micro level have potential for complementary application [2.7].

2.4 Co-evolution and pathway technologies

Co-evolution is a core concept in the MLP (Geels, 2018a) and becomes even more important when considering goal-oriented low-carbon transitions (*ibid*.). Transitions involving a co-evolution of multiple technologies, and of societal factors with technologies, have been described in numerous and varied case study contexts. These include the transition in piped water supply and accompanying cultural and behavioural changes in personal hygiene (Geels, 2005); co-evolution of waste and electricity regimes forming a Dutch biomass network (Raven, 2007); parallel advances in medicine and engineering plus 'outsider' developments in the transition from cess pools to sewer systems (Geels, 2006a); knock-on effects of the transition from propeller-piston engine aircraft to turbojets on aerodynamics, aircraft lightweighting, air traffic control technologies, airport infrastructures and consumer demands (Geels, 2006b); and micro-financing and payment schemes co-developing alongside pico-solar products such as portable lamps and phone chargers in a transition from kerosene generators to off-grid solar systems in Kenya (Ockwell et al., 2014).

Building this theory in a temporal context, Nykvist and Whitmarsh (2008) propose co-evolving 'pathway technologies' as bridging the gap between a current regime and a newer one: these "might include emerging information technologies" which are "associated with important behavioural and institutional changes (e.g., new user practices)" (*ibid*., p.1375). Indeed, Augenstein (2015) warns that the niche activity of electromobility, constrained as it is by powerful regime incumbents, will *only* become successful if different elements co-evolve to find new functionalities for the electric car, such as energy storage or as a component in intermodal transport systems. The co-evolution of digital technologies and communications systems has been cited as a potential factor in a transition in automobility (Sheller, 2012), and further investigation specific to electromobility is needed to understand this beyond a hypothetical level.

The visualisation *fig 2.i* below suggests possible ways in which co-evolving digital media and communications could be involved in the interplay between different regimes – transport, electricity supply, mobile services – as well as with more niche services such as car clubs and car-share schemes, to facilitate such new functionalities and stimulate transition.

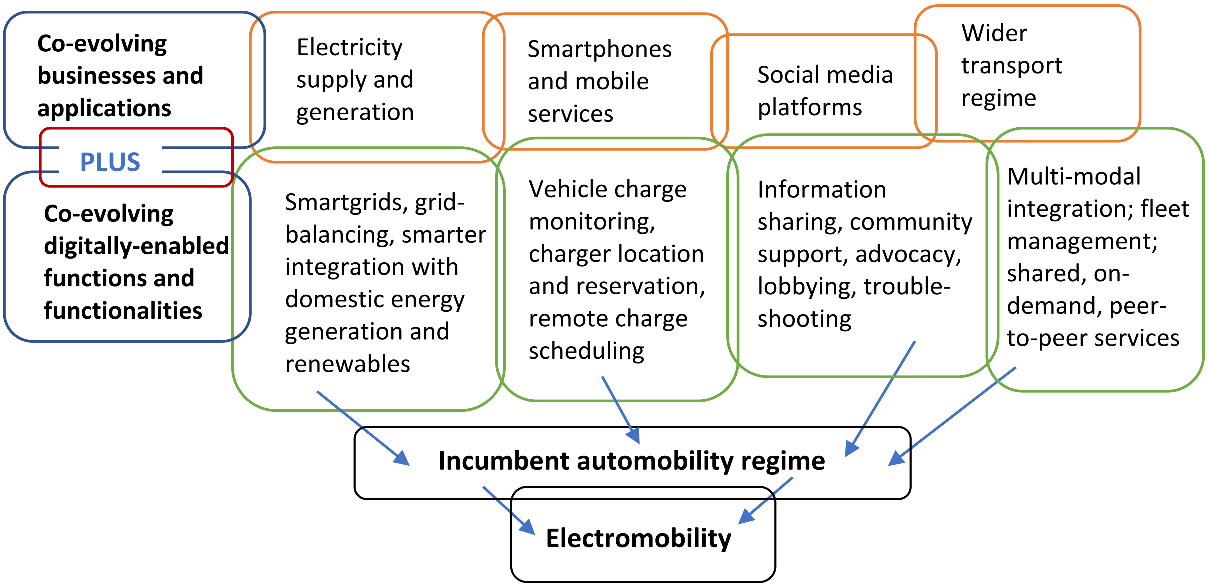

fig 2.i: Potential roles of digital media in a transition to electromobility

This indicates elements of a fit-and-stretch pattern (i.e. where electromobility impacts upon renewable electricity storage and supply) and factors leading to a reconfiguration of the wider mobility paradigm (i.e. integration into smarter multi-modal systems), as well as where digital media could potentially intervene as the enabling agent, pathway technology or linkage in an EV-ICE substitution (i.e. in terms of user convenience and information). While – at least in the nearer term – electrification of vehicles could just be an adaptation shoring up the existing automobility regime (Avelino and Zijlstra, 2012), the possibility of multiple transition pathways suggests greater long-term transformative potential to a fossil fuel-free regime with broader benefits.

2.5 The MLP on electromobility: prior applications

The MLP has been applied to explain resistance to change in the automotive industry and transition failure (Nieuwenhuis and Wells, 2012), to explain low EV take-up thus far (Nykvist and Nilsson, 2014), to model electromobility transition scenarios (van Bree et al., 2010); and recommend interventions (Nilsson and Nykvist, 2016). However, much outlook from these analyses has been negative: "the disruptive regime of full-electric mobility is currently insufficient to displace the ICE regime" (Dijk et al., 2016, p.77). This echoes more general conceptualisation of a socio-technical transition to sustainable mobility: not thought to be imminent (Wells and Xenias, 2015) although windows of opportunity may be emerging (Morton et al., 2017).

More recently, a favourable 'push' from landscape level has been identified to stimulate electromobility (Berkeley et al., 2017) but barriers to a transition are said to remain as a result of multi-level factors in two main areas: economic uncertainty and socio-technical issues (*ibid*.). These socio-technical concerns include issues as described [1.3.1] such as availability of public charging facilities, the time needed to recharge, limited driving range and worries over battery durability (Berkeley et al., 2018), and overall, as a radical niche innovation, electric vehicles are still yet to have an impact on the existing automobility regime and wider mobility system (Geels, 2018b); there is evidence for a technological substitution but major changes in culture and behaviour are needed for a reconfiguration of mobility (Köhler et al., 2018).

2.6 The MLP: criticisms

The MLP has been criticised, however, for a lack of methodological coherency and clarity on what constitutes a transition (Genus and Coles, 2008); over-reliance on niche-level analyses (*ibid.,* 2008; Berkhout et al., 2004); a lack of analytical depth (Smith and Raven, 2012); imprecision for mapping empirical data (Safarzyńska et al., 2012); lack of a spatio-temporal or socio-spatial element (Smith et al., 2010; Jørgensen, 2012; Avelino and Zijlstra, 2012); being weak on agency and power (Weber and Rohracher, 2012; Tyfield, 2014); needing cultural perspective (Sheller, 2012); problems of scale (Hodson and Marvin, 2010); assumptions of passive consumers, limited understanding of tensions between niche and regime actors (Nykvist and Whitmarsh, 2008); incoherent differentiation between actors and systems (Markard and Truffer, 2008) and a lack of detail on lock-in mechanisms and their inter-connectedness (Klitkou et al., 2015).

Smith (2013) notes wryly that the MLP "is problematic enough for people to make a contribution"; Shove and Walker (2010) call for the inclusion of bodily activities, meanings and understandings, and discussion of the patterns of everyday life; Smith et al. (2010) argue for more research on the relationship between functional and operational fields, and administrative, territorial and communicative spaces; and Smith (2009) suggests a "move from histories to geographies" (p.12), looking at empirical places and sites and how these contribute to broader (conceptual) niche spaces. Extrapolations from the MLP include the transitions management (TM) approach for governance (i.e. Voß et al., 2009) and strategic niche management (SNM); these have much in common though differ in their starting points, focus and approach (Loorbach and van Raak, 2006).

There has been further elaboration on typologies (Geels and Schot, 2007) and models proposed within the paradigm to enrich it (Geels, 2010); Raven et al. (2012) developed a second-generation 'multi-scalar' MLP with more explicitly spatial elements to understand time/locality contexts; and subsequent analyses and typologies have placed more emphasis on individual actors and user-consumers, such as in a comparison of the transitions to low-carbon electricity in Germany and the UK (Geels et al., 2016) and an analysis of the role of consumers in energy systems (Schot et al., 2016). This has helped address concerns that the MLP is best-applied in historical analysis (Urry, 2012) – although valuable lessons on transition failure can still be generated retrospectively (Seyfang and Smith, 2007).

2.7 The MLP and complementary approaches

To achieve a more granular level of detail or draw out complementary analyses, researchers have applied the MLP in tandem with other frameworks, which can compensate for some, if not all, of its suggested shortcomings and limitations and give a supplementary – and ultimately richer – understanding. For example, the MLP and new mobilities paradigm are complementary approaches (Tyfield, 2014); or combining the MLP with the Energy Cultures model (Stephenson et al., 2010; Stephenson et al., 2015), which considers energy use in the three key areas of norms, practices and material culture, provides new perspectives and ways to understand a transition (Hopkins, 2015).

2.8 Conclusion and proposal of hypotheses

2.8.1 Conclusion

In conceptualising electric vehicle adoption as a socio-technical transition, it can be integrated into a broad, multi-disciplinary debate on sustainable transport and behaviour, and on the adoption of new and more sustainable technologies. The Multi-Level Perspective on socio-technical transitions provides a simple, elegant yet effective theoretical structure and terminology well-suited to approach the research, describing not just interactions at micro, meso and macro levels, but identifying pathways and trajectories by which a technology might be adopted, and a transition occur.

The MLP is an established approach in the research literature on technology adoption, and although weaknesses and gaps have been identified, these are shown to provide opportunities to build an understanding of connections and linkages between its levels. It also accommodates analytical approaches using complementary frameworks to gain a deeper insight. As such, it offers a perspective through which the research can be undertaken in a novel way.

Using this framework to contextualise the insight gained from the existing literature on electric vehicle adoption [Chapter 1] and background interviews and project pre-planning [described, 3.2], and the areas and topics where a deeper knowledge and understanding is required [1.5], electric vehicle drivers – as the focus of the research – can be positioned as niche actors, engaging in specific and unique activities and practices both within the electromobility niche and in interaction with regime and landscape factors. The key concept of co-evolving and pathway technologies proposes a role for digital media and communications technologies in the electromobility transition, delineated and explained in terms of an interplay and potential linkage between the levels of the MLP. With this in mind, hypotheses can be generated.

2.8.2 Research hypotheses

- **[H1]** There are different spatio-temporal elements involved in driving and operating electric vehicles, involving issues including vehicle charging, journey planning and vehicle range.
- **[H2]** Digital media and communications technologies assist and support electric vehicle drivers in their journey planning, recharging and vehicle range optimisation.
- **[H3]** Digital media-based grassroots or community support, such as that offered via social media platforms, is important to the early-innovator electric vehicle drivers.
- **[H4]** Taking into account the above, digital media and communications technologies are a potential linkage in the transition of electromobility from a niche activity to a mainstream regime, and the configuration of a new mobility paradigm.

Chapter 3 **Methodology**

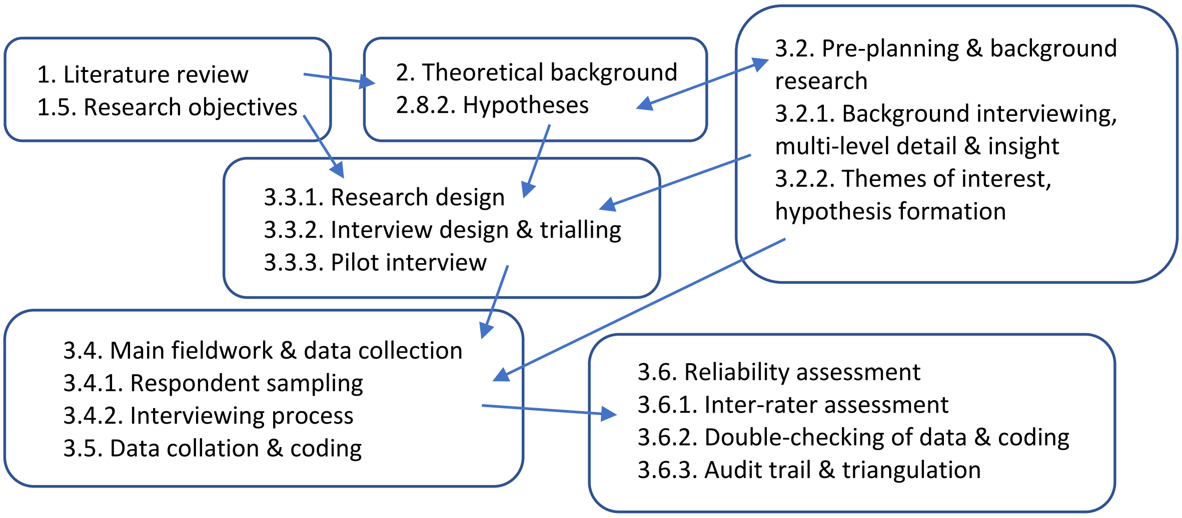

fig 3.i: Methodology schematic

3.1 Introduction

The intended research objectives and outcomes to address the shortfalls in understanding [1.5] and the subsequent proposed hypotheses [2.8.2] guided the research design with reference to the MLP theoretical framework and its ontology and epistemology. A methodology was determined to collect data suitable to address the hypotheses, involving a blend of quantitative and qualitative data collection through semi-structured interviewing, chosen as the most appropriate approach to gain a sufficiently rich level of detail and narrative content. The interview questions were informed by the findings and procedural learnings from background interviewing, and the interview structured into distinct sections with individual questions designed to address the research hypotheses. Sampling, identification and contact of the interview participants; issues raised and noted in relation to the interviewing process; and the taxonomy and coding strategy for data collection are described. Elements of the research procedure subject to the interpretative nature of the research methodology are identified, and reliability assessment, validation and triangulation techniques applied and considered.

3.2 Pre-planning and background research

3.2.1 Background interviewing; multi-level detail and insight

Three focused and in-depth discussions (February 2014) helped guide the development of the interview questions and to refine the research hypotheses, giving insight at all levels of the Multi-Level Perspective. These were with K, an experienced independent consultant, formerly an executive at a charging point supplier/operator and EV importer, whose input included discussion of landscape-level factors; at niche level, M, a high-mileage Nissan Leaf owner who was an active EV advocate on message boards and Twitter; and representing the regime level, B, the-then head of the electric vehicle programme at a major European carmaker. No set questionnaire was followed for these interviews, which were effectively informal conversations, but each subject was asked about what they saw as the barriers to EV uptake; how they saw the charging infrastructure; whether they used digital tools, apps or EV-related social media; if they thought these were useful or important; plus individual and ad hoc questions relating to their particular expertise or experience. Key insights are summarised:

- **K** (via Skype; written notes taken): He pointed to new business models for leasing or hiring charging equipment, and foresaw more integrated commercial charging networks, underpinned by EU legislation and mandates. He believed that range anxiety was a concern for many buyers – but the biggest barriers were EV purchase costs and lack of access to off-street parking for home charging, and very low general levels of EV awareness amongst mainstream consumers. He saw a highly-visible minority of enthusiasts on blogs and social media as having influence; and Twitter and the forums acting to good effect in stirring infrastructure providers. Presciently, he saw apps, the services offered through them, and the data they generate, as one of the next big commercial battlegrounds. He pointed out that vehicle manufacturers will want to 'own' data, giving a further revenue stream, but third-party apps may integrate with an OEM infotainment screen and offer cheaper services: "another one of those messy early-market shakedowns that has to happen."

- **M** (via Skype; written notes taken): Mainly using his (second) Nissan Leaf for an 85-mile daily round trip commute, he had clocked up nearly 13,000 miles in the previous seven months. An active Twitter user, he regularly posted his energy and cost savings and reported his charging routine and issues; he now drove more slowly to maximise battery range. He had become "evangelical" about air pollution and environmental issues, installing solar panels and a heat pump at home, saying that having an EV had made him more aware of energy usage; he had written to OLEV to request policy to encourage or mandate workplace charging facilities. He used Nissan's Carwings app for remote monitoring of his car's charge levels, as well as – with varying degrees of success – mobile apps and route-planners from charging providers, but preferred to maintain his own map of points on Google Maps. He wanted route optimisation taking into account factors such as weather, traffic conditions, topography and a minimising of charging downtime; and paid tribute to the social-media based EV community and grassroots support.

- **B** (in person, conversation recorded and transcribed): His firm's research with customers had found that about 90% of their charging was at home, but concerns over public infrastructure were a barrier to initial take-up – he saw this as an issue of mindset and pointed out the importance of experience and regular routines, charging becoming something that "fits into life". He saw a role for EV-sharing in particular contexts, and for peer-to-peer platforms such as Chargeatmyhouse to "give more flexibility to the public network"; he saw also a sense of community and co-operation amongst early-adopters, rooted in social media. For his own trips, he looked at Twitter for feedback on charging points in service; used the database of charging points in his EV's sat nav when route-planning; checked charger type, speed and availability online; and used the car's app to schedule and monitor charging, remotely check range, and pre-condition (heat/cool) the cabin. Running an EV had made him much more aware of energy efficiency and the renewable electricity mix, he said, and he now looked at the GridCarbon app most days.

3.2.2 Identification of initial themes of interest and hypothesis formation

Observations from the above exercise built upon general research forming the backdrop to the project and enabled a sketching-out of topics of interest with specific reference to the role of digital media in the electromobility transition. These themes were prompted by the interviews and conversational content, and were generated as initial indicators and ideas for further consideration; they were not identified and assessed in a formal methodology or thematic content analysis as such, but formed a vital part of the background research prior to developing the hypotheses [2.8.2] and determining methods for data collection.

- **Spatio-temporal adaptations**: The preparatory interviews suggested support for the hypothesis [H1] that driving an EV involved adaptations in terms of both time and place or location. Anecdotes illustrated how drivers changed their routines or habits to allow for vehicle charging downtime (typically eight hours on a domestic plug, at best 30 minutes for an 80% charge on the Ecotricity rapid-chargers coming into service at that point for cars suitably-equipped); and how journey-planning needed to be based around the typical 70-80-mile real-life battery range of cars available at the time.

- **Individualised interfaces**: An increasing variety of websites, apps, devices and digital resources were becoming available (Alkhalisi, 2012a) for plotting routes, planning journeys and to locate public charging points, in addition to manufacturer-supplied in-car navigation systems with charging point information, such as Nissan's Carwings and Renault Link, as used by the above interviewees. But amongst this multiplicity, what interfaces or platforms did drivers prefer or find most useful, user-friendly or relevant, and was there information and data that they would like to see, but was not yet available to them? Electric motorcycle manufacturers had reported enthusiasm for new technology as a main attribute of their customers, including software and apps for personalised settings to give an individualised riding experience that could not be offered on a conventional motorcycle (Alkhalisi, 2014a; Alkhalisi, 2011), underlining the potential for digital personalisation in appealing to new EV consumers. This suggested a further aspect to consider when addressing hypothesis [H2] that digital media and communications technologies support drivers in their journey-planning, recharging and vehicle range optimisation.

- **Learning experiences and changing driving style**: B described how building upon experiences and establishing routines were important, including prior knowledge as to where public chargers are located on a particular route, and how worries about public infrastructure waned once drivers became accustomed to mostly charging at home. Given the websites, apps and sat nav functions he mentioned deploying as part of his journey-planning, this raised the questions of whether such digital and connected tools play an especially crucial role in the early stages of EV ownership, and if they continue to support drivers in the longer-term too. M added an interesting point about now driving more slowly to conserve battery range, in the context of learning about his car's limits and energy-consumption characteristics. Both issues hinted that digital media usage could also change or evolve over time as drivers' experience grows. This is another important sub-theme, involving behaviour change, in addressing the hypothesis [H2].

- **Charger location and payments**: Although the UK's public charging network was growing, concerns were raised over online databases and maps of their locations being incomplete or out of date, while the membership schemes for access and payment were seen as being problematic – PAYG and 'roaming' agreements were called for, along with better reporting mechanisms for charger faults and technical problems for greater confidence in their reliability (Alkhalisi, 2012a). This highlights the potential role (and improvement) of digital technologies in tackling these concerns going forward, querying hypothesis [H2] on an ongoing, dynamic basis.

- **Grassroots activities:** Enthusiast groups, web forums and user communities were seen as supportive by all three pilot-phase interviewees. Social media and 'sharing' apps were deployed, sometimes in a stressful situation and for lobbying/complaints (as M and K described) rather than as aspects of daily routine. This led to the proposal of hypothesis [H3] that grassroots or community support as offered via social media platforms was important to early-innovator EV drivers.

- **Evolving environmental attitudes**: While environmental concerns were not his initial reason for purchase, M was adamant that he had become newly concerned about ecological issues; B too had become more interested in renewable energy and energy consumption. This supplemented input from a London private-hire fleet operator running 20 BYD e6 EVs, who hoped his cars could play a role in grid-balancing as a next step, also seeing this as a potential new revenue-stream (Alkhalisi, 2014b). Given fleet operators were already developing and using bespoke software for dynamic positioning and deployment to optimise EVs' efficiency with respect to charging downtime, prefiguring automation and wider internet-of-things connectivity (Alkhalisi, 2013), the question arose of whether individual drivers' engagement with digital technologies might be implicated in their adoption of new energy- or carbon-saving behaviours or attitudes – and to extrapolate, thus contribute to electromobility's future convergence with other sectors such as the energy supply chain (Alkhalisi and Thornton, 2015). This formed the basis of hypothesis [H4], that digital media and communications technologies are a potential linkage in the transition of electromobility from a niche activity to a mainstream regime and the reconfiguration of a new mobility paradigm.

- **Electromobility in the Multi-Level Perspective**: The narratives collected contained themes which evoked the levels and interactive elements of the MLP. For example, M's widened concerns about energy use and climate change showed an individual's engagement with landscape-level factors; lobbying OLEV for a workplace charging mandate is niche pressure on the regime; and installing a domestic heat pump and solar panels shows interaction between multiple niches. B mentioned peer-to-peer charger-sharing, an innovative niche activity, and the potential of open source-based ground-up or start-up innovations, again from the niche; K talked of regime-level developments from infrastructure and service providers, and the influence of landscape-level legislation. This all suggested that an analysis within the MLP framework could be rewarding and informative, and suitable for extrapolating results to a wider context.

The decision was made at this stage to focus on private car drivers for the ongoing research. Fleets, including postal and delivery services as well as car-share schemes and car clubs, were thought to be more likely to have an impact on early EV take-up (i.e. Green et al., 2014; Dijk et al., 2013; Orsato et al., 2012; Shaheen, 2012), with anecdotal feedback from operators suggesting that swapping to an electric car could be easier for professional, trained drivers or managers operating vehicles in a controlled, structured and suitably-equipped environment with its own dedicated charging facilities (Alkhalisi, 2012b). Encouraging private individuals – with more varied contextual circumstances – into making the transition would therefore be more of a challenge and demand a distinct understanding.

In addition, the preliminary observations underlined that yes/no answers and statistical data alone do not tell the whole story: individual narratives and anecdotes bring rich and beneficial illustration and insight, and such qualitative detail plays a part in supporting or refuting the hypotheses. This reinforced the value of personal interviewing, and thus informed the next stage of the research design, with reference to the MLP framework, although supplementary data collection methodologies were also considered for triangulation purposes.

3.3 Research design and trialling

3.3.1 Research design

The intended outcomes [1.5] centred around gaining *insight* – into the behaviours and practices of EV drivers and their engagement with digital technologies – with a view to informing the development of products and services to facilitate EV uptake, and in turn building an understanding of the role EVs could play in smarter, cleaner, convergent and more sustainable future transport systems. This guiding principle required an inductive approach with scope for methodological diversity and adaptability. Qualitative enquiry techniques were thus fundamental to the research design to yield a rich depth of personal narrative – ‘thick description’ (Geertz, 2003). This is consistent with the growing incorporation of social science and its perspective into the discipline of transport studies (Lyons, 2012b) to capture human behaviour change and social practices as well as technology fix solutions (*ibid.*), and the contextual and cultural backdrop of individual decision-making and performing of practices with reference to more sustainable travel and mobilities (Cairns et al., 2014). Applied here in a combined approach, qualitative methods complement the collection of numerical data. While qualitative-only research can yield valuable detail and depth of content when exploring very specifically-focused themes – i.e. Anfinsen et al. (2019)'s exploration of gendered aspects of EV driving – quantitative analysis is better-suited for testing hypotheses, validating theories and quantifying relationships (Sovacool et al., 2018b). Integrating both qualitative and quantitative methods thus draws on the strengths of both, important for more rigorous research in the fields of transport and energy consumption (*ibid*.).

An important reference was the idea of analysis not as passive observation but as a co-constructed assemblage of knowledge, "a complex, quilt-like bricolage, a reflexive collage or montage... a sequence of representations linking the parts to the whole" (Denzin and Lincoln, 2005, p.6), describing aspects of the social world with detail about meaning and experience (King and Horrocks, 2010).

> "Within the transport domain, qualitative methods are typically used for inductive purposes, to abstract concepts and strands of meaning... Combining experience of EVs with qualitative analysis may capture attitudinal, affective, and behavioural responses to EVs reflective of future mainstream consumers" (Graham-Rowe et al., 2012, p.142).

Such an approach is accommodated within the flexible Multi-Level Perspective (MLP) theoretical framework. While many of its definitive publications are case studies involving quantitative data, its originators note that it can also represent interpretative research, being "well-suited to study uncertain and messy processes such as transitions," (Geels, 2012, p.474) and for "studying a moving (or shape-shifting) target" which may defy an objective understanding (Geels and Kemp, 2012, p.74). It draws on Giddens (1984) for its concept of structuration and has "ad hoc crossovers to structuralism" (Geels, 2010, p.505), but demands both empirical domain and "interpretative creativity" (Geels, 2012, p.474). Actors, embedded into socio-technical regimes, are subject to the regime's rules as they reproduce, maintain or change system elements (Geels and Kemp, 2012) but have agency, making the MLP consistent with a methodology combining qualitative and quantitative enquiry. Within this approach, hypotheses can be treated as dynamic points for ongoing investigation and interrogation in a realist, inductive process, rather than being static statements.

As well as conventional focus groups, mapping and digital storytelling techniques were considered for the data-gathering, including the use of GPS tracking or smartphone data: mobile ethnographies capture and describe complex dynamics (Dalakoglu and Harvey, 2012), and these have been used to effect in ethnographic studies alongside interviews, subject videos and trip logs, i.e. the 'ride-alongs' of Harada and Waitt (2012) which explored the politics of transport, and

Zafiroglu et al. (2012), in which contextual concerns, personal narratives were mapped onto drivers' routes. Video has been used in observational work, such as 'follow and film' explorations of the car as a site of interaction, socialities and embodied practices (Laurier et al., 2005), doing work-related tasks while driving (Laurier, 2004), or investigating what people do while travelling in cars (Brown and Laurier, 2005). Travel diaries or trip logs were also considered as part of the triangulation process [3.6.3].

However, personal one-to-one interviewing was selected as the most appropriate data-gathering method for the main constituent part of the fieldwork, as a feasible, effective and practical means to collect both numerical and narrative data for comparison from a larger number of participants than the above techniques would allow. This nonetheless still enables the desired qualitative insight into the subjects' strategies, activities and experiences. As a technique, it creates "an occasion for purposefully animated participants to construct versions of reality interactionally rather than merely purvey data," (Gubrium and Holstein, 2002, p.14): the interviewer takes the metaphorical role of a 'traveller' on a journey, finding meaning in conversations en route, not as a 'miner' digging for nuggets of independently-constructed 'truth' (Kvale, 1996). The interview is a site of social action, not merely a resource (Dunne et al., 2005).

A semi-structured approach was taken, combining "some structured questions to obtain basic information with others that permit more flexible answers to convey ideas or perceptions in an open-ended manner" (Simon, 2006, p.166). This deployed different question types: both open-ended, free-response questions and closed questions involving Likert-type scales to measure attitudes (as suggested by Parfitt, 1997). Free-response questions may be difficult to answer and even harder to analyse (Oppenheim, 1992) but can be successful when directing the interviewee in a focused way to generate a code frame (Parfitt, 1997): they enable the identification of motivations and frames of references; allow the respondent to express themselves in their own words avoiding 'format effects'; and make interpreting deviant responses easier (Foddy, 1993). Drawbacks to this approach are that responses reflect the progress of the discourse (Cortazzi, 2001), involving the 'double hermeneutic' (Giddens, 1984) whereby researcher and subject differently interpret their interaction due to their different conceptualising of their knowledge; and that facts recalled by interviewees may be wrong, distorted or reinterpreted due to the selective nature of memory (Miller, 2000). Language-based narratives are open to both bias and interpretation on the part of the researcher (Skinner, 2012) – but can be replicable, comparable and verified if obtained and analysed in an objective fashion (*ibid*.).

In this approach, since the subject contributes detail beyond a yes/no answer and themes, threads of experience and issues of interest emerge, the continued testing and evolution of hypotheses can also be accommodated.

3.3.2 Interview design and trialling

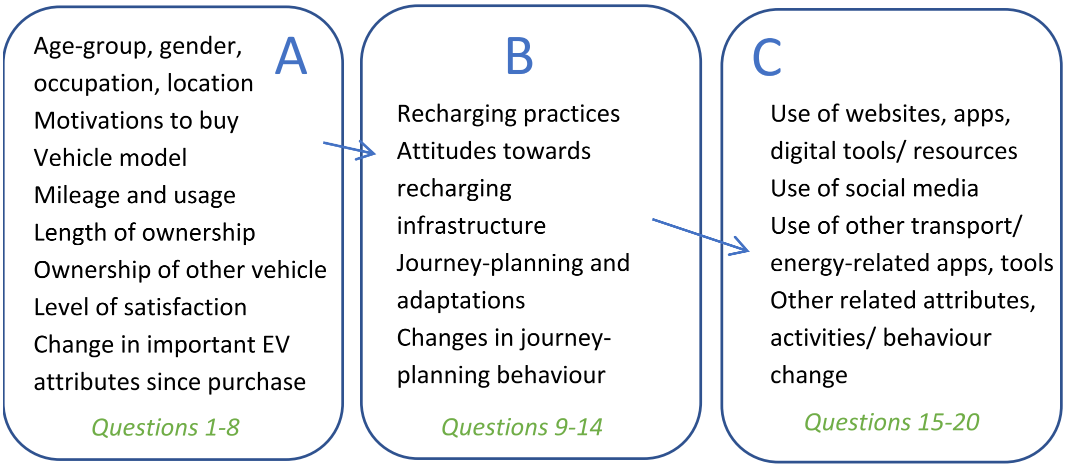

fig 3.ii: Thematic flow of questions

Informed from the insight from the background research and preliminary interviews, a set of questions [*Appendix i*] was drawn up with attention to fulfilling the research objectives and collecting sufficient data to address the hypotheses. While the focus was on the individual drivers – actors at niche (micro) level – the questions were intended to be sufficiently open-ended to prompt insight into how respondents interacted with infrastructure and regime (meso) level factors or institutions, and whether they were subject to landscape-level (macro) influence. The interview schedule was structured into three sections, as depicted [*fig.3.ii*], each conceived with a view to discourse flow and to feed contextual background into the data to enrich it.

In the first section (A), demographic and motivational details were acertained: gender, age-group and occupation [Q1]; vehicle model owned [Q2], how long they had been driving an EV [Q3], whether they had another vehicle in their household or that they could use [Q4], their typical weekly mileage and usage [Q5], initial motivations for EV purchase [Q6] and whether different or new aspects of driving or owning an EV had since become important [Q7]. Subjects were then asked [Q8] about their level of satisfaction with their electric vehicle experience, using a Likert-style 1-5 scale (as described by Adams and Cox, 2008).

The second section (B) looked for detail on drivers' charging habits, routines and attitudes: where they mostly charged their cars [Q9], what they thought of the UK's public recharging infrastructure and whether it was adequate for their needs [Q10] and whether they had ever run out of charge (or come close) when out and about [Q11]. They were asked to rate the public infrastructure, again using the Likert-style 1-5 scale [Q12], before being asked whether they had had to change or adapt their journey planning, compared to when they drove an ICE car [Q13], and then to what extent [Q14] on the 1-5 scale.

Section (C) zoomed in more specifically on digital media behaviour. Drivers were asked if they had used apps, websites or other digital tools [Q15], for example to locate chargers, schedule or monitor charging, and if so, for more detail about how these were of use or assistance. The distinction was drawn between using these tools and social media [Q16] as these could be discrete or mutually exclusive activities. They were then asked about their use of other transport-related apps or digital resources, and similarly of apps or digital tools related to sustainability, such as energy-saving calculators or domestic monitors, to give an indication of their willingness to use digital media in general [Q17]. Likert-type 1-5 scales were then deployed for interviewees to rate how important or of interest they found digital media [Q18] and social media [Q19] as EV drivers. Finally, Q20 was deliberately open-ended: "Do you have any further comments and suggestions about tools, information sources or other things which could either make your life easier as an EV driver, or that you think would encourage more people to drive EVs?"

As well as allowing for a relatively open-ended discussion, the questions were intended to draw out any links or dissonances between attitudes and personal experiences, such as any relationship or correlation between perception of the infrastructure [Q12] and the degree of reported adaptation in journey-planning [Q13], or between adaptation [Q13] and reliance upon/interest in digital media [Q18]. Part B's questions in particular were conceived to identify specific scenarios and situations where digital media may be deployed, including in 'emergency' situations when unable to charge [Q11] and as an aid in any learning processes drivers go through as their experience progresses. While the Part C questions were the most specifically-oriented to address the hypotheses, data gathered in parts A and B provides the context in which these could be supported or refuted: the detail to understand whether there are different spatio-temporal elements to driving an electric vehicle, including experiences with infrastructure and managing range; whether digital resources or social media are playing a role in EV adoption, adaptation and acclimatisation to a different energy source; whether they help in journey-planning or in crisis situations; and ultimately, informing on whether digital technologies play a wider role in the electromobility transition.

3.3.3 Pilot interview

The questions were subsequently trialled (September 2014) in a Skype interview with a personal contact, D, a 52-year old male journalist living in Ely, Cambridgeshire, who had owned a Renault Fluence for 10 months in addition to a petrol car. This interview lasted 35 minutes, which appeared to be a suitable length of time to yield sufficiently extensive detail without imposing too heavily on a respondent; it was recorded and then transcribed.

This run-through indicated that the closed questions, in which D was asked to rate experiences and attitudes on a Likert-style 1-5 scale, were easy enough to understand – although in a Skype interview, it was harder to push for a definitive number than if ticking a box on a paper document in person with an interviewee. There were elements of repetition in responses to the open-ended questions, but this reiteration suggested constancy of opinion; neutral prompts could have been better-used to explore more detail on certain elements, but overall, rich raw data was gained which looked suitable for analysis using a coding framework, and this interview was subsequently counted into the main case study sample [n=88].

D did not see the in-car charging point location and range-calculation systems in his Renault as being 'digital tools' or 'apps', showing that the definition of these needed to be clearly expressed to include such in-car digital systems accessed and operated via dashboard controls as well as via smartphone, tablet or similar. Significantly, he did not see apps (of any type) as important or useful, since he only used his Fluence locally within its range limits and did not charge it away from home, thus not needing to find public charging points – but he was a keen user of EV discussion forums, finding them a valuable source of information. This underlined the need to separate out questions about apps, databases and other such digital resources from questions about social media and online communities. The questions and interview structure were not changed as a result of this run-through, but care was subsequently taken to explain certain questions or elements more carefully, or repeat statements, if necessary.

This interview was furthermore a reminder at this early stage that (in contrast to the feedback from the previous conversations) digital tools or apps were not necessarily going to be of use or interest to all respondents, and that an open mind and neutral position should be kept about their importance.

3.4 Main fieldwork: interviewing and data collection

A wider sample of interviewees was then sought. For the purpose of this study, electric vehicles were defined as models operating mostly in an all-electric mode, thus increasing the potential pool of interviewees by including drivers of range-extended models (RE-EVs) which have a small engine acting as a back-up generator (i.e. the Vauxhall Ampera and 'REx' version of the BMW i3), as well as those of 'pure' battery-electric vehicles (BEVs) like the Nissan Leaf, Renault Zoe or Tesla Model S. Drivers of plug-in hybrids, with shorter electric-only range and an engine directly driving the wheels, were discounted.

Prior to fieldwork, the interview schedule and questions [*Appendix i*] were reviewed and approved by the University of Southampton Ethics Committee (April 2015; Ethics ID: 10640), and a risk assessment procedure completed (March 2015; FEERA 7744).

3.4.1 Respondent sample

Since no available sampling frame existed – beyond confidential data on vehicle registration and ownership held by the DVLA – a purposive or non-random sample was taken. This was intended to be at least *illustrative* (Valentine, 1997) if not perfectly representative. A single case study setting – users of a particular public charging facility, for example – ran the risk of being locally-specific, and members of EV enthusiast or advocacy groups also unrepresentative of British motorists as a whole. An initial 'batch' [n=6] of interviewees was recruited, however, via Twitter and the Speak EV web forum to get the fieldwork started and to iron out any further gaps or issues with the questions before a more comprehensive recruitment process. These interviews were carried out May-June 2015 and the interview structure and questions remained unchanged.

The majority [n=72] of interviewees were then recruited via an email mail-out. They were members of Which? (The Consumers' Association) who had taken part in the 2015 Which? Car Survey; of the 49,000 vehicle owners who had contributed to this, 180 electric car owners had responded, and the majority of these had consented to be contacted again. A group email [*Appendix ii*] appealing for their participation was sent by a Which? Cars staff member following the approval of both the Which? board and the Market Research Association. In this, it was made explicit that this was not a Which?-affiliated project, that data would not be shared between Which? and this research, and that participation would be anonymous.

The email yielded a high response rate [n=87], as might be expected from people who had already been willing to take part in a lengthy survey about their vehicle: of these, perhaps partly due to it being summer holiday-time, a few [n=15] did not respond to suggestions for a time to talk and effectively dropped out at this stage, and a few [n=4] asked to return written answers to the questions via email instead, but most [n=68] were interviewed via telephone or Skype (August-October 2015). A further number [n=10] presented themselves either via word-of-mouth from other participants or through personal contacts, bringing the total sample [n=88] including the initial batch. All participants received, in advance of the interview or alongside an e-mailed set of questions, a project information sheet [*Appendix iii*] and consent form [*Appendix iv*], including assurances on the security of their personal data, all reviewed and approved by the University Ethics Committee (Ethics ID: 10640).

Three further interviews were carried out (May 2018) with personal contacts to test the continuing validity of the original questions and to check that topics discussed were still relevant and applicable. This was part of a wider exercise in updating knowledge and assessing the progress of the electromobility transition (or lack thereof), discussed further in Chapter 8, and data from these interviews was not incorporated with that of the main [n=88] sample.

3.4.2 Interviewing process

Though most verbal interviews took around 30 minutes, much as envisaged [mean = 31 minutes, median = 28 minutes, to nearest minute] they varied from just under 10 minutes at one extreme to one hour, four minutes at the other. The interviews via iPhone or Skype were recorded using a high-quality Olympus sound recorder and subsequently transcribed without difficulty: all sound files were clear with very little inaudible content bar the occasional mumbled word or interruption from a third party (i.e. an interviewee's wife, child or barking dog). A neutral, conversational tone was maintained and while some interviewees were passionate about particular issues or had dissatisfactions they wished to air, discussions were generally good-humoured and not emotionally-charged.

While following through the questions was relatively straightforward and conversational in most cases, themes and topics arose which were not specifically addressed in the standardised interview schedule. The first few interviewees all mentioned solar panels in some context – either that they had them at home already, or that they were considering fitting some – so subsequently all respondents were asked if they had any renewable energy technology at home as part of 'any other business' [Q20], if not already referenced earlier in the conversation. It also became clear that it was worth guiding discussion to draw out more information on learning processes, routines, practices, and how drivers' relationships with their cars had changed over time – if the interviewee did not independently describe this, as many did – to more consistently capture a longitudinal element. More was also quickly learned about useful prompts and buzzwords to elicit further information. Some interviewees named specific newly-launched or unfamiliar apps and data platforms they used, for example, which it then proved helpful to name-check in subsequent interviews.

3.5 Data collation and coding

The transcripts [n=84], along with the four written responses to the questionnaire which were returned by email, were then individually evaluated. A data analysis taxonomy and coding framework [*Appendix v*] were created using an Excel spreadsheet, with reference to each of the questions [1-20], to collate the different types of data collected: categorical or discrete (i.e. the demographic details); ordinal (questions 8, 12, 14, 18, 19 involving the Likert-style affective scales); and the textual content for thematic analysis.

Papers on EV driving which influenced and inspired methodology included Graham-Rowe et al. (2012), in which an abbreviated grounded theory technique was applied to code extracts from the transcripts of semi-structured interviews; a thematic analysis with three-step coding process applied by Caperello et al. (2013) on audio recordings, field notes and interview observations; and Burgess et al. (2013) and Bunce et al. (2014) in which an initial semantic-level coding of content was created rather than a pre-existing framework. These demonstrate the accessible, flexible, theory-independent nature of thematic analysis (Braun and Clarke, 2006), which can accommodate both deductive and inductive approaches (*ibid*.).

3.5.1 Coding of affective-scale numerical data

The affective-scale questions, in which interviewees were asked to give a 1-5 number (1 indicating 'strongly disagree', 5 'strongly agree' and 3 'neutral') were straightforward to code, although the division of question 12 was problematic:

Q12: Please indicate how you feel about this statement: "I find the UK's national public EV recharging infrastructure adequate"

- Q12a: For you personally
- Q12b: For EV drivers in general, or for people thinking about driving an EV in the near future

Q12b failed to yield consistent, comparable numerical data with, in some cases, either a lack of understanding of how this differentiated from 12a, or interviewees saying that they really only knew about their own experience and could not rate the situation for others; the numerical data from this was discarded, but it did prompt further content and opinion within the narrative. Comments explaining numerical answers to all of the affective-scale questions added insight and were considered alongside the other textual data.

3.5.2 Coding of textual data

Coding of the textual data was on an explicit, semantic rather than latent, interpretative level (Boyatzis, 1998): for example, when interviewees were asked about how they used their electric vehicle [Q5], numerical codes were created for 'undisclosed' [0]; 'personal/leisure' [1]; 'commuting to workplace' [2]; 'business/work-related' [3]; 'in a multi-modal context' [4]; plus 'other' [5] as these specific activities were cited or mentioned – no interpretation or looking for meaning as such was involved in this. The flexible, inductive nature of this process was important as the taxonomy expanded. In the majority of cases answers fell easily within the numerical codes question by question, although in some transcripts, an overview of the complete text gave context and supported decisions when coding was less clear, as well as helping to explain or understand apparent contradictions in an account or to find appropriate data in response to a different question, i.e. when topics were returned to during the narrative or opinions were reiterated. An 'Other' category was created for some questions to accommodate single-instance responses, usually relating to something very specific to an individual, their circumstances, personal interests or opinions, and not comparable to anything mentioned by anyone else.

3.5.3 Dynamic coding, Parts A-C data

The demographic data (Part A) was straightforward to collate. Q1 covered age at time of survey, gender, occupation and location. Age was divided into five categories [0-4]: unknown; 35 years or less; 36-50; 51-69; and 70+, correlating to the well-known market research terms of 'millennial', 'Generation X', 'baby-boomer' and the oldest 'silent generation', as also used by the US Census Bureau. Gender was recorded as male or female – no non-binary identifications or ambiguities were presented in this sample, although additional categories could have been created if necessary. Occupation was coded [0-6] as undisclosed; retired; self-employed/company owner or director; engineer/IT/skilled technical; other professional; other non-professional. Some respondents were noted as fitting into two categories, i.e. self-employed IT contractors or retired engineers, in order to capture and communicate a sense of background as well as current status. Respondents were asked in general terms whereabouts they lived, although most had already volunteered this information in the preliminary emails; location was coded [0-3] not disclosed/ unclear; rural; suburban; urban, rather than by geographical position, given the sample size.

The yes/no questions such as [Q4]: "Do you have another vehicle in your household or that you can use?" were also straightforward, but a little interpretation was required from questions such as [Q5]: "What's your typical weekly mileage and type of usage?": while some drivers knew exactly the mileage they covered, either on a weekly, monthly or annual basis, others were much vaguer. Only doing local journeys within battery range therefore seemed well-represented by ‘always low’ [1], and 200+ miles a week by ‘medium-to-high’ [3], while ‘typically low with occasional longer trips’ [2] was representative of many usage patterns described – within range on a day-to-day routine basis, but the odd expedition further afield, i.e. to visit friends or relatives. Type of usage [Q5b] was categorised to differentiate between predictable ‘commuting’ journeys to a fixed workplace and ‘business/work-related’ trips to different locations, as described by, i.e., the doctor visiting patients or the building surveyor going out to sites. The number of codes created for Q6 and the different factors interviewees cited clearly showed that few had one single reason or motivation for buying an electric vehicle.

For Part B, covering charging routines and behaviour plus perceptions of the public recharging infrastructure, some judgement was required; with Q9, on where interviewees mostly charged their cars, the data could have been broken down further to identify those who exclusively charged at home or on public facilities – but on review of whole transcripts, nearly everyone who initially said they always charged at home had actually, on occasion, plugged their car in somewhere else, even if this was just at a relative’s house: ‘most/always’ better captured their experience. When targeting behaviour change in Q13: “Has your journey-planning changed since you’ve been driving an EV?” there were some contradictions between the initial yes/no answer [Q13a] and further comment, or activities and routines described elsewhere in the transcript [coded Q13b], and the latter was judged more meaningful for ongoing analysis along with the affective-scale answers to Q14: “Since starting to drive an EV, I have had to adapt the way that I plan my journeys”.

Part C questions proved the most open-ended with the largest number of codes or categories, particularly with regard to social media usage [Q16] and the wide range of platforms used and activities described – from participating in web forums to contributing crowd-sourced data, blogging or making YouTube videos, and building apps. Codes [0-11] were generated to accommodate ‘only as an observer’, and ‘non-digital social activity’, when transcripts started to show that some drivers were very keen to stress that they participated in an offline ‘real life’ EV-related community, club, pressure group or similar; or that while they actually had never joined or posted on a forum or social media platform themselves, they would read discussion threads and find these useful.

Having captured data on what drivers did – or had – already, the concluding Q20 collected drivers’ ideas and suggestions for additional information they would like to have access to, and their preferred interfaces or platforms by which to view or receive this. Some narrative data not accommodated in the Q1-Q19 coding with reference to a specific question was also coded in the Q20 framework, including mention of having renewable energy-related technology at home;

expressions of interest in issues such as load on the electricity grid or interest in energy storage; and specific charging habits and behaviours such as scheduling or optimising charging.

3.6 Reliability assessment

The methods deployed for data collection, collation and the subsequent analysis need to be assessed with reference to three key concerns: validity, reliability and generalisability (Noble and Smith, 2015), the latter two terms encompassing consistency in methodological procedures, neutrality, and the transferability of findings to other contexts (*ibid*.) Validity – the integrity and application of the methods, and the accuracy with which the findings reflect the data collected (*ibid*.) – can also be conceptualised as 'truth value' (Lincoln and Guba, 1985) and involves an assessment of perspectives and potential biases on the part of both interviewer and participants.

3.6.1 Inter-rater assessment

A brief inter-rater agreement exercise was carried out: several interview transcripts and textual extracts were given to three professional researchers for coding to the above framework. This was judged as being straightforward to use, with a clear categorisation of data: no discrepancies were identified although it was suggested that for the open-ended questions, more detail could be discerned from the 'Other' categories if additional codes were created. It was noted that overall, the judgements on coding were dispassionate: if, for example, an interviewee mentioned having used motorway fast-chargers, on-street slow-chargers and 'destination chargers' like those provided at National Trust properties, their charger usage was recorded as such, with no interpretation required. Even with the open-ended questions such as those on purchase motivations or preferred information interfaces, the categorisation and coding was based on the factors as identified, stated and expressed by the interviewees themselves; the themes as such were 'umbrella' categories describing very particular items, activities, artefacts or attitudes as defined or delineated by the participants, rather than any implied meanings constructed by the researcher(s). As such, this suggests that the data collection is consistent, not subject to bias, and the findings could be replicable.

3.6.2 Double-checking of data and expansion of coding

The transcripts and coding were, in effect, double-checked first during the initial data analysis [Results: Chapter 4]; then in additional re-reading and reassessment during the construction of the Typology [Chapter 5], with particular attention to the open-ended questions and how this textual data was expressed. The spreadsheet data was checked again during the process of further analysis and correlations [Chapter 6, Chapter 7]. Constant reference was also made back to the original transcripts when assembling qualitative detail to quote in support of the numerical data. During these processes, several adjustments and amendments were made.

The 'Other' categories for questions 6 and 7 were also reassessed during the analysis process to explore further detail: new codes [0-9, up from 0-7] were created for purchase motivations [Q6] to cover 'professional profile/image' and 'successful trial', with 'driving ease' and 'driving experience' combined since respondents' statements on this were not always distinct or separable; and for attributes since purchase [Q7], to add 'liking convenience', as it became clear that a number of statements could be categorised together as such, i.e. expressions that drivers liked recharging at home, or not having to visit petrol stations, to create an additional theme.

Similarly, to extract more insight on the additional information or functionalities drivers would like to see or have [Q20c], the 'Other' category was broken down to create new codes (to a total 0-10) for 'more information on battery degradation/charging cycles', 'more detailed information on car's electricity consumption', 'pre-booking charging facilities', and 'chance to communicate with other drivers over charger access'.

The record of cars owned was also reassessed to take into account EVs previously owned by respondents as well as just their current car: this increased the count of cars discussed from 99 to 105, and allowed for consideration of how routines or habits may have changed over time between different vehicles (or successive iterations of the same vehicle), i.e. since getting a newer model with improved battery range or additional communications technologies. This also fitted with the inclusion of multiple EVs within a household. In those scenarios a longitudinal element was involved as well: i.e. an early EV purchased as a short-distance second car by a family who subsequently replaced their main ICE car with an EV too. During these reassessments, several minor errors of data entry were identified and corrected.

3.6.3 Audit trail and triangulation

Chronological records were kept, including a log of all interview dates, along with a series of dated running notes on project progress and issues to address or consider: in effect an audit trail, which can support research transparency and credibility (Creswell and Miller, 2000; Lincoln and Guba, 1994). It was acknowledged that, in addition to an element of self-selectivity bias among the sample, some data might reflect post-hoc rationalisation among the respondents, particularly with reference to earlier decisions and actions such as their initial motivations (as more than one respondent put it, "I did the man-maths…", admitting that a desired purchase hadn't really added up financially in the end, given the cost of an expensive car). To counter this, along with other issues related to the reliability of retrospective recall and how memory may be distorted (Hakim, 2012), triangulation of results using other data collection methods was considered.

One respondent, a Nissan Leaf owner from Shrewsbury, kindly provided a very detailed spreadsheet with a mileage diary and trip log covering every journey he had made May 2014-August 2015, including his recharging stops and their locations; some notes on weather conditions and temperature and whether he had used the car's heater; the topography of the trip, i.e. steep hills; battery charge percentages before and after each journey; kWh of electricity drawn at each charge (based on meter readings from his home electricity supply plus estimates or readings from public chargers); and costs, where applicable, of each public charge. A section of his mileage diary covering the month prior to his interview is reproduced here with his permission:

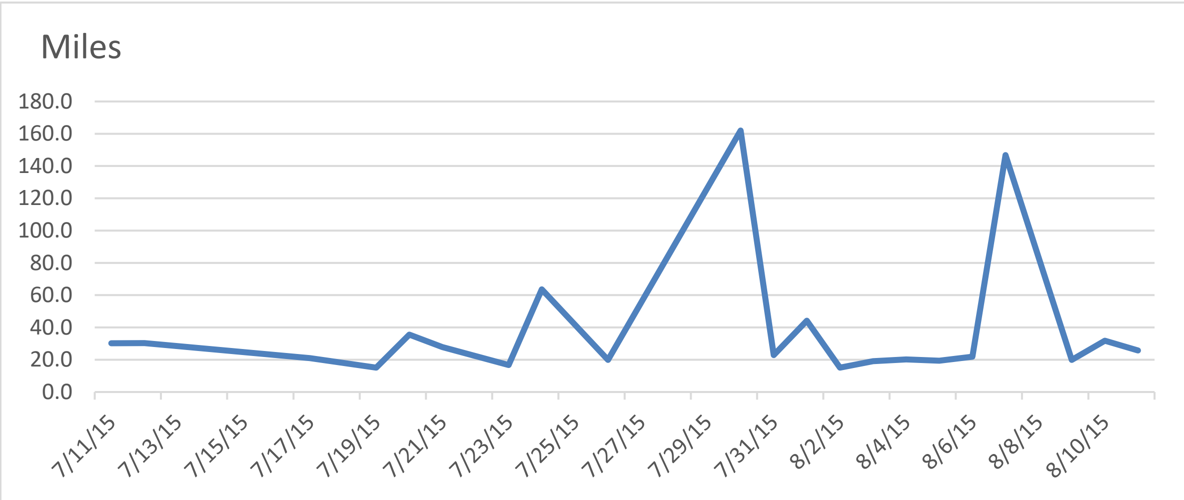

fig 3.iii: Sample mileage log, Nissan Leaf owner interviewed 11/08/2015

The pattern shown of his daily driving corresponded to the description he gave in his interview of a medium-to-high mileage with regular (rather than 'occasional') trips out-of-range (on average more than once a month); and it reflected that described by many other drivers.

Collecting further such mileage logs or trip diaries from a sample of drivers was considered, but given the granular level of detail as to routines, habits and charging practices that so many drivers had already described in their interviews, it was thought to be a time-consuming measure, demanding upon participants, which would not add a great deal of extra insight – especially given that those most likely to be prepared to contribute their time to this could well be demographically very similar, i.e. retired. While it could of course confirm the accuracy (or otherwise) of drivers' stated driving routines and mileage, the categorisation of the latter into the three categories – 'always low', 'typically low with occasional longer trips' and 'medium to high' – was in any case sufficiently broad to accommodate some vagueness on their part, with categorisation supported by the wider narratives and textual, qualitative data within each transcript. The level of detail expressed in these was also judged, post-interviewing and data coding, to be rich enough both to interrogate the hypotheses and to create a 'thick description': this again supports the credibility of an account, and can also help the reader understand how the findings or conclusions can be generalised to a wider context (Creswell and Miller, 2000).

Nevertheless, a theoretical triangulation has been observed throughout. Findings should be considered in comparison with those of other research (Adams and Cox, 2008), whether in support or not, to add weight to conclusions (*ibid*.); reference was made to the UK National Travel Survey (beta.ukdataservices.ac.uk), and drivers' mileage patterns were found to be typical and consistent with the travel diaries based on this data (as later described and analysed with reference to electric vehicle driving by Dixon et al., 2020). Besides this, additional validation exercises are discussed further throughout subsequent chapters with reference to the results and analysis of the data collected.

3.7 Conclusion

A flexible, interpretative methodology, compatible with the theoretical framework of the Multi-Level Perspective, has been well-suited to the aims and objectives of the project and has supported a blend of quantitative and qualitative data-gathering. Inductive, dynamic aspects have been inherent in development of the interview questions and then the coding framework as evolving themes were identified and data codes created. The textual transcripts from the personal interviews yielded a robust set of quantitative data and qualitative content in addition to the ordinal data from affective-scale questions.

The subsequent initial analysis resulted in a rich level of case study understanding [Chapter 4] forming the backdrop to the findings on drivers' engagement with digital technologies [Chapter 6], including sufficient data to explore meaningful statistical correlations and relationships. In addition, the qualitative data provided valuable illustration which fed into the development of a detailed Typology of Electric Vehicle Driving [Chapter 5]; and supplemented the quantitative findings first to develop an understanding of electric vehicle drivers considered as segmented groups, and then in the creation of individual archetypal composite personas [Chapter 7]. In tandem with an audit of the current EV marketplace, available infrastructure, equipment and technologies [Chapter 8], these exercises facilitated the construction of a theoretical model of EV drivers' digital engagement [Chapter 9].

Chapter 4 Results: Background & demographic findings

4.1 Overview

To understand and outline the sample's demographic characteristics and the case study context, an exploratory analysis and study of the numerical data was carried out. This first describes the participating electric vehicle drivers in terms of their demographic characteristics and motivations, and then explores reported behaviour, practices and habits surrounding electric vehicle ownership and use. Quantitative data, including responses to questions using the Likert-style affective scale, was collated and coded [as described, 3.5] in an Excel spreadsheet; simple tables were created to study the answers question-by-question, and a series of infographics created as quick and easy-to-read visualisations. Suitable numerical data was imported to SPSS, in which the Kendall's tau-b rank correlation co-efficient was run to explore a series of potential relationships between responses to specific questions, to a meaningful level of significance.

Qualitative detail was taken from interview transcripts to illustrate and illuminate the figures; since each transcript was labelled and identified by a code (date/sequence of interview, vehicle/vehicles owned) with cross-reference to each interviewee's row of data compiled in the Excel spreadsheet, it was deemed unnecessary to import the texts to a program such as Nvivo, given the relatively small and manageable size of the sample. Trends in the socio-demographic data are observed and initial correlations to address the first hypothesis [H1] are considered:

- **[H1]:** There are different spatio-temporal elements involved in driving and operating electric vehicles, i.e. issues around vehicle charging, journey planning and vehicle range.

This background data also forms the basis for further statistical tests and correlations [Chapter 6], and informs the subsequent segmentation of the sample and creation of archetypal personas [Chapter 7] but is insightful in its own right as a description of early-innovator EV drivers and their motivations, practices and reported behaviour changes.

4.2 Introduction to the case study

4.2.1 Demographic details

The largest proportion [45%, n=40] of the sample [n=88] were aged 51-69; 31% [n=27] were aged 36-50, and 18% [n=16] were aged 70+, with much lower representation in the youngest age-group of 35 or under: [n=4]. The age of one respondent was unknown.

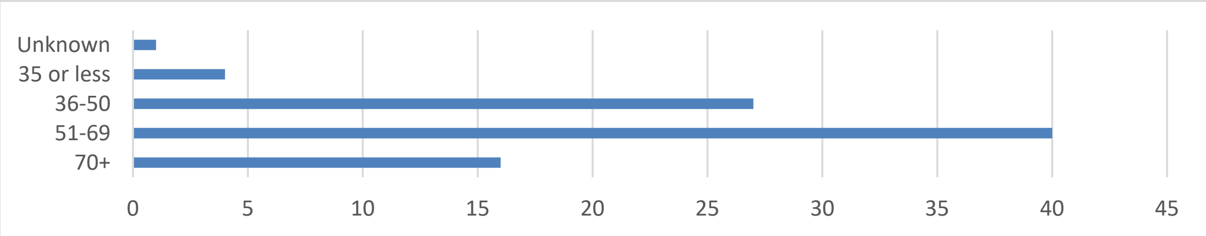

fig 4.i: [Q1a] Sample age, years [n=88]

Interviewees were asked in general terms about their occupational background [Q1c]: 47% [n=41] worked, or had worked prior to retirement, in engineering, IT or another skilled technical profession such as electronics. 25% [n=22] were, or had been, professionals in other fields, including medicine and dentistry, law, and education; and 16% [n=14] described themselves as self-employed or as a company owner or director, these people including surveyors, architects and property developers. 42% [n=37] were retired. There was some overlap – retired engineers and doctors, for example, or self-employed IT contractors.

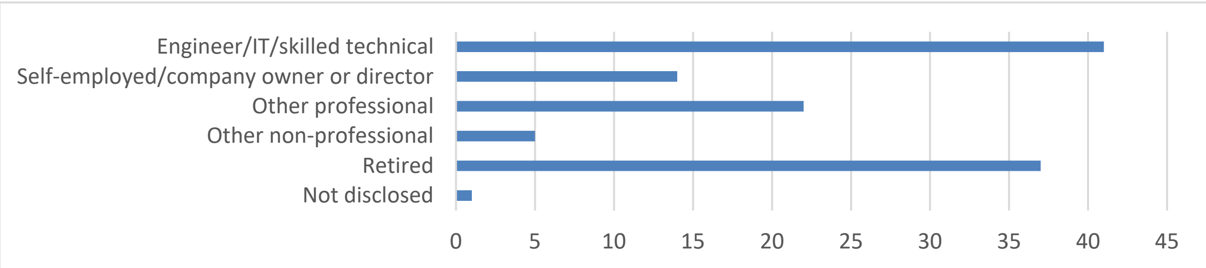

fig 4.ii: [Q1c] Occupational background [n=88]

Those describing themselves as living in an urban location accounted for 41% [n=36] of the sample; 34% [n=30] described themselves as rural, while 22% [n=19] considered themselves suburbanites [Q1d].

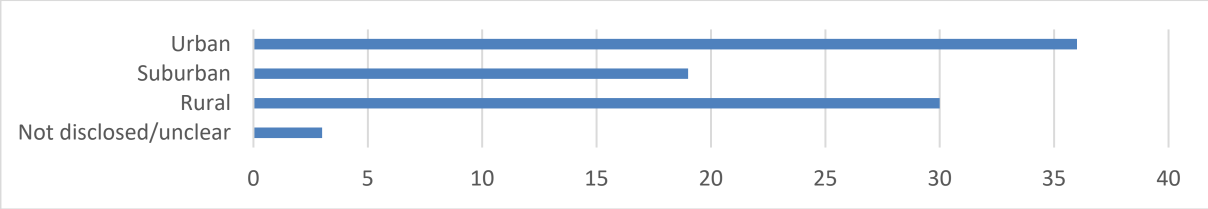

fig 4.iii: [Q1d] Residential location of respondents [n=88]

Although the sample was male-dominated [n=80] with only eight female respondents [Q1a], its demographic characteristics are quite consistent with those of existing EV owners found in other Western European studies: typically middle-aged men in suburban and rural areas (Plötz et al., 2014); of above-average income (Dütschke et al., 2012); mostly male and up to 60, with high socio-economic status and education level (Campbell et al., 2014); mostly male, middle-aged and highly-educated (Hardman et al., 2016). In the Nordic countries, high levels of education are associated with mostly-male EV adoption so far (Sovacool et al., 2018c) although buyers tend to be younger – typically 25-40 (*ibid*.); and internationally, they have been mostly male, living in small towns or cities and richer than average (CleanTechnica, 2016).

It is also worth noting that several more women beyond the [n=8] female respondents did contribute to differing extents, by listening in (via speakerphone or telephone extension) to interviews with their husbands or partners and adding their own comments and thoughts. They are represented in the qualitative elements of this study, i.e. some insights directly quoted; and in material used to develop the Typology [Chapter 5] and personas [Chapter 7]; but were not counted into any numerical data, and it was not possible to discern gendered differences in behaviour or narratives, as have been proposed by Anfinsen et al. (2019).

While the sample was in general older than other surveys have found, its age distribution was similar to that described in some UK-specific studies (i.e. Hutchins et al., 2013; Knight et al., 2015). It is reflective of UK retail new car buyers – as opposed to trial participants or fleet/company car drivers – in the EVs' price sector, given that the electric vehicles discussed were, at this point, quite recently-launched and most of the interviewees had made new or nearly-new (and relatively expensive) private purchases. This is in line with automotive consumer trends: the 55-64 year-old age-group is thought to have the largest proportion of new car buyers (statistica.com, 2018), over-50s spending more on their purchases (Corfe and Skero, 2015). Mainstream brand-names report a high average age for their private retail customers – up to 63 years old, for Toyota GB (Finlay, 2017); Kia UK reports that, in its experience, its electric and hybrid cars are "more likely to be bought by the 55-65 age-range" (*ibid*.) and in general, EV buyers are thought to be more heavily concentrated in the 40-69 age-group than ICE consumers (Knight et al., 2015). The growing number of older driving licence-holders (DfT, 2018) is also reflected.

In any case, there may be no one archetypal EV early-adopter anyway: studying affective and attitudinal characteristics of distinct niche groups may prove more meaningful than looking at traditional demographic data (Morton et al., 2017; Anable et al., 2016); and groups as-yet showing lower levels of take-up may actually hold the key to more widespread EV adoption, namely higher-income women and retirees or pensioners (Sovacool et al., 2018c) – so findings from this sample should give fruitful insight.

4.2.2 Vehicle ownership and usage

Of the vehicles owned [n=105], reflecting multiple EVs within a household or successive ownership of more than one, the all-electric Nissan Leaf [n=49] dominated [Q2]. While 72% of the vehicles which respondents had owned [n=75] were all-electric, the range-extended BMW i3 REx [n=15] and Vauxhall Ampera [n=14] were the next-popular choices. At the time of interviewing, the Renault Zoe and Tesla Model S were both relatively new to market and had sold only in very small numbers, reflected in this sample. Other cars owned by two more or participants were the Smart fortwo ed, all-electric BMW i3 EV, Tesla Roadster, Mitsubishi i-MiEV, Citroen C-Zero; and the Volkswagen e-Up!, Renault Twizy and Renault Fluence [all n=1] gave a total of 13 different models represented. Several respondents had previously participated in supported EV trials, but only cars bought or leased (i.e. as a personal business vehicle) by the individual were counted. The data captured cars previously owned as well as those currently within a household, as this represented either a change of model or upgrading to a newer version of the same vehicle, and in some cases, insights were offered around these experiences.

table 4.i: [Q2] Electric vehicles owned [n=105]

Nissan Leaf	BMW i3 REx	BMW i3 EV	Renault Zoe	Vauxhall Ampera	Tesla Model S	Tesla Roadster	Mitsubishi i-MiEV	Citroen C-Zero	Renault Twizy	VW e-Up!	Smart fortwo ed	Renault Fluence
49	15	2	6	14	7	2	2	2	1	1	3	1

Around a third of respondents [34%, n=30] had owned an EV for less than a year; 45% [n=40] had owned an EV for one or two years; and 20% [n=18] had been driving an electric vehicle for three years or more [Q3]. However, 76% [n=67] had at least one other – ICE – vehicle in their household or that they could borrow when needed [Q4].

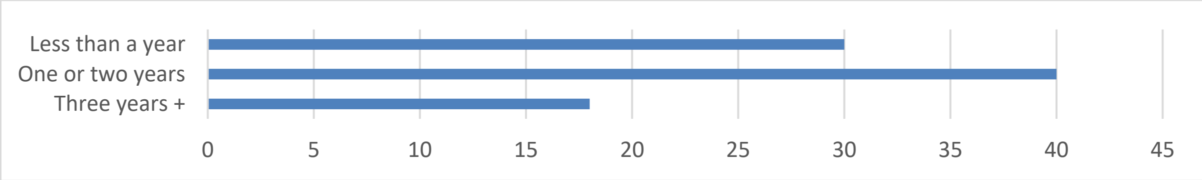

fig 4.iv: [Q3] Length of EV ownership [n=88]

A minority of 17% [n=15] described a low typical weekly mileage, defined in this instance as short local trips only. However, 39% [n=34] said that while their mileage was typically low, they made occasional longer trips out of battery range, and 44% [n=39] reported a medium-to-high weekly mileage of 200 miles or more, and regularly venturing out of range [Q5a]. This is consistent with the varied usage patterns seen in other UK research at the time, i.e. as reviewed and summarised by Knight et al. (2015).

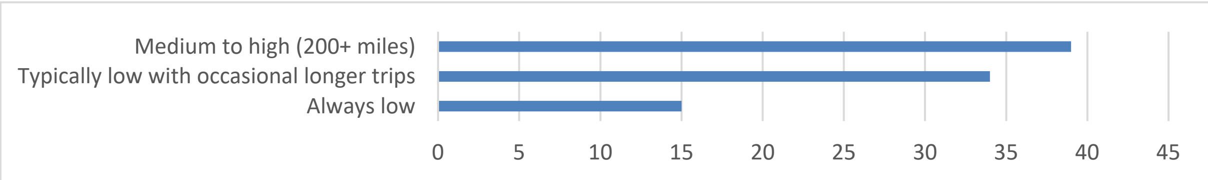

fig 4.v: [Q5a] Typical weekly mileage [n=88]

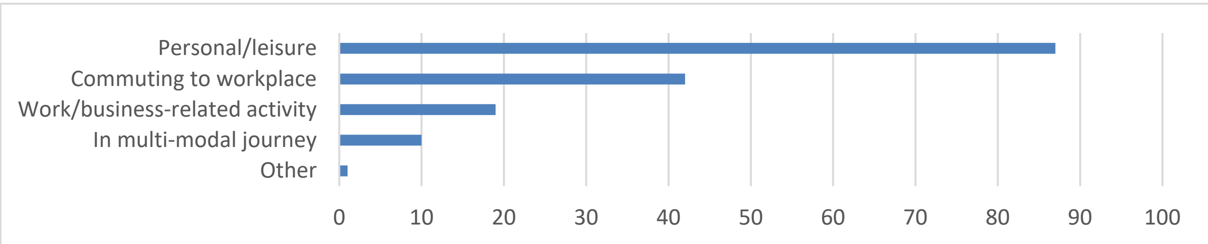

fig.4.vi: [Q5] Usage of electric vehicle [n=88]

Mileage was taken as that done by the car itself, i.e. as used by a household rather than an individual driver. The households of nearly all – 87 out of 88 respondents – used their electric car for personal or leisure purposes; 48% [n=42] used it to commute to a workplace, and 22% [n=19] for work or business-related activities, such as visiting clients or, in the case of a rural GP, patients. 11% [n=10] reported using their EV in the context of a multi-modal journey, i.e. travelling to a railway station to commute, or to a park-and-ride facility before completing their trip by other means [Q5b]. An 'other' use-case reported here was for voluntary work within a church group, offering transport to elderly people in the interviewee's local area.

4.2.3 Motivations for EV purchase

Although some research has found all-EV buyers to rank environmental and technical motivations ahead of the financial, i.e. in comparison with PHEV consumers (Lane et al., 2018), monetary incentives and price reductions in particular are important triggers for the EV purchase decision (Cecere et al., 2018). Here, environmental concerns and financial advantages were equally important and relevant to just over half the sample [both 52%, n=46]. Financial incentives frequently cited included zero-rated company car tax, as well as savings on fuel and parking; environmental concerns included ethical considerations around issues such as public health, for some interviewees in the context of their personal philosophy or beliefs:

> "I'm a Ba'hai and my wife is Buddhist, so we have religious points of view and you know, kind of non-materialistic views of the world as well, so we were interested in the environmental protection factor…"
> [male, 41, rural West Yorkshire, academic; Nissan Leaf]

Nearly half cited a specific interest in technology and a notable minority said that they realised that an EV would suit their needs or lifestyle in terms of daily routines and mileage, i.e. specifically to use for commuting or other familiar, regular journey.

> "At the time I was working in London and I had a diesel Passat, and the mileage I was doing was a seven-mile round trip every day to the train station, parking it there every day and bringing it back. Diesels take a bit of time to get warmed up, so what I was effectively doing was putting some serious damage on the engine… and I thought, if I can find a reasonably-priced electric car, that would be perfect to do that seven-mile trip every day. And, the obvious environmental benefits because of course diesel engines are worse when they're cold… And you know, part of it was just wanting to experiment with an electric car…"
> [male, 35, company director, Coventry; Mitsubishi i-MiEV and later, Tesla Model S]

Nearly half of respondents [49%, n=43] mentioned having domestic solar panels, wind turbines or other energy-saving home technologies such as ground-source heat pumps [also Q20b]. Recurring themes were maximising the benefits of this or making a logical next step – "I bought the car to go with the house!" – in 'greening' their household or cutting their living costs:

> "I built a house which is a very environmentally-friendly house, and really following through, we both love technology, so the house is very high-tech, and has a lot of environmental systems in it, and it makes sense to have the car."
> [male, 55, suburban Bromley, telecomms consultant; BMW i3 REx]

> "We're pretty wired up, we have a HIVE for our heating, we have a water harvester for toilet flushing and garden and car-cleaning use, we have solar panels, we have LED lights – my husband was an electrical engineer operations manager, and I worked for an electricity company as well, so we're pretty switched on with the most efficient things for us to do. We have monitoring, meter reads of everything each month, tariffs, we do the lot!"
> [female, rural Herefordshire, retired; BMW i3 REx]

The phrase “I just wanted something different…” or similar also recurred [n=11], and there were several motivations around the driving characteristics offered by an EV, coded as driving ease/experience [n=7]: quests for smooth, quiet and simple driving experiences, as well as purely for fun, i.e. a Tesla Roadster and a Renault Twizy. For one BMW i3 owner and his wife [retired, rural north-west England], long-time BMW drivers downsizing from their large X5 SUV, the electric powertrain was actually incidental: “The attraction was ease of use, the fact that it sits quite high off the ground – she’s quite small so she likes to have a good view.” Personal purchases were made as a direct result of having driven electric vehicles in a workplace context or trial programme [n=3] – and also through feeling the need to project an appropriate occupational image [n=4], i.e.:

> “I am involved in promoting electric cars in my county here, so it made sense to have one yourself, to practice what you preach, as it were.”
> [male, 68, Rutland, semi-retired but volunteering in community activities; BMW i3 REx]

Even an impulse purchase (coded as ‘Other’) was reported:

> “One nearly ran me over in Sainsbury’s car park! It was so quiet, I thought, ‘I don’t know what that is, I’ll go and find out’. So I went, loved it…”
> [male, 69, Peterborough area, retired; Vauxhall Ampera]

Most respondents reported multiple motivations with no one single factor determining or dominating their decision, i.e.:

> “I guess I like things that are different, so it looked an interesting car, and I thought well, why not? And I thought, I knew the journey to work, BMW were quoting 100 miles range capability, so I thought that’s within the range, so yeah, why not? Oh, and in my previous car, a Jaguar XF, I was getting through £110 of diesel every week, easy! So a bit of a financial element as well... But I also knew I was going to be a pioneer, the car was brand new…”
> [male, 55, urban Hertfordshire, IT industry; BMW i3 REx]

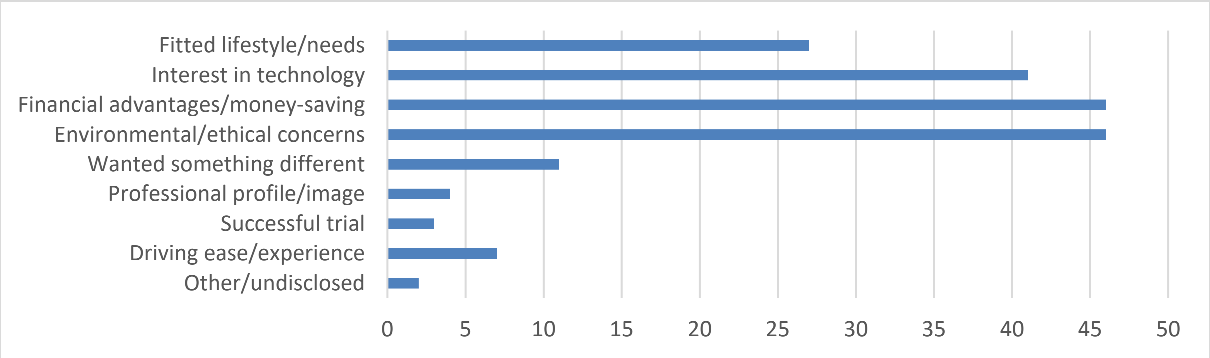

fig 4.vii: [Q6] Initial motivations for EV purchase [n=88]

While specific leading motivations and priorities vary across countries, regions and contexts, such a spread of factors and themes raised – encompassing the practical, technological, personal and ideological – is consistent with the heterogeneity observed or reviewed in recent studies such as Axsen et al., (2018) and Biresselioglu et al. (2018).

4.2.4 Behaviour, practices, and behavioural changes

Q7: "Have your reasons for driving an EV changed since then [initial motivations]? Are there new or different aspects of driving an EV which have now become important to you?" was to explore ongoing motivations and positive attributes of EV ownership discovered over the ownership experience. During interviewing, it became apparent that this was eliciting feedback on behaviour change as well. Some of the themes raised chime with the division of EV business users by Valdez et al. (2019) into the 'rational' who responded to incentives and infrastructure to optimise their systems and 'sense-makers' who found strategies to make EVs work for them and even subsequently created new business models, institutions and practices (*ibid*.).

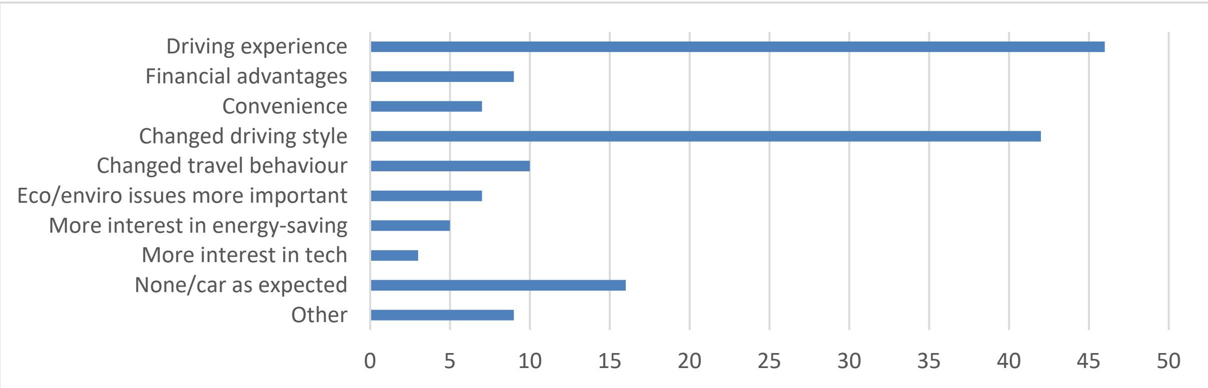

fig 4.viii: [Q7] EV attributes identified and behaviour changes since purchase [n=88]

While 18% [n=16] said that no, the car was as they'd expected – "it very much delivers what it said on the tin" [male, 61, rural Scotland, social researcher; Nissan Leaf]; "it's what I hoped it would be, and it's continued, we both love driving it" [male, 71, Dorset, retired; Nissan Leaf]; "I did my research beforehand and was aware of the advantages and some drawbacks" [male, The Wirral, retired; Nissan Leaf] – 48% [n=42] said that they had changed their driving style, either in response to this question or elsewhere during the interview.

Changes described reflect the strategic, tactical and behavioural modifications as observed by Labeye et al. (2016) such as optimisation of regenerative braking (*ibid*.), and adaptations to driving style to maximise range (Gjøen and Hård, 2002; Rolim et al., 2012). Driving to minimise energy consumption and maximise battery range were commonly expressed themes; and these responses are indicative:

> "Yes, I think my driving has become more patient and calmer, and I drive more with economy in mind rather than with speed in mind… I'm keen to use the regenerative braking as much as possible, so I start to slow down well ahead of obstacles like roundabouts and traffic lights and so on, and avoid using the brakes as far as possible."
> [male, 64, small town in Scotland, retired; Vauxhall Ampera]

> "Driving the Leaf is like a game to get the most miles from a charge, so we experiment with our driving style, eco [mode] on, eco off, brake on, brake off. Driving at around 55mph to 60mph on a motorway is a new experience, as is slip-streaming behind a lorry!"
> [female, 46, Yorkshire, craftsperson; Nissan Leaf]

The driving experience itself was a pleasant surprise or unexpected bonus to more than half [52%; n=46]: "It is much better than driving the petrol car or the diesel car, it's much easier, smoother, quieter and more relaxing," [male, 37, software developer, Peterborough; two consecutive Nissan Leafs] sums up much of the feeling, with another Leaf driver explaining in more detail:

> "I like it because it's relaxing. When we went down the first time to Sussex, [my husband] was not particularly well and I drove all but about 25 miles of the 200-plus, and I really wasn't that tired at the end of it. And I mean, normally you're constantly changing gear, you're having to listen to the engine noise, and be aware of the noise that the engine's making, have a change up, change down, whatever – and you have none of that, you just go forward. I would say that it's like driving a sewing machine. You just have your foot on the pedal, and sort of release it a bit, you don't always need to actually put your foot on the brake, because it's just slowing down that way…" [female, Shropshire, retired; Nissan Leaf]

As well as the characteristics of a regenerative braking system, which allow for one-pedal driving in certain conditions (as described above), the sheer simplicity of a single-speed automatic transmission was much-liked; while sportier-minded drivers praised the high on-demand torque and acceleration from a standstill, typical of an electric powertrain. One Tesla owner [quoted below] admitted, however, to accelerating more quickly and driving faster in his Roadster since he no longer paid for petrol.

Some 10% [n=9] of drivers who had *not* expressed financial advantages as an initial or primary motivation for purchase were particularly struck by the low day-to-day running costs of an EV, including for servicing and exemption from the London congestion charge, as well as on fuel and taxes. Themes raised also included the convenience of charging at home and not having to visit a petrol station:

> "I think one thing that's a bit of a surprise is how time-saving it is, not having to fill up with fuel… when I go back to driving a normal car, having to stop for fuel, queue to get into the pump, fill up at the pump, queue to pay, find that the kids have wanted 20 quids-worth of sweets or rubbish – that's actually a great thing not to have in your life…"
> [male, early 40s, Cambridgeshire, software company owner; Tesla Model S and Roadster]

Only a small number specifically indicated that they had changed their travel behaviour since owning an electric car [11%, n=10] but of those who had, there were some significant adaptations: choosing to take the train for longer out-of-range journeys, for example, using public transport more often, or making more multi-modal trips. One respondent had specifically purchased a folding electric pedal-assist bicycle that fitted in the boot of his car, to complete the last stretch of his commute from a charger-equipped park-and-ride facility. However, some changes actually involved more driving: now that the EV owners could park for free in a town centre, for example, or now they felt less guilty about making short trips –rebound effects as also observed by, i.e. Axsen et al. (2018) in Canada and Langbroek et al. (2017) in the Stockholm area.

Just a handful [n=7] said that they had become more interested in ecological and environmental issues since driving an electric car, with some heightened interest about general or domestic energy-saving [n=5], but for some of this small number, subsequent changes both in lifestyle and in attitudes had been quite profound:

> "Since I've had an electric car I've understood the full lifecycle of the electricity and looked at it full circle of things, so things like having solar panels put on my house, going with a renewable energy provider, things like that, I've only been… I've only made those choices since owning an electric car." [male, 27, Cambridgeshire, racing driver; BMW i3 REx and Tesla Roadster]

> "In the two years since I bought it, I've become much more and more convinced about climate change and the need for us to do something about that, so I'm a great advocate of renewable energy these days... Now, particularly I've taken a lot of interest in energy consumption over the past two years both in the house and in terms of transport, even to the extent of short-hop flights being replaced by rail." [male, 69, Derbyshire, IT technician; Nissan Leaf]

An increased interest in, and engagement with, technology was also reported [n=3] by drivers who had *not* seen it as an initial purchase motivation: they were enjoying EV features and remote app-controlled functions such as pre-conditioning (heating or cooling) of the cabin.

> "Since acquiring it I'm pleased with how quiet it is, and surprised by how relaxing it is much of the time. I think it's also made me a more conscientious driver, keeping my speed under better control to make sure I used the battery more efficiently. My absolute favourite thing about the car so far though is the way I could warm it up with the touch of a few buttons on my smartphone in the winter. I didn't have to scrap ice off my car in the morning once."
> [male, age/occupation/location undisclosed; Nissan Leaf]

It is also worth noting that overall levels of satisfaction were found to be very high [Q8], 70% [n=62] strongly agreeing with the statement "*I am happy and satisfied with my overall electric vehicle experience so far*", and 28% [n=25] agreeing. Just one neutral response was recorded, with no respondent disagreeing or expressing a negative sentiment about their vehicle itself – though dissatisfaction with the recharging infrastructure [below] was reported and recorded at this point as part of the discussion or in qualifying statements.

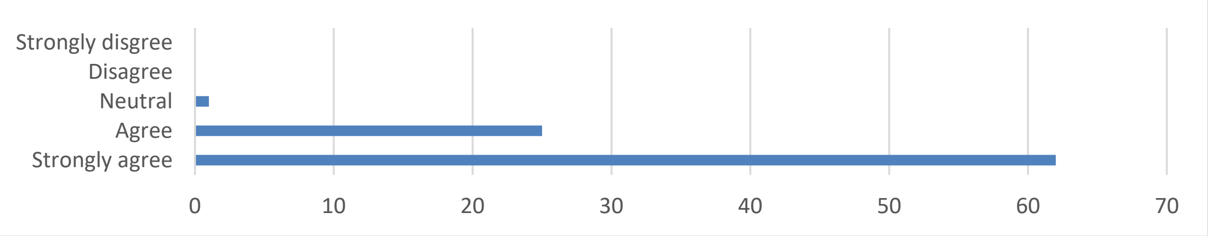

fig 4.ix: [Q8] "I am happy and satisfied with my overall electric vehicle experience so far"

4.2.5 Vehicle charging practices, routines, and attitudes towards infrastructure

Moving into Part B of the questionnaire, vehicle charging habits and routines were discussed [Q9]. 83% [n=73] always or mostly charged their vehicle at home; 7% [n=6] mostly or always used public facilities, such as on-street chargers; 8% [n=7] reported regularly using both private and public facilities; and 2% [n=2] always or mostly charged at their workplace. The use of public facilities by this sample appears to be a little higher than the assumed cross-EU average of 5% of charging events (T&E, 2018) and as found in some UK reports (i.e. Ofgem, 2018; Knight et al., 2015), with a lower level of workplace charging than found by, i.e. Baresch and Moser (2019) in Austria, but the actual proportion of private: public charging in terms of 'events' is unknown here.

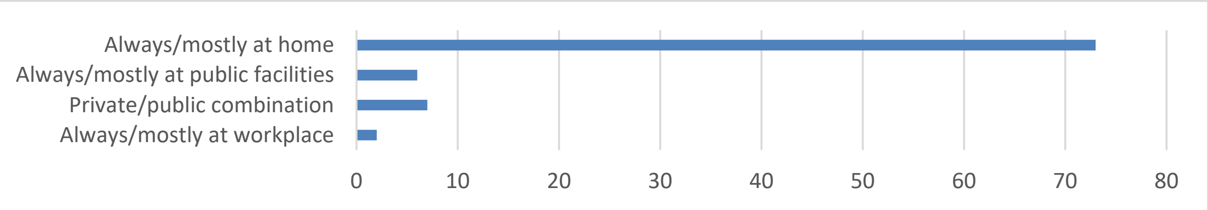

fig 4.x: [Q9a] Where do you mostly charge your EV? [n=88]

Further prompting about the different types and locations of charger that they had used gave further detail and insight [Q9b]. Even if routinely charging at home, most drivers had actually charged in a number of locations and tried out different charger types, even if only once on a specific trip or "just to experiment"; just 14% [n=12] had only ever charged their car at home.

So-called 'destination' slow chargers (3kW) had been used by 49% [n=43]; facilities at National Trust properties, shopping centres, supermarkets and hotels were mentioned; and non-motorway fast- (7-22kW) or rapid-chargers (43kW for three-phase AC, 50kW for DC) had been used by 33% [n=29] – notably those at IKEA outlets. Public slow-chargers, usually on-street or in municipal car parks, had been used by 32% [n=28]; and 16% [n=14] made use of marque-specific chargers, either at their local dealership (as offered by Nissan franchises) or the high-speed Tesla Superchargers (120kW). While most owners [81%, n=71] had a domestic wallbox or other dedicated vehicle charging equipment, 28% [n=25] relied on a standard 13amp socket for home charging, or used one elsewhere, such as at houses of friends or relatives – extension leads dangled out of windows were sometimes deployed.

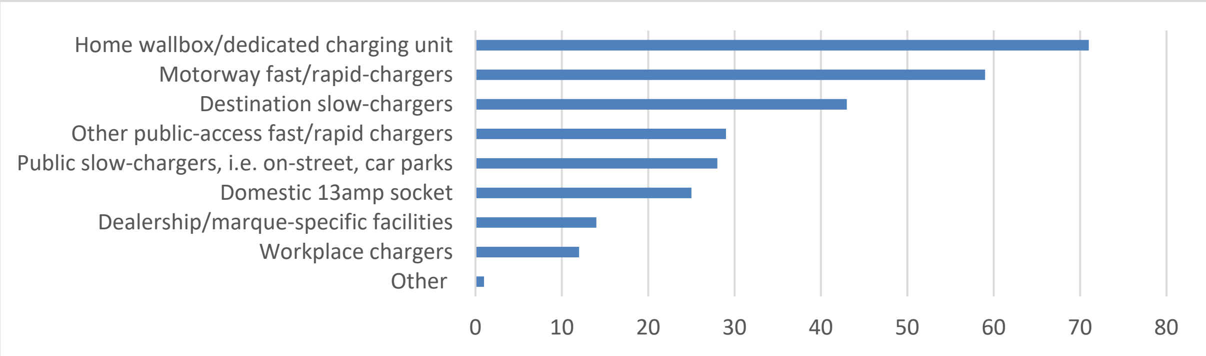

fig 4.xi: [Q9b] Types and locations of charging equipment used or experienced [n=88]

Although 23% [n=20] agreed [n=16] or strongly agreed [n=4] with the statement [Q10]: *"I find the UK's national public EV charging infrastructure adequate"*, there were qualifications, such as saying that they would use their car more (i.e. instead of their other ICE vehicle) or travel longer distances in it, were the infrastructure better. A higher proportion [44%, n=39] disagreed [n=28] or strongly disagreed [n=11] with the statement, 33% [n=29] remaining neutral.

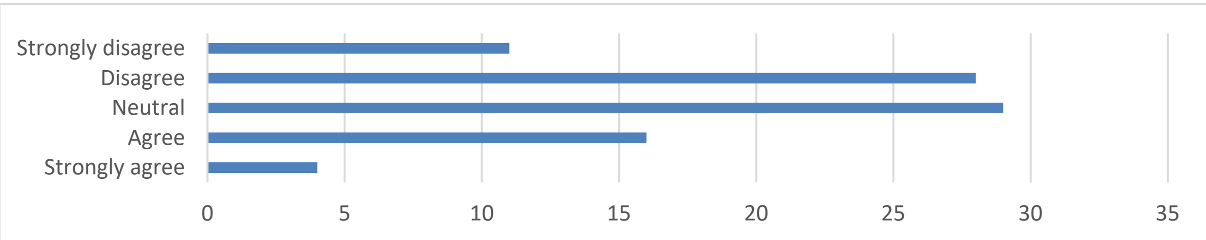

fig 4.xii: [Q10] "I find the UK's national public EV charging infrastructure adequate" [n=88]

When asked to volunteer a little more detail, only 6% [n=5] said that they were fine with the infrastructure as it was; 15% [n=13] wanted to see more of all types of charger; and 20% [n=18] mentioned a need for more fast- and rapid-chargers on motorways or trunk roads; though destination charging (speed unspecified) was seen as more-needed [25%, n=22]. This contradicts some studies in which preferences were expressed for fast-charging and motorway provision of services (i.e. Globisch et al., 2018), but reinforces the idea that there is a strong demand to 'top up' while parked (Anderson et al., 2018). However, actual numbers of chargers were considered by some to be less of a concern than the reliability of facilities already existing, or given the different standards and socket types, the compatibility of these with different makes and model of vehicle (coded as 'Reliability/Compatibility', n=31).

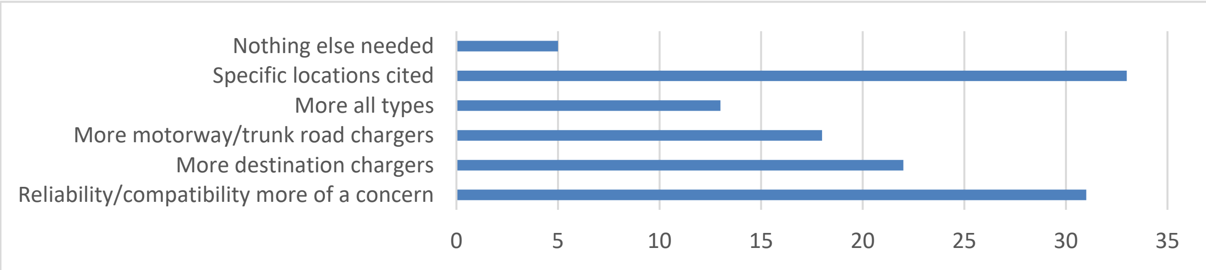

fig 4.xiii: [Q10b] Where would you benefit from or like to see more recharging facilities? [n=88]

Shortfalls in particular geographic locations were also mentioned by 38% [n=33]. Nonetheless, in practice few drivers had run out of battery charge and found themselves unable to complete a journey [Q11]: 14% [n=12], echoing the findings of Nilsson (2013) that EV drivers tend to avoid situations where they might be left stranded.

Given the long time-scale of this project and the continued roll-out and upgrading of public charging infrastructure since the interviews took place, attitudinal data collected in questions 9-12 may no longer be relevant in itself but add insight in a retrospective analysis of the electromobility transition.

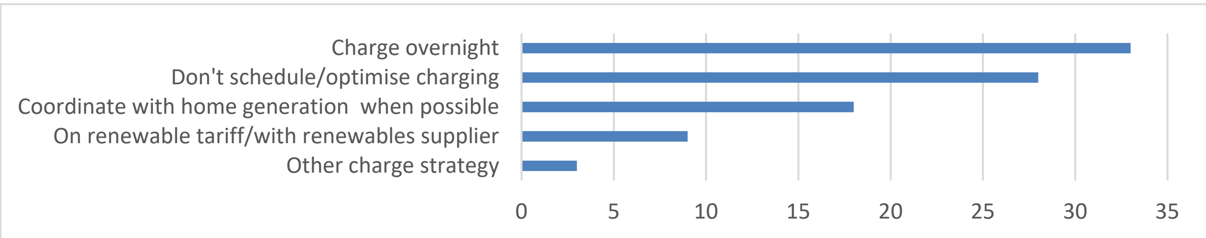

fig 4.xiv: [Q20b] Additional vehicle charging strategies [n=88]

Detail relating to routines and practices when charging at home was gathered throughout the course of interviews and during general discussion [Q20d]. While EV drivers have been thought to favour immediate battery replenishment (Philipsen et al., 2018) here less than a third [32%, n=28] did not schedule or optimise charging at all – typically just plugging in their car after each trip. A higher proportion were a bit more strategic: 38% [n=33] charged overnight, i.e. to take advantage of the Economy 7 tariff, and 20% [n=18] specifically described trying to coordinate charging with home electricity generation:

> "We have got two sets of solar panels… I'll tend to just look at the meter to see how the lights are flashing to mentally calculate how much we're generating at any time… I bought myself a 3-pin granny cable so if we're generating somewhere in the region of 3 to 3.5 kW, I'll tend to plug my car in for a bit while we're generating that much."
> [male, 48, Liverpool, IT technician; Renault Zoe]

> "Like today, my car has only about 35 miles on it, so this afternoon I will put it on charge because I'll use some of the solar that would otherwise be going into the grid, I'll be using it for my car instead." [female, rural Herefordshire, retired; BMW i3 REx]

This was effectively regarded as "free motoring" – although some other drivers had worked out that they would save more money by taking advantage of their grid feed-in tariff for excess solar generation and charging their car overnight instead. A small number [n=11] expressed an interest in domestic energy storage.

4.2.6 Journey-planning and preparation

No change in journey-planning was reported [Q13] by 13% [n=11] since starting to drive an EV: "I've not modified the sort of journeys that I make, within the accepted range. No, if I'm planning to do additional jobs, I might use the other car instead"; "I tend to limit where I go in the car, so I don't need to plan anything different" (both Nissan Leaf drivers). However, only four of these 11 drove all-electric vehicles – and one had a Tesla Model S with a range of around 300 miles. The remainder of those indicating 'no change' had range-extended EVs, although this did not necessarily mean that no forethought was involved:

> "Well, I always make sure it's fully charged, but then I decide if I'm going to use that charge up to start with, knowing that I can charge at the other end, or I might save it, if I'm going to Leeds for example, and I know I'm not going to have time to charge it while I'm visiting my son, or I might leave the charge for when I'm driving round the city that day and use the petrol for the motorway." [male, 68, Shropshire, retired teacher; Vauxhall Ampera]

A variety of practices and habits were narrated, as described and itemised in the typology subsequently created from the qualitative detail [Chapter 5]. 59% [n=52] thought about or changed their route, even if an intended journey was within range: "If I knew that there was a charger, by varying the route to some degree that I would go via a charging point, I would do that" [Tesla Model S owner]. 64% [n=56] researched available charging facilities, and 38% [n=33] prepared their battery-charging or topped up in addition to their usual routine; money-saving was an incentive to plan charging, too.

> "Well, basically it is better for the Leaf's battery to only charge it to 80%, so most days it's only charged to 80%, but if I know I've got a long journey the next day, I will then alter it and charge

> fully to 100%. And so that really needs thinking about the day before."
> [male, 76, Chester, retired; Nissan Leaf]

> "I try and organise how many miles, where I'm going in the next day, exactly where I'm going, so I know if I can charge up at home or whether I can charge up for free in the towns."
> [male, 44, Northamptonshire, self-employed mechanic; Nissan Leaf]

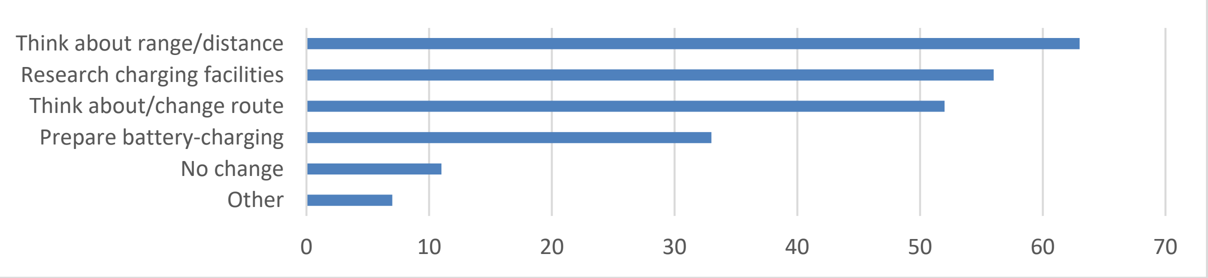

fig 4.xv: [Q13] Changes in journey-planning since driving an EV [n=88]

For longer journeys, the process was, for some, quite involved:

> "I'll typically plan the day before, so I can make sure that I have enough charge in my battery, because if I need to go somewhere on the spot and I don't have enough charge, it doesn't really matter how far away it is – I'm not going to get there. So I plan my charging first of all, and I see how many miles it is to my destination, and I consider can I charge, how long will I be at that destination, can I charge locally on a slow-charger.
> "If that's not going to be possible, then I have to choose a route where I will have rapid-charging available to me. And I will then make one of two choices: I will then decide to charge en route and leave early, or I will decide to charge on the way home again, and that will just be led by my diary as to whether I can do that." [male, 44, Scotland, company director; Nissan Leaf]

'Other' changes and adaptations at the journey-planning stage [n=7] included making the decision to take another form of transport or make a multi-modal journey [n=3], or to take an ICE vehicle instead – not always for reasons of battery range:

> "Because to make it fuel-efficient the ground clearance is minimal, if I'm going on roads I know are quite bumpy, or if I know there are speed humps or anything, then I'll take my wife's car."
> [male, 50, rural Sussex, computer programmer; Vauxhall Ampera]

Time factors were a recurrent theme – "I plan to take more time to allow for charging, and stop more for 'comfort' breaks" – and overall energy-saving consciousness and efficiency was important, i.e. for one of several drivers who had taken up 'trip-chaining':

> "I think about when I'm going to make journeys. And sometimes, I think about, do I have to do that NOW, or can I combine it with another trip the next day, that sort of thing. So I plan my journeys more carefully and combine what perhaps would have been two journeys into one and just say oh, I'm not going to do that today, I'm going there tomorrow, I can do whatever I was going to do tomorrow." [male, 69, Peterborough, retired; Vauxhall Ampera]

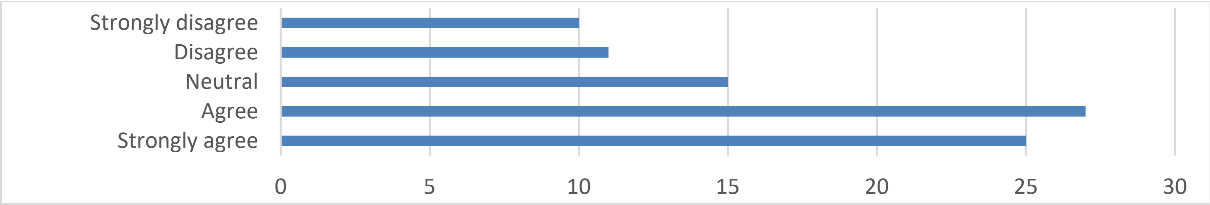

fig 4.xvi: [Q14]: "Since starting to drive an electric vehicle, I have had to adapt the way that I plan my journeys" [n=88]

A small 59% majority [n=52] agreed or strongly agreed that, since driving an electric vehicle, they had made adaptations in the way that they planned their journeys. 17% [n=15] were neutral, while 24% [n=21] disagreed or disagreed 'strongly' with the statement [Q14]: "*Since starting to drive an electric vehicle, I have had to adapt the way that I plan my journeys*."

The affective-scale responses to this statement showed no statistically significant correlation with either the mileage the drivers reported [4.2.2] or their stated opinion on the adequacy of the UK's recharging infrastructure for their needs [4.2.5]. To identify, explore and quantify potential relationships between variables, testing their significance, a Kendall's correlation co-efficient was run rather than a hypothesis test. As a non-parametric statistic suitable for tied ranks, i.e. Likert-style scores, and for variables with a relatively narrow range (Hanna and Dempster, 2012), it is subject to less stringent assumptions than a Pearson's correlation (*ibid*.), and unlike a chi-square analysis, it can indicate the strength of a relationship between two variables (*ibid*.). Correlations were later repeated for all of the statistical tests in this research using both Pearson's and Spearman's co-efficients, with no change in outcome seen in terms of significance, strength or weakness for any of the relationships explored, but the Kendall's co-efficient as used initially is quoted throughout for consistency.

In this instance, it indicated a positive but weak relationship between reported adaptation and mileage:

- tau_b = 0.120, p = 0.193 [n=88];

and a weak, negative relationship was seen with attitudes towards infrastructure:

- tau_b = -0.133, p = 0.132 [n=88].

This suggests that the factors contributing towards a need – or perceived need – to adapt journey-planning are more complex than just going out of range, and that availability of public charging equipment or facilities is not necessarily a definitive issue.

A negative, statistically significant relationship was also found between the levels of adaptation as stated in Q14 and ownership time, indicating the degree of acclimatisation and importance of personal experience involved in driving an electric car:

- tau_b = -0.189, *p* = 0.04 [n=88], the correlation significant at the 0.05 level (2-tailed).

The shorter the ownership time, the greater the degree of adaptation, reported adaptations tailing off once the drivers had their cars for three years or more – signalling that either any compromises or changes to routine had become less of an issue, or that they had ceased to see these as adaptations at all by this point.

table 4.ii: Adaptations in journey planning correlated against other reported factors

[Q14] "*Since starting to drive an electric vehicle, I have had to adapt the way that I plan my journeys*" versus:

Other reported factors or behaviours	**Kendall's co-efficient [n=88]**	**Relationship**
Mileage [Q5a]	tau_b = 0.120 *p* = 0.193, 2-tailed	Positive, weak
Attitudes towards infrastructure [Q12]	tau_b = -0.133 *p* = 0.132, 2-tailed	Negative, weak
Ownership time [Q3]	tau_b = -0.189 *p* = 0.04, 2-tailed	Negative, statistically significant at the 0.05 level

4.3 Driver adaptation with reference to hypothesis [H1]

The positive response to [Q14] *"Since starting to drive an electric vehicle, I have had to adapt the way that I plan my journeys"* [4.2.6] and the specific behaviour and practices cited indicate that there are different issues and factors to consider when driving an electric vehicle, compared to a petrol or diesel ICE car, especially at the early stages of ownership. These appear to be with reference to elements around place and location – where the car is charged, routes taken and destination – and time, most notably the need for advance planning and preparation, and to take into account charging downtime. This thus addresses the first of the hypotheses, and the premise on which subsequent hypotheses are based:

- **[H1]:** There are different spatio-temporal elements involved in driving and operating electric vehicles, i.e. issues around vehicle charging, journey planning and vehicle range.

Here, p[*agreement or strong agreement with Q14*]= 0.5909. This marks an agreement by more than half at over 59% of the [n=88] sample, in which the mean of the scores on Q14's Likert-type scale [1-5] = 3.5227 and standard deviation = 1.33026.

This initial hypothesis [H1] appears to be supported.

4.4 Conclusion

The case study background data have given insights into specific practices, routines and behaviour, well-illustrated by the parallel qualitative findings. Additions have been made to the knowledge of the demographic characteristics, motivations and affective attitudes of the electric vehicle early-adopter community, with trends observed. Elements of behaviour change have also been captured and quantified, again with qualitative detail contributing to a deeper understanding. As well as practices around journey-planning, decisions, habits and activities around vehicle charging (both at and away from home), driving style, money-saving and other factors have been described in considerable detail. These indicate that there is sufficient evidence of an element of behaviour change amongst electric vehicle drivers, supporting the ongoing approach which includes the formulation of a Typology of Electric Vehicle Driving [Chapter 5] and further addressing of the hypotheses.

Sufficient material and robust data have been collected for further statistical tests and correlations. The first hypothesis [H1] appears to have been supported thus far but will be tested further; and going on to determine whether there is any correlation between degrees of adaptation and digital engagement has been key to addressing the subsequent and main research hypotheses. In Chapter 6 and Chapter 7, the quantitative data around the use of and engagement with digital media are interrogated, and subsequent correlations and segmentation of the sample are then explored [Chapter 8] using this case study as a foundation.

Chapter 5 Results: Typology of Electric Vehicle Driving

5.1 Overview

As a complementary exercise in addition to the collection of numerical statistics; to better-understand and synthesise the qualitative material collected; and to illustrate and build on the case study background data as described [Chapter 4], an inductive process using a framework inspired by the Hierarchical Task Analysis of Driving (Walker et al., 2015) was carried out. A simplified version of the approach taken in the Hierarchical Task Analysis of Driving (HTAoD) enabled an aggregation and formulation of the textual data, and the generation of a typology which outlines certain EV driver activities in detail with particular reference to spatio-temporal factors and behavioural adaptations within the chronological journey-making process. As research around engagement with household technologies i.e. thermal storage (Haines et al., 2019) has shown, constructing typologies from qualitative interviewing is a valuable means of understanding consumer and user behaviour, and informing design and strategies to increase market acceptance of such technologies (*ibid*.).

The construction of the Typology of Electric Vehicle Driving [seen in full, *Appendix vi*] contextualises the drivers' reported behaviour and practices and expresses their considerations, decisions and activities as discrete elements. It clearly delineates and describes the aspects in which driving and operating an electric vehicle differs from running an ICE car, and the decisions, processes and activities which are a result of this for many (if not all) drivers. A wealth of specific practices and habits related to EV operation have been detailed and identified, including changes to household routines which diverge from the ICE vehicle ownership experience.

The typology further facilitates a mapping of qualitative themes against quantitative evidence, a validation strategy recommended by Geels (2012) when working within the MLP (Multi-Level Perspective). It thus provides evidence to address and test the first hypothesis:

- **[H1]:** There are different spatio-temporal elements involved in driving and operating electric vehicles, i.e. issues around vehicle charging, journey planning and vehicle range.

The Typology of Electric Vehicle Driving also itemises some of the digital media resources and tools used by the drivers in various scenarios, identifies where and when these may be deployed, and thus aggregates material which indicates support for the further hypotheses H2-H4 [2.8.2]. As Ben-Elia et al. (2018) suggest, qualitative research gives a necessary depth to partner quantitative work on ICTs and travel behaviour, and the typology here has been an effective means by which to compile qualitative evidence to be studied in tandem with the empirical findings in subsequent correlations and analyses. A series of distinct themes and recommendations can be also extracted, each with relevance to policy-makers, authorities, service or infrastructure providers, or even vehicle manufacturers.

5.2 Methodology

In the Hierarchical Task Analysis of Driving (HTAoD), drivers' tasks and goals are broken down into a flexible hierarchy (Walker et al., 2015). Driving activity is defined and delineated in terms of over 1600 individual tasks and operations (*ibid*., p.44) within six top-level sub-goals – pre-driving tasks; basic control, operational, tactical and strategic driving tasks; and post-driving tasks (*ibid., pp.46-47*). The HToD itself develops and draws upon the Task Analysis of Driving (i.e. McKnight and Adams, 1970) and hierarchical task analysis (as described by Annett, 2003), and can be used for validation and substantiation of observations (Walker et al., 2015, p.47); although not in itself a theory of driving, the HTAoD is "a tool for generating new theories" and taxonomies (*ibid., p.48*).

For the Typology of Electric Vehicle Driving [*Appendix vi*], a hierarchy as depicted in the HTAoD was simplified to three top-level scenario categories: pre-journey [1], during the journey [2], and after the journey [3]. In a further simplification of the framework, the Typology of Electric Vehicle Driving is reduced to a chronological list of possible factors, variables, decisions, choices and actions a driver might consider or undertake, rather than an 'if', 'then', 'while', 'else', 'and/or', 'go to' set of contingencies or sequenced routines and subroutines.

Each of the interview transcripts [n=84] and written answers [n=4] was studied as a narrative, and textual matter relating to the acts of driving and making a journey was categorised – and dynamically re-categorised – according to the themes which arose. A series of hierarchical sub-considerations and sub-actions was constructed below the three top-level categories, using a rapidly-growing series of columns on a spreadsheet, in which individual texts on the same theme were synthesised to express each specific, discrete element of the journey-making in succinct terms. The structure of the completed typology is shown [*fig 5.i*].

For example, Pre-journey [1] contained the sub-categories 'Journeys of any length (within or beyond battery range)' [1.1]; 'Journeys beyond battery range or involving (non-essential) charging' [1.2]; and then, when it became clear that there were considerations particular to certain EV models or types, 'Additional activities specific to Tesla Model S drivers' [1.3]; and 'Additional activities specific to RE-EV drivers (Vauxhall Ampera, BMW i3 REx) [1.4] were added.

1. Pre-journey

- 1.1. Journeys of any length (within or beyond battery range)
    - 1.1.1. Considerations and route planning
    - 1.1.2. Determining whether to take EV at all
    - 1.1.3. Determining EV vs. other transport modes
    - 1.1.4. Pre-journey charging
- 1.2. Journeys beyond battery range or involving charging
    - 1.2.1. Considering charging options
    - 1.2.2. Locating charging facilities and checking charger status
        - 1.2.2.1. Searching and identifying
        - 1.2.2.2. Updating and maintaining knowledge
        - 1.2.2.3. Checking specific charger availability and status
    - 1.2.3. Checking charger compatibility and access
    - 1.2.4. Adapting journeys and destinations with reference to charging
    - 1.2.5. Considering charging time (downtime)
    - 1.2.6. Considering charging cost
    - 1.2.7. Further pre-departure checks, activities and decisions
- 1.3. Additional activities specific to Tesla Model S drivers
- 1.4. Additional activities specific to RE-EV drivers (Vauxhall Ampera, BMW i3 REx)

2. Journey

- 2.1. At departure
- 2.2. Whilst driving
    - 2.2.1. Checks and calculations
    - 2.2.2. Changes to driving style/driving experience
    - 2.2.3. Driving style specific to RE-EV drivers
    - 2.2.4. Routing and range
- 2.3. Charging away from home
    - 2.3.1. Dynamic checking of chargers
    - 2.3.2. Charging stops
        - 2.3.2.1. Public slow charging
        - 2.3.2.2. Private charging (usually slow)
        - 2.3.2.3. Charging at public fast- or rapid-chargers
    - 2.3.3. While car is charging
- 2.4. Dynamic decisions and actions
- 2.5. Public charger access and payment
- 2.6. Inoperable or inaccessible charging point
    - 2.6.1. Issues arising
    - 2.6.2. In event of issues…
- 2.7. Further planned stops or routine habits

3. Post-journey

- 3.1. Recharging – back at home
- 3.2. Recharging – no private facilities
- 3.3. Post-journey analysis

fig 5.i: Typology of Electric Vehicle Driving – structure

Third- and fourth-level categories were created as necessary when new themes emerged or it became apparent that a degree of further division would give greater clarity, and these were expressed at each level to give a chronological sense of the drivers' decision-making processes.

For example, within ‘Journeys of any length’ [1.1], the elements were sub-divided at a third level into ‘Pre-journey considerations and route planning’ [1.1.1]; ‘Determining whether to take EV at all’ [1.1.2]; ‘Determining EV vs other transport modes’ [1.1.3]; and ‘Pre-journey charging’ [1.1.4]. In the full Typology of Electric Vehicle Driving [*Appendix vi*], a hierarchy comprising 14 second-level, 20 third-level and six fourth-level categories was constructed [*fig 5.i*], to accommodate a total 320 actions or considerations. A series of smaller taxonomies were then drawn up in tabular format to describe certain aspects of the journey-making.

5.3 Typology of Electric Vehicle Driving: summaries by journey phase

5.3.1 Pre-journey

Pre-journey, the planning process hinged upon whether an intended trip would be beyond a car’s battery range or not, with some considerations common to either scenario. In the initial stage of the planning process [*Appendix vi*, Typology 1.1.1], 16 different factors and discrete actions undertaken – sometimes, but not always, contingencies – were identified [*table 5.i*, some as described, 4.2.6].

table 5.i: from Typology 1.1.1: Pre-journey considerations and route-planning: journeys of any length (within or beyond battery range)

Considerations	Mileage: to destination; return journey; round trip Nature of journey, i.e. load-carrying needs, need to tow trailer Whether journey or errand can be combined with another to reduce mileage driven (‘trip chaining’) Taking longer to make journey due to driving more slowly or taking slower route Leaving miles ‘in hand’ in case of detours, delays or other unexpected diversions Weather conditions (i.e. need to stop to charge in rain; energy-hungry windscreen wipers) Temperature (i.e. likely use of heating or air conditioning, which affect battery range) No pre-planning of journey at all, known to be well within range
Actions	Look at paper maps and/or road atlas Plot mileage using AA/RAC route planners, Google Maps or similar online/mobile app tools Plot mileage using TomTom, Garmin or similar, or built-in sat nav in car Choose shortest or most direct route to destination Plan different route to a regular destination, to find most efficient (including at different times of day) Plot most efficient route between stops or tasks Choose cross-country route to avoid motorways or high-speed roads Plot route specifically to avoid steep hills or demanding terrain

Besides considering mileage, the nature of the journey (i.e. load-carrying needs) and weather and temperature (since both may affect battery range) were also important considerations. Plotting and planning routes by different methods and according to different concerns, such as directness, road topology, avoiding motorway or maximising efficiency; time-related factors, such as driving more slowly or stopping to recharge; and trip chaining – combining errands or intended journeys – were also considered at this stage. Experimentation – i.e. intentions to test different routes to find the most energy-efficient – was reported, though of course, the pre-journey process develops and changes through experience, as this driver illustrates in his explanation of his commute:

> "There's a few routes I can go to knock a mile or two off… I sat down, worked out where all the chargers were, and over time I've tweaked the route a little bit, and I've tried going through the town centre in the early morning when it's really quiet… a couple of miles makes a big difference when you do it both ways, and I've got a nice little route now. I get to a certain point and I know right, I've got to be at 87% [battery capacity] here to be doing well…
> "Monday for example, I got to work on 49%, I don't know why, perhaps because it was colder, and I had to charge going home, but yesterday I got to work on 54% and that was plenty for coming home…" [male, 50, Peterborough area, computer programmer; Nissan Leaf]

Existing knowledge informed planning or deciding upon a route, but three distinct research methods were noted when drivers referred to external information sources: paper maps or road atlases; online journey-planning tools or mobile apps; and satellite navigation systems, either integrated in-car or removable aftermarket devices such as TomTom or Garmin units.

> "[To go] somewhere I'm not familiar with, I use the websites of the different [charging] networks, because they usually give you real-time information about the charging points, so looking out for ones which are offline – I usually use Zap-Map, and also Google Maps but they don't show you charging points yet [at time of interview].
> "Nissan has launched on their site a map application that can work out better your range based on geographical features: you can take into account incline, for example, so you can calculate fastest or most economical routes, and it will tell you what your battery status is likely to be at the end of the route, or help you calculate then how far you can really go, as opposed to just the map distance. So that's quite a good application."
> [male, 43, rural Hampshire, software engineer; Nissan Leaf]

One consideration was, in effect, no consideration at all, if a journey was known to be well within battery range – particularly pertinent for the low-mileage drivers who never took their cars out of range anyway. Some of these deliberations resulted in a further choice or decision: whether the electric vehicle was the most appropriate means of transport for that specific journey or trip; and 11 discrete factors were identified for drivers choosing to take another (petrol or diesel) vehicle they had in their household, or that they had access to borrow. Time constraints, i.e. charging downtime, were important as well as infrastructure provision:

> "I've only taken one journey in the last 12 months where I would have wanted to use the Leaf, but I took the wife's car instead. And that was because it was to Norwich: at that time once you got to the Cambridge area, beyond that you were in the wilderness, and although I could reach Norwich I wouldn't have been able to recharge to get back. Since that time, they've got rapid charging points [there], so there's no journey I'd envisage at the moment where I wouldn't use the Leaf – unless I was in a real rush, if I had a phone call saying you've got to get up to Birmingham in the next hour and a quarter; then I couldn't do that in the Leaf, I'd have to stop for a 25 minute charge at the services." [male, 54, Newbury, IT consultant; Nissan Leaf]

While choosing to drive their electric vehicle was considered to be the default option, two further use-cases were described in multi-vehicle households, perhaps involving swapping cars with a partner that day: specifically deciding to take the EV instead of the ICE vehicle, if a journey was likely to involve lots of stop-start traffic or traffic queues, as it was more relaxing; or if there was no need to take large items, such as children's pushchairs or car seats, as per usual routine.

table 5.ii: from Typology 1.1.2, 1.1.3: EV, ICE or other transport mode?

Take ICE car instead	If journey/round trip is beyond battery range If journey/round trip is over personal (psychological) threshold of range comfort To avoid 'hassle' of charging away from home If no convenient or suitable charging facilities en route or at destination If no suitable charging facilities within range of home anyway Due to time constraints – to avoid charging stops and downtime Due to time constraints – want to drive faster, take motorway Due to passenger/load-carrying needs (if ICE car larger or can tow) Due to terrain/road type (i.e. take SUV/4x4 for ground clearance, off-road ability) If very hot/cold and journey is pushing limits of range To avoid carrying large/expensive charging equipment (adaptors)
Take other transport mode or make multi-modal journey	If journey/round trip is beyond battery range If journey/round trip is over personal (psychological) threshold of range comfort To avoid 'hassle' of charging away from home If no convenient or suitable charging facilities en route or at destination Due to time constraints – to avoid charging stops and downtime If it makes sense in terms of distance/charging availability, i.e. facilities at park-and-ride or station
Drive EV instead of ICE car/other mode	If free/advantageous parking for EVs is offered at destination If charging facilities are available at a destination If journey now costs less in comparison Because now feeling 'less guilty' about car use If expecting stop-start traffic (EV 'more relaxing') If no need for ICE car's load-carrying/towing capabilities

In most multi-car households (excepting those with a Tesla Model S) the EV was the smaller vehicle and making decisions as to whether to drive it or not for a particular journey were often reported on that basis, rather than on the grounds of any range or powertrain-related limitations [4.2.6] – and not just for the Smart Fortwo ed owner: “parking is much easier for a small two-seater car!”

Many of the same factors had an influence over decisions involving the use of other modes of transport; to use public transport if this is more convenient than charging away from home, or if there are doubts about range, as suggested by Langbroek et al. (2018). Some interviewees indicated they were now more likely to take a train for longer and cross-country journeys, for example, or to split their journey between transport modes, with the availability of charging, i.e. at a train station or park-and-ride, a further consideration.

> “When we go out on runs, days out, we might go to York or somewhere like that; you’re getting in some of these big cities now park and rides where you can park up and charge while you’re parked, and then bus into the town – we’ve found that useful, we’ve just recently purchased the [optional adaptor] lead so we can plug into the public chargepoints.”
> [male, 66, rural Cumbria, retired; Vauxhall Ampera]

Relative costs for a trip were an issue as well as the practicality:

> “I tend to use the local railway station because I can get a free charge then use the train to go into the city centre. It only costs me £3, £4 to charge it [at home] but I can charge at the station for nothing and I can use my over-60s travel card to get me free transport on the train, so it’s a win-win situation!” [male, 64, Birmingham, retired; Renault Zoe]

However, factors such as charging availability at a destination and cost savings – i.e. free parking, or exemption from the London congestion charge, as well as savings compared to petrol or diesel consumption – also meant that in some cases, a trip the interviewee might previously have taken by other means was done in their EV [as discussed, 4.2.6]. Similarly, some short local journeys previously cycled or even walked were now driven, a rebound effect suggested by Langbroek et al. (2018). These drivers were not alone in their admissions:

> “In terms of the lack of tailpipe emissions, the fact that I’m not contributing to pollution is an important thing, but it probably makes me more likely to jump in the car and feel less guilty about using it for short distances or journeys when I might use other forms of transport.”
> [male, 37, London, doctor; BMW i3]

> “Living in the country, using the [diesel] Skoda as we were previously as our main car, you think, oh gosh, I forgot to buy eggs, and oh, I can’t go back into town just for that, three miles each way – I’d feel quite guilty for doing that. This has taken away that sort of guilt about polluting the planet, because the electricity, especially if we take it off our roof, we make it ourselves… and we’ve got a green tariff, so it’s definitely coming from a renewable source…”
> [female, retired, Shropshire; Nissan Leaf].

With all the above in mind, the drivers then thought about charging: the level of charge currently in their battery; the range they would need for their next desired journey; a safe margin to alleviate any range anxiety; the level they needed to charge to; and more, with reference to charging at home before setting out. Given the time taken to achieve a full 100% charge level – up to eight or even nine hours, depending on vehicle and the speed or type of charging equipment – the planning process involved deliberations over when to set the car to charge, the advantages of deferring charging if possible, and possible needs to deviate from a usual routine or practice.

> "I try to plan a day in advance: for instance, today I know the car's only going to be used locally, but tomorrow I'm going to Dundee and back, so it's got to be fully-charged for doing that, if I want to get there and back." [male, 68, Perth, retired engineer; Nissan Leaf]

> "If there's nothing specific planned, I will put it on to charge overnight if, as a rough rule of thumb, I'm below 50% capacity. I normally charge it up to, on the Leaf it's got what's called the battery long-life mode that charges up to 80%, so I normally do that… It's set on the dash in the car, there are two settings I have set: one is four o'clock till seven o'clock in the morning charging to 80%, the other one is till seven o'clock in the morning with no specified start time, letting the car work that one out, charging to 100%, which is for when I'm scheduling a long journey for the following day." [male, retired engineer, rural Shropshire; Nissan Leaf]

table 5.iii: from Typology 1.1.4: Pre-journey charging

Considerations	Whether charging is needed before departure Whether to charge at home or to take advantage of (free) chargers at destination Whether car has enough range to get to a charger at destination or not Whether to charge to 80% or 100% in advance Possibility of unexpected extra mileage needs, detours or similar Time of departure, and time needed for a full or sufficient charge level Whether automatic charge settings can be relied upon within usual routine Consider if a journey needs to be made soon/urgently, or if charging can wait, i.e. to take advantage of off-peak tariff or solar generation No planning or scheduling of charging – always keep car fully charged as a matter of routine Research available chargers on intended route or at destination 'just in case', even if unlikely to need
Actions	Check battery charge level via car/ charger interface Check charge level via smartphone or tablet app, iWatch, Pebble, smartwatch app or other wearable 'Top up' charge if necessary, to give enough to get to a destination charger Set charger according to 80% or 100% charge need Charge to allow some extra range 'in hand' Set charger to charge off-peak or for full charge in time for departure Reset charge timer if setting out earlier than usual the next day Defer journey for favourable charging, i.e. if sunny and to use solar energy, or to use off-peak tariff Plug in or switch on charger manually, i.e. if car not suitably charged and journey imminent Use app, Pebble, iWatch or similar to remotely start charging or monitor progress, i.e. if car not suitably charged and journey imminent

For drivers who always recharged their car as soon as they returned home (or arrived at a charger) this was of little concern, but for others, this sometimes meant starting charging to ensure they would have enough range for an unplanned trip, or if range was lower than anticipated: digital tools such as smartwatch apps as well as phone or tablet apps were used to start charging remotely, provided the car was plugged in to a charger.

> "There have been times when I've looked at the range before leaving work on a cold day and thought ooh, I'd like a little bit more headroom. I've got the charger at work now, so during the winter months I plug it in in the mornings and then probably activate the charging via Leafspy mid-afternoon, so I just top the battery up a little…" [male, 37, Bristol, dentist; Nissan Leaf]

table 5.iv: from Typology 1.2: Journeys beyond battery range: considering charging options

Considerations and pre-trip checks	Whether to rapid-charge en route, or charge at destination Journey time and downtime needed to charge to sufficient level Length of stay at destination, i.e. if enough time to slow-charge Availability of private charging, i.e. at family/friends' houses Availability of private charging, i.e. at hotel, B&B, holiday cottage; how to pay Whether to stop on outbound or return journey to charge, if only one stop needed Possible detours or extensions to journey, need for second charge Types of charger availability (compatibility with car) Call or email network/service providers to check if chargers are working Look online at EV forums, social media, i.e. Facebook groups, Twitter, for news on charger status or availability Check emails for mailing list updates on charger status (i.e. Ecotricity) Check if new RFID tags or network cards needed, or apps Request (well in advance) new RFID cards/tags, especially if driving abroad Pack any adaptor cables/connectors needed, i.e. Nissan Leaf's 'brick'
Searching for, locating and identifying chargers	Search online for chargers using Google, Google Maps or similar Research charger availability and status online or via app using Zap-Map, National Chargepoint Registry or similar Research charger availability and status via local authority/council websites or similar Research charger availability and status via service provider websites or apps, i.e. ChargeYourCar, Polar, Ecotricity Research charger availability and status via carmaker's website or app, or via in-car sat nav/browser (i.e. Tesla Model S) Research charger availability via open-source databases i.e. OpenChargeMap, Plugshare Ask other EV drivers for charging suggestions/status reports via social media Update existing knowledge on charger availability, i.e. new facilities installed on intended route or around destination Consult/update own spreadsheet, Google Doc, Google Maps map or similar of charging locations/charger types Check own self-developed app, i.e. aggregator of feeds from network operators, for charger locations and status Update and refresh any apps used for access/payment Use app to 'send to car' postcodes from Google Maps as destinations for in-car sat nav (i.e. in BMW i3) Enter charger postcodes as 'points of interest' in sat nav Look at OS map and mark charger locations in pencil; update paper list or reference document to take in car

For journeys known or found to be beyond battery range, involving charging away from home, an additional set of considerations and factors were identified, along with means by which to address these – including digital tools and resources.

As a result of this research and these considerations, decisions may be made such as choosing to take an ICE car or other transport mode instead, having found no convenient charging facility, or if charger status (availability or reliability) looks risky. Once feasibility of making the journey in an EV has been established, any necessary detours and adaptations to that journey are then identified. These include planning to charge at an unconventional location for vehicle fuelling, taking a different route to travel via a charging opportunity or to avoid motorways – "I have occasionally [gone] non-motorway across country as that is going to be more energy-efficient, so I can get more miles out of one charge" [male, 37, London, doctor; BMW i3] – and even choosing a different destination, i.e. to go shopping, based on charger availability: the specific and direct spatio-temporal adaptations.

> "It doesn't make a huge difference for local journeys, but going further, the sort of distance where you would need to charge the car as part of the journey, then we would certainly choose it around both where we knew there were charging points, and also where we know that there are charging points that we'd used before and it worked. And we might go out of our way distance-wise in order to use one that we know is easy to access."
> [male, 59, rural Dorset, retired doctor; BMW i3]

table 5.v: from Typology 1.2.4-6: Adapting journeys with reference to charging

Spatial adaptations (i.e. location, route)	Choose route according to charger availability, i.e. rapid-chargers at motorway services Develop back-up plan, alternative stop or route in case a charger is occupied/blocked/out of action; Plans B, C, even D reported Detour or go out of the way, if this enables using a charger known to be reliable and easy to access Decide which town to shop in, based on on-street or public car park charger availability (or price) Plan route according to energy efficiency, i.e. avoiding motorways to travel at lower speeds Plan shopping/leisure trips to specific retail parks or retailers, i.e. IKEA, based on charger availability Plan around charging at dealership for supplying brand (especially Nissan) or to use marque-specific facilities (Tesla Superchargers) Choose leisure destination to visit based on charger availability (and/or price) Choose to visit or stop at National Trust properties, specifically as they have chargers in key out-of-the-way locations, i.e. remote rural areas Identify/use charging facilities in unusual places, i.e. local businesses, sports centres or village car parks; industrial estates, harbours, agricultural facilities Even book holidays based on charger availability, i.e. at hotels, or campsites with electricity hook-up

Temporal adaptions (i.e. time-related)	Plan journey breaks or lunch stops, etc., around charging needs and charger availability Plan to stay somewhere overnight rather than risk long late-night journey home (i.e. ref to uncertain charger availability, lack of out-of-hours support) Consider charging downtime depending on speed/type of charger Plan journey and charging stops around diary or tasks for the day/trip Allow for a slower journey if avoiding motorways or higher-speed roads Plan around the journey taking longer due to charging downtime Schedule meetings or appointments to allow for charging stops en route or charging availability at destination (i.e. leaving car to charge while meeting) Build in schedule flexibility if possible to allow for charging issues, i.e. detouring to another charger Check [again] whether a multi-modal journey or taking another car/mode is quicker and easier, given charging downtime

Although ICTs or digital media have been thought to have more of an effect on temporal aspects of activities and transport, or travel to undertake these activities (Alexander et al., 2011; Hubers et al., 2008), here spatial factors are seen to be more prevalent and varied.

A series of further pre-departure checks, activities and decisions were also identified [Typology 1.2.7], including the use of apps and social media for last-minute updates to charger status and activating the pre-conditioning function to pre-heat or pre-cool the car's cabin – as well as the possibility of no pre-planning at all, i.e. if all rapid-charger locations are known on a driver's regular routes, they were confident that there would be plenty of chances to charge on the way or at their destination, or they were confident that they could find any chargers needed 'on the fly' using their satellite navigation system.

Tesla Model S drivers noted that they needed to do less planning [Typology 1.3], given their cars' much longer battery ranges, and pointed out that all Superchargers within reach were automatically identified and, if used, subsequently stored as destinations in their sat navs:

> "We simply research where the charging points are if they're not on the Tesla network, so, for example, driving to Leamington Spa we'd look at the Ecotricity points going up to the M40 [although] there's now a Supercharger, so we don't have to worry about that... I mean, the car itself has a web browser with the stations, you can load them on the fly, you don't have to do too much planning in advance…
> "We're quite spoilt on that [Tesla connectivity], the user interface is phenomenal, and it provides a lot of very, very useful information… if you're planning a journey it'll tell you if you have to make any deviations, so if there's a Supercharger point 10 miles off-route that you'll need to go to, it'll direct you to one of those points, it'll always warn you if you put in on the sat nav where you're going: it'll say OK, you're going to get there with 4% battery, so bear that in mind…"
> [male, '35-40', London, architect; Tesla Model S]

Drivers of the range-extended electric vehicles (BMW i3 REx, Vauxhall Ampera) also had less of an imperative to plan or stop to recharge, given their back-up petrol engines, but some did consider where to switch between petrol and electric modes in order to optimise efficiency or emissions, and whether they needed to top up with petrol [Typology 1.4]: several noted that they did not tend to keep a full tank as a matter of course, in order to save weight and optimise battery range.

5.3.2 On the journey

While heading to a nearby rapid-charger or Supercharger to recharge, or to top up on charge, is not in essence different to a driver of a petrol or diesel car going to fill up before embarking upon a journey, the longer time needed to recharge and the possibility of having to queue for a charger (or divert to a vacant or functioning facility) was borne in mind by EV drivers who did not have their own home charging facilities, or who had not pre-prepared or allowed enough time to charge sufficiently prior to departure [Typology 2.1].

Adaptations and changes to driving style and on-road behaviour [Typology 2.2.2, 2.2.3] are discussed more fully in Chapters 7 and 8, along with a reported series of dynamic checks and calculations of remaining range [Typology 2.2.1] and available charging facilities, but the latter impacted upon route and destination to supplement the spatio-temporal adjustments previously outlined: i.e. taking extra care to avoid getting lost and adding mileage to a trip; or using an app such as Waze to find a free-flowing traffic route to 'smooth it out' and optimise efficiency [Typology 2.2.4]; as well as changing route or even destination as a result of these 'on the fly' checks. If a charger was shown to be in use or to have become out of order, for example, a driver might head to a different car park or service station, if battery range allowed [Typology 2.3.1].

> "For example at my local shopping centre, when you're about two or three miles from there you'll go onto the [ChargeYourCar] app and you'll see, there's five different car parks and there's chargers in two of them, but you'll go onto the app and see which ones are free rather than drive to it first and find someone's using it." [male, 38, Newcastle, manufacturing worker; Nissan Leaf]

A wide variety of charging locations – and activities undertaken whilst a car was charging – were also described (*table 5.v*) according to the speed of charging and whether the driver would be able to leave the car for an extended period of time or only relatively briefly [Typology 2.3.2.1-2.3.3]. These included using toilet facilities, having a coffee, snack or meal, shopping, taking part in a leisure activity or work-related meeting, or going somewhere quiet to do some work – and sometimes making unplanned detours:

> "I did one where we stopped at Oxford services on the motorway and it wasn't working, so we picked up a KFC and drove around to BMW Mini at Oxford and sat eating the KFC in the car there while the car was charging, did it about 10 minutes and then got the rest of the way down to Chieveley [services]…" [male, 42, Staffordshire, software tester; BMW i3]

table 5.vi: from Typology 2.3.1-2.7: Dynamic decisions during a journey

Dynamic decisions	Change route to optimise efficiency Change destination, i.e. chosen car park, due to charger availability Change route to go via different charging stop, i.e. service station, due to charger availability Move vehicle from charger if someone else needs it more urgently (i.e. if alerted via ChargeBump app) Stop for unplanned charging if 'caught short' or plans change and need extra top-up Stop earlier en route than planned, if (or in case) later charging point is inoperable/unavailable Decide to use park-and-ride if running lower on range than anticipated Divert to nearby known charger if running lower on range than anticipated Shorten journey, defer errands or adapt trip if running lower on range than anticipated Stop at fast- or rapid-charger if deciding to go on somewhere else before going home Stop at fast- or rapid-charger on way home if running low on range Stop at fast- or rapid-charger on way home if going out again later or early next day
Specific issues leading to change of plan	Finding charger out of action due to technical issue Finding charger out of action due to vandalism or deliberate damage Finding charger inoperable as not reset or 'charge ended' by previous user Finding charger inaccessible outside of business hours or if business is unexpectedly closed Finding charger inaccessible without appropriate pass, i.e. to business park, campus car park Unable to find charging equipment at all at a location, i.e. fitted in obscure position Finding charger obstructed or its parking space blocked by ICE vehicle Finding charger blocked by other (fully-charged) EV or PHEV left parked there Finding charger already in use and likely long wait/a queue to access it Finding charger inaccessible due to other issue, i.e. supermarket delivery lorries unloading Be unable to operate charger due to poor mobile reception for app, or glitchy app Be unable to operate charger as no/wrong RFID tag (i.e. network operator changed since last visit)

Some 23 discrete actions and decisions [Typology 2.6.2] were reported as a result of encountering unexpected issues, including calling emergency helplines for remote technical support; requesting service station staff to have vehicles moved; requesting access to a service road to get to charging equipment on the other side of a motorway; diverting to other public chargers or even to the houses of family members, friends or business associates to get a top-up charge; and using a variety of apps, crowdsourced resources and social media platforms to locate alternative facilities.

5.3.3 Post-journey

Upon returning home, EV drivers described further practices, routines and decisions they made with regard to recharging their car. While plugging in straight away has been thought to be a preference (Philipsen et al., 2018) drivers here described a variety of habits or tendencies, including deferring charging until later – i.e. to take advantage of electricity tariffs such as Economy 7, or to sync with domestic solar generation – or, if they did not have charging facilities at home, whether to make a specific trip to a local charging point, and if so, whether they needed to move their car and repark after it had charged.

> "When I get home if it needs charging, I tend to just plug it in: I'm not on Economy 7 or anything so it's not worth messing around... I sometimes have a look on the Carwings to see how charged it is before I come home, and think, should I plug it in? I might see whether I need to, because I don't tend to plug it in every night: I tend to know where I'm going the next day and if I know I'm going a long distance I'll plug it in, if I'm just going locally, I won't bother."
> [female, 45, Derby, accountant; Nissan Leaf]

table 5.vii: from Typology 3.1, 3.2: Post-journey decisions and actions

EV drivers with home charging	Plug car in straight away to recharge upon return Plug car in to recharge later, charge activated via timer or remote app Check weather forecasts or look at weather apps to time charging, i.e. to sync with solar generation Plug in car to top up, but with view to fully recharging at public charger Reset charge timer according to next day's plans Reset charge levels (i.e. 80% or 100%) according to next day's plans Leave car unplugged if remaining range sufficient to next day's needs
EV drivers with no private facilities	Park on-street at public charger Park off-street at shared charging facility, i.e. within housing development Make additional trip later (i.e. after peak demand times) to fast- or rapid-charge, i.e. at nearby IKEA, Tesla Supercharger Make additional trip later to find on-street slow-charger Move and repark car again later once charged Don't recharge post-journey, but plan to charge when setting out on next trip Don't recharge post-journey, have sufficient range for next trip or to reach convenient charging facility, i.e. at workplace or service station en route

These post-journey decisions and activities [*table 5.vii*] represent a further dimension in which driving an EV differs to operating (and specifically, refuelling) a petrol or diesel car. Additional items [Typology 3.3] underline this: elements of post-journey analysis such as checking data on mileage travelled and battery charge; downloading logged data and comparing this with other drivers'; feedback and discussion on charging issues, i.e. in a web forum; giving feedback and reporting faults to network operators; or sharing useful information to crowdsourced platforms such as OpenChargeMap and with other drivers via social media [discussed in greater detail, Chapter 6].

5.4 Evidence to address hypotheses [H1, H2, H3]

The typology provides a framework in which qualitative data can be compiled to further describe the case study background [Chapter 4] and assess material addressing the first hypothesis [H1], the premise on which the subsequent hypotheses are based:

- **[H1]:** There are different spatio-temporal elements involved in driving and operating electric vehicles, i.e. issues around vehicle charging, journey planning and vehicle range.

The Typology of Electric Vehicle Driving [seen in full, *Appendix vi*] shows that – while not all of the drivers reported adaptations to their journey-planning, routines and household practices – a wealth of new practices and habits related to EV operation have been detailed and identified, many involving spatio-temporal elements and considerations, and elements of behaviour change. The sheer number and variety of these, as seen itemised in both the full typology and by-topic tabular formats, emphasise the degree to which driving and operating an electric vehicle may differ from the ICE vehicle ownership experience.

This insight supplements the finding of a majority agreement [4.2.6] that EV drivers believe that they have had to adapt the way they plan their journeys, underlined by the negative, statistically significant, relationship between levels of adaptation and ownership time: the longer the drivers had owned EVs, the lower their perceived adaptations, indicating the need for acclimatisation in the earlier stages of ownership. As such, hypothesis [H1] appears to be supported.

Indications of support for the subsequent hypotheses are also seen: *table 5.iii* and *table 5.iv* in particular (representing Typology 1.1.4 and 1.2 respectively) show the itemisation of activities involving digital media such as smartphone apps, websites and mapping tools, as well as references to social media use, giving material to address hypotheses [H2] and [H3]:

- **[H2]** Digital media and communications technologies assist and support electric vehicle drivers in their journey-planning, recharging and vehicle range optimisation.
- **[H3]** Digital media-based grassroots or community support, such as that offered via social media platforms, is important to the early-innovator electric vehicle drivers.

These hypotheses will be considered further and addressed in Chapter 6, following analysis and discussion of the empirical data specific to digital media engagement.

5.5 Conclusion and implications of themes outlined in the typology

Building a typology has been an effective methodology for formalising and tabulating the textual and narrative detail, in order to provide additional understanding. It has clearly delineated and described the aspects in which driving and operating an electric vehicle differs from running an ICE car, and the decisions, processes and activities which are a result of this for many (if not all) drivers. As discussed here, it gives particular insight into the journey-planning considerations of electric vehicle drivers, especially with regard to vehicle range and recharging. It sets out clear indications that there are spatio-temporal factors specific to driving and operating an electric vehicle, which have implications for journey-planning, decision-making and on-the-move dynamic considerations; that these involve an element of behaviour change and adaptation; that digital media has a role to play in these processes; and in combination with the empirical findings as discussed in Chapter 4, it confirms that the first hypothesis [H1] is supported.

A series of distinct themes can be also extracted from the typology and the above tabulations, each with relevance to policy-makers, authorities, service or infrastructure providers, or even vehicle manufacturers.

1. The sheer number of discrete actions and considerations pre-journey which drivers have reported illustrates that switching to an electric vehicle is not just a simple case of swapping one vehicle for another: a more complex decision-making and planning process is involved in journey-making, including determining which vehicle in a multi-car household to drive. Understanding this process is crucial for future user experience design, including the design of HMI (human-machine interfaces) within vehicles and of services related to electric vehicle operation, as well as for understanding the continuing barriers or off-putting factors (whether perceived or actual) that consumers may face.

2. Inherent in this decision-making, there are indications that EV drivers consider and respond to financial incentives, i.e. free parking for EVs or cheaper travel costs for a particular journey – and will change their plans, routines or even transport mode and destination accordingly. This represents an opportunity for policy-makers at both national and local levels, alongside businesses and commercial service providers, to leverage infrastructural provision to mutual benefit, i.e. to reduce congestion or inner-city parking demand by encouraging park-and-ride or multi-modal journey-making – but with care not to incentivise more driving.

3. The Typology of Electric Vehicle Driving gives a comprehensive description of potential problems and 'pain points' of EV journey-making, such as inoperable or inaccessible charging equipment; how these issues are negotiated; and the impact that they may have on a particular

journey or routine. This underlines the need for better facility maintenance and governance in particular, as well as highlighting areas for improvement such as apps or systems for cross-network charger access or payment.

4. The adaptations and modifications drivers make to accommodate their battery-charging or their vehicle's operational range can be analysed in spatio-temporal terms; this provides a framework to consider appropriate service provision and commercial opportunities, i.e. to develop a mapping of driver practices and routines within a defined area to inform the installation of charging equipment, and the other activities or facilities offered around it.

5. Planning and considerations around home recharging are also outlined and described, suggesting that there are a variety of practices and preferences around time and source of electricity – whether opting to simply plug in upon returning home in the car, scheduling to charge on an off-peak tariff or trying to synchronise charging with energy generation from domestic solar panels. It appears that some, but not all, EV drivers are prepared to schedule their charging to optimise demand on the grid or renewable energy integration, indicating that automated vehicle-to-grid (V2G) communication and smart-charging will be necessary to support increasing numbers of EVs, smooth out energy demand peaks or troughs, and for vehicles to play a role in renewable energy storage.

Further details from the typology will be discussed in Chapter 6 with specific reference to digital media engagement, where it will again formulate and represent qualitative material to supplement the statistical findings. The typology also informs the understanding of the segmented user groups and the subsequent development of individual archetypal personas [Chapter 7].

Chapter 6 **Results: Digital engagement**

6.1 Overview

Building on the background data as discussed in Chapter 4, the data most directly addressing the hypotheses on digital media are now considered. The ordinal data, including that generated by the affective-scale questions, are outlined to represent findings on digital media usage and engagement: firstly, that involving websites, smartphone or tablet apps, in-car interfaces and other such resources, and then social media in its different forms and on different platforms. Participation in specific digitally-enabled activities and affective attitudes towards digital technologies are captured and described with reference to the typology as discussed, Chapter 5 [*Appendix vi*], and data from the textual coding are further expressed in infographics. The Kendall's tau-b rank correlation co-efficient was run to explore a series of potential relationships between responses to specific questions, to a meaningful level of significance. Levels of digital media engagement are correlated against reported adaptations in journey-planning, demographic background (i.e. age) and factors including mileage and length of EV ownership experience. These relationships are discussed, illustrated by qualitative feedback to enhance the numerical analysis. Findings from this data form a basis to address the below research hypotheses [H2 and H3], and further inform the targeted breakdown or segmentation by user type in Chapter 7.

- **[H2]:** Digital media and communications technologies assist and support electric vehicle drivers in their journey planning, recharging and vehicle range optimisation.
- **[H3]:** Digital media grassroots or community support, as offered via social media platforms, is important to the early-innovator electric vehicle drivers.

6.2 Engagement with digital media

6.2.1 Usage of websites, apps, digital tools and resources

Interviewees were asked [Q15] if they used, or had used, any websites, smartphone or tablet apps, in-car digital tools or similar, to locate charging facilities, schedule charging, remotely monitor their vehicle's state of charge, optimise their route or similar. Prompts were deployed, including asking about visits to particular websites such as Zap-Map or OpenChargeMap, and use of specific apps such as Nissan's Carwings, the third-party Leafspy, apps from charging providers such as Polar, Ecotricity or Chargemaster, and 'sharing' apps or those enabling communication with other EV drivers, such as Plugsurfing, Plugshare or ChargeBump. Two-thirds of interviewees [66%, n=58] were at least frequent users of such digital technologies, a small number [n=6] saying that they used these on, or prior to, most of their journeys, and indicating that they felt dependent upon such tools:

> "I'm using them all the time and keeping up to date with what's happening on the networks, that kind of thing. At the moment, until there's enough infrastructure all over the place and you can just drive and know you'll pass one [a charger] at some point, you really need to know where they are and whether they're working, so you're kind of reliant on apps to find all of that stuff." [male, 42, software tester, Staffordshire; BMW i3 REx].

The responses of a further sizeable number [19%, n=17] indicated that if not regularly using digital technologies or resources, these would occasionally be deployed, for example if travelling outside a usual everyday routine, or if the driver found themselves unable to charge as planned or unexpectedly short of battery range. Deploying apps for tasks such as remote pre-heating of their vehicle's cabin or for scheduling charging also indicated a willingness to use such technologies and a degree of engagement with digital tools:

> "When I'm going up to central London, I'll see if there is a charging point in the area which I'm going to, because that's convenient… I look on the local authority's maps, so if I'm going into Westminster then I'll look on the London Borough of Westminster's map of where they say their charging points are… I use the Source London website, of course, because I'm signed up with them…
> "I tend to use my desktop [computer] before I go. Smartphone apps, it's a bit late when you've arrived in an area and there aren't so many charging points around that you can be sure of finding one. But I've got one I use occasionally, it's more of a toy than a real thing. It's Smart's own app: when [the car's] plugged in at home I do have the ability to turn the charging on with a remote app; and also the very nice facility in winter and summer when it's plugged in, the air conditioning to cool it off, and on a frosty morning when I think it would be quite nice to have the car defrosted and warm to get into." [male, 75, retired, outer London; Smart Fortwo ed]

A small number [n=8] said that while they had used digital tools and resources when they first got their electric car, typically as a novelty or until they had discovered where charging points were in their local area, they no longer did so:

> "To be fair we don't go that far generally, and I would know where they [charging points] all are anyway, but it would be the Carwings system within the car itself, it's more than adequate for our needs. I also have Leafspy, now, again, all that stuff, when I had the first car, was all new and interesting and all the rest of it, we used to show a bit of an interest in all that, but to be honest I no longer, we just get into it and drive it now… as I say, at the end of the day, we know how far we're going, we know what the car's done, I think probably part of it comes down to it's a learning curve, once you know what, how many miles you get out of a bar on the car and so on, it really isn't a problem." [male, 47, engineer, rural Northern Ireland; Nissan Leaf]

> "I've had it [Nissan Leaf] nine months so I know where they [chargers] are off by heart now, but initially I'd just go online and check to see where the chargers are before I went on a run somewhere to see if I could find somewhere to charge… any of the Zap-Map type things, just websites that have listings, there's Zap-Map, Nissan do their own listing of chargers, and I've also

> found that you have to check more than one, because there's about four or five different websites which have different charging points, and none of them list the same charging points! I've got them saved on my computer. Yes, I have got a smartphone app, although I would only use that as an emergency if I was out and about and I get stuck, and I've got nothing on the sat nav from the Nissan." [male, 44, mechanic, Northamptonshire]

Never charging away from home was a factor in not needing to research charging facilities: "I've got nowhere to plug it in, I've got no adaptor, so it would be a pointless exercise," said one Vauxhall Ampera owner without the necessary cable to use public equipment. A further minority [n=5] said that they "never" used any digital tools or apps – although in further conversation, in most cases it transpired that they had at least looked at charging point locations on their sat nav (i.e. "out of curiosity"); checked out distances or routes using Google Maps, AA Routeplanner or similar; or at some point set up charging, pre-heating or pre-cooling via in-dash systems such as Nissan's Carwings. Programming charging times and rates using controls on home charging units were also mentioned.

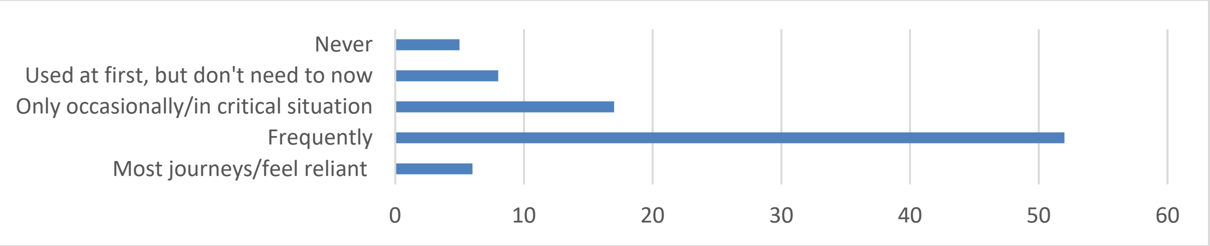

fig 6.i: [Q15a] Usage of digital media – websites, smartphone/tablet/in-car apps [n=88]

When asked or prompted for further information, and with full interview transcripts reviewed, only one interviewee actually "never" used any type of digital tool, resource or intervention; 86% [n=76] referred to websites and 65% [n=57] to smartphone or tablet apps; and 58% [n=51] used in-car or charger interfaces, including sat nav, for seeking charging points or programming charging. Half [n=44] remotely monitored their vehicle's state of charge or scheduled charging via an app, and 32% [n=28] engaged in other remote-control practices such as pre-heating or pre-cooling of their car's cabin.

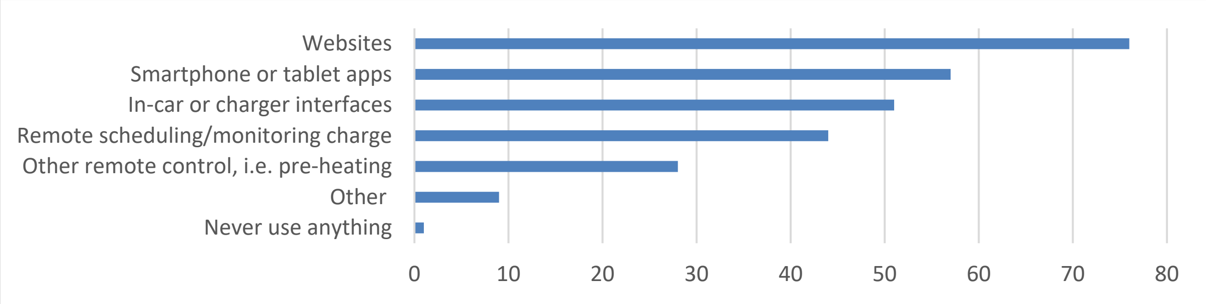

fig 6.ii: [Q15b] Types of digital tool used [n=88]

'Other' tech-related activity [n=9] included the use of third-party mapping and charger database tools such as those available on TomTom or Garmin sat navs, smartwatch apps, and other forms of charge monitoring or more detailed analysis:

> "I've got a clip-on ammeter, I think it reads up to 600amps, which I can stick on the electricity main and read what's going into the house."
> [male, 71, retired engineer, suburban Surrey; Vauxhall Ampera]

> "Plugshare is now on the Apple Watch, so you just tap it to see where the nearest charging points are, and that's good, because it's got everything on it, you actually set your car on it, so the app knows what chargers are compatible with your car, there's no point it taking you to a ChaDeMo when you're a CCS…" [male, 55, telecomms consultant, Bromley; BMW i3 REx]

In this category also come those creating their own tools and apps [n=6]:

> "I use Leafspy, but for different reasons than you might expect, because what I'm doing is recording the charge; and at the moment I'm analysing the usage of electricity, because I want to improve the calculation on EV Route [own route-planner]. So I don't use it for orientation, how well my car is charged; I use it as the tool to find the mathematical curve of using the energy depending on the speed, acceleration, height, you know, those things, so it's rather investigation than information." [male, 57, Bournemouth, software developer; Nissan Leaf]

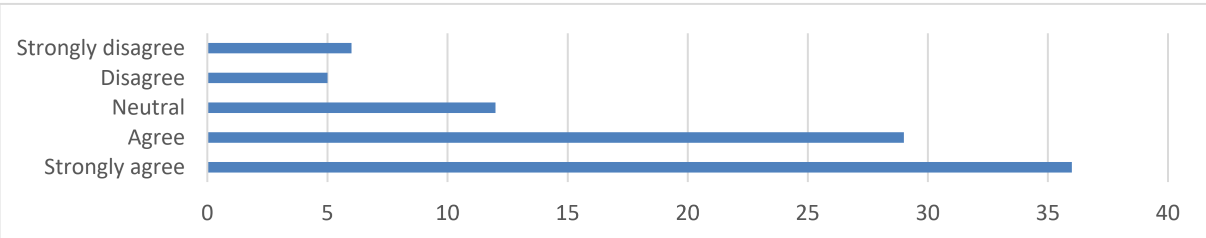

fig 6.iii: [Q18] "I find apps and digital resources important and of interest to me as an electric vehicle driver" [n=88]

A similar pattern was observed in the affective-scale data collected to gauge digital media engagement [Q18] in that a minority [13%] disagreed [n=5] or strongly disagreed [n=6] with the statement: "*I find apps and digital resources important and of interest to me as an electric vehicle driver*". A higher proportion [14%, n=12] expressed a neutral sentiment, but the bulk of interviewees [74%] either agreed [n=29] or strongly agreed [n=36].

There appears also to be a relationship between digital engagement and stated level of adaptation in journey-planning, as explored by affective-scale answers to the statement [Q14] "*Since starting to drive an electric vehicle, I have adapted the way that I plan my journeys*", with which hypothesis [H1] was supported.

table 6.i: Importance of digital media vs adaptations in journey-planning [n=88]

	"I find apps and digital resources useful and of interest to me as an electric vehicle driver" [Q18]				
"Since starting to drive an EV, I have adapted the way that I plan my journeys" [Q14]	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Strongly agree	13	8	3	0	1
Agree	13	8	3	2	1
Neutral	6	5	1	2	1
Disagree	2	2	5	1	1
Strongly disagree	2	6	0	0	2

A Kendall's tau-b rank correlation co-efficient, suitable for tied ranks, was run to determine the relationship between responses to the two statements [*table 6.i*] amongst the [n=88] sample. This was found to give a statistically significant positive correlation:

- tau_b = 0.214, p = 0.017; the correlation is significant at the 0.05 level (2-tailed).

This confirms that more agreement to one statement is related to more agreement on the other, and is backed up by the positive, statistically significant correlation also found [below] between the Q14 affective-scale responses and the coded responses to Q15 around digital media usage habits and frequencies [*table 6.ii*]:

- tau_b = 0.282, p = 0.002 [n=88]; correlation is significant at the 0.01 level (2-tailed).

Both these Kendall's correlations suggest that the use of websites, apps and in-car interfaces is a means of negotiating the different spatio-temporal elements of EV driving as identified in Chapters 4 and 5, such as adapting household routines or routes to encompass vehicle charging, and in adopting new practices around operating an EV. Hypothesis [H2] appears to be supported.

table 6.ii: Adaptations in journey-planning vs frequency of digital media usage [n=88]

"Do you use, or have you used, any websites or smartphone/tablet/in-car apps…?" [Q15]

"Since starting to drive an EV, I have adapted the way that I plan my journeys" [Q14]	Never	At first but now don't need to	Only very occasionally/in critical situation	Frequently	Most journeys/feel reliant
Strongly agree	1	1	2	18	3
Agree	0	2	6	17	2
Neutral	2	1	2	10	0
Disagree	1	2	5	3	0
Strongly disagree	1	2	2	4	1

The age-distribution of responses on the affective scale suggests that while the (few) younger participants aged up to 35 and Generation X (36-50) tended to be the digital enthusiasts, the middle-aged and older baby-boomer drivers (51-69) and even the oldest age-group (70+) expressed some interest in digital technologies too. As the visualisation below implies, there is a concentration of younger drivers in the 'agree' and 'strongly agree' sectors, and Kendall's correlations found a statistically significant, negative relationship between age and digital engagement – the younger drivers were more likely to use digital media, and more often.

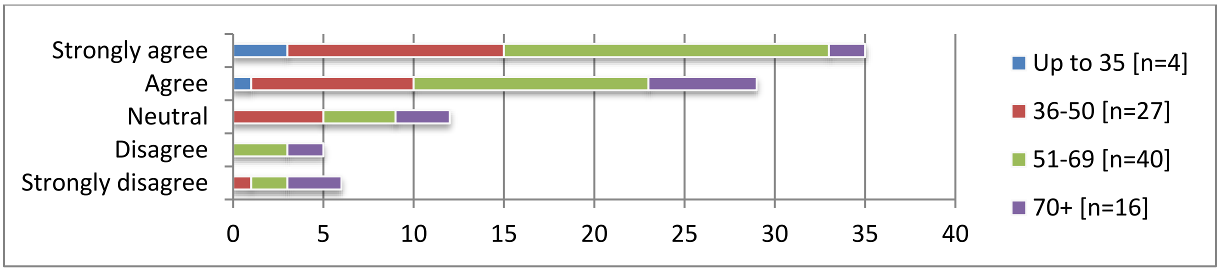

figure 6.iv: [Q18] "I find apps and digital resources useful and of interest to me as an electric vehicle driver" – by age [n=87]

Correlations against the ranked factors of age, ownership time, mileage and satisfaction with public recharging infrastructure showed very similar results for both the affective-scale rating [Q18] and the reported frequency of digital media usage [Q15]. Only a very weak, and not statistically-significant, relationship was found with mileage. This indicates that engagement with digital media is not necessarily a needs-must exercise for those regularly or frequently travelling outside their vehicle's battery range – bearing in mind that, for some drivers, this may simply reflect the decision to take another household vehicle or other transport mode for longer journeys [as described, Typology 1.1.2 and 1.1.3]. The relationships between digital media usage and EV ownership time were also negative – i.e. the shorter their experience, the more likely drivers were to use digital media, but weak. This does suggest that digital media plays a role for drivers newer to owning an EV, perhaps as part of an acclimatisation process, albeit not to a statistically significant level. The negative relationship between drivers' rating of the UK's public EV recharging infrastructure [Q12] and digital media engagement was also very weak: while the drivers who expressed a negative view of the infrastructure were a little more likely to use digital tools and resources, this was not statistically significant either.

table 6.iii: Summary of digital media correlations

"I find digital media useful and of interest to me as an electric vehicle driver" [Q18] vs:

Age [Q1]	tau_b = -0.255 *p* = 0.006 [n=87]	Negative, statistically significant at the 0.01 level (2-tailed)
Ownership time [Q3]	tau_b = -0.140 *p* = 0.135 [n=88]	Negative, weak relationship (2-tailed)
Reported mileage [Q5]	tau_b = 0.047 *p* = 0.622 [n=88]	Positive, very weak relationship (2-tailed)
Rating of public charging infrastructure [Q12]	tau_b = -0.036 *p* = 0.691 [n=88]	Negative, very weak relationship (2-tailed)
Adaptation in journey-planning [Q14]	tau_b = 0.214 *p* = 0.017 [n=88]	Positive, statistically significant at the 0.05 level (2-tailed)
Usage frequency of digital media (apps, websites) [Q15]	tau_b = 0.617 *p* = 0.000 [n=88]	Positive, statistically significant at the 0.01 level (2-tailed)
Frequency of digital media use [Q15] vs:		
Age [Q1]	tau_b = -0.393 *p* = 0.000 [n=87]	Negative, statistically significant at the 0.01 level (2-tailed)
Ownership time [Q3]	tau_b = -0.154 *p* = 0.105 [n=88]	Negative, weak relationship (2-tailed)
Reported mileage [Q5]	tau b = 0.116 *p*= 0.224 [n=88]	Positive, very weak relationship (2-tailed)
Rating of public charging infrastructure [Q12]	tau b = -0.071 *p* = 0.438 [n=88]	Negative, very weak relationship (2-tailed)
Adaptation in journey-planning [Q14]	tau_b = 0.282 *p* = 0.002 [n=88]	Positive, statistically significant at the 0.01 level (2-tailed)

6.2.2 Digital media use in the Typology of Electric Vehicle Driving

Just as smartphone apps have transformed urban transport in general [as discussed, 1.4] i.e. in terms of temporal or spatial distribution of activities and in relationship to space or travel time (Aguilera and Boutueil, 2018), apps and other forms of digital media appear to have an influence on electric vehicle usage. Use of digital media (i.e. websites, smartphone or other mobile apps) with relation to the spatio-temporal aspects of EV driving is illustrated by the specific activities identified and delineated in the typology [*Appendix vi*]; and as noted by Ettema (2018) in a more general travel context, the use of different apps and tools is quite specific to their contexts and purposes. In addition to the use of apps, websites or connected tools for mapping a route (which, of course, a driver of an ICE vehicle may also do), the EV-specific deployment of digital media is noted and described at each stage of the journey-planning.

From preparing and checking charging pre-journey [Typology 1.1.4], researching public charger availability [1.2.2.1] and updating, refreshing and maintaining knowledge of facilities [1.2.2.2]; through dynamic checking of charger status while on route [2.3.1], plotting alternative routes or stops [2.6.2], negotiating with other EV drivers over access to chargers via apps such as (the since-defunct) Chargebump [2.3.3] and payments for charging via app [2.5]; to post-journey scheduling or activating the next home charge [3.1], drivers reported a variety of possible digitally-enabled elements in their journey-making. Those keen on analysis reported downloading journey data [3.3], maybe to share and compare with other EV owners via an app or to make calculations such as cost comparisons, mileage on renewable energy, perhaps using their own self-developed app; contributions to crowdsourced or user-generated resources or data comparison apps were noted.

The typology plots and positions the possible interventions of digital media tools at each stage of the decision-making process, and as such, underlines the role that digital media is playing in the adoption of electric vehicles. It also identifies activities, habits or routines – enabled or supported by digital media – which are specific to EV ownership or driving and gives further support to hypothesis [H2].

table 6.iv: Digital media deployment or interventions as outlined in the Typology

Pre-journey	Plot mileage, route using AA/RAC online route planners, Google Maps or similar; or on mobile app Check battery charge levels via smartphone or tablet app; or iWatch, Pebble or similar Use app (mobile or on wearable) to schedule or remotely start charging, or monitor charging progress, before departure Research available charging facilities at destination/en route/by location online or via mobile app; check connector types, network providers etc. Check charger availability/status online or via mobile app

	Check out open-source/shared resources to locate chargers, i.e. at private houses/businesses Consult/update own spreadsheet, Google Doc or similar online personal record of chargers Check own app (i.e. aggregating feeds from network providers) for charger status on intended route Use app to 'send to car' charger postcodes from Google Maps as new destinations/points of interest for in-car sat nav Update/refresh any apps used; download any needed to access new/different charger networks Use website/app i.e. Google Maps to see whether multi-modal journey is quicker, given charging downtime Check charging (and parking) costs using app or website Use app to remotely check/monitor charge levels, last-minute pre-departure Use app to activate pre-heating/cooling of cabin
During journey	Read Carwings statistics or similar on start-up Double-check charger availability/status on start-up, re-route accordingly Use app i.e. Waze to find free-flowing traffic route, optimise energy efficiency Check status of next/desired chargers while en route, in time to re-route or choose when to stop/where to park Use in-car browser 'on the fly' to locate Superchargers (Tesla) Check network/charger status for updates for onward journey when charging en route/at destination Check app to monitor charge levels/pick up alerts while car is charging en route/at destination Use app (i.e. ChargeBump) to communicate with other EV drivers over charger needs/access Use app to access charging point or pay for charging (network members' app or pay-as-you-go) Use mobile app to locate different charger/solution if desired facility occupied/out of service Upload photo of charger or useful information to open-source/crowd-sourced database i.e. OpenChargeMap.org (i.e. while waiting for car to charge)
Post-journey	Plug in car to recharge later, charging to be activated via app Check weather apps to decide when to recharge, i.e. to sync with solar generation Download journey data or check data-logger, i.e. for EVStatus, FleetKarma Upload data (i.e. on range or energy efficiency) to other crowd-sourced project/resources, online or via app Compare data directly with others via app i.e. Leafspy, Carwings Input data to own spreadsheet or app; share via Google Docs or private app

6.3 Engagement with social media

6.3.1 Use of EV-related social media

Usage of social media with reference to electric vehicle ownership or operation was less enthusiastic: a minority 42% [n=37] agreed or strongly agreed with the statement [Q19] "I find social media important and of interest to me as an electric vehicle driver"; just under 41% [n=36] disagreed or strongly disagreed, while a small 17% proportion [n=15] remained neutral. Social media was defined in this case as web forums and online discussion groups, and platforms such as Facebook, Twitter, YouTube and Google+.

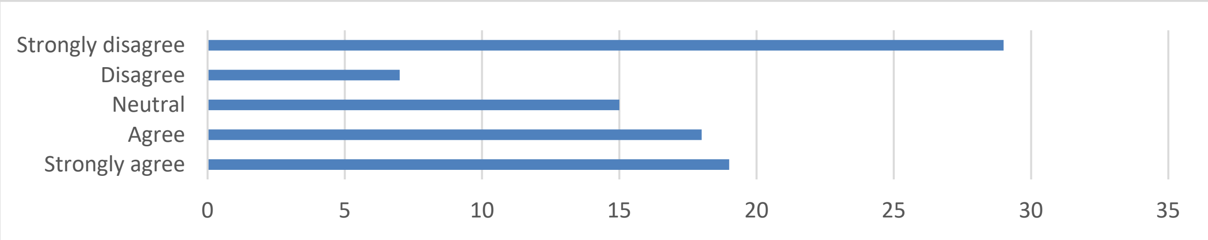

figure 6.v: [Q19] "I find social media important and of interest to me as an electric vehicle driver" [n=88]

While 45% described themselves as frequent [n=16] or regular [n=24] users of social media in the context of discussion or learning about electric vehicles, more were only occasional participants [32%, n=28], such as when they had a specific question or query [n=22]. A small minority [n=6] reported that they had sought information via social media when they first had their electric car, or when they were planning their purchase, but had not done so since. A more sizeable proportion were emphatic that they never used social media at all [23%, n=20].

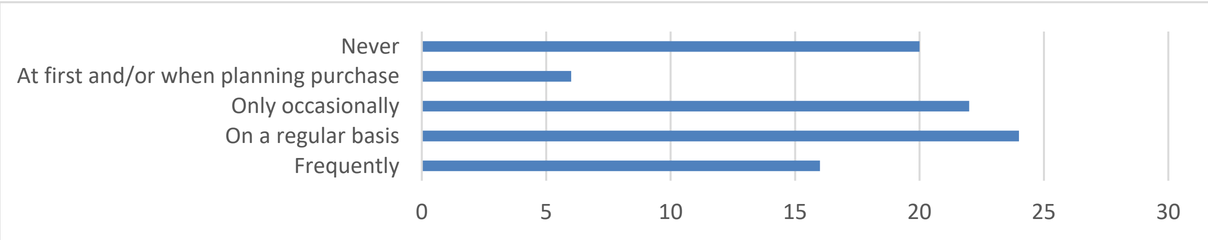

figure 6.vi: [Q16] Participation in EV web forums, EV-related social media activities [n=88]

General electric vehicle forums – SpeakEV, in particular (www.speakev.com) – proved the most popular social media activity, visited by 44% [n=39] of interviewees; and model-specific discussion groups, such as Leaftalk for Nissan owners or Renault's ZE [zero-emissions] forums (albeit both now defunct) were visited by 39% [n=34].

> "Speak EV is the one I go to when I have a question; I started a thread about trying to understand the different names of all the different types of charger."
> [male, 71, rural Hampshire, retired doctor; Volkswagen e-Up!]

> "Oh, it was trying to learn about how to manage with an electric vehicle, it was very useful, because of this nonsense with all the different [RFID] cards [for public chargers] you should have all over the country and nobody tells you about that. A dealer doesn't know... so I had to find out that for myself and there was a web page where guys were sharing that sort of information."
> [male, 69, Peterborough, retired; Vauxhall Ampera]

Those who did use social media were asked about its benefits: 27% of all respondents [n=24] cited the importance of contributing information and helping others; and 20% [n=18] mentioned media-driven advocacy, activism or lobbying, promoting electric vehicle uptake or campaigning on issues affecting EV usage, such as provision of charging facilities, sometimes through membership of a club or organisation such as the Electric Vehicle Drivers Association of Scotland (EVDAS), the Battery Vehicle Society, or very locally-specific groups such as Stretton Climate Care in Shropshire. 25% of the sample [n=22] described themselves as active on Twitter, including using hashtags such as #ukcharge or #ivebeenICED (to complain about blocked chargers).

> "I suppose that's really where I'm cracking off now on the SpeakEV group, trying to get them all together and sort out what we need from a charging network rather than just moaning about all the ones that are there at the moment… Whether it's lobbying the government and letting them know what's going wrong with the way they're dishing out money to the councils, or trying to find out where the network's not got good coverage, it's really just digging in and help trying to get it going as I know it needs doing." [male, 42, software tester, Staffordshire; BMW i3 REx]

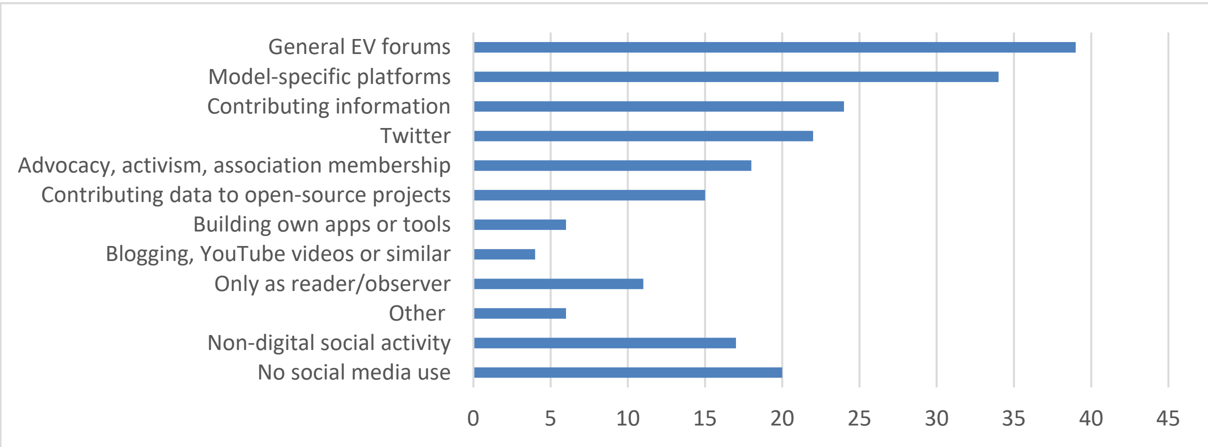

fig 6.vii: [Q16b] Participation in EV-related social media activities [n=88]

Contributing information or data to open-source or crowd-sourced resources or projects, such as EVStatus (data on Nissan Leaf battery life and energy usage; https://evstatus.com) or the OpenChargeMap charger mapping database (www.openchargemap.org), was reported by 17% [n=15]. Activities such as sharing screengrabs of vehicle data, i.e. battery capacity and charging rates, have also been noted in a study of a Tesla owners forum by Meelen et al. (2019), and echo observations on other topics, such as the sharing of self-tracked health or fitness data on social media (Lupton, 2015).

Some 7% [n=6] were building, developing or involved in testing apps or tools, such as ChargeBump (to communicate with other EV users at charging points; now defunct), and 5% [n=4] engaged in some form of content creation such as blogging about their EV, making YouTube videos, or similar. Interestingly, no-one cited Reddit, Tumblr or Instagram (not so widely used at that point in time), and even Facebook was little mentioned (some Facebook-based discussion or group membership was recorded under 'Other').

Though they did not actually participate in discussions or make their own postings, 13% [n=11] noted that they had looked at social media to read and learn from the contributions and experiences of others; and 19% [n=17] were keen to stress that although they did not use social media, they were involved in some form of non-digital social activity, such as holding or attending EV meet-ups or showcase events, or giving talks to local organisations – not to be discounted as unimportant, since face-to-face discussions and workshops are valuable in educating those not yet driving EVs and developing positive evaluations of EVs (Kurani et al., 2018).

6.3.2 Social media use in the typology

As with apps and online digital tools, social media featured at all stages of the journey-making process as outlined in the typology [*Appendix vi*]. From asking other EV drivers for any advice or suggestions, i.e. on charging options when planning a new or long journey [Typology 1.2.2.1]; checking Twitter for news on updates to, or problems with, charger networks and public facilities [1.2.2.3; 1.2.7]; through dynamic checks of ongoing charger status [2.3.3] or sharing news of technical issues or blocked chargers [2.6.2]; and then sharing experiences and handy observations upon return [3.3], social media is seen to play a role before, during and after a journey.

Since the 2015 fieldwork, general shifts in social media uptake and preferences are expected to have an impact; specific Twitter hashtags have changed (i.e. #ukcharge or #IvebeenICED were popular at the time but more have since been deployed; the rather ruder #ICEhole and #ICEtard are current at the time of writing); and specific forums such as Leaftalk are now defunct – although SpeakEV.com continues to grow (to around 17,800 registered members mid-January 2019). However, the observed ways in which EV drivers use social media, and the nature of the content they post or discuss, appear to be little-changed and are similar to those described by Meelen et al. (2019), including its use as a means to communicate with service providers, authorities and other infrastructural stakeholders (*ibid*.).

Again, the EV-specific activities delineated – especially the community-based help and support – are in line with hypothesis [H3] that digital media-based grassroots or community support is important to EV drivers, corresponding with the conclusions of Meelen et al. (2019), although the support seen here is not as strong as that for [H2] referencing websites and apps, and there is less evidence that social media could actually contribute to EV uptake, as argued (*ibid*.). Social media also does not appear to be used in as wide a variety of situations or scenarios – or to the same extent – as other forms of digital media.

table 6.v: Social media usage as outlined in the Typology

Pre-journey	Ask other EV drivers for advice or suggestions on charging when planning new/long journey, i.e. in web forum such as SpeakEV.com Look at forums, Twitter or other platforms for news on updates to/problems with specific charger networks or facilities Plan route or charging stop based on feedback from other EV drivers on social media Pre-departure checks of social media (i.e. Ecotricity Twitter feed) for last-minute updates to charger availability/status
During journey	Check social media feeds, i.e. while charging, for updates on charger availability/status for onward/return journey Notify service provider or chargepoint operator of any issues on-the-spot via social media, i.e. Twitter Seek alternative charging solution via social media, i.e. using Twitter hashtag #ukcharge Share news of technical issues or complain about/shame drivers blocking chargers, i.e. #ivebeenICED on Twitter Charge at private facilities found (or offered) via social media
Post-journey	Share and discuss the driving/charging experience, i.e. efficiency data Share information from the journey, i.e. handy observations, charger status Feedback of information or complaints to service providers, i.e. about malfunctioning chargers Lobbying bodies such as local authorities on enforcing regulations i.e. designated charging bays/time limits

6.3.3 Social media and journey-planning

The relationship between perceived adaptation to EV ownership and social media use was also not as strong as that involving other forms of digital media.

table 6.vi: Importance of social media vs adaptations in journey-planning [n=88]

	"I find social media useful and of interest to me as an electric vehicle driver" [Q19]				
"Since starting to drive an EV, I have adapted the way that I plan my journeys" [Q14]	**Strongly agree**	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
Strongly agree	7	5	4	1	8
Agree	8	4	8	1	6
Neutral	2	5	1	4	3
Disagree	1	2	1	0	7
Strongly disagree	1	2	1	1	5

A Kendall's tau_b rank correlation co-efficient was found to give a weak, positive, non-significant correlation between the affective-scale responses to both statements [Q14 and Q19]:

- tau_b = 0.166, p = 0.58 [n=88].

However, correlating the affective-scale responses to Q14 with the coded responses to Q16, which asked about social media in more general terms, showed a different output:

table 6.vii: Usage frequency of social media vs adaptations in journey-planning [n=88]

	"Do you participate in any EV web forums, discussion groups or Facebook pages, or identify as an EV driver on Twitter, for example?" [Q16]				
"Since starting to drive an EV, I have adapted the way that I plan my journeys" [Q14]	**Never**	**At first and/ or when planning purchase**	**Only very occasionally/for specific queries**	**On a regular basis**	**Frequently**
Strongly agree	5	0	3	11	6
Agree	3	3	9	5	7
Neutral	2	0	5	5	3
Disagree	6	1	4	0	0
Strongly disagree	4	2	1	3	0

The Kendall's tau_b rank correlation co-efficient was found to give a positive correlation:

- tau_b = 0.280, p = 0.001 [n=88]; the correlation is significant at the 0.01 level (2-tailed).

Younger participants and those tending to do a higher mileage were more likely to find social media useful or of interest to them as an electric vehicle driver, though the relationships were not as strong as those with other forms of digital media [6.2.1]. There was no statistically significant relationship between importance of social media and either ownership time (EV experience) or ranked perceptions of public recharging infrastructure, i.e. those negative about provision were not much more likely to seek or share information about it via social media than those who found it adequate for their needs. Similar patterns were also seen between *frequency* of social media usage and these factors.

A further relationship was explored between the affective-scale responses to the statement [Q18]*"I find apps and digital resources useful and of interest to me as an electric vehicle driver"* and the statement on importance of social media [Q19]: as expected, a positive and statistically significant correlation was found; and similarly, between frequency of usage of social media and that of other EV-related digital media, i.e. apps and websites. This suggests that those engaging with digital tools such as smartphone apps do also participate in EV-related social media – although not universally.

table 6.viii: Summary of social media correlations

"I find social media useful and of interest to me as an electric vehicle driver" [Q19] vs:

Age [Q1]	tau_b = -0.251 *p* = 0.006 [n=87]	Negative, statistically significant at the 0.01 level (2-tailed)
Ownership time [Q3]	tau_b = -0.020 *p* = 0.825 [n=88]	Negative, very weak relationship (2-tailed)
Reported mileage [Q5]	tau_b = 0.189 *p* = 0.040 [n=88]	Positive, statistically significant at the 0.05 level (2-tailed)
Rating of public charging infrastructure [Q12]	tau_b = -0.110 *p* = 0.215 [n=88]	Negative, very weak relationship (2-tailed)
Adaptation in journey-planning [Q14]	tau_b = 0.166 *p* = 0.58 [n=88]	Positive, weak relationship (2-tailed)
Digital media importance/interest [Q18]	tau_b = 0.408 *p* = 000 [n=88]	Positive, statistically significant at the 0.01 level (2-tailed)
Usage frequency of digital media (apps, websites) [Q15]	tau_b = 0.344 *p* = 0.000 [n=88]	Positive, statistically significant at the 0.01 level (2-tailed)
Frequency of social media use [Q16] vs:		
Age [Q1]	tau_b = -0.237 *p* = 0.009 [n=87]	Negative, statistically significant at the 0.01 level (2-tailed)
Ownership time [Q3]	tau_b = 0.042 *p* = 0.981 [n=88]	Positive, very weak relationship (2-tailed)
Reported mileage [Q5]	tau b = 0.263 *p*= 0.04 [n=88]	Positive, statistically significant at the 0.01 level (2-tailed)
Rating of public charging infrastructure [Q12]	tau b = -0.083 *p* = 0.350 [n=88]	Negative, very weak relationship (2-tailed)
Adaptation in journey-planning [Q14]	tau_b = 0.280 *p* = 0.001 [n=88]	Positive, statistically significant at the 0.01 level (2-tailed)
Digital media importance/interest [Q18]	tau_b = 0.372 *p* = 0.000 [n=88]	Positive, statistically significant at the 0.01 level (2-tailed)
Usage frequency of digital media (apps, websites) [Q15]	tau_b = 0.401 *p* = 0.000 [n=88]	Positive, statistically significant at the 0.01 level (2-tailed)

Conclusive refutation or acceptance of hypothesis [H3], therefore, would be better-informed by a more focused and nuanced look with reference to segmented user type [Chapter 7].

- **[H3]** Digital media-based grassroots or community support, as offered via social media platforms, is important to the early-innovator electric vehicle drivers.

6.4 Engagement with energy-saving and other transport-related digital technologies

To further gauge levels of engagement with digital technologies, interviewees were also asked [Q17] whether they used apps related to any other transport mode, or any apps related to energy-saving or carbon-saving. 17% [n=15] reported no use of any of these, but a majority [63%, n=55] stated use of apps related to public or active transport, including for bus or train timetables, cycling maps and multi-modal journey planning tools, as well as for flight departure and arrival information. Just 16% [n=14] used carbon- or energy-saving apps or calculators, but some very enthusiastically.

> "Well, the house has smarthome capability, which means it's all controllable from an app, so I use that to control the house, and the heating scheduling actually, it all predicts weather and decides whether to run the heating and stuff as well. That's all controlled by an app as well…
> I use Oyster now on the Apple Watch, and National Rail, Citymapper, that's quite a good one. I use something called ETA as well, which is quite useful, it estimates time of arrival, and I use National Rail app and I also use tube, that's got quite a good app as well, but Citymapper is probably my favourite one right now." [male, 55, Bromley, telecomms consultant; BMW i3 REx]

Over a third [35%, n=31] added that they had a digital domestic energy monitor such as a Nest, Hive or similar – and 14% [n=12] were keen to point out that they kept a close eye on their energy consumption by other means. Reference was also made to weather apps ('Other').

> "What I do is do my own spreadsheet and I know exactly how much we're generating and how much electricity we're using… I read all the meters every Monday morning, and I read the peak generation meter, the electricity and the gas, and during the summer we're not using any gas at all because the solar panels, whenever we're not using any of the power I divert it to our immersion heater…" [male, 71, Hampshire, retired doctor; Volkswagen e-Up!]

> "The only things I use is the weather apps, because I've got solar at home, so I will work out whether I can put my electric stuff on at home before I disappear for the day, if it's going to be a sunny day or not." [male, 44, Northamptonshire, mechanic; Nissan Leaf]

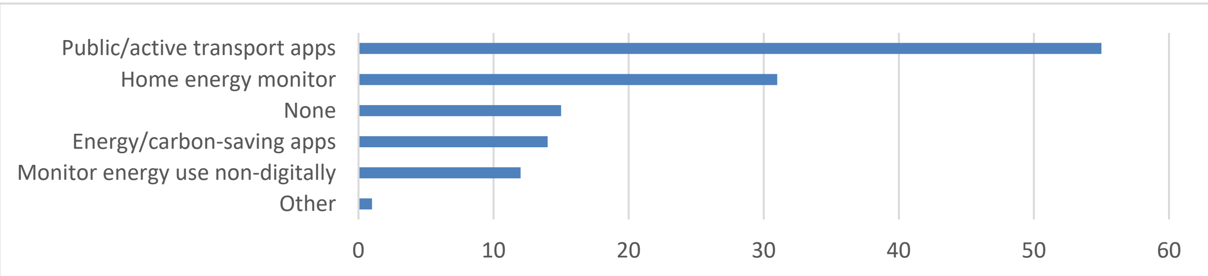

fig 6.viii: [Q17] Use of other transport and energy/carbon-saving apps, digital tools [n=88]

The majority usage of other transport apps underlines that car owners are not always driving: this suggests a role for interventions around modal choice and wider transport behaviour with specific reference to EV ownership. The relatively low engagement with energy- or carbon-saving apps and devices, however, indicates less potential for nudging or stimulating behaviour in this way, i.e. to incentivise timing of vehicle charging to optimise grid-balancing or integration of renewable electricity, if these are issues of lesser interest.

While this dataset in itself does not directly address or provide evidence to support or refute a particular hypothesis, it serves as a reference point in the subsequent segmentation of participants [Chapter 7], giving a more focused look at different user types classified by their levels of digital engagement.

6.5 Drivers' concerns and proposed solutions

As part of Q20, interviewees were asked for any comments and suggestions about information, data and tools which would either make their lives easier as EV drivers, or that they thought would encourage more people to drive EVs. While again not directly addressing hypotheses, and also now less relevant given subsequent developments, the feedback and qualitative detail gleaned from this exercise does propose a series of useful suggestions and sheds light on some of the drivers' areas of concern. Two key themes are highlighted: firstly, a thirst for real-time data and information on public charger status; and secondly, the need for integration of the infrastructure, both in terms of access to charging equipment and payment – ending the need to sign up to multiple networks and carry different RFID tags, for example – and in common standards and compatibility of charger types across all EV models.

More detailed information on a car's electricity consumption, including with reference to running costs [16%, n=14], or more information on battery degradation and charging cycles, was also mentioned [6%, n=5] though more drivers expressed an interest in more sophisticated range calculations and routing [20%, n=18]. Just 7% [n=6] felt that they had all the information and data they needed to happily run their vehicle. A further problem for several drivers was that while systems such as Nissan's Carwings (since superceded) depended upon mobile phone connectivity, they found this to be patchy or even non-existent in their area, rendering certain apps redundant and at times precluding app-enabled activation of charging.

Categorised as 'Other', the desirability of being able to pre-book public charging facilities was minimal, and likewise interest in battery-swapping or induction charging: each were mentioned by just three or fewer interviewees, as was the ability to communicate with other EV drivers over access to chargers, as mentioned by drivers who were not already aware of the ChargeBump app.

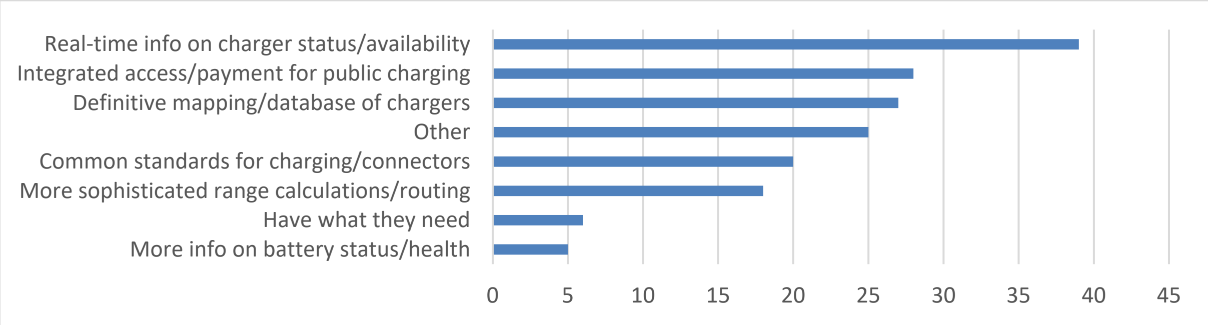

fig 6.ix: [Q20c] Other information, data or tools drivers would like to have [n=88]

6.5.1 Real-time information on charger status

A key theme was the availability of real-time information on charger status [43%, n=39] – whether a charger is operational or being used by another driver. Drivers were keen on receiving information specifically relating to the installation of new facilities, and on repair of broken or out-of-order charging units:

> "I think if the reliability of charge point information was more robust, that would be a huge big win. I think the other thing is that when charge points fail, there is no public-facing information on their repair time, and we have seen, certainly up in Scotland, anything from 24 hours to several months before machines are repaired…
> "And so to get public-facing information about expected repair time, or better still, guaranteed repair time, would be hugely helpful, in that I might plan a journey for next week on a charger that is currently offline, but if I had confidence that it would be repaired within a guaranteed seven days, for example, I can still think about that route in particular, rather than having to check every single day to see if an engineer happens to have been out there."
> [male, 44, urban Scotland, company director; Nissan Leaf]

6.5.2 Infrastructure integration and compatibility

Integrated access or payment schemes for using public chargers [32%, n=28], rather than the then-current system of having to sign up with individual (and often multiple) service providers, was the next most-common request. Along with more comprehensive and definitive mapping of public charger locations [wanted by 31%, n=27], provision of these services has been much-improved since the interviewing period, with pay-as-you-go and 'roaming' charging now widely available, and charger information and mapping all better-provided since the consolidation of many individual and regional charging schemes into wider networks and the establishment of the National Chargepoint Registry. Increased and rapidly-developing data provision from mapping and data services players (such as HERE and RouteMonkey) has also played a role, with new products both supplied to car manufacturers as feeds for in-car communications systems and available third-party, including through the dashboard integration of platforms such as Apple CarPlay and

Android Auto [discussed further, Chapter 8]. However, compatibility between different vehicles and charger points – a continuing issue – was raised, which 23% [n=20] wanted addressed.

Linking mapping, real-time data on availability, and route-planning was, in effect, the ultimate outcome:

> "There's no joined-up app that integrates, that knows where all the chargers are, knows the availability and that can plan routes, there's nothing there at the moment, I know that there's supposed to be a national database but I don't think that's particularly good, so if there was one point that I could go to that had all the chargers or their availability, open-source, the app could pick up for that and give you all the information, you could plan your route, that would make my life a lot easier!" [male, 50, rural Midlands, sound engineer; Nissan Leaf]

6.5.3 Interface preferences

Interviewees were finally asked [Q20d] about their preferences in terms of interfaces (as available at the time) by which such information or services would be delivered: where would they be likely to pick up useful news, or how would they like to engage with the data they wanted to see?

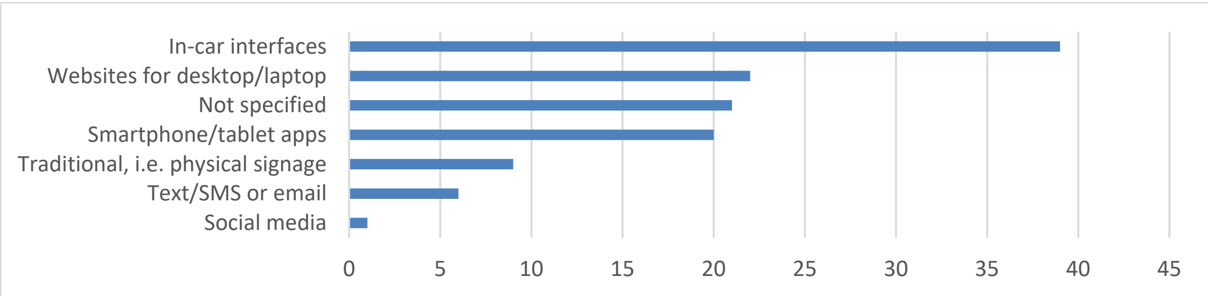

fig 6.x: [Q20d] Preferred interfaces to receive EV-related information or data [n=88]

In-car interfaces, including those of satellite navigation systems, were the preferred option by a considerable margin [44%, n=39] although doubts were raised as to reliability of the information and how often it would be updated. Third-party providers and large-scale aggregators of data were seen by many as being more dependable, with websites for desktop or laptop computers a first point of call for some and a back-up option for others to use in addition to in-car systems [25%, n=22]; smartphone or tablet apps were similarly appraised [23%, n=20].

> "I think truthfully in-car sat navs are, they're never very good. I think the online Google version or something very similar is really much better at the moment."
> [male, 50, rural Midlands, sound engineer; Nissan Leaf]

Just one interviewee stated social media as his first preference and 7% [n=6] wanted to be able to sign up for email or text/SMS mailing lists. Traditional and non-digital communications methods were also seen as important by a small proportion [10%, n=9], who cited physical signage (such as information on charger status at the upcoming service stations, or on availability of chargers in public car parks) and information on charging facilities included in radio traffic alerts, for example.

> “I don’t know what a text message alert system might look like, I’m just imagining here, but if I’m saying look, I’m going to Aberdeen tomorrow and I would like information on the following chargers, then I could put that into a website, and if any of those chargers went offline I could get a text message in the next day… I want to subscribe to those four chargers, I want to know the minute they go offline, and I would pay money for that…
> “You can imagine in years to come with increasing EV use, pick-up, when Radio One, Radio Two do their travel updates about motorway junctions they also say that the EV charger at Junction 6 on the M4 is offline, just so you know – but we’re not at that level of national awareness yet.”
> [male, 44, urban Scotland, company director, Nissan Leaf]

Again, the feedback proves valuable in the ongoing segmentation of EV user types [Chapter 7], especially with reference to their preferences for particular media platforms – or for non-digital means of communication.

6.6 Conclusion

Some themes and patterns can be seen in this data breakdown and analysis, further described and illustrated by the qualitative detail including the itemisation by the typology. The Typology of Electric Vehicle Driving further plots and positions the possible interventions of digital media tools at each stage of the journey-making process, and as such, underlines the roles that they are playing as an information source, as mediating factors in negotiating infrastructural elements of EV operation, or as a platform for community support; technology has also been a significant motivating factor in EV uptake and purchase [4.2.3].

The typology also identifies activities, habits or routines enabled or supported by digital media which are specific to EV ownership or driving – and thus highlights the limitations of provision to drivers and their perceived shortfalls in information [6.5], whether in terms of the provision of real-time cross-network data on the availability of charging facilities, or for integrated multi-modal journey-planning taking into account factors such as charging downtime. This represents an opportunity for the development of new and improved digital tools and services, via both connected in-car interfaces and mobile devices.

Both the typology and the case study data do also indicate that some drivers show very low levels of engagement with digital tools, thus emphasising the need for alternative information provision as well. Yet digital and social media are described by many as convenient and useful resources for journey-planning and for dynamic checking and reassurance, and as a means to connect with others in the perceived EV community; and appear to be implicated in evolving new practices and behaviours distinct to EV ownership and operation. These include activities around more than just driving: habits and routines around the charging process; the use and engagement with an infrastructure and energy supply network different to that for ICE vehicles (i.e. refuelling at home and at private locations, and in different time-frames); and indeed, a positioning within a wider system of new values, attitudes and social concerns.

The statistical correlations do not, however, suggest many strong quantitative factors to definitively test the hypotheses:

- **[H2]:** Digital media and communications technologies assist and support electric vehicle drivers in their journey planning, recharging and vehicle range optimisation.
- **[H3]:** Digital media grassroots or community support, as offered via social media platforms, is important to the early-innovator electric vehicle drivers.

Nonetheless, both the statistically significant correlations identified and the weak relationships observed are at least indicative of trends to support [H2] and, to a lesser extent [H3], pending more nuanced testing with reference to segmented user types [Chapter 7].

Chapter 7 Results: User groups segmented by levels of digital engagement

7.1 Overview

To supplement the correlations as discussed in Chapter 6, the sample [n=88] was subdivided into three groups (A, B, C) according to their ranked-order levels of engagement with digital media (as reported in their affective-scale response to Q18, "*I find apps and digital resources important and of interest to me as an electric vehicle driver*"). Correlations were explored, again using Kendall's tau-b; and both the background and demographic data [as described, Chapter 4] and qualitative data were deployed to create first a detailed description of each group, and then a series of composite archetypal figures – 'thick' personas (Jacobs et al., 2008), drawing upon the concept of personas developed by Cooper (1999) to inform product design. This strategy to represent characteristics, motivations and behaviour expressed by a group's members, often used in ethnographic research, gives insight beyond the usual representation of 'users' (*ibid.*), since it can add a more vivid sense of personality – so long as it remains strictly faithful to the data and input from the 'real' subjects (Jacobs et al., 2008). In the fields of ergonomics and product design, it facilitates a focus on specific consumers and their needs (Brangier and Bornet, 2012).

As well as further synthesising the qualitative themes – including the activities, practices, habits and routines as outlined in the typology [Chapter 5] – this has enabled the expression of a higher degree of nuance and fine detail to address the hypotheses than can be seen in the numerical and statistical summaries alone. It adds an extra level of understanding of the differences – and similarities – between each user group in a sample which was not, on the surface, particularly diverse. It is concluded that while the sample of drivers is demographically rather homogenous, there is a considerable variation in terms of their behaviour and attitudes, and not just with reference to their engagement with digital media. This is illustrated by the composite personas, who highlight the differences within each group as well as between the groups.

This exercise gives material to again address and support hypotheses [H2] and [H3], and evidence to query [H4] prior to the final discussion [Chapter 9]. The insights from the segmentation and persona creation are then used to construct a model [7.6]. This suggests the offering and application of particular digital tools and apps by level of driver digital engagement, and the interfaces or platforms by which these are best delivered at each level, mapped into each segment. Areas of potential are identified and indicated for the incorporation of new functionalities and technologies, including those which may result from co-creation or collaboration between stakeholders and users at the different levels of the MLP (Multi-Level

Perspective). However, in order to address the final hypothesis [H4], and to better-understand the findings in the context of the MLP with their relevance for future application, further follow-up and validation exercises are needed.

7.2 Correlations by segmented user types against the ranked answers

A segmentation approach was taken to subdivide the sample [n=88] into three groups which were, although not of equal size, each large enough to give the potential for meaningful comparison. To most directly address the hypotheses [H2] and [H4], the descriptor variable was taken as engagement with digital media, as measured by responses to the Likert-style affective statement [Q18]: *"I find apps and digital resources important and of interest to me as an electric vehicle driver".* This was considered a more objective measure than drivers' reported frequencies of digital media usage [Q15], which nonetheless correlated to the importance they placed upon it [6.2.1]. Since this theme had already been defined as the core point of interest of the research, and the sample was relatively small and demographically homogenous, this single variable gave a simple and easily-executed basis for the grouping.

This approach was deemed more appropriate than exploring other similarities in characteristics in a more complex cluster analysis involving multiple variables, as might be used to identify and model potential EV buyers within the wider population, i.e. Morton et al. (2017), Anable et al. (2016) or in larger-scale stated-preference surveys and choice experiments, i.e. Clayton et al. (2020). Similarly, aiming to first generate a series of themes and natural associations for grouping in a factor analysis (i.e. Anable, 2005) in a two-stage approach to develop typologies (*ibid.*) was thought unrealistic, given the size and nature of the sample and the scope of the data available.

The respondents were thus classified – and nicknamed – as follows:

- **Group A [n=23]: Digitally disengaged or neutral**, scoring 1, 2, 3, 'strongly disagree', 'disagree' and 'neutral' on the affective scale [Q18]
- **Group B [n=29]: Confidently connected**, scoring 4 [Q18], 'agree'
- **Group C [n=36]: Happy-appys**, scoring 5 [Q18], 'strongly agree'

There were too few 'strongly disagree', 'disagree' or 'neutral' responses for these drivers to be considered in individual groups in a statistically robust analysis – and since even those considering themselves very unenthusiastic about digital media tended to report some degree of website or app use [6.2.1], differentiation between those giving these three answers was problematic. As such, all of those considering themselves 'neutral' or negative were treated as a single Group A. Correlations were then explored between the three coded groups and the data collected in response to the other affective-scale and ranked-order questions, to see if the assumptions made in Chapter 6 were still supported. Kendall's correlation co-efficient was again deployed.

Groups A, B, C are seen to sequentially represent the least digitally-engaged; moderately digitally-engaged; and most digitally-engaged respectively. Correspondingly, they showed rising levels of frequency of use of both general digital media (i.e. websites and smartphone apps) and social media. They also placed a rising degree (A-C) of importance on social media; and reported rising levels of adaptation to their journey-planning. This reinforces the ungrouped findings [Chapter 6] and backs up the validity of this segmentation, in that it strengthens the basis on which it is made: the drivers' perception of how useful, relevant and important digital media is to them.

table 7.i: Kendall's correlation co-efficient and significance by group A-C

FACTOR	**tau_b**	***p* =**	**Statistical significance** ****at the 0.01 level (2-tailed)***
Age [Q1a]	-0.245	0.01	Negative relationship*
Ownership time [Q3]	-0.145	0.132	None
Mileage [Q5]	0.034	0.725	None
Infrastructure perceptions [Q12]	-0.037	0.691	None
Level of adaptation [Q14]	0.209	0.022	Positive relationship*
Website/app use frequency [Q15a]	0.592	<0.001	Positive, strong relationship*
Social media frequency [Q16]	0.365	<0.001	Positive, medium relationship*
Social media importance [Q19]	0.414	<0.001	Positive, medium relationship*

The negative correlation between grouping and age – the younger drivers more likely to report higher levels of digital engagement, and vice versa – was also seen in Chapter 6; and the weak, negative relationship between digital engagement and ownership time [*table 6.iii*] was again not statistically significant once the drivers neutral and negative about digital media were combined into the single Group A. The relationships between digital engagement and mileage, and digital engagement versus ranked perceptions of the UK's recharging infrastructure, were again not statistically significant.

This exercise further exposes that even where statistically significant relationships are found, the correlations are not very strong – they indicate general trends rather than incisive factors from which robust theories of cause and effect can be constructed. As such, a breakdown of the drivers' characteristics by these groups needs to also consider the qualitative findings to develop a deeper understanding through which these trends can be analysed.

7.3 Visualisation of data describing the three groups

Along with the background and demographic data [Chapter 4], coded textual data from the interviews [as discussed, Chapter 4 and Chapter 6] were reclassified into the three groups A-C as above. The data by group are expressed in a series of infographics [*figs 7.i-xxiv*] showing proportional percentages (except for EV models owned) to aid a visual understanding and clearly identify the differences – and similarities – between each group. These data inform the subsequent descriptions of each user group; the individual personas created; and then the model [7.6] of digital tools and their recommended application by user segment.

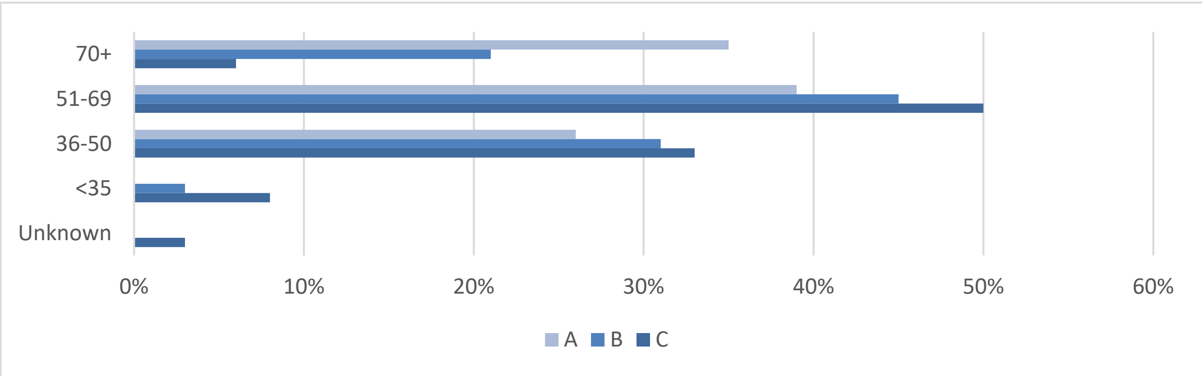

fig 7.i: [Q1a] Age in years, by proportion of groups A, B, C [n=88]

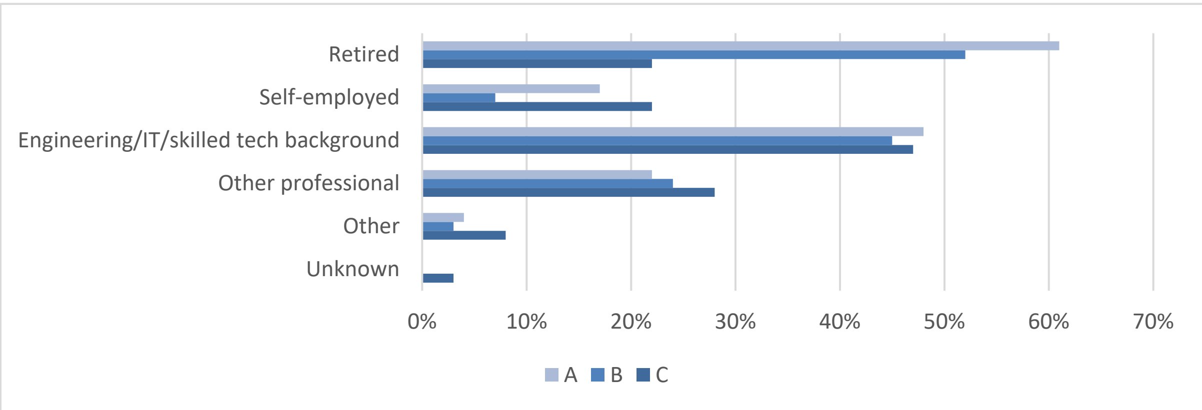

fig 7.ii: [Q1c] Occupational background, by proportion of groups A, B, C [n=88]

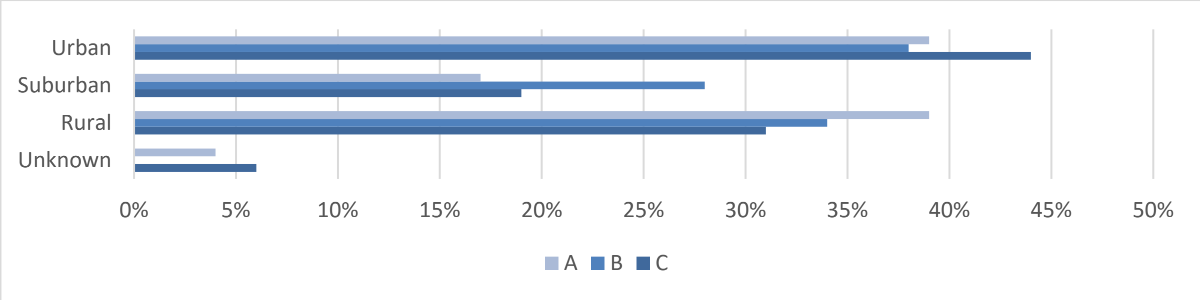

fig 7.iii: [Q1d] Residential location, by proportion of groups A, B, C [n=88]

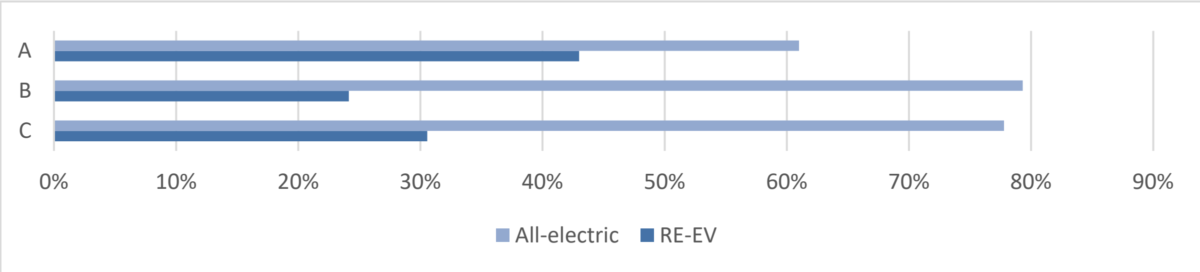

fig 7.iv: [Q2a] Type of EV owned, by proportion of groups A, B, C [n=88]

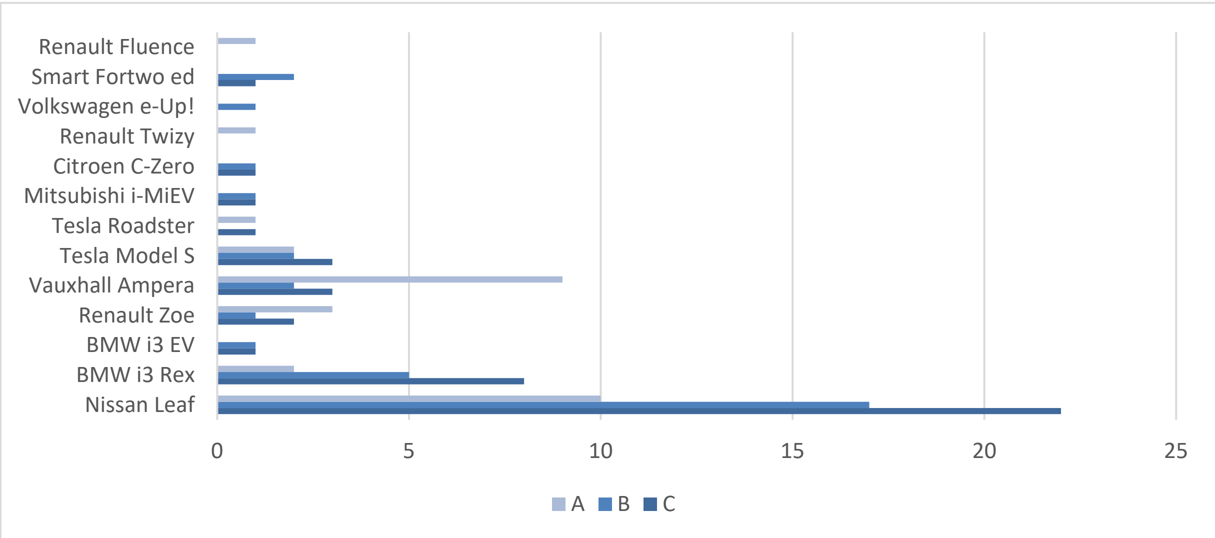

fig 7.v: [Q2b] EV models owned, by groups A, B, C [n=105]

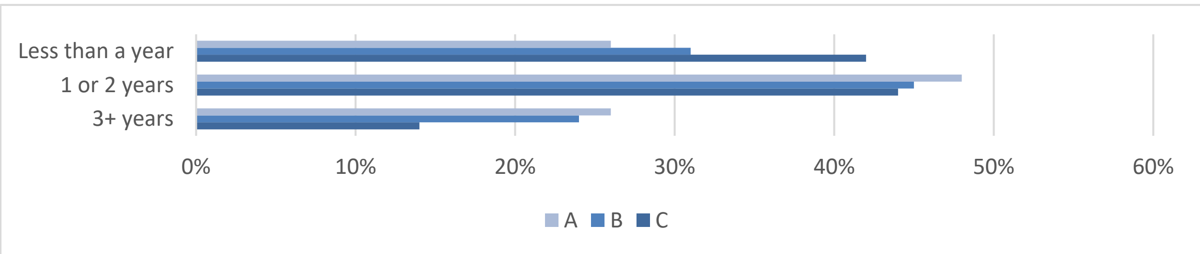

fig 7.vi: [Q3] EV ownership time/experience, by proportion of groups A, B, C [n=88]

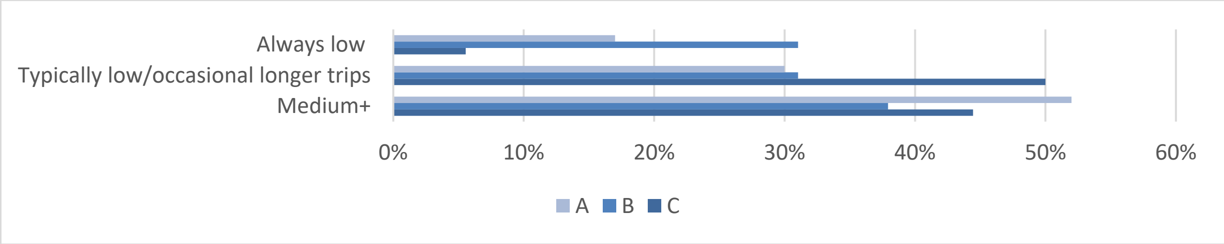

fig 7.vii: [Q5a] Typical weekly mileage, by proportion of groups A, B, C [n=88]

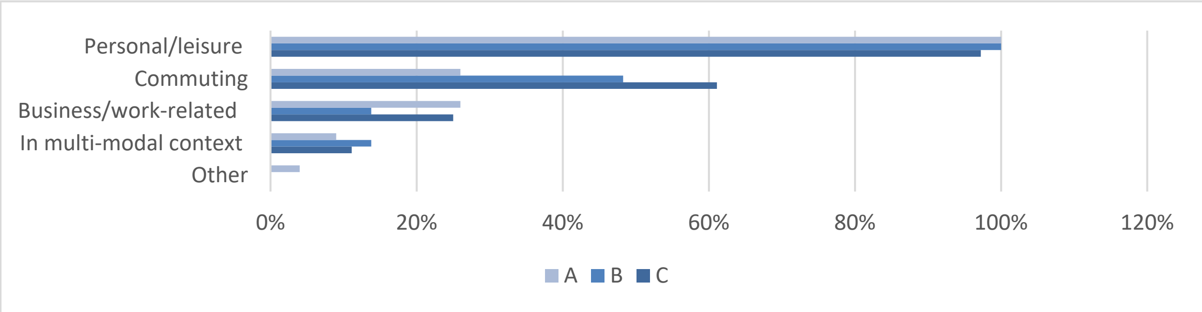

fig 7.viii: [Q5b] Type of usage of EV, by proportion of groups A, B, C [n=88]

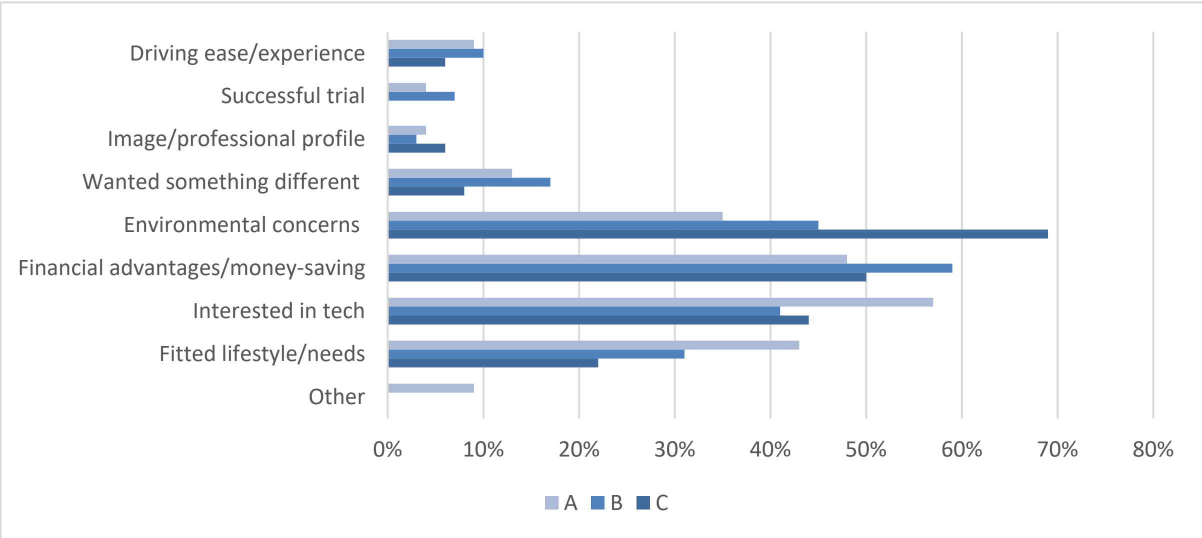

fig 7.ix: [Q6] Initial motivations for EV purchase, by proportion of groups A, B, C [n=88]

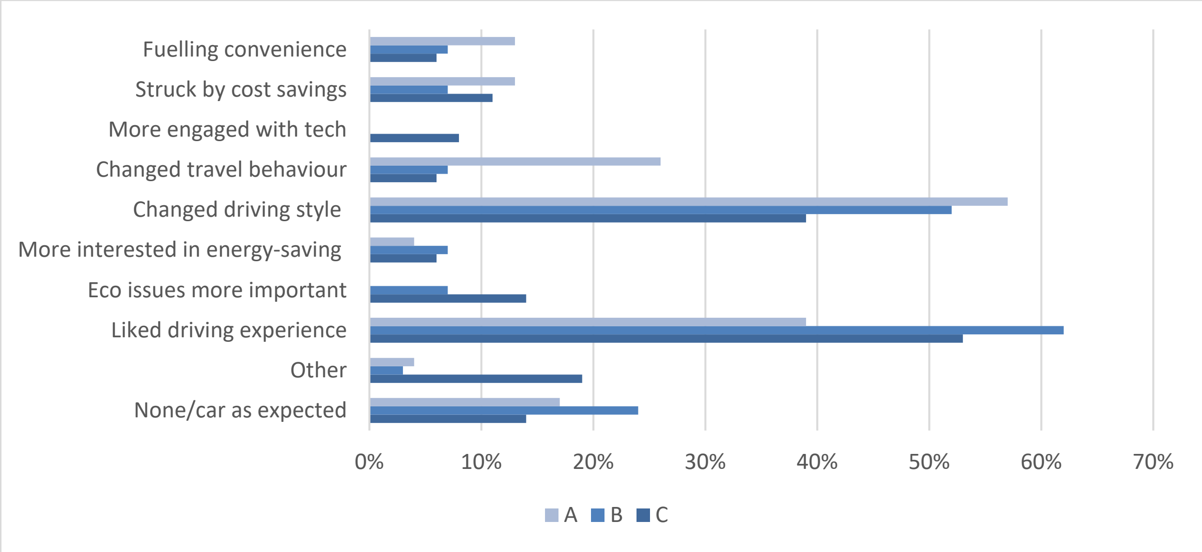

fig 7.x: [Q7] New attributes, changes noted since EV purchase, by proportion of groups A, B, C [n=88]

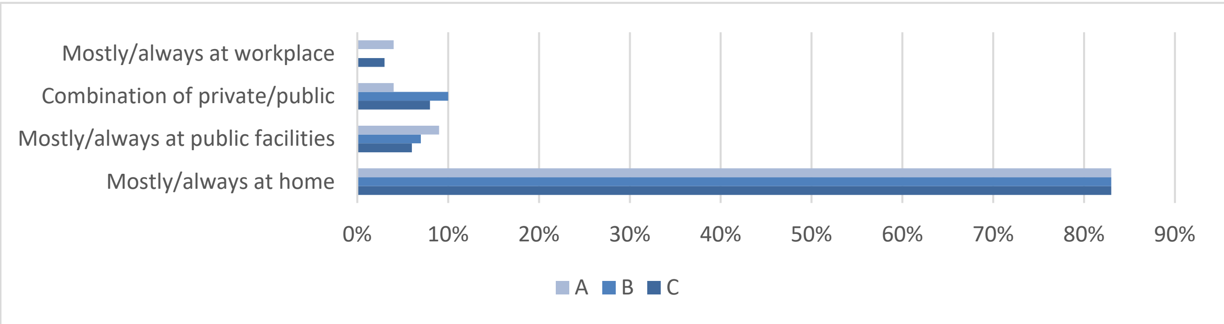

fig 7.xi: [Q9a] Usual charging locations, by proportion of groups A, B, C [n=88]

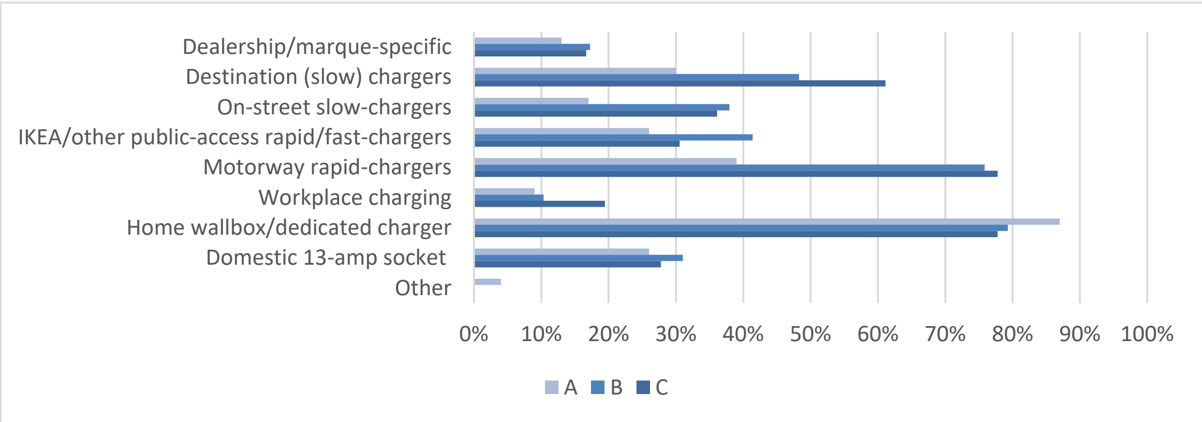

fig 7.xii: [Q9b] Charger types used, by proportion of groups A, B, C [n=88]

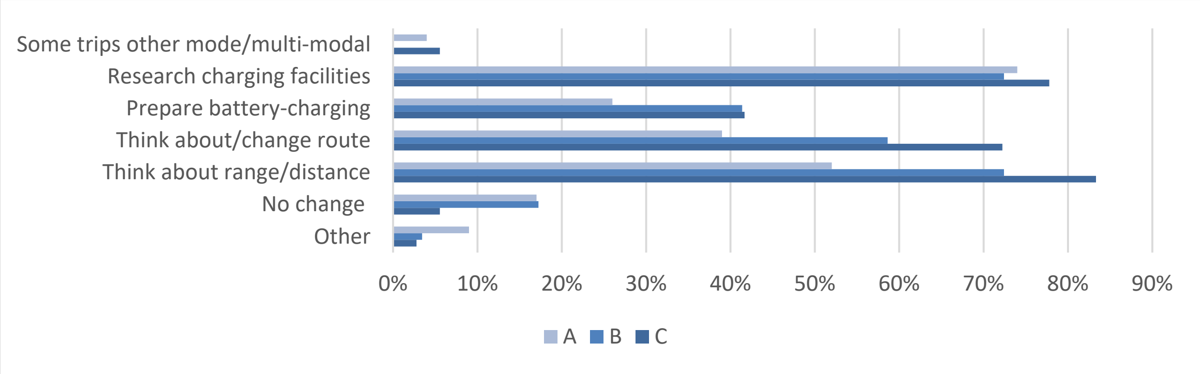

fig 7.xiii: [Q13] Changes to journey-planning, by proportion of groups A, B, C [n=88]

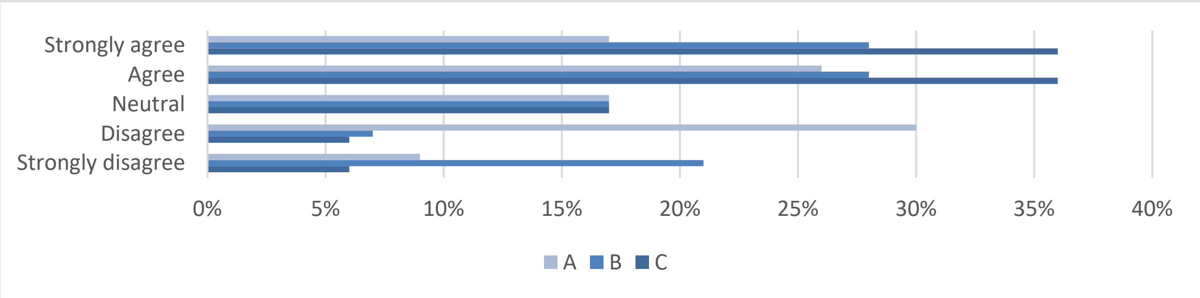

fig 7.xiv: [Q14] "Since starting to drive an electric vehicle, I have had to adapt the way that I plan my journeys", by proportion of groups A, B, C [n=88]

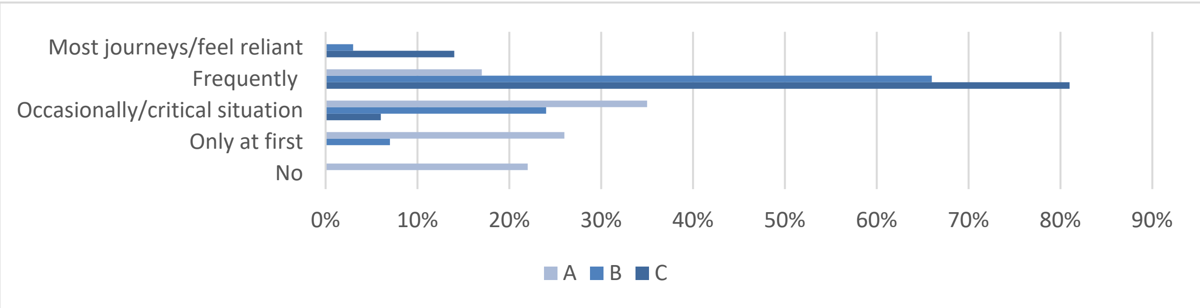

fig 7.xv: [Q15a] Frequency of digital media use, by proportion of groups A, B, C [n=88]

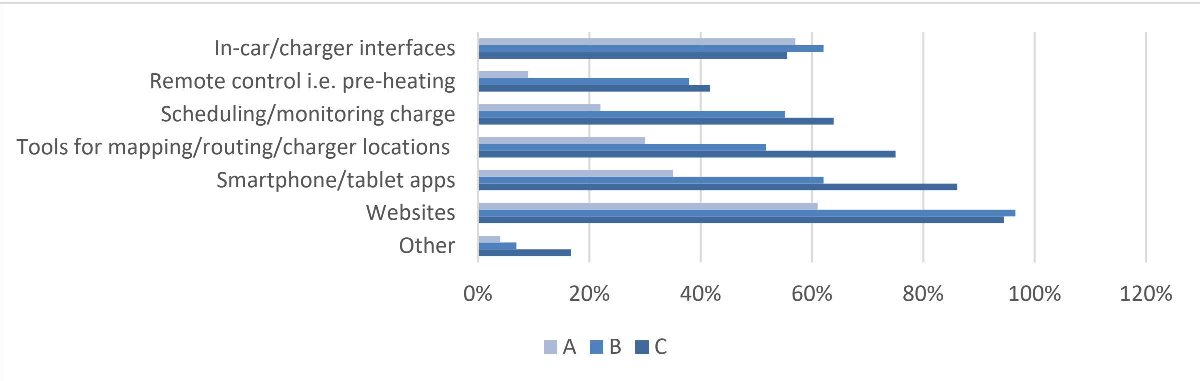

fig 7.xvi: [Q15b] Digital tools and media used, by proportion of groups A, B, C [n=88]

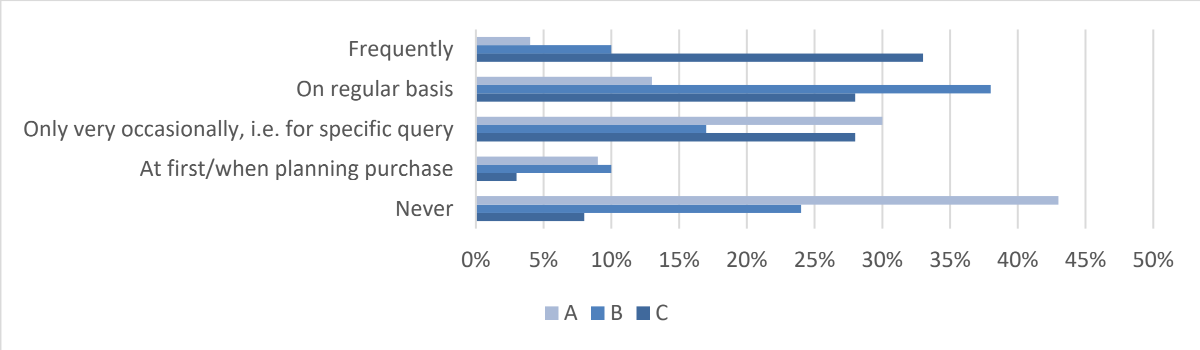

fig 7.xvii: [Q16a] Frequency of social media use, by proportion of groups A, B, C [n=88]

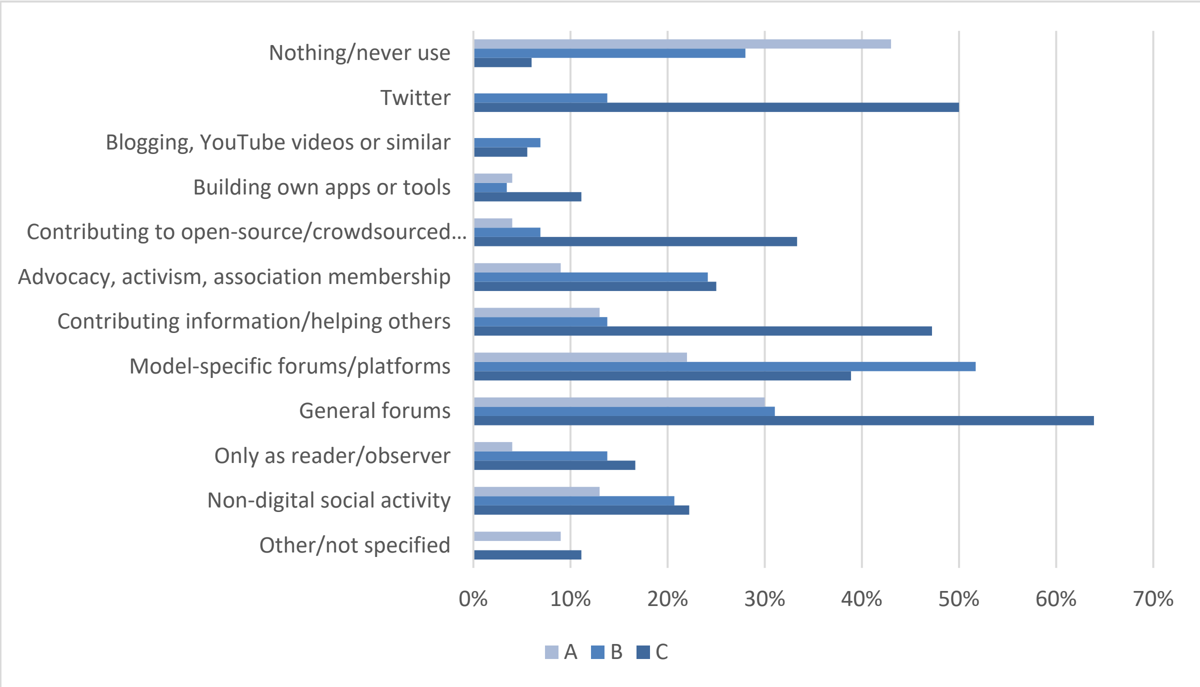

fig 7.xviii: [Q16b] Social media activities, by proportion of groups A, B, C [n=88]

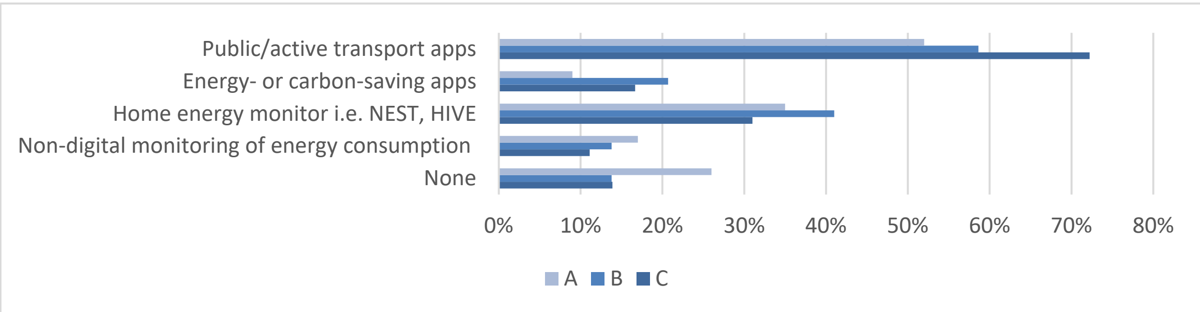

fig 7.xix: [Q17] Use of other transport or energy-related digital media, by proportion of groups A, B, C [n=88]

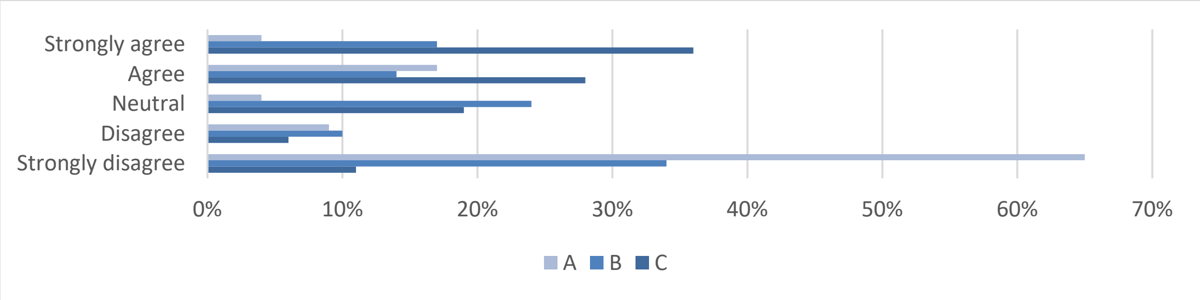

fig 7.xx: [Q19] "I find social media important and of interest to me as an electric vehicle driver", by proportion of groups A, B, C [n=88]

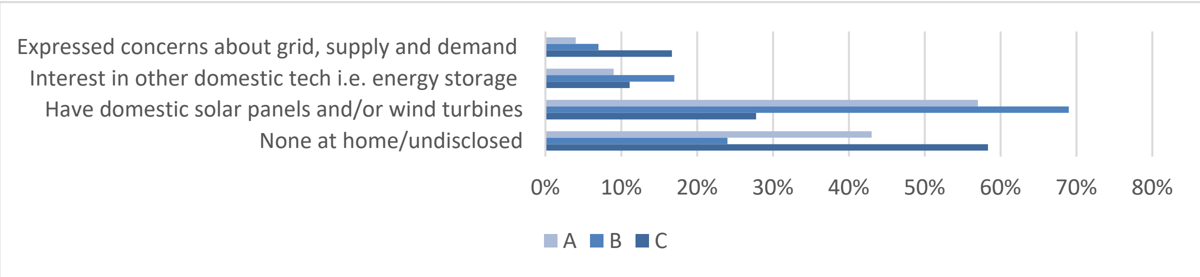

fig 7.xxi: [Q20a] Other energy-related tech interests/ownership, by proportion of groups A, B, C [n=88]

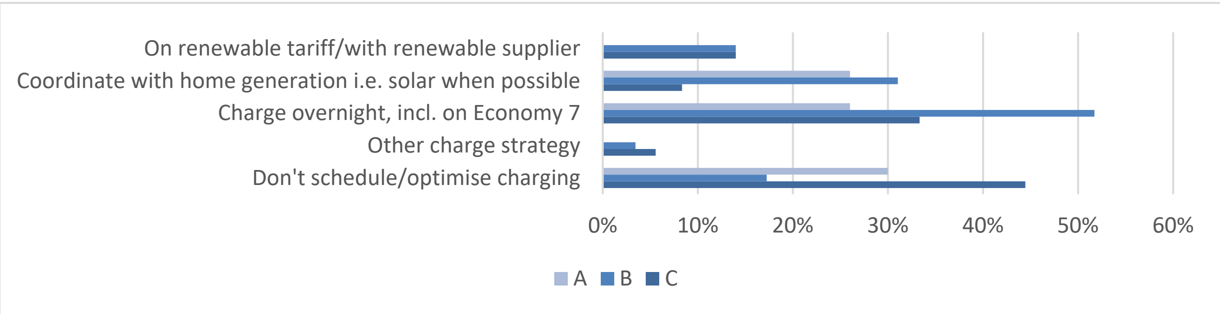

fig 7.xxii: [Q20b] Home charging strategies reported, by proportion of groups A, B, C [n=88]

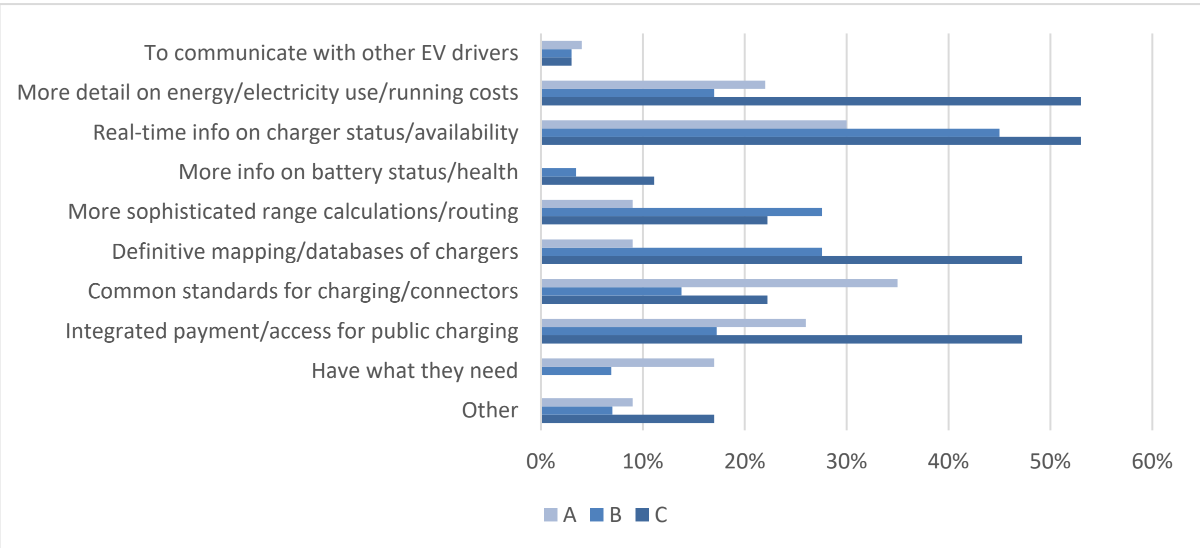

fig 7.xxiii: [Q20c] Interest expressed in other technologies, by proportion of groups A, B, C [n=88]

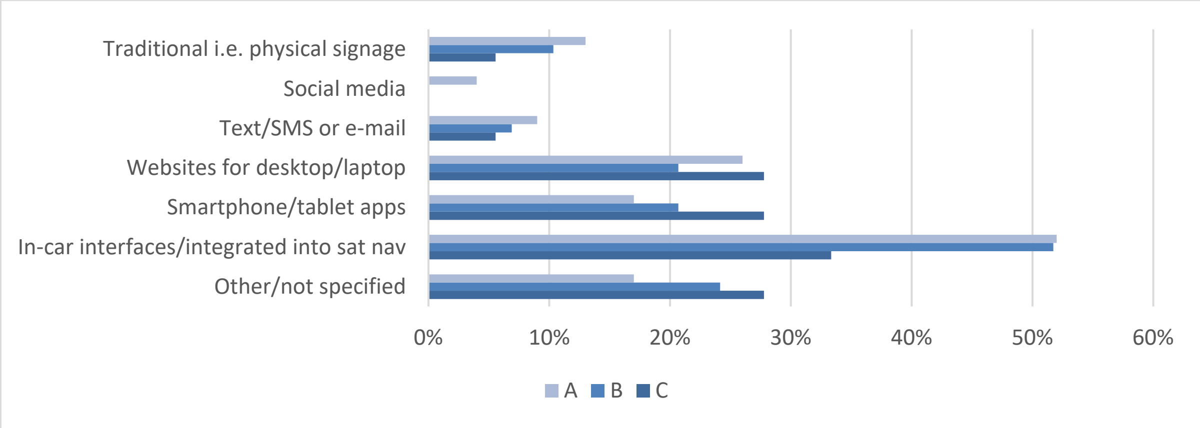

fig 7.xxiv: [Q20d] Preferred interfaces to receive info/data, by proportion of groups A, B, C [n=88]

While all of the above visualisations express data relevant and informative for the subsequent exercises, *fig 7.xxiii* and *fig 7.xxiv* are particularly relevant to the creation of the model [7.6] for digital tools and their recommended platform by user segment.

7.4 Description of each group and creation of personas

The differences observed in each of the groups as illustrated above are described to draw up an overview of each group's trends and characteristics. Some resonances were observed with the three groups identified by Anable et al. (2016) as the most likely mainstream consumers to adopt an EV in future: in terms of attitudes and some demographic and behavioural characteristics, Group A shows similarities with the 'willing pragmatists', while Groups B and C are loosely reminiscent of the 'zealous optimists' and 'plug-in pioneers'. As with the cluster analysis of Morton et al. (2016) which showed significant differences between 'keen greens' and 'early adopters', both groups positive towards EVs, the premise that there are distinct subgroups within this small market niche (*ibid*.) is supported.

These group profiles are then supplemented with reference to data on individual drivers within each group, qualitative material from the original interview transcripts, and activities outlined in the typology [Chapter 5], to draw up a series of personas: composite typical figures representing the group's members and the themes which emerged in their narratives, but which also explore and illustrate the differences within each group.

7.4.1 Group A: Digitally disengaged or neutral

Group A electric vehicle drivers [n=23] are predominantly in the two older age-groups (51+), and this group contains the highest proportion of over-70s; they are equally split between urban and rural locations, with a smaller proportion living in suburban areas. This group is most likely (87%) to also have an ICE vehicle in their household or available to them to borrow as needed. They are the most likely to be retired or semi-retired (i.e. working part-time) and tend to have an occupational background in engineering, IT or another skilled technical profession. Their driving is predominantly for personal or leisure use – and they are the most likely to be doing a medium or high mileage, i.e. driving over 200 miles a week. This may be partly explained by their being the most likely group to own a range-extended electric vehicle (RE-EV) with a back-up engine-generator; and those with a RE-EV tend to rely on that as necessary rather than using (or trying to use) public charging facilities. They mostly or always charge their vehicles at home and are the least likely to have used the different types of public charger available.

Group A are mostly likely to have been motivated to buy their EV by an interest in technology; particular financial incentives such as saving money on fuelling; and an EV fitting their needs or lifestyle, such as doing lots of short journeys and/or complementing a domestic solar array, are other key considerations. They are thoughtful about their journey-planning and are very unlikely to get 'caught short' or run out of battery charge; but are the least likely to report major changes or adaptations to driving routines, routes or household plans. Nonetheless, they are more likely than other groups to have changed both their overall travel behaviour and driving style since getting an EV – now taking the train for longer journeys, or using a park-and-ride when going to a nearby town, for example, and driving more slowly and smoothly to conserve battery range.

This group is the least likely, by a large margin, to use social media: they may have looked at websites or web forums for information, tips and advice pre-purchase or in the early stages of ownership, but report low ongoing use. Some use apps related to public transport and general mapping, such as Google Maps or AA Route Planner, but they tend to rely on in-car interfaces such as their satellite navigation and range-remaining displays, and prefer pre-planning on websites rather than smartphone or tablet apps.

A1: A retired engineer, he has a strong belief in the superior efficiency of electric propulsion: it suits his routine of lots of short local journeys when a diesel engine wouldn't get sufficiently warmed-up to operate at peak efficiency. He is delighted with how much money he saves on day-to-day motoring; he keeps track of his mileage and electricity costs on a spreadsheet and has calculated the pay-back time on what was initially a rather expensive purchase. He only very occasionally uses petrol in his Vauxhall Ampera RE-EV – on longer trips to visit family or friends, for example – and decided that, given the infrequency of these expeditions, it was not worth buying the expensive adaptor cable the Ampera needs for connection to most public recharging equipment. Therefore he very rarely charges away from home, except via an extension cable and

13amp socket at familiar destinations such as his daughter's house, or by arrangement at his golf club. He does not desperately need to locate public charging equipment anyway, as he has the Ampera's petrol engine to fall back on, although he may look at websites such as Zap-Map occasionally just out of interest, as he is considering whether to replace the Ampera with an all-electric car in a few years' time and wonders whether this will be viable. Otherwise, he does not use social media, he does not have a smartphone, and he prefers to use a paper map or road atlas rather than sat nav, Google Maps or similar.

A2: He and his wife share their Nissan Leaf between them: their larger diesel vehicle (a Volvo estate car) now sits unused for much of the week and is only deployed for their longest journeys, or when they need to carry a full load of family members (grown-up children, grandchildren). The Leaf, meanwhile, originally bought as their second car, is clocking up a hefty mileage, including commuting a few days a week – though he has retired, she still works part-time – and they use it as their option of choice, both to save money on fuel and because they simply prefer the quiet, easy driving experience. Often, he will drop her at work, continue to use the Leaf during the day, then return to fetch her later – it's so nice to drive around in, and why spend money on diesel for the Volvo? They mostly charge at their countryside home, where they have solar panels and a garage with a dedicated wallbox for charging, but have noticed that several local supermarkets and shopping centres have charging points, and that there are on-street chargers in convenient places in their nearby towns: all good for topping up on free electricity, and for a free parking space, even if they don't really need to charge. They also happily utilise the facilities they've spotted at the National Trust properties in their area, favourite destinations at the weekend. Nearly all their driving is within familiar territory, and given that for longer trips, such as down to London or to other major cities, they now prefer to take the train (it's much less hassle, given the cost and difficulty of parking), they are debating whether to replace the old Volvo when it starts to need expensive repairs. Perhaps if they could buy a larger and more versatile electric estate car or SUV, they wouldn't need to run two cars…

7.4.2 Group B: Confidently connected

Group B drivers [n=29] are the most demographically diverse: they are more varied in age than groups A and C, although most are still in the 51-69 age-bracket and over half are semi- or completely retired; they too are likely to work or have worked in engineering, IT or skilled technical professions. They are the most likely group to live in suburban locations, though are quite evenly split between location types. They own a variety of vehicles: the Nissan Leaf is still by far the most popular choice, though some have RE-EVs, more likely the BMW i3 REx than the Vauxhall Ampera. A number of this group have more than one EV in their household, i.e. running an older model like a Citroen C-Zero, Smart ForTwo ed or Mitsubishi i-MiEV alongside a newer, longer-range EV like the Leaf, Zoe or even Tesla Model S, and a notable minority (28%) does not have an ICE car in their household at all. They are represented the most evenly between the mileage categories, although they are the most likely group to report doing an 'always low' mileage. Around half use their EV for commuting and business purposes, as well as for private and leisure travel.

Group B drivers are the most likely to be motivated by financial incentives, including the tax breaks for business motoring, although environmental concerns and an interest in technology were also important factors in their purchase decisions. They have been particularly impressed with the electric driving experience, i.e. its smoothness and quietness, and a majority have subsequently changed their driving style. They mostly charge their cars at home, but a majority have used or tried out motorway rapid-chargers, and a strong proportion have used other public facilities of all types.

A small majority of Group B report that they have changed their journey-planning; their most common adaptations are in considering range and distance, researching charging facilities, and considering their routes – though it is worth noting that those reporting no change gave a much more unequivocal response ('strongly disagree', Q14) than Group A. They are likely to use websites or apps frequently to plan journeys; websites are used the most for pre-planning, but apps are used as much as in-car or charger interfaces, especially for scheduling and monitoring of vehicle charging and remote vehicle control, i.e. pre-heating and cooling. They use tools for route-planning, mapping and charger location, and over half of Group B use public transport apps as well, i.e. for bus timetables and cycling routes. Social media is a minority activity, but a significant proportion do report that they use forums, likely to be model-specific, on a 'regular' basis. A small minority are members of an EV club, association or advocacy organisation.

This group is the most likely to have solar panels and/or wind turbines at home (69%), and are also the most likely to charge overnight, i.e. on Economy 7 or other favourable tariff, and to try and co-ordinate their car's charging with their home solar electricity generation. They prefer to use integrated in-car interfaces for information, but are prepared to use other platforms, such as smartphone apps, where and when necessary; they show a strong demand for real-time data and information on public charger status and availability.

B1: In his mid-50s, he bought his Nissan Leaf to replace his previous Toyota Prius hybrid; both cars were bought on a PCP finance scheme, and he made the jump to an all-electric model having seen a very favourable monthly payment plan. Driving something 'clean' is important to him but to be honest, it was that deal plus saving even more on fuel that swung it. He and his wife don't own another car, though she can borrow her sister's if she really needs to; neither of them particularly enjoy driving and he doesn't consider himself a car enthusiast, but he likes the gadgety aspect of owning an electric car – especially the remote pre-conditioning, which is great when setting out early on winter mornings. Both he and his wife find the Leaf an easy, pleasant drive. He uses it the most (his wife gets the bus to work) and he uses the Nissan app to set it to charge overnight; they are on Economy 7, so this saves money, but also, the car is away from home during the day anyway. He sometimes has to drive to different locations for meetings and site work, but these are not usually very long journeys and he knows the motorway service stations where he can rapid-charge – so he is not strongly dependent on a lot of pre-planning. He is not always confident, however, that the chargers will be reliable, nor that they will not be blocked by ICE vehicles, having had a few difficulties, and has a Plan B for charging if he is venturing out of the Leaf's range or his own comfort zone: an IKEA rapid-charger he's used several times as a fall-back option on his way home. All the same, he expects never to go back to an ICE car, and hopes that when his current lease plan is over, he can trade up to a newer model with a range of 200 miles or more – that would make all the difference in terms of no-hassles ownership.

B2: An affluent retired professional, he has owned a wide variety of cars including some quite exotic sports models and fancied something a bit different as an everyday runaround. He admits he's not terribly environmentally-minded, but likes to think that driving his BMW i3 REx offsets the consumption and emissions of his Jaguar convertible and his wife's SUV (he hasn't managed to persuade her to replace that with a Tesla yet, though he's working on it). The BMW's a bit of a toy for him really, but he was intrigued by its powertrain technology and also, they're generating so much electricity from their new solar array at home that they might as well make use of it: they're planning to get a domestic battery for storage, too, when that technology matures. He doesn't actually do a very high mileage in the i3 – mostly nipping around suburban/outer London – but he has taken it to different chargers just to try them out, and has used Source London on-street points in the city centre (when he's also taken advantage of exemption from the congestion charge). He often remotely checks its state of charge via the BMW app, pre-heats and pre-cools the cabin, and since he opted for the highest-specification satellite navigation system, is quite happy that he could find a charging point if he wanted to – he's had a good play-around with all its features, and has saved some charging locations as 'points of interest' just in case. He has used the BMW app to plan or map a route, and the 'send to car' function to save this into the sat nav. However, this is more for general interest than out of necessity – as is his enjoyment discussing his car on social media, where he often talks about tech with other i3 owners and likes sharing handy tips or things he's discovered about it.

7.4.3 Group C: Happy-appys

The largest group [n=36], it contains the smallest proportion of retired people, the most under-35s and the largest number aged 36-50, though half are aged 51-69. Most of the women interviewed (albeit only four out of six) are in this group, too. These factors may contribute to the wide variety of themes and topics raised in the analysis of textual content, which suggest a wider diversity in behaviour and attitudes than seen in other groups: this therefore calls for a greater number of archetypal characters.

A majority of Group C are from engineering, IT, skilled technical and other professional backgrounds, including medicine and dentistry, and most have an all-electric EV: the Nissan Leaf is again the most-commonly owned. As with Group B, a notable proportion (28%) have no ICE car in their household. Group C are the least EV-experienced, with the highest proportion of members owning their electric car for a year or less at the time of interview, and the lowest proportion having had one for three years or more. They are the most likely group to be using their EV for commuting (over 60%) or business; and are likely to do a medium-to-high mileage or a low mileage with occasional longer trips: they have the smallest proportion of drivers reporting an 'always low' mileage. While they mostly charge at home, they are the most likely group to use workplace facilities to charge (19%).

Group C is the most likely to have been motivated by environmental concerns, although financial incentives and an interest in technology were other important factors in their purchase decisions. They are the most likely to say that ecological or environmental issues have become more important to them since owning an EV, albeit still in small numbers (14%); and the most likely to report having made changes and adaptations to their journey-planning: they have the largest majority considering range and distance, thinking about or changing routes, and researching charging facilities. It is unsurprising, therefore, that they are also the most likely to use websites and apps in their journey-planning 'frequently' or to express that they "feel reliant" on digital technologies with reference to operating an electric vehicle.

Websites are the platform most commonly used by Group C, for pre-planning, but this group is also the most likely to use smartphone or tablet apps; tools for mapping, routing and charger location; and tools or apps for scheduling or monitoring of vehicle charging. They are the most likely to use social media 'frequently' with reference to EVs, with the highest usage of general EV forums (64%) and Twitter (50%); and to say that they find social media important and of interest to them as an electric vehicle driver [Q19]. They are most likely to use social media for contributing information and helping other EV drivers; and to contribute to open-source or crowdsourced projects and databases (i.e. OpenChargeMap, EVStatus); and they have the largest proportion (24%) involved in EV associations, activism or advocacy of some kind.

Group C is also the most likely to use public or active transport apps, indicating a strong level of multi-modality in their transport and mobility routines, but are the least likely to have home solar panels or other renewable generation technologies; perhaps since they are the youngest group, they have the lowest rate of home ownership as well as less disposable income. They are, therefore, the least likely to try and optimise their charging to synch with solar generation, as well as the least likely to schedule their charging in any way. They are the most likely to want real-time information on public charger status and availability and a definitive mapping or database of chargers; integrated payment and access systems for public charging are also important to them. They marginally prefer to receive information via in-car interfaces, such as integration within satellite navigation, but are prepared to use or consider a wide range of digital options.

C1: She does a medium to high mileage in her Nissan Leaf – mainly driving her teenage children around – though most of this is within range, and she plugs her car in to recharge each time she gets home so it's always ready to go when needed. She does not have solar panels (too expensive, at the moment) but is keen to point out that she is signed up to a renewable electricity provider. She runs her own business and mostly works from home, but sometimes has to visit clients and will then carefully map out a route, the distance involved, and potential charging locations. Her kids have downloaded a lot of different apps for her, and like to play around with the remote functions such as the pre-conditioning and monitoring of charge, though she herself mainly uses Zap-Map to check where charging points are, and the Ecotricity website to check that the motorway rapid-chargers she needs are working. She sometimes tops up on charge when out and about, i.e. at the leisure centre when she takes the kids to sports activities, and occasionally makes longer trips to an out-of-town shopping centre where she uses the rapid-chargers: if she can leave the Leaf charging while she does something else, so much the better. However, she is frequently annoyed by public chargers being blocked by other cars and complains about this on Twitter – #IvebeenICED – tagging in the service provider or chargepoint operator. She was of course aware of the tax incentives to run an EV as her business car, but it also supports her activities and credentials as a member of her local Transition Town group; as part of this, she has been lobbying her council for more charging points in the area.

C2: In his mid-30s, he lives centrally in a large city where he rents a flat – so has neither solar panels nor anywhere to charge his Renault Zoe at home. However, there are several little-used on-street slow-chargers within a few blocks, and he can usually charge when he wants; only occasionally he has to park and then go out again later to see if a charger has been freed-up. Some of his charging is done while he is at work, anyway: though he has no facilities provided as such, he has a season ticket for a car park which has chargers – though these are not always functioning or available, so he tries as a general rule to keep the Zoe topped up as much as he can, charging “opportunistically” so he’s never reliant on a single facility. His commute is actually only a few miles, but as a junior doctor, he works long hours and does night-shifts, so it’s good to have a quiet, relatively relaxing and private journey home; when he does have a free weekend and goes out of town, he tends to take the train. However, though rarely planning long journeys, he frequently uses apps to check on the progress of his Zoe’s charging and its charge levels; often looks at different mapping apps to see where new facilities have been installed; and would like a more reliable and up-to-date data feed on the availability and reliability of on-street and public points: this could save him circling around the block when he returns home tired. Automatic routing to the nearest available charger would be brilliant, he says, and he hopes to continue running an EV, though he might have to reconsider this when he changes his working location.

C3: There has to be a Tesla-owning techie. He’s in his 40s and put his name down for a Model S as soon as he heard about it – absolutely the right thing to be seen in, as he runs his own IT business, and it’s also one of very few desirable family cars (i.e. not an MPV) in which you can fit three child seats across the back, which they needed at the time. And it’s fantastic: such a great drive, and the whole Tesla ownership experience has been like joining an exclusive club. When the lease on his wife’s car ends, they’ll be getting her the new Model 3: they’ve paid the deposit already. The Tesla in-car interface and its navigation system with automatic routing to Superchargers is all he really needs, so he tends to just get in and go, knowing that he has a 300-plus mile range if he drives carefully, and will be directed somewhere to charge if necessary. The only time he’s nearly been caught out was on a long trip to East Anglia, but he managed to get to an M25 fast-charger (thankfully, he has the necessary connector cable and adaptor) that he found on the Zap-Map web app via the in-car browser. He thinks it’s silly that the sat nav [at the time of interview] only shows Superchargers, though those are the only away-from-home facilities he usually uses, as they’re by far the quickest. He has a Tesla wallbox at his suburban home – and hopes to get the Powerwall static battery to store power from the solar array – but he actually likes using the Superchargers at the new service station near his office, as he often sees other Tesla owners there for coffee and a chat. He’s a member of the Tesla UK club; is active in several different online owner groups and forums; and he tries out a lot of the different third-party apps including those for his smartwatch. It’s all part of the fun of owning a car like this.

C4: On a much tighter budget: he bought his ex-fleet Nissan Leaf secondhand, cheaply. A single, eco-aware tech enthusiast keen to try something new, his long (and tedious) commute across the Midlands means that an EV is saving him a lot of money on fuel, but he’s had to plan quite meticulously. He charges overnight at home on Economy 7 and as long as he drives steadily and doesn’t put the heating or air conditioning on too high, he can comfortably make it to his workplace: he’s quite relaxed about running it down to ‘turtle’ mode now, having tested it right to its limit – and finished a couple of trips on a tow truck, in his early experiments. He petitioned his employer to apply for an OLEV grant to install a charging point, better than the extension cable he used at first, and his early-model Leaf (which now has an 80-mile range at best) is charged again during the day, though he has to be careful if he is detouring on his return journey – shopping or going to the gym, for example – and will sometimes stop for a quick top-up at the service station en route. He always checks the status of that rapid-charger before leaving work and has a back-up detour plan if necessary; when plotting a route outside his usual daily routine, he will work out a number of different options for charging. He’s hoping the batteries of his Leaf will hold out for a few years yet and is monitoring them carefully via a third-party app; now his car is out of its warranty period, he’s planning to hack further into its CANbus. He downloads and shares data for comparison; has been testing apps co-developed with other EV forum members; and uploads information about chargers that he thinks other drivers would find useful to OpenChargeMap and Zap-Chat. Having become much more interested in energy supply issues since getting the Leaf, he’s also tracking developments in static batteries and storage; ideally, he’d move to the country and go completely off-grid, perhaps when he retires.

7.5 Insights from segmentation and archetype construction

The creative exercise of constructing the eight archetypes shows that although this sample of drivers is relatively homogenous in terms of age, gender, occupational background and general socio-economic status, they are by no means all alike. The qualitative analysis identifies and highlights considerable variation in motivations and attitudes; and importantly, in lifestyle, routines, behaviour and practices, which are described in these composite portraits which represent the members of each of the groups.

The variety of characters and habits observed *within* each group is also in many ways more striking than the differences *between* each of the groups as segmented by their reported engagement with digital media, and especially between Groups B and C, all of whom use websites, apps or social media to some meaningful extent. Similar themes also emerge in both of these groups, most notably related to the model of EV: owners of the shorter-range Nissan Leaf in different groups had more in common with each other than with, for example, the drivers within their group of the high-range Tesla Model S, equipped with more sophisticated charger mapping and navigation systems. Drivers of the RE-EVs also differed little across the three groups in their demographics or actual reported practices.

This exercise further provides illustrations which cannot be seen in numerical data alone: this applies in particular to the drivers' engagement with social media; the instances in which this is deployed; and the reasons they like using it. This gives an understanding of how social media (including the contributing to open-source and user-generated data resources, as well as participation in forums and online communities) has played a role in supporting the early-innovator electric vehicles drivers, and why it should not be underestimated. As such, further support is found for hypothesis [H3]:

- **[H3]** Digital media-based grassroots or community support, as offered via social media platforms, is important to the early-innovator electric vehicle drivers.

The composite figures also describe further how digital media is used as a mediating factor in negotiating the different spatio-temporal elements of driving an EV [4.2.6, 4.3]: entwined into the lives and lifestyles of the Group C drivers in particular, though involved to some extent in both the less-engaged groups as well. It is a resource both at the journey-planning stage and for more dynamic checking and reassurance – as well as a means to connect with others in the perceived community, which in itself plays a role for these early-innovators, encouraging and advising each other, testing and developing new technologies, and evolving new practices and behaviours distinct to EV ownership. These include activities around more than just driving: habits and routines involved in the charging process; engagement with an infrastructure and energy supply network different to that for ICE vehicles (i.e. refuelling at home and private locations); and a positioning within a wider system of values, attitudes and social concerns.

As such, building on the knowledge, insight and statistical findings as discussed in Chapters 4, 5 and 6, hypothesis [H2] was supported, but only for Groups B and C.

- **[H2]:** Digital media and communications technologies assist and support electric vehicle drivers in their journey planning, recharging and vehicle range optimisation.

The understanding and insights gained from the segmentation and persona exercises now enable construction of a model [*fig 7.xxv*] to propose appropriate digital tools and apps for drivers at each level of digital engagement, and the interfaces or platforms most suitable or preferred for their delivery.

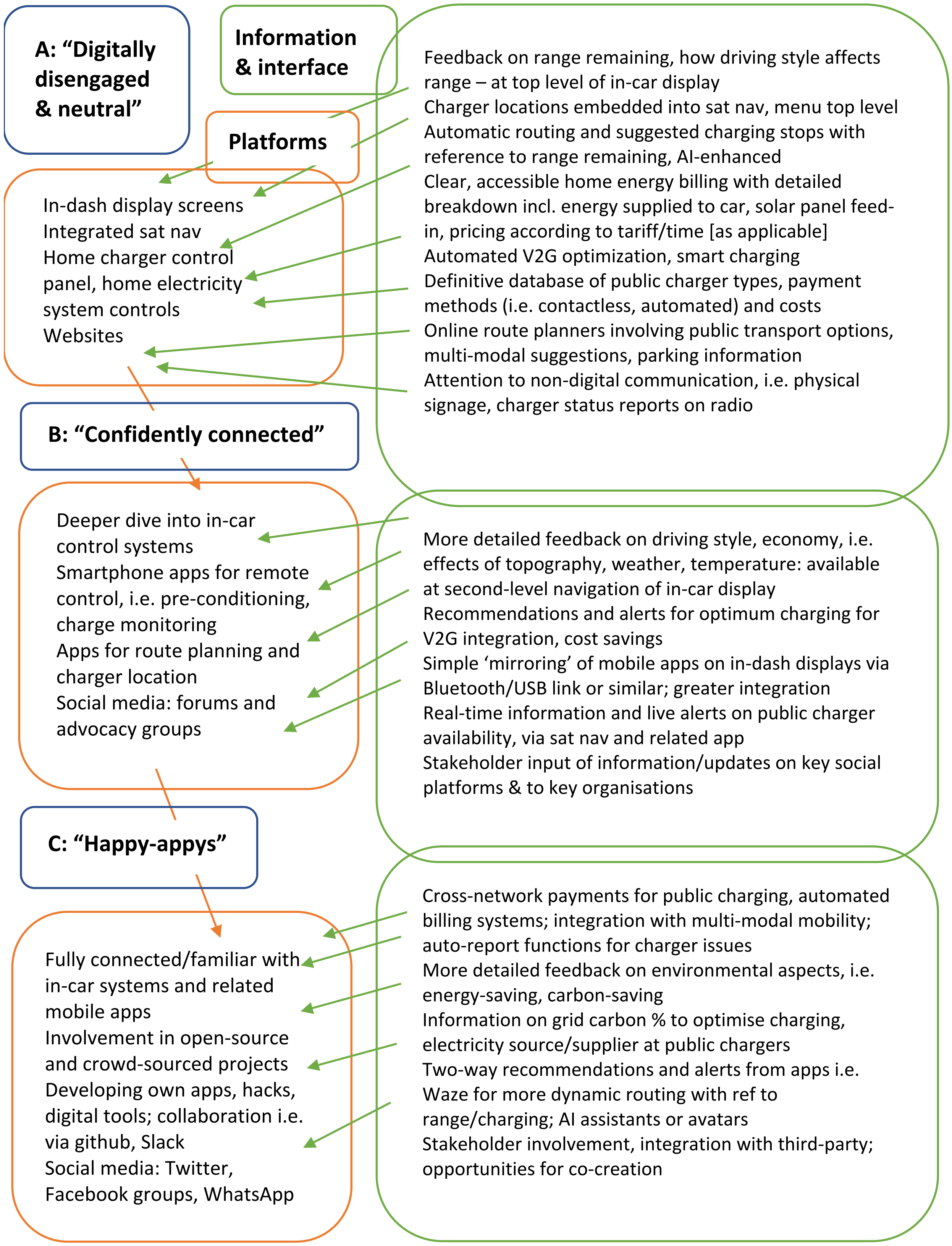

fig 7.xxv: Digital tools and their recommended application by user segment

7.6 Digital tools and their recommended application by user segment

The model [*fig 7.xxv*] is constructed using the insights from the segmentation, taking into account the three groups' driving routines; charging practices; and preferred information and interface platforms. The flow diagram takes a layered approach whereby a minimum level of information provision, and the interface by which this is best delivered, is proposed for Group A, the least digitally-engaged drivers. Groups B and C are considered progressively more willing to engage with dynamic interventions with reference to their higher levels of adaptation and greater variation in routines. Areas of potential are indicated ['information & interface'] for the application and incorporation of new functionalities and technologies as well as for co-creation and collaboration between stakeholders such as service providers and car-makers, and the users, the drivers themselves.

The new functionalities and interventions as represented in this flow diagram [*fig 7.xxv*] have been identified in a comprehensive audit of technologies and services now available, or potentially soon to be available, to electric vehicle drivers as part of an updating of knowledge and validation process [discussed further, Chapter 8]. They include some which may result from co-creation or collaboration between stakeholders and users at the different levels of the MLP (Multi-Level Perspective), as well as suggesting the possibility for an increased degree of interaction between niche actors (i.e. the drivers) and regime players.

Multiple regimes may be implicated, i.e. payment and monetary, media and communications, IT and computing, as well as transport-related service provision for parking or public transit, and the general energy supply, national infrastructure and automobility regimes. This further shows the potential of digital media interventions with reference to hypothesis [H4] in the theoretical context of a socio-technical transition, as described in the terms of the MLP:

- **[H4]** Digital media and communications technologies are a potential linkage in the transition of electromobility from a niche activity to a mainstream regime and the reconfiguration of a new mobility paradigm.

7.7 Conclusion: Insights from the model

As informed by the segmentation exercise and creation of personas, the model maps out the different preferences and digital habits of each user group, and matches them to different digital media platforms, interfaces and information sources according to their interests and levels of engagement. Appropriate application, deployment or offering of new and upcoming technologies can now be suggested for each group.

However, thus far the research describes mostly the activities and characteristics of the early-innovators at the niche level, as viewed using the Multi-Level Perspective, and it is these niche players who form the basis of the model. While the research has given a rich and detailed look at micro-level behaviour – the learning processes, new routines and practices, experiments and bottom-up knowledge production (i.e. Geels and Kemp, 2012; Smith, 2013; Geels et al., 2012) there is less illustration of how the individual actors at this niche level may be interacting with regime players, and as yet little insight as to how these niche activities could contribute or play a role in the electromobility transition as queried by hypothesis [H4].

A greater understanding of the provision of new technologies, products, infrastructure and related services from the regime level is needed, including advances in the electric vehicle market since the original fieldwork was carried out. To address this final hypothesis, the research findings so far must also be validated in terms of their continuing relevance, given the time-span since the original interviews and the progress which may have since occurred, including that as a result of landscape-level factors. Future applications in which digital media might help push electromobility to regime-level status should be considered in the context of ongoing developments.

Chapter 8 **Validation and updating of knowledge**

8.1 Introduction

To validate the consistency of the research findings over time – from the initial pilot interviews [3.2] through fieldwork to the concluding data analysis – follow-up interviews were carried out to check that the questions and topics discussed were still relevant and applicable to the contemporary state of play in the electromobility transition. Specific developments were then audited in terms of the electric vehicles now available to UK consumers; the public recharging infrastructure and how it can be accessed; vehicle battery ranges and interfaces, including new functionalities and information provision; and apps and mobile services now available.

Tables were compiled [8.3] to depict the availability of models (both new and older secondhand vehicles); the national public recharging infrastructure and different charging speeds of equipment installed; technologies enabling access to public charging equipment, payment methods and other related services; vehicle battery range and in-car interface technologies, model-by-model, related to EV operation; and mobile apps or standalone web tools for EV drivers.

These exercises established that while certain new technologies and digital functionalities have been introduced, and some advances (mostly incremental) have been made in terms of both vehicle capability and infrastructure provision, the fundamental issues as explored in this research have remained consistent and the behaviour and practices as reported by the case study sample are still representative of the electric vehicle community.

The audits further informed the development of the model [7.6] for digital tools and their recommended application by user segment; an additional model [8.4] mapping new digital functionalities against potential interventions and driver behaviour changes; and the research conclusion [Chapter 9] in which the final hypothesis [H4] is addressed in an analysis with reference to the MLP (Multi-Level Perspective) on socio-technical transitions.

8.2 Follow-up interviews

As a validation exercise, further interviews were carried out (May 2018) with three electric vehicle owners, following the questions as used in the main fieldwork. The data from these three, recruited via personal contacts, were not counted or incorporated into the case study sample [n=88]. The interviews covered the topics as discussed with the earlier sample and the responses and discussion were consistent with these, suggesting that the original questions remained valid and relevant. No new issues were raised, and no new actions or practices were mentioned or described which could supplement the Typology [Chapter 5]. One of the three interviewees (A3) was also the earlier trial subject (D) piloting the interview questions in September 2014 [3.3.3], adding a longitudinal element to the research and the benefit of his now five-year EV experience – but he gave exactly the same numerical responses to the affective-scale questions as in his first interview, and described his EV-related routines and practices in a very similar way. This suggested that his personal needs or travel habits had not changed over time, neither through his increased experience of owning and running an EV nor external factors which might be relevant to him, such as improved or additional recharging infrastructure introduced in his area.

The nature of the original sample, and to which it might be representative of EV drivers in general, was considered again in light of the demographic analysis [4.2.1] and the feedback on their motivations for EV purchase. While the sample was mostly self-electing people who were already engaged enough on the subject to participate in the Which? Cars survey, the nature of Which? is such that these were not necessarily all dedicated car enthusiasts, as might have been recruited via a specialist motoring magazine; their interests were more general consumer concerns and as such, reasonably reflective of a wider public. A degree of self-selectivity bias is, however, inevitable when interviewing people who have put themselves forward to participate and this was acknowledged. Nonetheless, for the follow-up interviews, two younger drivers were chosen since the under-40s were not well-represented in the original sample. The input from the three drivers is summarised as follows:

D: Interviewed previously (September 2014; 3.3.3) he still drives a Renault Fluence – but his second one, the first having been damaged in an accident. Now 56 and mostly-retired, he covers a very low mileage in this cheaply-bought secondhand saloon, which he keeps for within-range trips around rural East Anglia. He actually now has two other (ICE) cars but has enjoyed the lower costs of an EV as his day-to-day local runaround for five years, pointing not just to fuel savings but to reduced servicing and maintenance costs, given relative mechanical simplicity: "The Fluence I've got is a '12' reg, it's about six years old, that's the sort of time you usually start thinking about things like, on a petrol or diesel, cam belts, an exhaust or spark plugs and things like that will be replaced, but there's none of that on an electric car." He sees a major appeal of an EV as being the quiet, relaxing and also quick-accelerating driving experience: "Every time I get back into the petrol or the diesel after driving an electric car, it just feels so crude… it's a completely undersold aspect of it, no-one really mentioned it at all [when I first bought an EV]." He almost always charges at home, noting that his Fluence is not compatible with rapid-charging, and thus he sees no gain in time or convenience in doing inessential top-ups, while not trusting the infrastructure enough to really venture out of range anyway. He feels no need to seek out public charging points or to plan journeys, since he only uses his Fluence within its limits, and though active on social media, he 'disagrees' that he finds digital media important or of interest [Q18]:

> "I think, to some extent, the fact that I don't bother with the apps despite being quite geeky is a sign of how an electric car is quite a normal thing for me… Even though I'm an early-adopter and I'm interested in the technology and all that… the fact that I don't use them is really a reflection of the fact that an electric car is a practical proposition, because I'm just treating it like a normal car in lots of ways."
> [male, 56, rural East Anglia, part-retired/some home-working; Renault Fluence]

However, he suggests that this may be partly due to the limited scope for digital interaction with the relatively low-tech Fluence, which lacks the connectivity and information provision of newer EVs: "I suppose if I drove something like the latest Leaf, which has got far more by way of fancy displays, I might engage a bit more with the car in that sense, so that might be a function of the vehicle I'm driving."

J: Aged 36 and based in suburban Leeds, he has had a BMW i3 EV for 18 months, chosen largely for its modern design and user experience: he is a self-employed design consultant and lecturer specialising in user interfaces. Underpinning his decision was the i3's cost-effectiveness as a company car and a very attractive monthly lease plan he saw advertised; plus free parking for EVs in Leeds' city centre car parks. He and his wife use the i3 on a daily basis during the week for taking their young children to nursery and travelling to their workplaces, but their petrol Skoda Octavia for longer weekend journeys. He also travels frequently for work, often via Manchester Airport which is a round trip at the outer edge of his i3's battery range, so tends then to stop for a top-up rapid-charge at a service station; he sometimes charges at car parks, but mostly at home. Though early in his ownership he plugged in every night, he now only charges once or twice a week, "because I know how far I can go, I can do into Leeds and back the whole week without needing to charge up, more or less… that's the mindset I've changed." He schedules it to charge off-peak, and to pre-condition – "that is an absolute massive bonus that I love about having an electric car! It's just so good in the winter!" – but as his journeys are quite repetitive, he rarely needs much pre-planning now. He uses the search function in the i3's sat nav to locate chargers, "but I tend to default to planning at home on my phone, on Google Maps, and sometimes within the BMW Connected app… it is pretty good, you can sort of ping things around between your phone and the car." He 'strongly agrees' [Q18] that he finds digital media important and of interest to him, with social media now less important, though he found the BMW i3 owners' Facebook group very useful when deciding which wallbox home charger to buy. He would like to use an integrated transport app such as Daimler's moovel, giving different mobility options plus an integrated cross-platform payment system, but warns:

> "The reason to go to a phone is it's that much quicker and better to put in a destination on Google Maps than in the BMW. And I think the BMW system is one of the better ones: I like the scroll wheel and I've got a bugbear with touchscreens, but it can take so much flipping time to

> enter stuff, and the search functionality is so badly integrated... I'd prefer to do it in-car but every in-car system is worse and more fiddly and just sort of messed up from a UX perspective compared to the phone… that's an area they all need to work on quite seriously."
> [male, 36, suburban Leeds, designer; BMW i3]

W: Also 36, he lives in outer south-west London and commutes to near the City, doing around 750 miles a month, including some mileage for occupational reasons. Air pollution is a key motivating factor for running an EV, and he has regularly driven EVs for around six years: "I've got a four-year-old and a two-year-old now, and I don't want them to grow up in a world where they're being pumped full of toxic fumes." Running costs of the Renault Zoe (since replaced) he used for a six-month trial were also favourable. He has nowhere to charge at home but used a contract-parking facility near his workplace where there are a number of chargers of different types: this provided most of the Zoe's charging, with the occasional stop at public facilities. For longer journeys and leisure trips, his family use his wife's Citroen MPV, though they used the Zoe at weekends too: "I could charge up on the Friday morning, go home on the Friday night with a full battery, drive it all weekend with my kids in the car and then go back to the office on a Monday morning and charge up." Also 'strongly agreeing' on the importance of digital media, he used lots of different apps for various purposes: "The Zap-Map app is quite good now and they've got some good community updates and so on. I didn't tend to use the Renault navigation at all, I didn't trust it, either for routing or for charging point status." He found the Charge Your Car app difficult to get on with, but the Ecotricity app "very good", and further notes:

> "I had a plug-in hybrid BMW [225xe] before the Renault, and on both cars, I used the manufacturers' app. The BMW's was quite good, the Renault's was less good: all it did was tell me the current state of charge and allowed me to turn on the air conditioning and pre-condition the car. The BMW one was better in that you could find a route on the map on the app and then send it to the car and it would be ready for you."
> [male, 36, suburban London, editor; Renault Zoe]

These reports do contain a little detail pointing to new developments. J is likely to have benefited from some new charging points in his area installed since the time of the original fieldwork; and W's commute has been made viable in an EV by the installation of chargers at the car park near his office. J's reference to an i3 Facebook group, and D's mentioning that the Renault ZE forums have become defunct, suggest that some of the favoured platforms for social media may have shifted. One theme has also emerged which could be explored further with a larger sample: both J and W scored 5 for 'strongly agree' on Q18, with reference to their digital media engagement and were frequent users of digital technologies – including apps for public transport as well as driving – but both 'disagreed' that they had had to adapt their journey-planning [Q14], counter to the correlation found [6.2.1]. This suggests an EV may appear less of a compromise to them than to drivers earlier on the adoption cycle, or perhaps that they do a lot of digital journey-planning anyway – or simply that, without having cited this as a purchase motivation as such, an EV is a good fit with their lifestyle and needs, given that they both had ICE vehicles in their household as well.

Otherwise, the basic premise of how all three of these drivers operate their EVs and approach their charging or journey-planning is consistent with the practices described by the original sample, reassuring that no striking changes have altered the background scenario in terms of influencing driver behaviour. Although a larger sample for this exercise had originally been intended, no further interviews were deemed necessary at this stage, and this exercise provided a little more illustration of the variations in behaviour and attitudes, both between the user segments and within them.

8.3 State of the market – developments 2015-2018

The background scenario has, however, changed to some extent in terms of the variety of EV models available, their capabilities in terms of battery range and their technological functionalities; the provision of recharging infrastructure, both in terms of sheer numbers of charging facilities and the types of charger provided; and the means or interfaces with which drivers can engage with both their cars and the infrastructure. These developments are summarised in the sections below.

8.3.1 Electric vehicles available

Most of the OEM-supplied electric passenger cars on sale in the UK in 2015 (or at least, those readily available for members of the general public to purchase, outside of trial fleets) were reflected in the cars owned by the original research sample, except some then very newly-launched or around only in tiny numbers, such as the Ford Focus Electric and Volkswagen e-Golf.

Updates have since been made to many of the older models, most notably to the popular Nissan Leaf, now in its third iteration; these have brought increased battery range and new features and functionalities. A number of all-new models have also brought to market a wider variety of vehicle bodystyles to choose from, most notably fashionable SUVs and crossovers such as the Hyundai Kona, Jaguar I-Pace and Tesla Model X, all arriving with claims to offer a significant step forward in terms of range and technology. However, as the listing [*table 8.i*] shows, the discontinuation of many of the earlier EVs without direct replacements means that the actual number of models to choose from has been little increased. Consumer choice remains limited (Mohamed et al., 2018):

a remaining potential barrier to purchase and an indicator that electric vehicles are still some way from becoming mainstream, mass-market propositions.

table 8.i: Electric vehicles available in the UK 2015-2018

Models available/type (August 2015)	**Since launched (by end of 2018)**	**References/source**
BMW i3, i3 REx/supermini	BMW i3s/supermini (sportier model)	press.bmwgroup.com
Chevrolet Volt/small family hatchback*	Hyundai Ioniq EV/small family hatchback	newspress.co.uk; hyundaipressoffice.co.uk
Citroen C-Zero/city car	Hyundai Kona Electric/subcompact SUV	uk-media.citroen.com; hyundaipressoffice.co.uk
Ford Focus Electric/small family hatchback*	Jaguar I-Pace/luxury crossover	fordmedia.eu; newsroom.jaguarlandrover.com
Kia Soul EV/small family car	Kia e-Niro/family hatchback	kiapressoffice.com
Mercedes-Benz B-Class B25e/compact hatchback*	Nissan e-NV200 Combi/MPV	mercedes-benz-media.co.uk; nissanpress.co.uk
Mitsubishi i-MiEV/city car*	Smart EQ ForFour/supermini	mitsubishi-media.co.uk; mercedes-benz-media.co.uk/smart
Nissan Leaf/small family hatchback	Tesla Model 3/family car	nissanpress.co.uk; tesla.com/en_GB/
Peugeot iOn/city car	Tesla Model X/crossover	peugeotpress.co.uk; tesla.com/en_GB/
Renault Fluence/compact saloon*		press.renault.co.uk
Renault Kangoo Z.E. Maxi Crew Van/MPV		press.renault.co.uk
Renault Twizy/two-seater quadricycle		press.renault.co.uk
Renault Zoe/supermini		press.renault.co.uk
Smart ForTwo ed [now EQ ForTwo]/city car		mercedes-benz-media.co.uk/smart
Tesla Roadster/sports convertible*		tesla.com/en_GB/
Tesla Model S/large luxury family car		tesla.com/en_GB/
Vauxhall Ampera/small family hatchback*		media.vauxhall.co.uk
Volkswagen e-Up!/city car		vwpress.co.uk
Volkswagen e-Golf/small family hatchback		vwpress.co.uk

** = since discontinued*

8.3.2 Public EV charging facilities

The UK's network of charging facilities has expanded and developed since the early phase of this research. As of January 9th 2014, the National Chargepoint Registry (now at http://www.national-charge-point-registry.uk) listed and mapped 4358 individual 'connectors' of different types and 2201 charger units: of these, there were 75 rapid-chargers (40kW AC, 50kW DC); 3786 fast-chargers (7-22kW, single- or three-phase); and 497 3kW 'slow' chargers (13 amps, as per a domestic power socket). As of 31 January 2019, it recorded "recent activity" at 7077 connectors and 3789 devices (http://www.national-charge-point-registry.uk/network-activity/) although data from key network operators such as Ecotricity and Source London had not been updated for, in some cases, over a year. A more accurate reflection of numbers may be found at Zap-Map, cited by many research participants as being the most reliable resource: 19,342 connectors at 6775 locations, including 4441 rapid-chargers in 1348 locations (https://www.zap-map.com/statistics/; 31 January 2019). Zap-Map's data also show that most of the growth in chargers 2011-2018 (full years) has been the addition of fast and rapid-chargers (both AC and DC, including the Tesla Superchargers, 43kW Mennekes 'Type 2', and 50kW CCS and CHAdeMO charger types):

table 8.ii: Charging connectors by speed/type: Zap-Map, 2011-2018

	Slow	**Fast**	**Rapid DC**	**Rapid AC**
2011	1325	178	34	0
2012	1611	1193	79	0
2013	2126	3309	204	80
2014	2448	4734	595	249
2015	2228	5946	1265	542
2016	2451	7143	1529	642
2017	2743	8754	1909	754
2018	3293	11459	4366*	*(AC+DC combined figure)

Source: Zap-Map: https://www.zap-map.com/statistics/

8.3.3 Access to public infrastructure

The reliability and functionality of apps enabling access to charging infrastructure, payment for electricity and information on the UK's network are thought to have improved, as Driver C6 points out [8.2]. Apps available from the leading service providers have been updated, i.e. the app from Chargemaster's POLAR network, the largest in the UK (Chargemaster plc, 2018a), which now includes features such as direct links to Google or Apple Maps for directions to chargers, although an RFID membership card to 'unlock' charging points is still required (*ibid*.). Some chargepoints originally launched in small schemes such as those operated by municipal or local authorities have been integrated into national-level commercial networks by becoming accessible on a 'roaming' basis to network members, and operators offer both pay-as-you-go access and monthly network membership tariffs (i.e. Chargemaster plc, 2018b). However, on a national level – as well as EU-wide and internationally – network provision remains fragmented, without universal interoperability either in terms of charger access and payment, or charger connector types (Spöttle et al., 2018; Hall and Lutsey, 2017).

Regime-level corporations in both the transport and energy systems are becoming increasingly involved in the niche business of electromobility, however. Notable examples of this are the acquisition of Chargemaster by BP (Chargemaster plc, 2018c) for forecourt charging; and in the US, the buyout by Shell of Greenlots, a provider of EV charging and energy management software and technology services, including platforms to deploy smart-charging and to integrate and store renewable energy (Greenlots, 2019). Other potentially influential moves include the expansion of a leading Swedish energy firm into this market (Vattenfall Group, 2018); and Shell's rolling out of chargers across its fuel station forecourts (Shell United Kingdom, 2017).

And as well as an expansion of the facilities on offer, the latest and upcoming equipment is bringing new technologies for ease of use: contactless payments are accepted by, for example, the InstaVolt rapid-chargers (InstaVolt, 2018), the latest Engenie units, which also take ApplePay tap-and go (Engenie, 2018), and Chargemaster's Ultracharge rapid-chargers as supplied for London taxi drivers (Chargemaster plc, 2017) and to be rolled out for consumer usage. Products such as the Ubitricity lamp post-mounted chargers and UEone Urban Electric pop-up chargers use SmartCable recognition to identify a car linked to a user account, again requiring no RFID card or app (Ubitricity, 2018), as with the units from Dutch firm Fastned (expanding into the UK) which use the CCS protocol to establish a unique ID for each registered car (Fastned, 2017). These pave the way for increasing degrees of automation of the charging process – from vehicle identification to payment – and thus driver convenience.

8.3.4 In-car interfaces

An audit was carried out of the manufacturer-supplied interface technologies relevant to operating an electric vehicle, covering official OEM-supplied and supported EVs available in the UK (new or now secondhand) as of August 2018. Third-party aftermarket conversions, commercial vehicles, exotic sports models and cars only available within trial programmes were not included. Data were sourced from manufacturers' media material as supplied to the UK or European press.

The listing compiled [*table 8.iii*] also shows the maximum battery range of each vehicle as claimed at its launch. The figures are not necessarily directly comparable due to changes in the standardised international test procedures for European type approval as of 1 September 2017, when the WLTP (Worldwide harmonised Light-duty vehicles Test Procedure) replaced the former

NEDC (New European Driving Cycle), intended to result in more realistic fuel consumption figures for ICE vehicles and more representative battery range figures for EVs (VDA.de, 2017); in this, a higher average speed on the test cycle gives a higher energy consumption (*ibid.)*. It is also believed that significant differences between claimed range and 'real life' mileage persist for many EV models (Huntingford, 2019). However, an impression is provided of how vehicle range has, in some cases, been improved over successive updates or new iterations; and also shows that, until some recent launches, i.e. of the Jaguar I-Pace and Kia e-Niro, the battery range of all-electric models has continued to be very low compared to the mileage capabilities of ICE vehicles between fill-ups. It is still, for most models, some way off the 300 miles thought to be necessary to appeal to 90% of mainstream consumers (Beard et al., 2019) and in some cases, still shy of the 200 miles which might appeal to 50% (*ibid*.).

This is relevant both to owners' charging needs and to the stakeholders involved in infrastructural provision and associated digital support, not least because older, lower-range EVs are filtering onto the used car market and will remain in operation alongside newer models. And indeed, since the August 2018 audit, several all-new models have been confirmed for 2020 which – for reasons of cost and market positioning – will be offered with relatively low-range batteries too: these include the Honda e, with a range of just 125 miles (hondanews.eu, 2019a) and the entry-level version of the Volkswagen ID.3 which promises a still-modest 205 miles (volkswagen-newsroom.com, 2019a), although more expensive variants giving up to 342 miles (550km) will also be available (*ibid*.).

table 8.iii: Interface technologies and battery range by model, EVs available in the UK August 2018

Make/model	**Features, functionalities**	**Max range* (miles)**	**Notes/ reference**
BMW i3 (2017-)	Standard-fit Professional Navigation: charger mapping, availability; dynamic range calculation by driving mode; Apple CarPlay, Amazon Alexa compatibility; OTA updates; multi-mode navigation; route planning incl. charging stops; Digital Charging Service for optimised charging, integration with home renewable generation, Wallbox, V2G; general UX, Connected+, ConnectedDrive service updates; new smartphone apps for charger access/control	146-158 (EV; WLTP) 125-mile 'everyday' range cited, based on internal testing	Cars ordered from August 2017; (press. bmwgroup. com, 2017)
BMW i3 94Ah, 33 kWh (2016-2017)	[As below] NB: 50kW rapid-charging now standard, previously extra-cost with connector upgrade. Upgraded battery from July 2016	195 (EV), 276 (REx) (NEDC)	press. bmwgroup.com
BMW i3 (60Ah, 22kWh model, 2013-2016)	Smart-home connection with Wallbox Pro upgrade. Chargemaster points displayed on sat nav, in app, some live data; ChargeNow account cards; dynamic route planning; multi-modal route planning, last-mile routing; Eco Pro, Eco Pro+ modes said to add 15% to range. Remote charger operation, timing, monitoring, pre-conditioning via app + charger locations can be sent to	100 (EV), 186 (REx)	Functionality – of UX, data analysis, speed – varies considerably between levels of sat nav system;

Make/model	Features, functionalities	Max range* (miles)	Notes/ reference
	sat nav. Data uploads for community comparison + sharing. Optional upgrades: BMW Business Advanced + Professional Multimedia navigation		press. bmwgroup.com
Citroen C-Zero (2011-)	Nothing beyond trip computer, range indicator (no sat nav or display screen). Remote pre-conditioning, charge monitoring an extra-cost option	93	Peugeot iON, Mitsubishi iMiEV; uk-media. citroen.com
Ford Focus Electric (2013-17)	'SmartGauge' range calculator, feedback on regen braking. From summer 2017: Ford's SYNC 3 control system with AppLink: supports Apple CarPlay, Android Auto; additions to MyFord Mobile app for remote charge monitoring + scheduling, pre-conditioning, charger locations; energy efficiency calculations	100; 140 from summer 2017	Mainly on fleet trials, very few sold; fordmedia.eu
Hyundai Ioniq EV (2016-2019)	Apple CarPlay, Android Auto smartphone app integration; TomTom live services + alerts; dynamic range calculations + graphics in sat nav mapping	174	Updated model due mid-2019; hyundaipress office.co.uk
Hyundai Kona Electric (2018)	As above	279 (150kW, 64kWh), 180 (99kW, 39kWh)	hyundaipress office.co.uk
Jaguar I-Pace (2018-)	MyEV menu to configure driving experience/mode, regen braking levels, range optimisation (eco mode). 'Smart Settings' AI; data aggregation on driving style, number of occupants, weather, topography, traffic for real-time range calculations. Chargepoint mapping + dynamic navigation. InControl Remote app for pre-conditioning, charge timing + monitoring, Alexa integration + voice controls; HomeLink Connect, 4G wifi, OTA updates. InControl apps (third-party) integration; sync to multi-modal travel app	298	QNX OS w/Apple CarPlay coming later; no Android Auto integration as yet; newsroom. jaguarlandrover. com
Kia Soul EV (2014-2019)	Sat nav with charging point locator, traffic messaging; dynamic 'learning' range calculation based on driving style, temperature (new model from mid-2019 will add upgraded HMI, connectivity as per e-Niro)	132	New model mid-2019 kiapressoffice. com
Kia e-Niro (2019-)	Sat nav with charging point locator, traffic messaging; dynamic 'learning' range calculation plus efficiency recommendations and 'coast' alerts; Apple CarPlay, Android Auto with voice controls	282 (64kWh), 179 (39kWh – tbc for UK)	(deliveries from April 2019) kiapressoffice. com
Mercedes-Benz B-Class B250 e (2014-18)	Optional Energy Assist package incl adaptive energy recuperation (topographical, traffic conditions), 'Range Plus' button. Connected services via optional COMAND system and/or My Mercedes Electric app; iPhone + Android integration via Bluetooth + USB	124	Need COMAND for full connectivity mercedes-benz-media.co.uk
Mitsubishi i-MiEV (2011-15)	Trip computer, range indicator	93	mitsubishi-media.co.uk
Nissan eNV200 Combi Estate/ Evalia (2016-)	Smartphone integration: Nissan ConnectEV app via sat nav interface	106; 124 from spring '18	Popular taxi; also van; nissan press.co.uk

Make/model	Features, functionalities	Max range* (miles)	Notes/ reference
Nissan Leaf (2018-)	Nissan Connect EV: adds V2G connectivity, sync with xStorage Home; Apple CarPlay (with optional sat nav upgrade); new interface for phone app	235	All-new 2nd-generation model; nissan press.co.uk
Nissan Leaf (2015-18)	Nissan Connect EV system replaces previous Carwings with revised sat nav: charging station mapping, charger types, live status; phone app for remote monitoring + charge scheduling, pre-conditioning	155	September 2015 – 30kWh battery; nissan press.co.uk
Nissan Leaf (2011-15)	Carwings app for remote charging monitoring, pre-conditioning; smartphone integration via Nissan Connect touchscreen (except entry-level Visia models); Carwings chargepoint mapping (with optional upgrade)	109; 124 from spring 2013	Mapping very limited. nissanpress. co.uk
Peugeot iOn (2011-)	Trip computer, range indicator	93	peugeotpress. co.uk
Renault Fluence Z.E. (2012-13)	Trip computer, range indicator; optional My Z.E. Connect Pack for smartphone integration, connectivity to PC; app for remote charge monitoring. Carminat TomTom Z.E. Live sat nav with Live services – range, charger locators, routing to chargers, traffic info, Google search; sat nav calculates range/feasibility of destination	115	<60 still on the road in UK (howmanyleft. co.uk); press.renault. co.uk
Renault Kangoo Z.E. Maxi Crew Van (2011-)	Connected Pack (as above); also fleet telematics. Optional sat nav brings more connected services, chargepoint mapping	106; 170 from late 2017	Five-seat van; press.renault. co.uk
Renault Twizy (2012-)	Trip computer, range indicator	62	press.renault. co.uk
Renault Zoe (2012-)	Android Auto from 2018 model-year. Standard R-Link infotainment system with voice-controlled TomTom sat nav (charger mapping), Z.E. Connect app: remote monitoring of battery levels and charging status; (optional) subscription to Z.E. Interactive app for remote charge scheduling + activation, pre-conditioning; Z.E. Trip (Euro charger mapping, real-time status) + Z.E. Pass (charge payments) accessed in-dash via R-Link nav system	186 (250 on NEDC cycle) from late 2016; 149 from summer 2015; 130 (NEDC) at launch	press.renault. co.uk
Smart ForTwo EQ (2017-)	Sync with 'smart control' app; pre-conditioning, charge monitoring + control; new functions incl programmable departure times; Google Now, Android Auto, Siri; 'Charge Spot Finder' in sat nav ('cool & media' pack); USB + Bluetooth	160; 155 for cabriolet	Fourth-generation; mercedes-benz-media.co.uk/ smart
Smart ForFour ed (2017-)	(as above)	155	mercedes-benz-media.co.uk/ smart
Smart Fortwo ed (2013-17)	Remote monitoring, pre-conditioning, charge setting, charger location via 'Smart Vehicle Homepage'/web portal (browser-based, also for smartphone/tablet); email/Twitter alert system, dynamic route planning incl topography, route profile, charging needs	90	Third-generation; mercedes-benz-media.co.uk/ smart
Smart Fortwo ed (2009-12)	Local charging stations shown in sat nav for car2go fleet; browser-based remote monitoring, pre-conditioning	84	mercedes-benz-media.co.uk/ smart
Tesla Roadster (2008-12)	Many aftermarket upgrades to replace/hack original-issue (optional) sat nav, incl USB + Parrot connectivity, add CarPlay, Android Auto, third-party mapping; third-party apps via OVMS	227; retrofit 3.0 upgrade pack gives up to 400	Lacks connectivity of later Teslas; tesla.com/ en_GB/

Make/model	Features, functionalities	Max range* (miles)	Notes/ reference
Tesla Model S (2014-)	Chargepoint mapping (Superchargers, Tesla partner destination chargers, previously-used chargers), dynamic range calculations incl topography, routing, Google Maps, wifi, Bluetooth; GPS-enabled Homelink connectivity; energy optimisation app, OTA updates. Tech Pack: permanent 3G/4G for real-time live data; home wifi connection. (Powerwall control via Tesla app)	240-424; different models/ battery packs, updates, retrofits	Frequent updates to software, firmware, tech features; tesla.com/ en_GB/
Tesla Model X (2016-)	(as above)	351	tesla.com/ en_GB/
Tesla Model 3 (2019-)	UK spec tba; expected as above albeit with single touchscreen display	220/310 ('Long Range')	tesla.com/ en_GB/
Vauxhall Ampera (2012-2015)	Energy efficiency analysis, range indicator. Optional sat nav (fitted in Electron models) but no charger mapping. (USB input enables aftermarket solutions/hacks via portable wifi router/dongle for phone screen mirroring in display)	25-30; 310+ w/ range-extender engine	Sister model = Chevrolet Volt (Mk1); media.vauxhall.co.uk
Volkswagen e-Up! (2014-)	Connectivity via Car Net e-remote app, smartphone integration; pre-conditioning, remote monitoring; 'maps + more' app for sat nav incl charger mapping, route planning, efficiency advice. (Updated spring 2017)	93; 99 from spring 2017	vwpress.co.uk
Volkswagen e-Golf (2014-)	As above. (Updated Discover Navigation Pro sat nav with charger mapping + improved interfaces from September 2017)	99; 124 from Sept 2017	vwpress.co.uk

**Range as cited at launch according to legal requirements at the time, i.e. NEDC/WLTP, unless otherwise specified*

The audit clearly shows that as new or updated EVs come to market, the sophistication of the available interfaces and features has been increasing along with battery range itself, with even relatively mainstream-oriented vehicles like the Hyundai Ioniq EV and latest Nissan Leaf provided with a high level of connectivity and provision of real-time services, including support for vehicle-to-grid (V2G) communications. The integration of third-party features such as Apple CarPlay and Android Auto also brings functionalities previously accessed via external mobile apps to in-dash screens and displays, such as Apple Maps or Google Maps with charging stations, either embedded in factory-fit connected systems or 'mirror linked' from a mobile device, i.e. via Bluetooth or USB. This further enables, in some cases, voice-activated controls, i.e. Google Assistant, Siri or Amazon's Alexa, which can be used to seek charging- or range-related information. However, automated, fully-embedded fuel payment systems such as Exxon Mobil Speedpass+, now available in the USA within the touchscreen of selected General Motors (ICE) vehicles (media.buick.com, 2018), are not yet available in the UK to EV drivers for charge-ups.

The audit implies too that a number of the original sample of interviewees had not identified all of their car's available tools, information features and functionalities, which also differ according to individual model variants and options chosen: when drivers were asked what additional information or digital functions they would find useful [Q20c], i.e. what they did not already have, some cited features that were indeed available within, for example, their car's satellite navigation system or control menu. This could be down to poor briefing from a supplying dealer with poor technical knowledge and even unwillingness to sell an EV (de Rubens et al., 2018b), as described by some respondents in this research. The qualitative evidence collected also suggests that even where drivers were aware of functionalities, these were not necessarily usable or useful, i.e. due to outdated databases of charger locations, as follow-up interviewee W relates [8.2], or poor connection with supporting servers. And as interviewee J points out [8.2], EV owners may prefer to use "less fiddly" and more intuitive smartphone apps anyway. This points to issues of complexity which may need to be addressed in UX design for EV drivers.

While the quite significant improvements in vehicle range will of course have an impact on drivers' journey-planning, and the more advanced latest-generation or upcoming built-in tools and functionalities will be differently implicated in driver behaviour, routines and practices to those described by the sample of EV drivers in 2015, these developments apply to newer cars introduced: existing EVs as available in 2015 will continue in use either by current owners keeping them long-term, or by second, third and subsequent owners as a market for used EVs forms. It is yet to be seen whether vehicles will remain in service with their current limitations, or whether aftermarket upgrades – to batteries, or to communications systems and connectivity, for example – will become widely available and affordable as new business models develop.

8.3.5 EV apps

Smartphone and tablet apps available to electric vehicle drivers were also assessed, along with tools available online (web apps) and third-party apps integrated into in-car connectivity suites (i.e. Apple Car Play and Android Auto). As discussed above, the latter form the basis of a growing number of connected services and can be integrated into in-car displays either as a factory-fit function or 'mirrored' via a mobile device linked with i.e. USB or Bluetooth. Apps available to, or relevant for, UK drivers from bona fide service providers, institutions or stakeholders were considered, as well some from independent or third-party developers which had been rated on Google Play or Apple App Store; been launched or updated within the previous year; and which had 100+ downloads.

Not included are apps which are simply reskins of open data, i.e. from Open Charge Map, National Chargepoint Registry (NCR), Zap-Map, the result of 'scraping' data from a provider, nor embeds of data and maps with no added functionalities or features. Commercial fleet management software tools are not included except where worthy of note due to particularly innovative features which may be extended or available to private consumers at a later date. Compatibility and functionality may vary between models of EV.

The full list of 110 apps and their discrete functionalities is not necessarily exhaustive but should represent a snapshot of the apps a consumer could have easily found or downloaded, as of August 2018. A key development for UK drivers since then has been the integration of charging station locations to Google Maps (Foster, 2018) and subsequent addition of real-time information on charger availability (Donaldson, 2019), following Apple's earlier introduction of EV chargers to its UK maps (Lanxon, 2017), although the data are believed not to be comprehensive as yet (Porter, 2019). Prior to this point drivers could 'manually' add charging stations to a Google map as points of interest, as described by participants in this research. Another new service, offered by BMW, adds a further dimension: the ability to check availability of a specific charging point identified on the BMW-affiliated ChargeNow network, and then reserve it (BMW Group, 2019a).

The bulk of apps available (August 2018) appear to be specifically relevant to accessing or otherwise interfacing with recharging infrastructure. These fell into five key areas:

8.3.5.1 Apps for public charger mapping, navigation and route-planning

Services and functionalities available include real-time status reports, with some offering community and chat features. Key offerings include Next Green Car's Zap-Map apps (zap-map.com), leveraging the National Chargepoint Registry (NCR) data; OpenChargeMap (openchargemap.org) and Plugshare (Recargo Inc., plugshare.com), based on open data and crowdsourced content; and the extension of existing navigation apps, i.e. MyRouteMonkey (web app; my.routemonkey.com), HERE Charging Stations (here.com) and TomTom EV Services (tomtom.com) to add EV-related information. Use of such apps was described by the case study sample pre-journey [Typology 1.2; *table 5.iv*], and as part of the dynamic process of checking charger availability and remaining battery range during a journey [Typology 2.2; *table 6.iv*].

OEM and vehicle-specific apps [discussed further below, 8.3.5.4] integrate with in-car satellite navigation systems, and newer examples amalgamate services into a comprehensive suite: Hyundai Access Point, for example, brings dashboard integration of live connected services for the Ioniq and Kona EVs, including Siri, TomTom navigation and live status data on charging points. Third-party mapping apps such as EVTO for Tesla promise range calculations using parameters including weather conditions, while others such as Teslarati leverage community-sourced data for updates on charging facility availability specific to the Tesla Supercharger network.

table 8.iv: EV apps available in the UK (August 2018): public charger mapping and route-planning

Useful abbreviations:
OCPP = Open Charge Point Protocol; OVMS = Open Vehicle Monitoring System; OBD = on-board diagnostics

App/developer	**Platform/source**	**Function**	**Notes**
Android Auto	In-dash	Integration of Android smartphone apps, incl Google Maps with charging stations; Google Assistant voice controls	Via USB link or in-car platform
Apple CarPlay	In-dash	EV functions built into iPhone integration; incl charger location, mapping, navigation; Siri compatibility. Charging points can be shown in Apple Maps	June 2018 update to support third-party mapping apps, i.e. Waze, Google Maps
Charge Finder X (Jack Spacie)	iOS/ Apple App Store	Mapping; uses + reskins NCR data, but limits downloaded points to 7-mile radius of selected area, claims 'quicker download times'	
Chargemap (Chargemap)	iOS, Android, web app; Apple App Store, Google Play, chargemap.com	Mapping, filters by charger type; crowdsourced data; community reviews, comments, photos; network access + payment with Chargemap Pass card	Europe, limited in UK; partnering with Hubject/Intercharge
ChargePoint (Charge Point Inc)	iOS, Android; Apple App Store, Google Play, chargepoint.com	Mapping, navigation, real-time status (ChargePoint + 'other major networks' with OCPP); home charger control; community tips	US, but expanding in UK; takeover of GE network
ecarNI (ESB)	Web app for smartphone; ecarni.com	Mapping, charger types + live status data; access to ecarNI network via RFID card	Northern Ireland; mapping also covers Republic
EVHighwayStatus (Andrew Lees)	Web app for smartphone; evhws.uk	Route planning based on battery charge; dynamic updates; charger status history; RSS feed from Ecotricity data	DIY tool cited as useful; Twitter: @EVHighwayStatus, @EVHighwayMap
EV Range Calculator (Limosoft)	Android; Google Play	Estimates range of selected EV, ref to external parameters, to complete specific journey	
EVTO for Tesla (Digital Auto Guides)	iOS, Android; Apple App Store, Google Play	Third-party Electric Vehicle Trip Optimizer – mobile trip planning using weather data, Google Maps, state of charge; calculations i.e. charging downtime, energy consumption; multiple itineraries	Based on Supercharger network only for non-US users
Evway (Route220)	Web app, iOS, Android; evway.net	Pan-European mapping, data on facilities + suggestions for things to do/visit locally	
Garmin Smartphone Link, Garmin nuMaps, StreetPilot (Garmin Live Services)	Android, iOS, Windows Phone; Google Play, Apple App Store, Microsoft Store; buy.garmin.com	Chargepoints can be identified as points of interests in mapping	For upload to/pairing with Garmin devices i.e. sat nav units; smartwatch pairing

App/developer	Platform/source	Function	Notes
Google Maps	Web app, iOS, Android; Apple App Store, Google Play, maps.google.com	Can search for EV charging points, create own local map	NB: web app very widely used on desktop/laptop; also on smartphone
HERE EV Charging Stations (HERE)	Supplied to OEMs, fleet clients, businesses; here.com	Mapping (by HERE mapping cars), charger locations + types, routing + recommendations based on sat nav; claimed high degree of granularity/detail; live traffic data	Not yet integrated into HERE WeGo consumer app
Hyundai Access Point (Hyundai)	Apple App Store, Google Play; hyundai.com/eu/en/ Innovation/Connectivity	Dashboard integration of Live Services via Apple CarPlay, Android Auto; incl. Siri for Ioniq EV, Kona EV, TomTom nav + traffic alerts, charger locations, status + connector types	
MyRouteMonkey (Route Monkey)	Web app; my.routemonkey. com	Charger mapping, navigation; route-planning by battery capacity, range, preferred charge levels, connector type	Free in-browser version for consumers; fleet subscriptions
NEXTCHARGE (Go Electric Stations)	iOS, Android, Windows; Apple App Store, Google Play, Microsoft Store; goelectricstations.com	Mapping, navigation; itinerary planning; some real-time status; web app has network operator, status, pricing incl. for peer-to-peer facilities	US, Australia, Europe, some UK but not comprehensive or up-to-date
National Chargepoint Registry (Cenex)	Web app; national-charge-point-registry.uk	Mapping, identification of charger type; data also supplied to i.e. ecarNI (Northern Ireland), Greener Scotland + various other regional networks	open data download + API available to developers
Open Charge Map (Webprofusion)	Android, iOS, Windows Phone; Firefox, Chrome web apps; Google Play, Apple + Microsoft app Stores; openchargemap.org	Crowdsourced/community open data on charger locations, types; with images, tips, fault reporting; Q&A page	Global, non-profit, Creative Commons license; developer API; available as widget, embed into browser-enabled in-car touchscreens
PlugShare (Recargo Inc)	Web app, iOS, Android; Apple App Store, Google Play; plugshare.com	Mapping, navigation; crowd-sourced data incl. tips, photos, ratings; some live status data; filters by car/charger type	Global community; UK coverage now looks comprehensive
Spark EV (Spark EV Technology)	Mobile app by subscription; spark-technology.com	Cloud-based AI analysis of live driver + vehicle data + weather, traffic, trip history (ref to fleet deployments)	Claimed 20% more journeys completed between charging
Superchargers for Tesla (Ndili Technology)	iOS, Android; Apple App Store, Google Play	Global Supercharger mapping, ‘Range Circles’ (distance from each Supercharger); charger status, network updates + alerts, photos + forum, comments	Third-party
Teslarati (Teslarati LLC)	iOS, Android; Apple Apps Store, Google Play; forums.teslarati.com	Real-time Supercharger + destination charger updates, crowdsourced info, tips + photos, news	Third-party, community-focused; on Twitter @TeslaratiApp

App/developer	Platform/source	Function	Notes
TomTom EV Service	By subscription; supplied to OEMs, partners; tomtom.com	Info on charger/connector type, real-time availability; adds to TomTom sat nav charger mapping	API to be opened to developers; also APIs for routing + range
WattsUp (Sanctus Media Ltd)	iOS; Android to follow; wattsup.app	Rapid-charger mapping, route-planning, live status, charger compatibility	UK; uses Apple Maps
Zap-Map (Next Green Car)	Web app, iOS, Android; Apple App Store, Google Play; zap-map.com	Mapping, navigation; extensive (but not comprehensive) dynamic status updates, live feeds from operators; crowd-sourced data and information; community/chat; sharing of private chargers; filters by car/charger type	UK & Republic of Ireland
Zap-Map EV Route Plan	Android, iOS, web app; Google Play, Apple App Store, zap-map.com	Route planning ref to range, speed, topography, further customisable choices; suggested rapid-charging stops, available chargers; filters by model/compatibility; Google Maps navigation	Supplements existing app (above)

8.3.5.2 Apps for network access and payment

These fell roughly into three sub-categories: apps developed and offered from specific charging network providers, such as ChargeYourCar (chargeyourcar.org.uk) or Chargemaster's POLAR Plus (polar-network.com); apps to give cross-network access, i.e. on a pay-as-you-go or 'roaming' basis, such as MOOvility (moovility.me) or Plugsurfing (plugsurfing.com); and apps to give access to particular charger brands across networks, i.e. GeniePoint (chargepointservices.co.uk), POD Point Open Charge (charge.pod-point.com) or Vattenfall InCharge (goincharge.com). These are mostly based on individual user accounts, and can enable payments via QR code, credit card, PayPal, ApplePay or similar (i.e. intercharge, from hubject.com); and can be connected to energy providers – Ecotricity customers can link EV charging and billing to their home energy accounts, for example (ecotricity.co.uk). Further functionalities coming online include auto-identification (intercharge; hubject.com); compatibility with Amazon Echo/Alexa (JuiceNet; emotorwerks.com); embedding and mirroring on in-dash screens (i.e. Plugsurfing); and chargepoint reservation (i.e. Allego's Smoov, for Shell ReCharge stations, smoovapp.eu; or Bluepoint's Source London, sourcelondon.net).

As research participants reported, using such apps was not always straightforward – problems and glitches were noted with existing technologies [Typology 2.6].

table 8.v: EV apps available in the UK (August 2018) – network access and payment

Useful abbreviations:
OCPP = Open Charge Point Protocol; OVMS = Open Vehicle Monitoring System; OBD = on-board diagnostics

App/developer	Platform/source	Function	Notes
Chargemap Pass (Chargemap)	iOS, Android, web app; Apple App Store, Google Play, chargemap.com/pass	Access, billing, payment across Europe; Chargemap community; account + RFID card	Intercharge/Hubject network
Charge Your Car (CYC) (Corethree Limited)	iOS, Android, web app; Apple App Store, Google Play, chargeyourcar.org.uk	Access to CYC OCPP network, charger locations, payment via access card (+ direct debit from account) or app; phone helpline	Notably very negative reviews!
Electric Highway (Ecotricity)	iOS, Android; Apple App Store, Google Play; ecotricity.co.uk	Access to Ecotricity network; charger locations and navigation, compatibility info, payment as guest user by credit card, app or via account ID; live status feed	Can link to Ecotricity home energy account
E.On EasyPark (EasyPark)	iOS, Android, Windows; Apple App Store, Google Play, Microsoft Store; eon.dk	Location + payment, E.On charging points; EV extension of EasyPark (parking space finder + payment app)	Denmark; UK launch possible
EV Driver (Fortum Charge & Drive)	iOS, Android; Apple App Store, Google Play; fortum.com	Account-based payments; optional RFID fob access; charger maps (i.e. for East Anglia network)	Back-office provider for various network operators
EV Plug In (ESB)	iOS, Android + mapping web app; Apple App Store, Google Play, esb-evsolutions.co.uk	PAYG for ESB London + Coventry rapid-charging networks; management of accounts	Public, business and taxi accounts
GeniePoint (ChargePoint Services)	Web app; chargepointservices.co.uk	Mapping, access to GeniePoint network; management of payment accounts (payments online or via RFID card)	Network mainly in south of England; private + business accounts
intercharge (Hubject)	iOS, Android, also via individual network/service providers; Apple App Store, Google Play, hubject.com	Cross-platform access to multiple networks on-demand, payment via account, credit card or PayPal; QR code and auto-identification; live status data	Mainland Europe but launching in UK; offered as 'white label' solution for operators
JuiceNet (eMotorWerks)	iOS, Android; Apple App Store, Google Play, emotorwerks.com	Smart-charging at JuiceNet-compatible points, charging point management; energy consumption/GHG reduction calculations; compatibility with Amazon Echo/ Alexa	US & Europe, expanding into UK; diff versions for residential, fleet, commercial use
MOOVILITY.me (Cirrantic)	Web app, smartphone-enabled; moovility.me	Location + reservation of chargers, status reports, data on charger type, power; payment option; reporting ICE-ing by user and parking sensors	Newly launched in UK
NewMotion (NewMotion)	iOS, Android; Apple App Store, Google Play; newmotion.com	Mapping, access to public chargers; dynamic info + alerts, pricing, payment via chargecard; remote charge activation; add available charger to network	Aimed primarily at users of its charging equipment, incl. fleets/businesses

App/developer	Platform/source	Function	Notes
Plugsurfing (PlugSurfing)	iOS, Android, web app; Apple App Store, Google Play, plugsurfing.com	PAYG or fixed monthly fee, Europe-wide charging networks via app/ RFID tag; mapping, real-time data on charger availability. Can be embedded/mirrored in telematics	Supplied third-party i.e. to Jaguar Land Rover customers. Also LeasePlan Charging fleet app
POD Point Open Charge (Pod Point Ltd)	iOS, Android, web app; Apple App Store, Google Play; charge.pod-point.com	Location and access to POD Point chargers on public networks; logs charging, costs; fault reporting; social media sharing	
POLAR Plus (Chargemaster plc)	iOS, Android, web app; Apple App Store, Google Play; polar-network.com	Monthly membership; access to points on Chargemaster network; payments via card/key fob; access to ‘EV experience fleet’, live mapping	POLAR Instant still available, but not updated
Share&Charge (MotionWerk)	For integration into partner service provider apps; motionwerk.com	Blockchain-enabled open network access for operator roaming, peer-to-peer	UK pilot trial
Smoov (Allego)	iOS, Android; Apple App Store, Google Play; smoovapp.eu	App starts/stops charging; data on charging sessions; notifications; community reviews; reservations to follow; payment via chargecard, credit or debit card	For Shell Recharge
Source London (Bluepoint London Ltd)	iOS, Android, web app; Apple App Store, Google Play; sourcelondon.net	Source London network chargepoint location, reservation (up to 40 min in advance)	Payment/access via card only
Vattenfall InCharge (Vattenfall AB)	iOS, Google, web app; Apple App Store, Google Play, goincharge.com	PAYG open access to Vattenfall InCharge network, ‘roaming’ other network operators	Use with InCharge charging equipment
Virta (Liikennevirta Oy)	iOS, Android; Apple App Store, Google Play; virta.global	Back-end for mapping, navigation, start/stop charging, charger reservations on European roaming; auto billing + payment by account	Expanding across Europe; fleet application

8.3.5.3 Peer-to-peer EV charging apps

Active apps to offer or share private charging facilities were relatively scarce; Carchargo (carchargo.com) and Bookmycharge (bookmycharge.com) are relatively new-to-market for reservations and payments. Zap-Home and Zap-Work (Next Green Car, zap-map.com) are membership-only add-ons to the other Zap-Map apps [above] to enable sharing of home or workplace facilities. In terms of other peer-to-peer co-operation, Powermystreet.co.uk invites people to nominate locations for installation of new public chargers, while ChargeBump (chargebump.com), mentioned by a number of research participants, offered anonymous communication between registered EV drivers (by numberplate), i.e. to enquire how long they will be at a public charger, or to request them to move on if sufficiently charged – but appears (01/02/2019) to be defunct.

Relatively few stand-alone EV-related tools and platforms for peer-to-peer activities are offered in general, and participation in these seems to have remained quite marginal in the UK, although some degree of digital communication between drivers was noted [6.2.1], i.e. to communicate over charger needs [Typology 2.3.3] or in the event of problems and issues with infrastructure [Typology 2.6.2]. Some peer-to-peer activity is enabled, nonetheless, via chat, community and crowdsourcing functions within other services or apps, such as Zap-Map's Zap-Chat or the Teslarati app for Tesla drivers [*table 8.iv*].

table 8.vi: EV apps available in the UK (August 2018) – peer-to-peer

App/developer	**Platform/source**	**Function**	**Notes**
Bookmycharge (Bookmycharge Ltd)	Web app; bookmycharge.com	Reservations to charge at private facilities/offering private charging facilities (fee payable)	App to follow
Carchargo	Web app for smartphone, carchargo.com	Peer-to-peer; offer + pre-book charging facilities; payment platform	Yet to launch; iOS + Android apps tbc
ChargeBump (Paul Mullett)	Android; Google Play; chargebump.com	Anonymous communication between registered EV drivers (by numberplate), i.e. to enquire how long they'll be at a charger, request them to move if charged	Others replicating idea but less-downloaded; appears defunct 01/02/2019
Powermystreet (Source London)	Android; Google Play; Web app; powermystreet.co.uk	Submit request for on-street chargers by nominating specific location on London map, supporting others' nominations (Zap-Map running similar service too)	Partners: Zap-Map, Evening Standard, SSE, LEVC, Clean Air In London
Zap-Home, Zap-Work (Next Green Car)	Android, web app; Google Play; zap-map.com	Membership-only add-ons to Zap-Map, enabling sharing of home/workplace chargers	

8.3.5.4 OEM or model-specific EV charging interface apps

Remote monitoring of charge levels, and remote scheduling and activating of charging, were used by half the research sample [6.2.1] and described in the Typology at all stages of the journey-making process [*table 6.iv*]. Numerous apps, whether offered by a vehicle manufacturer or developed third-party, integrate such EV-specific functionalities with other remote-control features such as pre-heating and pre-cooling of the cabin or locking/unlocking, as well as with other journey-planning aids and calculations.

Renault's by-subscription ZE Trip and ZE Pass (renault.co.uk/owners/renault-ze/ze-services) add information on public charger status/availability and pay-as-you-go respectively. However, myAudi (audi.co.uk/owners-area/my-audi) for electric e-tron models gives data on charging cost/tariff and solar generation, and integration with suitably-equipped home energy management systems, albeit with an extra-cost 22kW ‘connect charging’ system upgrade; Tesla’s official app (tesla.com/en_GB/support/tesla-app) brings Siri plus synchronisation with home energy and Tesla Powerwall storage. Both of these, like Honda’s SmartCharge app currently under beta-testing in California (smartcharge.honda.com), mark advances towards vehicle-to-grid communication, grid-balancing and renewable energy integration – as well as illustrating how automotive manufacturers are increasingly offering a range of products and services beyond simply supplying and maintaining the vehicles themselves.

table 8.vii: EV apps available in the UK (August 2018) – OEM/model-specific charge scheduling, monitoring and remote control

App/developer	Platform/source	Function	Notes
BMW i Remote (BMW)	Android, iOS; Google Play, Apple App Store; bmw.co.uk/bmw-ownership/ connecteddrive/digital-services	Remote monitoring, charging status + range, dynamic range map; driving efficiency + CO2 calculations, community comparisons, optimisation advice; other remote i.e. pre-conditioning	
EVAccess (evnotion)	Android; Google Play; rvtechtools.com	Third-party for Mercedes-Benz/Smart EV/PHEVs; remote charge monitoring + notifications, mileage/range, driving style; vehicle location (w/Mercedes Me)	No longer on Apple App Store
EVA: Leaf (Rob Winters)	iOS; Apple App Store	Third-party for Nissan Leaf. Simple charging control, timing + battery level monitoring, pre-conditioning	Alternative to Nissan Connect
EV Watch for Tesla (Excelsis Consulting)	iOS – Apple Watch, iPhone, iPad; Apple App Store	Third-party for Model 3; remote charge monitoring, charge reminders + alerts, set charging; check locking, sunroof, climate control status, multi-Tesla support	
Honda SmartCharge (eMotorWerks for Honda)	iOS; Apple App Store; smartcharge.honda.com	Finds best time to charge according to grid conditions, demand response, energy pricing; monetary incentives to shift. Extension to existing HondaLink app (wider roll-out planned)	JuiceNet platform. On California-only beta trial for Fit EV
KeyMote for Tesla (Brand&Mobel GmbH)	iOS – iPhone, iWatch; Apple App Store	Third-party. Remote functions via touch ID, i.e. start/stop, pre-conditioning, locking, sunroof, charge/battery monitor, live data	Claimed to be quicker than Tesla’s own app
Leaf Manager (Gyathaar)	iOS, Android; Apple App Store, Google Play	Third-party for Nissan Leaf. Charge control + monitoring of battery levels; pre-conditioning	Third-party Carwings substitute
Leafy Live (Filip Jurik)	iOS; Apple App Store	Checking charging status of Nissan Leaf; customisation of home screen, multiple car control, scheduling air con/heating	Leverages Nissan’s ConnectEV
myAudi (Audi)	iOS, Android, web portal; audi.co.uk/owners-area/my-audi	Adds for e-tron: charging, range and status management; cost/tariff + solar optimisation; integration with home energy management system; personalised newsfeeds (as per ICE) incl. from Twitter	22kW ‘connect charging’ option needed for full functionality

App/developer	Platform/source	Function	Notes
MyB (John Jacob)	iOS; Apple App Store	Third-party for Mercedes-Benz B-Class; charge scheduling ref to departure time; push notifications; connects to web app	Simplifies Mercedes-Benz interface
MyFord Mobile (Ford)	iOS, Android; Apple App Store, Google Play; myfordmobile.eu	For Focus Electric + PHEV models; remote charge monitoring + activation; charger location; pre-conditioning	
My Mercedes Electric (mbrace)	iOS, Android; Apple App Store, Google Play	Official for B-Class Electric Drive; browser-based (pre-dates Mercedes Me digital ecosystem). Remote charge monitoring, nav to charging points, pre-conditioning	M-B pushing Mercedes Me Adaptor app instead now
Nissan Connect EV (Nissan)	iOS, Android; Apple App Store, Google Play; nissan.co.uk/ownership/nissan-infotainment-system/nissanconnect-ev	Remote charge level monitoring, charge activation, range calculation, pre-conditioning	Replaced Carwings
Porsche Charging Service (Porsche)	iOS, Android; Apple App Store, Google Play; connect-store.porsche.com	Charger location, automated payments, navigation; access via QR code, app or RFID card; also available for non-Porsche drivers	On Hubject platform; not currently in UK
Recharge Reminder for Tesla (Ndili Technology)	iOS; Apple App Store	Third-party. GPS monitoring, geo-fencing; charge timing + monitoring, battery health, logging; push notifications + alerts	
Remote S for Tesla (Rego Apps)	iOS; for iPhone, iPad, iWatch; Apple App Store	Third-party; monitoring of charge, data visualisations i.e. instant charging rates, remote functions i.e. pre-conditioning, unlocking; tracking and vehicle statistics	Consolidates Tesla app commands/ stats onto one screen
Renault My ZE Interactive; ZE Trip, Z.E. Pass (Renault)	iOS, Android; access in-dash through R-Link sat nav; Apple App Store, Google Play; renault.co.uk/owners/ renault-ze/ze-services	Remote charging control, pre-conditioning; Z.E. Trip for charger location, info on status, payment method, charging speed, availability, Euro chargers; Z.E. Pass for PAYG payment	Subscription required
Smart Control (Daimler)	Web app [since discontinued]; iOS, Android; Apple App Store, Google Play; smart.com/en/en/index/app-center/	Remote monitoring, pre-conditioning, charge setting, charger location via ‘Smart Vehicle Homepage’/web portal (browser-based, also for smartphone/tablet); email/Twitter alert system, dynamic route planning incl topography, route profile, charging needs	Compatible with Smart ForTwo Electric Drive models 2009- + more functionalities for Mk4 (‘17-)
Smart Timer (Mark Allen)	iOS; Apple App Store	Third-party for Tesla; phone alerts + charging reminders, schedules for pre-conditioning; activate Valet mode; remote charge timing	
Tesla	iOS, Android; Apple App Store, Google Play; tesla.com/en_GB/ support/tesla-app	Monitor, start/stop charging; pre-conditioning, remote locking/unlocking, vehicle location/tracking, valet mode; summon car from parking space; Powerwall connection; Siri	The official one
TezLab (HappyFunCorp)	iOS, Android; Apple App Store, Google Play; tezlabapp.com	Third-party. Journey + energy efficiency tracking, community comparisons, optimisation tips	

App/developer	Platform/source	Function	Notes
Visible Tesla (Joe Pasqua)	Web app – Mac, Windows + Linux; visibletesla.com	Third-party; replicates official Tesla phone app functions via desktop; some additional commands, alerts, notifications	Linked to TeslaClient – opensource GitHub project
Volkswagen Car-Net (Volkswagen)	iOS, Android; Apple App Store, Google Play; volkswagen.co.uk/ technology/car-net/ app-connect	For smartphone + smartwatch integration; usual Car-Net security/remote services plus battery/charge level monitoring, charge stop/start, pre-conditioning for e-models	Mirror linking, Apple CarPlay + Android Auto

8.3.5.5 Apps for home or workplace charger control and vehicle-to-grid (V2G)

Similarly to the vehicle-specific provision, apps supplied by charging equipment manufacturers or providers for home or workplace charging show V2G functionalities; for example, eoApp (eocharging.com) integrates with renewable charging and storage as well as enabling pay-as-you-go on EO chargers; Hey EVBox (evbox.com) claims to optimise solar energy integration and storage, as well as distributing supply and demand across multiple chargers; Jedlix (jedlix.com/en/) brings charge scheduling by renewable electricity mix and dynamic pricing tariffs; sonnenCharger (sonnen.de/ladestation-elektroauto/) has a blockchain-enabled connection with home renewable generation and storage, allowing grid optimisation and pooling of energy within a ‘sonnenCommunity’; and both the renewable-optimising Zappi (myenergi.uk) and ZapCharger (zaptec.com) allow load-balancing across a site with multiple chargers.

table 8.viii: EV apps available in the UK (August 2018) – charger control, V2G

App/developer	Platform/source	Function	Notes
eoApp (EO Charging)	iOS, Android; Apple App Store, Google Play; eocharging.com	Remote charger control, PAYG on EO chargers (via QR code), session history + notifications; IoT/cloud connectivity. For private, fleet, commercial chargers	To integrate with renewable generation + storage
Hey EVBox (EV-Box BV)	iOS, Android; Apple App Store, Google Play; evbox.com	Optimisation of solar integration + energy storage for EVBox users; charge cards + power distribution, balancing	For subscribers, home/business; facilities management; with IBC Solar
EV ChAmp (DC & Co)	iOS, Android; Apple App Store, Google Play	Sets charge to lowest possible amperage to achieve desired range by set time (believed to preserve battery life)	Optimised for Tesla Model S and X
Jedlix (Dutch Living Lab Smart Charging)	iOS, Android; Apple App Store, Google Play; jedlix.com/en/	Smart charge management/scheduling by renewable mix, dynamic pricing tariffs, departure time	Tesla-compatible; tbc Renault + BMW
JuiceNet (eMotorWerks)	Mobile apps by subscription; emotorwerks.com	Connects to cloud platform for charging, V2G, control; various solutions for corporate/fleets	Supplied to OEMs i.e. Honda

App/developer	Platform/source	Function	Notes
LITE-ON EV Charging (Lite-On Technology Corp)	Mobile app by subscription; liteon.com	Mobile app to manage charging at LITE-ON chargers, back-end management incl pricing + electricity usage data, wireless functionality	For operators; but also i.e. workplace
Parking Energy (Parkkisaehkoe Oy)	iOS, Android; Apple App Store, Google Play; parkingenergy.com	Charger control, remote vehicle functions; with 'smart' sockets + cables for system management (for property developers)	Nascent but big installation in Finland
Siemens VersiCharge SG (Siemens AG)	iOS, Android, web app; Apple App Store, Google Play; new.siemens.com	Monitoring, scheduling + control of Siemens VersiCharge device; built-in metering + data analysis; notifications	Based on Siemens cloud platform
sonnenCharger (sonnen GmbH)	tbc; sonnen.de/ladestation-elektroauto/	Connects Sonnen chargers to home renewable generation, home battery; grid optimization, pooling + energy-sharing with sonnenCommunity, blockchain-enabled	UK launch expected soon
Zappi (myenergi)	iOS, Apple App Store; myenergi.uk	Use with Zappi 3-mode home/ workplace charger with load-balancing + renewable-use optimisation (i.e. link to solar panels)	UK launch imminent
ZapCharger (Zaptec)	iOS, Android; Apple App Store, Google Play; zaptec.com	Control of Zaptec charging equipment, charger configuration (for load-balancing across multiple chargers i.e. at a site)	Norway, but expanding

8.3.5.6 Other types of EV app available

Over a third of the case study sample expressed a desire for more detailed information and calculations on their car's electricity consumption, on battery cell degradation, charging cycles and diagnostics, or for more sophisticated range calculations and routing [6.5]. Third-party developers have created tools for such monitoring and data logging – used for activities such as post-journey efficiency analysis [Typology 3.3; *table 6.iv*] – as well as to integrate remote controls with other app-controlled functions such as smart-home and audio controls. In some cases, such apps are offered for owners of older vehicles for which OEM-supplied remote-control technologies were not available, or to supplement an OEM's digital system.

table 8.ix: EV apps available in the UK (August 2018) – other/misc.

App/developer	Platform/source	Function	Notes
App For Tesla (Tesla Forum Clubs)	iOS, Apple App Store	Third-party. Browser for Tesla forums, clubs + resources; access to My Tesla configuration + status pages	
caniOn (Martin & Xavier)	Android; Google Play	Third-party for Citroen C-Zero, Mitsubishi i-MiEV, Peugeot iOn; visualisation of data from CANbus, i.e. battery voltages	
Dashboard for Tesla (SG57)	Android; Google Play; sg57productions.com	Third-party: some widgets + functions + to Tesla app; Android Wear integration	
EvBatMon (EVpositive)	Android; Google Play	Battery monitoring, visualisation; Citroen C-Zero, Mitsubishi i-MiEV, Peugeot iOn	

App/developer	Platform/source	Function	Notes
EVE for Tesla (Evolved Vehicle Environments)	Dashboard integration via web browser; teslaapps.net	Third-party. Personalised dashboard for Model S, Model X, Model 3; infotainment + connected home/IoT device integration	EVEConnect iOT product
EVNotify (GPlay97)	Android; Google Play; evnotify.de	Remote monitoring of charging via Bluetooth connection; open-source; charging point locator; push notifications	For cars without own app/ connectivity
EV Range Target (Martindale Software)	Android; Google Play	Necessary energy efficiency for desired journey/battery levels, charge remaining, ref to energy consumption read-out	
Leaf Energy (Eric Marschner)	iOS; Apple App Store	Third-party. Energy efficiency calculator, range + energy usage predictions; parameters incl. temperature, battery degradation	Alt to 'Guess-o-Meter' in older Leaf models
Leaf Spy Pro (Turbo3)	Android with Bluetooth; Google Play	Third-party for Nissan Leaf; battery monitoring by cell voltage, temperature, degradation; range calculation, charging history, data logging, some diagnostics	Builds on earlier Leaf Spy, Leaf Spy Lite
mycarma	Consumer version of fleetcarma; availability tbc; mycarma.com/ products/myev/	Data logging + analysis + aggregation; community + comms w/other drivers via QR code	Partnered with OBD device; not model-specific
My EV App (Terry Billingsley)	iOS; Apple App Store; myevapp.com	Trip + energy use logging, efficiency by state of charge; range predictions	Deliberately simple
Open Vehicles (Network Box Corporation)	iOS; Apple App Store	Remote monitoring of state of charge, locking/roof/trunk status, tyre pressures + temperatures; core temperatures i.e. battery, motor; GPS tracking; charger mapping w/open-source OVMS data	Used by owners of older EVs i.e. Tesla Roadster
PowerTools for Tesla (Ndili Technology)	iOS; Apple App Store	Third-party. Real-time data streams for Model S, X, 3; performance, charge, range	
Tesla Cockpit (Jones Software)	Web app; beta.teslacockpit.com	Third-party. Cloud-based trip/charging logging, data analytics + visualisations, range estimations, efficiency + cost analytics, geo-fencing, remote commands, Amazon Alexa	
Tesla Explorer (Marcus Roskosch)	iOS; Apple App Store	Third-party for Model S, 3, X. Data logging, analytics, playback + visualisation; data export; works for multiple Teslas	
TeslaFi (TeslaFi LLC)	Web app; firmware.teslafi.com	Third-party. Cloud-based trip logging, charge tracking, data analytics incl temperature efficiency; Amazon Alexa	

There appears to be a counter-trend too to create apps which are in effect simplified alternatives to an OEM's interface or own products, i.e. related to specific tasks or for data visualisation. This highlights the need for digital tools to be comprehensible and easily navigated by the non-expert mainstream user, if drivers are going to engage with the functionalities and possibilities offered.

Apps for people not yet driving an EV [*table 8.x*] are another emerging theme in terms of consumer availability. Although telematics tools and data platforms to log mileage, estimate whether journeys could have been done in an EV, predict charging needs, cost savings and suchlike have long been available to fleets and for trial programmes (i.e. Gautama and Putrus, 2014), EV 'simulator' apps are becoming part of the marketing programme for new electric vehicles to persuade potential customers that they are a viable choice (i.e. Jaguar, 2018; Mercedes-Benz, 2017; Renault, 2018). However, although some energy apps with elements of gamification have enjoyed high levels of user engagement (Beck et al., 2019) these do not feature in the EV sector much as yet either.

table 8.x: EV apps available in the UK (August 2018) – EV simulation

App/developer	Platform/source	Function	Notes
e.CODRIVER (University of Ghent, University of Northumbria)	iOS; Apple App Store	Simulates battery state of charge + range based on trips, driver behaviour; matched to EV model	NB: 2014, not updated (Gautama, 2014)
e-mobile CHECKER (minnosphere GmbH)	Android, iOS; Google Play, Apple App Store	Trip analysis, checks feasibility of EV use, vehicle suitable, charging equipment needs	
EValuation (EneSys/Ruhr-Universität Bochum)	Android, web app; Google Play; elektromobilitaet.rub.de	Records routes, generates list of EV/PHEV/RE-EV models feasible, energy consumption/range buffers; costs; parameters I.e. acceleration, passenger/luggage needs, weather	
ev-drive (EVenergi)	iOS; Apple App Store	Trip recording; EV recommendation based on typical journeys; identification of charging places on these journeys; cost calculations	
Go I-PACE (Jaguar)	iOS, Android; Apple App Store, Google Play; jaguar.co.uk/about-jaguar/jaguar-stories/see-how-i-pace-can-fit-into-your-life.html	Uses journey data to calculate charging needs, cost savings, battery charge use per trip if driving I-PACE; chargepoint mapping; comparisons to ICE car	("GO I-PACE app puts electric Jaguar in your pocket", media.jaguar.com, 2018)
Mercedes EQ Ready (Mercedes-Benz)	iOS, Android; Apple App Store, Google Play; mercedes-benz.com/en/eq/about-eq/eq-ready/	Tracking function, journey recording + analytics, comparison with EV/PHEV parameters, calculates EV/hybrid viability, suggests Mercedes EQ model	("The EQ Ready App. Are you ready for e-mobility?", mercedes-benz.com, 2017)
MyGreenCar (Lawrence Berkeley National Laboratory)	iOS, Android; Apple App Store, Google Play; mygreencar.com	Detects when driving, records trips; calculates journey costs, range viability, charging needs + types; parameters incl. driving style, traffic conditions, hills; car comparisons	
Range Calculator (Kurt Huwig)	Android; Google Play	Tracks journeys, suggests EV models suitable; estimates energy consumption + range	

App/developer	Platform/source	Function	Notes
Smart experience-e (Daimler AG)	iOS, Android; Apple App Store, Google Play; smart.com/en/en/index/app-center/app-center	Interactive info on Smart electric drive models + range simulator/calculator	
Virtual Electric Vehicle (Daniel Gratwicke)	Android; Google Play	Journey tracker based on GPS data; calculates an EV's energy use and battery status	Few downloads; but example of simple DIY app
ZE Explore (Renault SAS)	iOS, Android; Apple App Store, Google Play; group.renault.com/RCW_BINARIES/ze-explore-application/	Journey simulator, trip + charging planning; calculations on energy consumption, range, CO2 savings, charging point locator; suggests most suitable Renault EV	("Renault Z.E.", group.renault.com, 2018)

8.3.6 Themes raised in the app audit

As with the in-car interface audit, it can be seen that the sheer variety and diversity of mobile apps and digital tools on offer has increased considerably. Those on offer now include interconnectivity with the latest IoT- and cloud-connected charging equipment, as well as vehicle-to-grid functionality, and elements using machine learning or artificial intelligence (AI) are starting to emerge, including for more accurate personalised battery range prediction, an important area for development (University of Essex, 2019) given that the provision of information on energy consumption is a key factor in educating EV drivers (Günther et al., 2019). With the commercial introduction of more V2G platforms, AI can further profile drivers' charging needs, and aid or reward drivers to monitor and control their interactions with charging equipment and energy supply or storage infrastructure (i.e. moixa.com, 2018), as well as just interact with their own personal vehicle.

Blockchain-based security is a further emerging element underpinning such interactions and is also applied to vehicle settings in the upcoming smartphone-EV pairing technology from Hyundai and Kia, announced since the above audit: this will allow drivers to adjust performance parameters including torque output, acceleration and deceleration capability, regenerative braking capacity and energy usage from climate control via an app (Hyundai Motor Group, 2019), and importantly, since these custom settings are stored in the cloud, they can be applied to any suitably-equipped EV the user is driving, i.e. a shared or hired car, and not just confined to an individual personal vehicle (*ibid*.).

Research into the download rate and usage frequency of these newer apps and products – including those not linked to specific infrastructure – would indicate further the potential of digital engagement and its role in supporting drivers' routines, practices and new behaviours.

These newer tools can, however, be linked to the requests of the different user groups and their characteristics, with particular platforms, interfaces, services and functionalities appropriate to each [as shown in the model, 7.6] – and can also be mapped against the potential new activities and practices which may be associated with, or prompted by, their usage.

8.4 Mapping app functionalities versus potential interventions and behaviour changes

Themes from the app audit are depicted in *fig 8.i* [below], which maps potential new activities and behaviour changes among EV drivers against the different types of app (excluding 'simulation' apps) and their key functionalities. These activities are synthesised from the typology and other qualitative interview material, including responses to the question [Q20]: *"Do you have any further comments or suggestions about tools, information sources or other things which could make your life easier as an EV driver, or that you think would encourage more people to drive EVs?"*; and from proposals summarising content from the app audit, i.e. suggestions from developers or digital tool providers as to what their product could enable. Areas of overlap are indicated, i.e. where digital services could be integrated or combined, or where different practices could be prompted or evoked as a result.

This model highlights the role of smart digital interventions in V2G communication and integration in particular: crucial as vehicle charging must be co-ordinated (Muratori, 2018) and energy demand shifted away from peaks (Ofgem, 2018). Potential for peer-to-peer energy-pooling and storage within local microgrids is indicated as well as integration with smart-meters, very important for EV uptake (Hall, 2018); a broad range of co-benefits thus becomes possible in conjunction with electromobility, including solar feed-in, renewable energy storage and supply, and even emergency power back-up (Noel et al., 2018).

The model also draws an explicit link between charger mapping, journey-planning and transport modal choice: a theme or functionality underserved in existing EV-specific app provision, and where suggestions for more appropriate transport choices could be made, i.e. where charging infrastructure provision is sparse; a journey is pushing range limits; or even where or when a local authority or service provider needs to relieve pressure on charging facilities, i.e. at peak demand times. Such a tool could further provide a mechanism for reducing traffic congestion or parking demand, perhaps in conjunction with charger-equipped park-and-ride facilities and appropriate incentivisation. EV drivers will consider alternative transport modes and travel patterns if convenient and accessible (Langbroek et al., 2018), and the deployment of non-car transport- and travel-related apps by a majority of the drivers in this research does indicate use of, or an interest in, other transport modes or making multi-modal journeys.

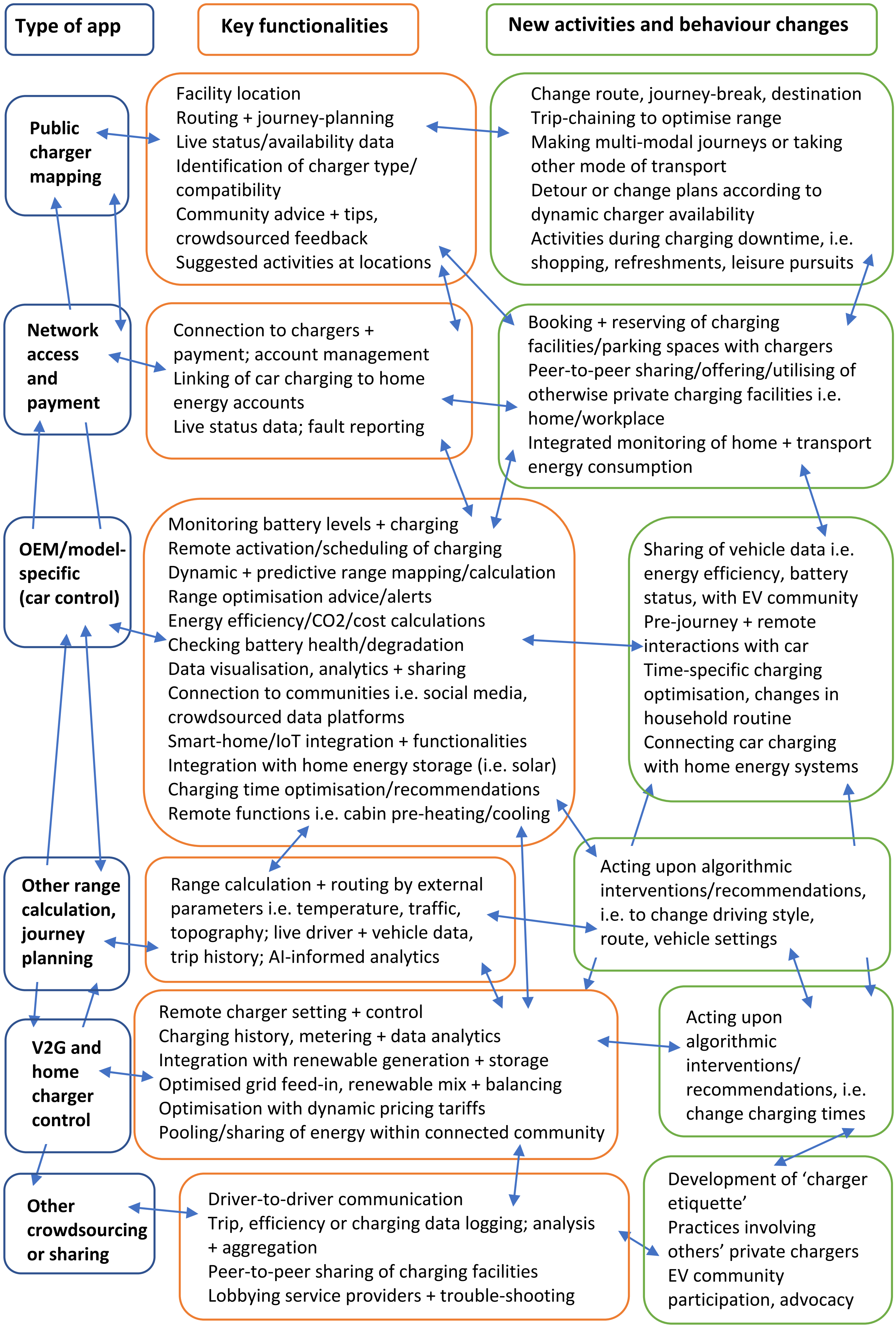

fig 8.i: Model suggesting app functionalities and potential interventions or behavioural changes

8.5 Conclusion

The snapshot audits of representative apps and digital technologies showed a diversity of tools to fulfil defined tasks. Vehicle-to-grid (V2G) communication, energy storage, cloud-based and internet-of-things (IoT) functionalities can be augmented by AI-informed elements to offer personalised predictive services and battery charging or range optimisation, an emerging development. Apps to encourage consumer take-up of EVs, i.e. by tracking journey patterns and assessing their viability by EV, are becoming more widespread, but participation in peer-to-peer platforms, i.e. for sharing of charging equipment, and tools involving gamification, appears to remain marginal.

Mapping app functionalities against potential adaptations in driver routines and practices [8.4] highlights the possibilities for interventions and incentives to better-optimise vehicle charging habits, balance energy demand and integrate energy storage technologies, i.e. by automating and personalising more information provision and functionalities, as well as to prompt different modal choices and wider changes in transport behaviour.

Yet while these developments 2015-2018 as audited in terms of new products, services and functionalities have a potential impact on EV usage and the behaviour and specific practices of electric vehicle owners, as indicated by the model [*fig 8.i*], the follow-up interviewing suggested that the fundamental issues as explored in this research have not yet changed – and are unlikely to do so until many more longer-range EVs, and EVs with more sophisticated communications systems, are widely available to the general consumer. As such, the hypotheses [H1, H2, H3] remain supported while electric vehicle ownership and usage still remains within the realm of the innovators and early-adopters. The role of digital media in scaling up beyond this point must now be considered in the context of the electromobility transition and addressing of hypothesis [H4]:

- **[H4]** Digital media and communications technologies are a potential linkage in the transition of electromobility from a niche activity to a mainstream regime and the reconfiguration of a new mobility paradigm.

Chapter 9 **Concluding discussion**

9.1 Overview

As intended in the original objectives [1.1] this research has explored, analysed and explained the role of digital media in supporting electric vehicle usage and operation. The analysis and discussion have tackled issues and topics which were identified as under-represented in the literature [1.5] – namely, the identification of distinct spatio-temporal elements of EV ownership and operation, and how these are negotiated; the engagement of EV drivers with sources of information and data external to their vehicle; their engagement with communications technologies such as smartphone or tablet apps; and their EV-related social media activities, including involvement in crowd-sourced and peer-to-peer platforms. Drivers' usage or ownership of other sustainable-energy products, and non-driving transport habits or practices, were also considered with reference to their digital media engagement. The research was guided and structured using the theoretical framework of the Multi-Level Perspective (MLP) on socio-technical transitions [Chapter 2] which provided an effective terminology and model for analysing and discussing the findings; and a methodology was chosen [Chapter 3] to incorporate both quantitative assessment and rich qualitative detail.

The initial analysis of the data collected [Chapter 4] yielded valuable demographic background and case study context, also describing participants' motivations, behaviour, practices and habits around their ownership and use of EVs; this gave initial support to the hypothesis [H1] that spatio-temporal adaptations were implicated. This was explored further [Chapter 5], where the Typology of Electric Vehicle Driving [*Appendix vi*] synthesised the qualitative detail to describe and contextualise driver activities, further supporting hypothesis [H1] and indicating agreement with [H2] and [H3] on the importance of digital media and social media respectively to give assistance and support to drivers. These hypotheses were additionally supported by data correlations [Chapter 6] which in turn informed the segmentation and creation of personas [Chapter 7]; these added extra nuance and insight; highlighted characteristic and behavioural differences both between user groups and within them; and informed the model [7.6] for recommending appropriate digital tools by user segment.

Validation exercises [Chapter 8] defended the ongoing relevance and applicability of questions and topics; and enabled discussion of the research findings with reference to developments in available products, services, infrastructure and digital tools, which were audited. Another model [8.4] was created mapping the potential intervening impact of these upon driver behaviour. This has fed into and influenced the concluding discussion and addressing of the final hypothesis [H4] in this chapter, where the role of digital media in the electromobility transition is addressed.

The MLP is applied first to construct a model of niche activities, drawing out where the actions and practices of the drivers – as actors within the niche – interface with the regime and landscape players, or could do, given the upcoming new products or services identified [Chapter 8]. This supplements an assessment of the progress of the electromobility transition, and the pathway it is taking; and leads to the conclusion that hypothesis [H4] is only partially supported, since the transition has not yet gathered progress beyond an early stage of ICE-EV technological substitution; reconfiguration of the mobility regime is still a long way off; and digital media is neither a sole solution nor a sufficiently strong co-evolving linkage between levels to overcome other socio-technical barriers which remain.

However, recommendations can be made as to the potential role digital media could continue to play in scaling-up and accelerating the transition, as well as for further research in this area.

9.2 Electromobility in transition: MLP analysis

9.2.1 Creation of niche activities model

To draw out and better understand how the digital media-related practices, behaviour and actions of the drivers – niche actors – might correlate to and interface with the levels of the MLP, a table [below] was drawn up to summarise key activities as identified in this research and the digital tools or services drivers could deploy, with reference to whether these were largely acting (or would in future take place) within the niche of electromobility innovation; as a result of, or involving, direct interaction with regime-level actors; or with landscape-level actors. The focus is on the driver-level tools or functionalities, since users play a critical role in this particular low-carbon transition (Daramy-Williams et al., 2019).

Activities which were mostly personal or domestic, or involving interaction with other niche actors, were classed as 'within niche'; but, for example, utilising services or tools as supplied by a regime-level provider or OEM were 'niche-regime' interactions. The niche activities were considered in three themed areas, a strategy inspired by mobility cultures research (i.e. Hopkins, 2015; Hopkins and Stephenson, 2014), as introduced [2.7] as a means to extract and represent discrete types of behaviour between elements within the MLP. In this case, the three themes were determined to be energy and recharging (indicating interaction with infrastructure external to an individual vehicle); engagement with personal vehicle (indicating individual operational practices); and EV community involvement, engagement and activism (indicating individuals' interactions with other EV drivers and actors in the wider electromobility system).

Within these areas, the potential role of digital media was proposed in relation to each activity or practice, as reported in the research interviews with individual drivers and as outlined in the typology [Chapter 5]. An additional element was then added with reference to the technology audits [Chapter 8], and new products, services and functionalities which have since become available, or which will soon be available, to consumers.

table 9.i: Niche activities with reference to role of digital media & interaction levels within the MLP

Energy and recharging	**Potential role of app or digital interface**	**Level, interaction**
'Refuelling' (charging) at home	Scheduling/activating via app/digital interface	Within niche
Charging at other private locations, i.e. workplaces, others' houses	Arrangement/reservation via social media or sharing/peer-to-peer app	Within niche
Charging at unconventional locations, i.e. sports clubs, leisure destinations	Location of/access to facilities + payment; checking charger status/type/availability	Within niche
Charging with electricity from own PV/ similar; smart home energy management	Digitally activated/controlled or optimised; AI enhancements	Within niche
Engagement with home energy storage, vehicle-to-grid, smart home energy management	Digitally activated/controlled or optimised; AI enhancements	Within niche; niche-regime
Charging at established service station locations	Chargers located, accessed or paid for by app/digital interface; checking of charger status/type/availability	Niche-regime
Charging at facilities provided by local authorities; or national/international service operators	Chargers located, accessed or paid for by app/digital interface; checking of charger status/type/availability	Niche-regime
Communicating with service providers, i.e. for remote resetting of inoperable charger	Automated contact in place of phone helpline, i.e. chatbot	Niche-regime
Payment for public charging	PAYG or contactless services; cloud-based management of accounts	Niche-regime

Engagement with personal vehicle	**Potential role of app or digital interface**	**Level, interaction**
Pre-heating/cooling of car, remote checking of charge levels	Remote activation/operation of functions + monitoring systems	Within niche
Journey-planning	Researching mileage, route, availability of charging, time + other variables	Within niche
Planning parking	Reservation, payment for space with charging; + automated valet service	Niche-regime
Use of voice controls/personal assistants/avatars i.e. Amazon Alexa, Siri; third-party infotainment i.e. via Apple CarPlay, Android Auto	Provision of information and media as requested; activation of various functionalities	Niche-regime

Engagement with personal vehicle	Potential role of app or digital interface	Level, interaction
Adapting driving style, journey route or destination to conserve battery range	Monitoring range, dynamic checking/adjustment; AI-informed interventions + recommendations	Within niche; niche-regime
Adapting charging practices/routine according to planned vehicle usage	Checking/setting charge levels + timing; AI-informed interventions	Within niche; niche-regime
Adapting charging, range or route according to weather/temperature	Checking/adjustment with reference to weather/temperature; AI-informed automation + optimisation	Within niche; niche-regime
On-the-fly changes of route/destination i.e. due to charger problems	Dynamic charger location; live alerts, automated routing/re-routing	Niche-regime
Calculating + checking costs of EV usage vs petrol or diesel (energy itself + other i.e. tax, parking, servicing, insurance)	Dynamic per-mile price comparisons; could compare vs other household vehicle/ICE	Niche-regime
Use of third-party apps + maps to plan journeys, locate facilities (from provider i.e. Google, TomTom)	Meeting need not satisfied by in-car information provision i.e. from supplied sat nav	Niche-regime
Maintaining own maps + databases of charging facilities, building own apps/tools	Meeting demand/curiosity not satisfied by products on market	Within niche
Maintaining own spreadsheets or databases of vehicle data i.e. energy efficiency, battery capacity	Logging + visualising data, access to greater output/analysis of technical information	Within niche
Taking advantage of incentives i.e. free parking, toll/congestion charge exemption	Awareness, checking eligibility	Niche-regime
Making multi-modal journeys to avoid public charging/charging downtime	Multi-modal journey-planning + ticketing, parking space reservation	Niche-regime
Following recommendations to conserve range, i.e. slower acceleration, maximising regen braking, turning down air con	Dynamic guidance via OEM-developed in-car interface; AI enhancements	Niche-regime
Using EV-optimised route guidance i.e. for smoother traffic flow, topography	Smarter dynamic routing from key provider i.e. Waze, Here, TomTom	Niche-regime

Community involvement, engagement + activism	Potential role of app or digital interface	Level, interaction
Establishing social protocols, i.e. over unplugging other cars, access to chargers	Communications between drivers, facilitating negotiation	Within niche
Memberships of EV clubs, owners' groups + associations or lobby groups	Online forums, information sources + discussion spaces; social media-based campaigning	Within niche; niche-regime; niche-landscape
Membership of sustainability/eco (non-EV-specific) clubs or groups, i.e. Transition Towns movement, local organisations	Online forums, information sources + discussion spaces; social media-based campaigning	Within niche; niche-regime; niche-landscape
Contributing data/information to crowdsourced + user-generated initiatives i.e. OpenChargeMap, EVStatus	Platform for information- + data-sharing, i.e. reports of charger status, pictures of facilities; discussion	Within niche
Contributing data to crowdsourced + swarm intelligence platforms i.e. on traffic conditions	Commercially-driven platform for information- + data-sharing, potentially automated	Niche-regime
Offering own charging facilities via peer-to-peer 'sharing' app	Platform for participating in sharing of facilities	Within niche

Community involvement, engagement + activism	Potential role of app or digital interface	Level, interaction
Seeking + sharing information on social media i.e. web forums, Twitter, Facebook groups; making videos i.e. YouTube	Dissemination of information + opinion; some entertainment + social activity/validation	Within niche
Lobbying service providers or local authorities for facilities/complaining about problems i.e. ICE-ing	Platform for lobbying, complaints mechanism; utilises momentum of social media for governance	Within niche; niche-regime
Lobbying government, regulators or international bodies (i.e. EU) on policy i.e. financial support, mandates for workplace charging, more public infrastructure	Platform for lobbying, international connections + support; information from other countries/regions	Niche-landscape

The above table both expands upon and validates the models proposed in Chapter 2 [*fig 2.i*] and Chapter 7 [*fig 7.xxv*], adding clearer insight into the positioning of the drivers as niche actors within the MLP. It suggests that a substantial proportion of the interactions are still contained within the niche, with most other activity involving niche-regime interaction; top-down activity still tends to dominate in terms of infrastructure and technology provision, although bottom-up pressure from the niche actors is seen in terms of their community involvement and activism as well as their demands as consumers. On a user level, the role of niche actors in a process of transformation, i.e. as part of lobbying communities, has been described by Meelen et al. (2019). This highlights the importance both of the role of individuals in upscaling a socio-technical transition to more sustainable energy consumption (Hyysalo et al., 2018; Schot et al., 2016); and of the process of collaborations between users and with non-users in challenging existing regimes and practices (Sopjani et al., 2019).

In terms of day-to-day EV operation and ownership (as distinct from factors which may influence purchase or pre-purchase attitudes), interactions with landscape-level actors such as governments or regulators are confined to the realm of community engagement and activism, however. Yet more recent developments in terms of products and services bring more niche-regime and niche-landscape interactions, in contrast to the more ‘DIY’ early-innovator activities such as personal app-building, contributing to open-source initiatives and charging at unconventional locations, which took place largely within the niche. This illustrates how, as the available technologies, services and functionalities develop, involvement is growing of regime-level actors in the electromobility system, whether carmakers, energy providers or large-scale technology firms.

Royal Dutch Shell’s purchase of solar energy storage specialists Sonnen (Shell, 2019) illustrates how such activity has become multi-sector and cross-regime; fuel supplier BP, meanwhile, has invested (via its venture capital division) in PowerShare, a provider of software to manage and optimise energy demand for EV charging (BP, 2019). Nevertheless, new players or niche actors continue to emerge, such as Gridserve, to build 100 solar-fuelled ‘electric forecourts’ with facilities including shops, cafes and airport-style lounges in strategic locations across the UK (Gridserve, 2019).

The above exercise [*table 9.i*] also suggests that as automated or artificial intelligence-based interventions or recommendations become more common in connected vehicles, the potential is for these to communicate and interface with a wider range and variety of regime actors, especially with reference to infrastructural factors; these could include parking providers, city authorities, other transport and mobility modes and retail or commercial opportunities – i.e. as offered through digital ‘concierge’ services – as well as just charging point operators and energy providers. And importantly, a degree of intelligent automation brings the prospect of digitally-integrating consumers and users who would not otherwise engage ‘manually’ with tools such as apps or certain interface functionalities – the otherwise digitally disengaged Group A drivers as described in the segmentation exercise [7.4.1]. They can have the confidence that they will receive alerts, advice or assistance as necessary, i.e. to re-route to a different rapid-charger if one programmed into their sat nav is out of order or occupied, or to help connect to a network’s charging equipment and pay; meanwhile, the more digitally adept Groups B [7.4.2] and C [7.4.3] could appreciate a lessened need for pre-planning of journeys, feel more confident about venturing further into unknown territories, and welcome new functionalities and gadgets to ‘play’ with – another consumer attraction.

Automation of such personalised information would have relevance to vehicle charging within a smartgrid network to optimise renewable electricity resources, for example; or for more accurate battery range forecasts, automatic routing to suitable charging facilities, or automated vehicle identification (for compatibility), network access and service payments. Indeed, smart systems including automation are seen as crucial to managing demand on the electricity network, as vehicle charging must be shifted away from peaks (Ofgem, 2018) and co-ordinated (Muratori, 2018); and automated driving functionalities can enable more flexible and adaptive system control (Tsakalidis and Thiel, 2018). Households have indicated that they are willing to be flexible about when they charge an electric vehicle (Sharp et al., 2019), but want more information about costs and tariffs and have expressed concern about reliance on smartphone apps for smart-charging (*ibid*.), stressing the need for a variety of solutions if it is to be widely adopted (*ibid*.).

Similarly, cloud-based payment, access and account management systems facilitate platforms for on-demand services beyond vehicle charging, and the integration of smart home or personal assistant technologies becoming familiar from outside the vehicle, such as Amazon Alexa or

Apple's Siri, add a further element to multi-way interactions and data exchanges – as well as bringing further potential revenue streams for service providers.

The simple and deliberately imprecise graphic [*fig 9.i*] depicts the relationships as suggested by the above table: niche interactions with landscape-level actors are seen as being more general influences on the zeitgeist, given the focus here on day-to-day driver practices and activities involving digital media engagement, but there are interlinked spheres of activity both within the niche and at regime level as distinct fields relevant to electromobility.

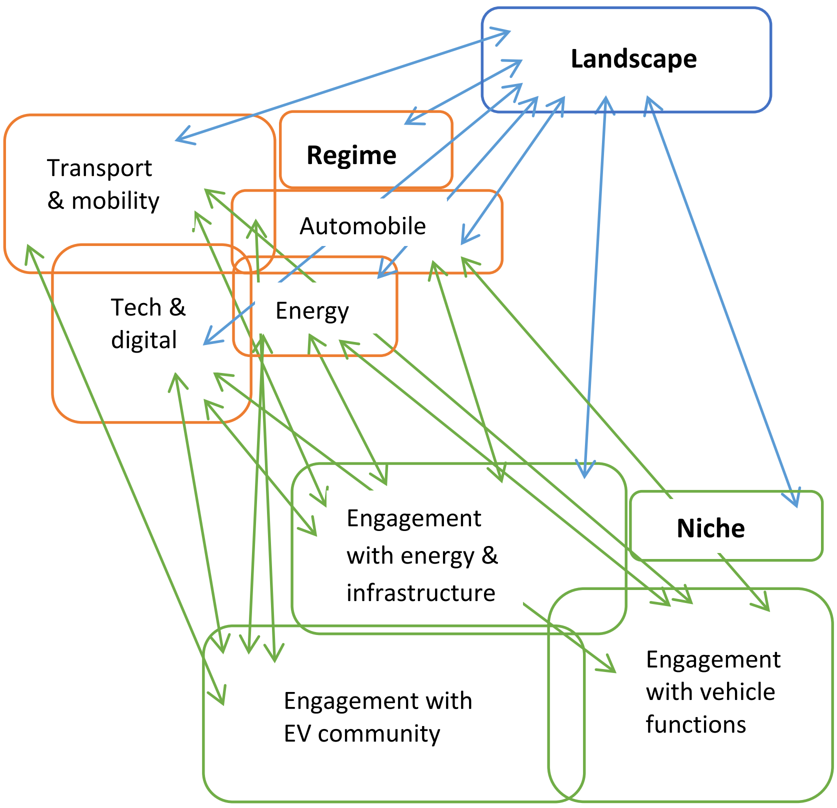

fig 9.i: Niche activities model: user practices with reference to regime and landscape

The landscape level does, however, exert particular influence on regime actors, particularly in terms of legislation and setting of national or international incentives for industries, authorities and businesses; to some extent, landscape pressures have been favourable (Berkeley et al., 2017). Both national and local policies, in turn, are thought to have a direct effect on both uptake of electric vehicles and everyday charging behaviour (i.e. Wolbertus et al., 2018). These relationships – to some extent two-way, given the power of large regime-level industry players (such as the German carmakers) to resist landscape-level policy changes, or to force delays and amendments, for example – all attest to the claim that electromobility is moving beyond a self-limiting niche experiment. As such, this indicates the potential for scaling up, and that a transition is underway, albeit still in its early stages.

9.2.2 Progress and pathways of the electromobility transition

The above conclusion corresponds with other MLP-based analyses of the progress of the electromobility transition. Summarising research thus far, Berkeley et al. (2017) argue that more significant disruption of the regime is needed for a transition to happen and point out that there are spatial variations in protected niche space; they see mass-market adoption of EVs as still a long way off; and recommend more support at niche level. Tsakalidis and Thiel (2018) suggest that the shift is gaining momentum and that EV take-up is growing, but more research and development, and more supportive policies, are needed. Figenbaum (2017) describes the strong background of niche experimentation in Norway and the role of governance and policy in accelerating the transition, underlining the importance of keeping windows of opportunity open; but claims true breakthrough is only possible when mainstream OEMs are involved and the EV regime becomes assimilated into the ICE (fossil-fuel) regime.

Köhler et al. (2018) argue, meanwhile, that while there is empirical evidence to support an initial stage of electric vehicle adoption, this is only technological substitution as yet, and not part of a transition in wider mobility lifestyles (*ibid*.): to achieve a reconfiguration, more major changes in culture and behaviour, and infrastructural support, will be needed (*ibid*.). Their analysis raises the importance of studying and understanding the main types of transition pathway as defined by Geels and Schot (2007), as outlined [2.3]. The findings in this research support the above contention that technological substitution is underway – not only in the replacement of private ICE vehicles with electric by individual consumers, but in the growing appearance of charging facilities on fuel station forecourts, for example – but that de-alignment and re-alignment, when a regime disintegrates and re-forms in a new relationship with niche actors, has not yet occurred.

A small degree of transformation has been observed, nonetheless, with regime actors modifying their activities as a result of landscape pressures. The Volkswagen Group's recent announcement of an "electric offensive" and the launch of nearly 70 new electric models by 2028 (volkswagen-newsroom.com, 2019b) is just one high-profile example of a – proclaimed – change in focus and industrial investment, although to put this in context, the projected 100,000 units a year it intends to build of its first all-new model, the Volkswagen ID.3 hatchback (volkswagen-newsroom.com, 2019a) will remain a tiny proportion of its annual global output – 6.2million cars for the Volkswagen brand alone in 2018 (Volkswagen AG, 2019a) and 10.83 million across all the Group's brands (Volkswagen AG, 2019b); and even by 2040, EVs are only projected to take up just over half of all global car sales (McKerracher, 2019).

Ford, meanwhile, has made a $500 million investment in EV start-up Rivian, in order to co-develop and build next-generation electric pick-up trucks on Rivian's chassis and technology platform (Ford Media Center, 2019) – an example of the regime absorbing niche innovations. There are also promising signs that niche innovations from other sectors are being adopted within the automobility regime as supplementary or complementary technologies, such as new and upcoming products and services leveraging vehicle-to-grid energy flow and communications, as described in the technology audits [Chapter 8]. Potential for reconfiguration within the regime itself is shown again by co-option of and collaboration with niche players; Honda's investments in UK-based Moixa, whose AI-informed GridShare technology aggregates energy storage across home and vehicle batteries for grid-balancing (Moixa.com, 2019), and in charging equipment-maker Ubitricity (hondanews.eu, 2019b) are an example of such developments. However, challenges remain for the diffusion of vehicle-to-grid technologies, including consumer awareness and battery degradation (Kester et al., 2018), and different implementations of technical standards in different socio-technical or institutional contexts (Kester et al., 2019).

Further showing transformation within the automotive regime, carmakers are even starting to offer energy supply services themselves: for example, through its new subsidiary Elli Group GmbH, Volkswagen Group is now selling electricity from wind, solar and hydro power in Germany (Volkswagen AG, 2019c), although it is also pursuing more conventional partnerships such as its tie-up with Pod Point to put chargers on Tesco fuel forecourts in the UK (Tesco plc, 2018) – and collaborating with BMW, Daimler and Ford in the IONITY joint venture to develop a rapid-charger network across mainland Europe (Volkswagen AG, 2019d), effectively demonstrating how carmakers are diversifying into infrastructure-building.

It remains unclear, however, whether the electromobility transition is following a 'fit-transform' or 'fit-stretch' reconfiguration pathway (Meelen et al., 2019), 'fit-stretch' indicating incremental introductions or accommodations within a regime which then 'stretch' its parameters (Geels and Kemp, 2012) rather than achieving a more substantial transformation. This would involve electric vehicles taking on a wider range of functionalities beyond fuel-type substitution; not just playing a more widespread role in grid-balancing, but by becoming better-integrated into the wider transport and mobility regime. Proposals to launch and expand on-demand shared fleets continue and consolidate, i.e. BMW's joint mobility services investment with Daimler AG (Daimler, 2019), but despite trials by many of the world's carmakers, EV-sharing is still a long way from gaining traction as a mainstream alternative to private vehicle ownership, although affinities for EVs and car-sharing are closely connected (Burghard and Dütschke, 2019); and experience of car-sharing is positively associated with EV acceptance (Schlüter and Weyer, 2019), giving encouraging implications for mobility regime change (*ibid*.). The risk also continues of unintended consequences, such as households buying EVs additional to their ICE cars, and driving more, as reported in this research and by Bauer (2018) and Axsen et al. (2018).

To further understand the transition pathways electromobility might take, a wider range or combination of models, including societal frames, may capture more aspects and factors (Sovacool, 2017; Sovacool and Axsen, 2018) and 'see' different user perception categories (Axsen and Sovacool, 2019); and more focus may be needed on societal embedding, including user contexts and cultural meanings (Kanger et al., 2018), to see how EV adoption can move beyond substitution (*ibid*.). With regard to transitions in general, a modular approach is useful to supplement the socio-technical aspects in the MLP (Geels and Johnson, 2018) and Geels et al. (2017) remind that there is a multiplicity of factors driving a transition, including the stimulation of learning and experimentation.

As such, the supplementary theoretical influences taken in this research to form the Typology [Chapter 5] and niche activities model [*fig 9.i*] have added extra detail with reference to the individual niche actors – and their behaviour as technology users. This describes further the role of digital media as a supplementary technology co-evolving alongside the electric vehicles themselves, and whether it is playing a role in defining and influencing the transition pathway. Hypothesis [H4] can now be addressed:

- **[H4]** Digital media and communications technologies are a potential linkage in the transition of electromobility from a niche activity to a mainstream regime, and in the configuration of a new mobility paradigm.

9.3 The role of digital media as a linkage in the electromobility transition

Digital media has been shown to be important and useful to the early-innovator electric vehicle drivers, facilitating their uptake and operation of their cars in the early 'shakedown' stages of this niche experiment, both with regard to driving (i.e. in familiarising themselves with their cars' limited range and how to optimise it) and to recharging (whether locating public facilities or timing/scheduling their home charging). There are indications that digital media engagement is implicated in behavioural changes, including adaptations to practices, habits and lifestyle routines; and that it could play a further role in encouraging and facilitating adoption of new sustainability-related technologies and functionalities such as vehicle-to-grid integration; social media too has been seen to aid the early-innovators, and sufficient and substantial evidence has been found to support hypotheses [H1-H3] as introduced [2.8.2].

However, in considering hypothesis [H4], engagement with digital media was found to be by no means universal, with a substantial minority proportion (segmented as Group A) declaring that they did not find it useful or of interest to them as an electric vehicle driver; this suggests that it is not crucial at the user level. Other factors are clearly implicated in digital media engagement, too. For example, using digital tools specifically to save money, i.e. by scheduling or remotely activating vehicle charging to synch with home solar power generation, or simply to find free-to-use public charging points, has been described by many of the participants in this research. EV drivers have also been seen to engage and change their behaviour the most when offered digitally-monitored dynamic energy pricing models (Octopus Energy, 2018); and EV drivers are thought to be more willing than other consumers to switch to smart time-of-use tariffs (Nicolson et al., 2017): all this suggests a strong financial incentive to engage with digital tools, as expected given that money-saving has been shown to be a leading motivating factor in buying and driving an EV in the first place. Yet design of interfaces is entwined into digital engagement as well, and has been found to be more important than payment to get people to participate in vehicle-to-grid (Geske and Schumann, 2018).

This highlights that digital media does not serve in a vacuum or act as a sole solution: it is just one of many contributory and complementary factors which may be linking niche and regime activities to push the transition – or one of the 'little things' that help to reach a tipping point (Gladwell, 2000) – and might not even have an effect beyond helping initial awareness and acclimatisation. Recent research with carbon calculators has found no long-term behavioural changes and that app-based interventions do not actually lead to long-term electricity savings (Wemyss et al., 2019), with socio-technical and psychological barriers persisting (Buchs et al., 2018) – and this may be true too for EV adoption.

Ultimately, such barriers to uptake need to be addressed for the electromobility transition to be successful. Further to factors described earlier [1.3.1], remaining concerns or dissonances include a poor choice and availability of different EV body types (Mohamed et al., 2018) and ongoing tensions between price and perceived desirability or status (Jones, 2018); even an affectual divide between manufacturers' communications and the experience or attitudes of consumers (Kershaw et al., 2018) has been suggested. Yet the long-established issues of vehicle range, home charging availability and vehicle price persist and must be tackled if more drivers are to be converted (Cecere et al., 2018; ACEA, 2018). Even range is, in most cases, still a long way off the 300 miles thought necessary for EVs to appeal to 90% of mainstream consumers (Beard et al., 2019).

Digital media in itself, while important and attractive to younger consumers, is also no substitute for reliable, convenient and accessible charging infrastructure – nor a mitigating factor against poor and inadequate vehicle battery range (whether perceived or actual), incompatibility and lack of common standards for charging equipment, or the rapid obsolescence of many products or services (i.e. vehicles such as the Vauxhall Ampera). It is also not sufficient to tackle unfavourable or poorly thought-out landscape-level policies and political attitudes – dynamic policy mixes and looking beyond supply-side issues are germane to stimulating a transition in general (Geels et al., 2017), alongside "actively managing phase-outs in addition to stimulating innovation" (*ibid.,* p.463) – an important point given the continuing dominance of ICE vehicles.

Hypothesis [H4] is therefore only partially or weakly supported. Digital media and communications technologies are certainly playing a notable role in the transition of electromobility from a niche activity to a mainstream regime, which can be described as linking these levels. However, that role is, as yet, limited since the deployment of digital media is neither crucial or universal among individual drivers, and other, arguably more significant, barriers to the transition persist. Furthermore, the configuration of a new mobility paradigm remains at a theoretical stage with few quantified indicators that the electromobility transition is progressing on a pathway beyond technological substitution within the early-innovation niche. An optimistic interpretation would be to support the hypothesis [H4] but with the caveat of emphasising the word "*potential*" with respect to the implied linkage.

9.4 Scaling up the transition

Valuable knowledge has been gained nonetheless, and on the basis of the findings of this research and the understanding gained through the analysis using the MLP framework, three insights are outlined to inform the acceleration or scaling-up of the transition. These are in addition to the models already outlined [7.6; 8.4] for digital tools, their recommended application by user segment and potential behavioural interventions, with reference to the wider electromobility system beyond the niche actors.

1. Firstly, it has become clear that more regime action in general is needed to push forward the transition; niche experiments alone will be in no way sufficient. With specific reference to digital media, while this may not be critical at the user level, it is crucial for it to be at least offered and supplied by the regime, both to underpin the consumer offering in terms of user experience, and to later incorporate new functionalities such as vehicle-to-grid, car-to-infrastructure communications and networked services. While grassroots innovators and start-ups may offer creative solutions, digital tools supplied by regime actors (i.e. known and established brand-

names) imply a higher degree of trustworthiness and accountability, attractive to mainstream consumers. The technology audit [Chapter 8] shows that advances have been made in this area, although these tools are yet to be implemented or deployed on a large scale until a new generation of connected electric vehicles comes to market in significant numbers.

2. Secondly, the transition could accelerate more rapidly if automated or AI-informed information provision and service functionalities can be integrated into vehicle interfaces, as the models [7.6; 8.4], technology audit [8.3.5] and understanding of digitally-facilitated activities at niche (user) level [*table 9.i*] illustrate, rather than manufacturers and service providers expecting or assuming that individual drivers will seek such information or personally choose to engage with digital tools. Added incrementally, automated functions and interventions could bring considerably more ‘stretch’ to the ‘fit-stretch’ transition pathway, subsequently resulting in earlier or more profound transformation.

3. Thirdly, at all levels of connectivity, while there is user demand for quite sophisticated levels of knowledge and data related to their vehicles, it must be accessed, presented and displayed with appropriate simplicity. The observed third-party apps claiming to offer simpler, more stripped-down alternatives to an OEM’s offering [8.3.5] are testament to this. Obviously, this has particular pertinence for vehicle designers, but also for service and UX/UI designers developing interfaces and apps for charging equipment and other infrastructural elements. Greater collaboration with third-party developers and actors within the digital technology regime is important here: given that even the most digitally-disengaged were observed to be happy to use online tools such as Google Maps, there is a distinct role for familiar (non-automotive) interfaces, and the added advantage is that these can be provided in-car either by smartphone mirroring or platforms such as Apple CarPlay or Android Auto – easily updated and more future-proof than proprietary OEM systems. However, their integration into in-dash screens, for example, must be carefully managed and designed at OEM level: again, the role of regime-level actors is emphasised.

9.5 Recommendations for further research

Going forward, it cannot be assumed that future EV buyers and those not yet tempted to switch from an ICE vehicle will share traits and behave in the same way, nor show a similar willingness to adapt or modify their behaviour and household routines as the early-innovators studied in this research. This has been also noted by researchers including Axsen et al. (2018), pointing out that the early ‘pioneers’ are not necessarily representative of the wider motoring population; hence the needs of the mass-market must be differentiated (Beard et al., 2018) and more research is necessary with mainstream consumers (Daramy-Williams et al., 2019). Additional insight is needed both into how newcomers to EV usage might behave in ways general to EV adoption, and specific to their use of digital media. However, characteristics of early-innovators appear to be consistent across some different technologies and innovations, i.e. in their perception of EVs and shared or automated mobility (Axsen and Sovacool, 2019), which has implications both for adoption of technologies associated with electromobility (i.e. household energy storage) and encouraging behavioural changes, and such similarities – or differences – are again an issue worthy of further exploration.

Spatial factors in technology take-up are also important to understand; Meelen et al. (2019a) cite spatial heterogeneity between the levels of the MLP and the need for geographical analysis; and demand for EVs is clustered and location-specific (Morton et al., 2018). Differing spatial diffusion patterns for consumer adoption of EVs and PV (photovoltaic) technology (van der Kam et al., 2018) give particular implications for V2G integration and smart-grid management as well.

More areas of interest and alternative lenses through which to view EV take-up include lifestyle factors (Axsen et al., 2018); life events are believed to have an impact on car-share and peer-to-peer transport uptake (Uteng et al., 2019) and taking a life-oriented approach (as described by Zhang and Van Acker, 2017, with reference to travel behaviour) could be rewarding in terms of a deeper understanding of EV usage and decision-making across different demographic groups. Drivers' engagement with in-vehicle technology is generally thought to vary by age, gender and type of technology (Parnell et al., 2018) although opinion in the tech sector varies – "ability, aptitude, and attitude" are much more accurate predictors of behaviour than age, argues Spool (2018) – and this topic is provocative. Older drivers were well-represented in this research and showed considerable variation in their digital skills and levels of interest, supporting this idea that they are not necessarily technically disadvantaged, but may have different motivations (or lack thereof) to engage with digital technologies than younger cohorts.

Gamification is being seriously considered and studied as a way to drive engagement with V2G (i.e. Ecotricity, 2018), and BMW has launched an app called BMW Points, to encourage drivers of its PHEV models to run on electric power in geo-fenced 'eDrive Zones' (BMW Group, 2019b); the outcomes of such incentivisation merit further investigation, as does more research into how purchase motivations affect ongoing energy-related behaviour; unsurprisingly, so far the eco-motivated are thought to be more consistent in their sustainable behaviour than those getting an EV for financial or technological reasons (Peters et al., 2018), but this could well change as EVs become more mainstream choices. More behavioural analysis will also help develop a strategy for infrastructure; lessons have already been learned over siting of rapid-chargers (Nicholas and Hall, 2018), but there is a need to better understand how demand for these may change or develop as both EV numbers and their battery ranges grow, and as more drivers without home charging facilities enter – or wish to enter – into electric vehicle ownership.

With regard to methodology and representation of the data, the insights from the typology are fruitful in their own right, but such an exercise can serve as a framework on which to map and validate or illustrate empirical data on the same themes; as Ben-Elia et al. (2018) suggest, qualitative research gives necessary depth to partner quantitative work on ICT and travel behaviour. Having identified spatio-temporal themes, the Typology of Electric Vehicle Driving could well-complement analysis of data such as trip diaries or studies of vehicle utilisation (i.e. Mattioli et al., 2019) to model where and when vehicles might be charged; or EV demand, deployment and charging needs in shared fleets. The typology could be used to inform subsequent analysis, i.e. of the different activities or practices of segmented EV user groups; or to generate hypotheses for further research. Such hypotheses could focus more sharply on, for example, lifestyle changes or adaptations to household routines; or drivers' interactions and interfaces with recharging infrastructure, an important theme with reference to future vehicle-to-grid communication, energy demand and integration of renewable-source electricity. The typology also suggests an alternative psychogeography and affective mapping for electric vehicle driving – an area of interest for further informing knowledge of automotive consumer behaviour.

While not all these topics might appear immediately relevant and pertinent to the digital media element, ultimately, all of these factors are (or will be) connected and linked, and not just in electromobility: to paraphrase Shove and Trentmann (2018), infrastructures and daily life are entwined, inseparable and interdependent in the modern networked society in relation to energy demand and consumption behaviour – and in moving to a more sustainable future.

9.6 Conclusion

In investigating and analysing the role of digital media in the electromobility transition – where it has been shown to play an important and significant part in supporting the early stages of technological substitution, if not as yet a more substantial reconfiguration of the mobility regime – this research has contributed to an understanding both of factors and topics directly related to electromobility and electric vehicle uptake or operation, and of themes with relevance to technology adoption scenarios and socio-technical sustainability transitions in general.

Real-life lived experience has been reflected and analysed in detail, both quantitatively and qualitatively, giving insight into the behaviour of consumers and individuals who were not participants in formal, managed electric vehicle trials. Appropriate recommendations have been made for stakeholders at different levels of the electromobility system based on this understanding, which could inform development of future products, services, and infrastructural or legislative support. This research has also contributed to the knowledge of niche-level behaviour and the role of niche actors in a socio-technical transition, with the possibility to draw further inferences relevant to other sustainability-related technology adoption scenarios involving behaviour change, lifestyle adaptations and engagement with digital technologies.

9.7 Presentations and publications

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- Alkhalisi, A.F., and Waterson, B.J., 2018. **Digital media: a pathway technology in the electromobility transition?** Conference paper, available via https://pure.soton.ac.uk or http://utsg.net/archives/2018-ucl
- Alkhalisi, A.F., 2020. **Creating a qualitative typology of electric vehicle driving: EV journey-making mapped in a chronological framework.** Transportation Research Part F: Traffic Psychology and Behaviour. Vol. 169, pp. 159-186. https://doi.org/10.1016/j.trf.2020.01.009

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Appendix i: Interview schedule

A (To get an outline of basic demographic details and motivations)

1. Some background, please – (age-group, gender, occupation, location of respondent, rural/suburban/urban)

2. What electric vehicle do you drive?

3. How long have you been driving an EV? (and any idea of total mileage covered in it?)

4. Do you have another vehicle in your household or that you can use?

5. What's your typical weekly mileage and type of usage, i.e. mainly commuting to work?

6. Why did you *initially* decide to buy or drive an electric vehicle?

7. Have your reasons for driving an EV changed since then? Are there new or different aspects of driving an EV that have now become important to you?

8. Please indicate how you feel about this statement: "I am happy and satisfied with my overall electric vehicle experience so far"

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree

B (To learn about vehicle charging routines and behaviour, perceptions of the charging infrastructure, some personal narrative)

9. Where do you mostly charge your EV? (and if you have used the public infrastructure, which types of chargers, i.e. slow-chargers in public car parks, the Ecotricity fast-chargers? Do you have particular chargers you regularly use?)

10. What do you think about the current UK national recharging infrastructure? Is it adequate for *your* needs?
10a. (if yes) Tell me why this is…
10b. (if no) Where would *you* benefit from or like to see more recharging opportunities? Or which types of chargers?

11a.(for EV) Have you ever run out of battery charge or been unable to recharge when out and about, and if so, how did you deal with this?

11b. (for RE-EV) Have you ever faced difficulties with recharging and your all-electric range, or run out of battery power and petrol completely? If so, how did you deal with this?

12. Please indicate how you feel about this statement: “I find the UK’s national public EV recharging infrastructure adequate”

12a. For you personally:

1. Strongly disagree	2. Disagree	3. Neither agree or disagree	4. Agree	5. Strongly agree

12b. For all current EV drivers or those thinking about driving an EV in the near future?

1. Strongly disagree	2. Disagree	3. Neither agree or disagree	4. Agree	5. Strongly agree

13. Has your journey planning changed since you’ve been driving an EV, compared to when you were in an ICE car? (and how about your driving style?)
13a. (if no) Tell me more?
13b. (if yes) Tell me more? Do you feel you have to think more carefully where or how far you drive, or change your route, for example? Or plan beforehand to ensure you will have enough battery charge?

14. Please indicate how you feel about this statement: “Since starting to drive an electric vehicle, I have had to adapt the way that I plan my journeys”

1. Strongly disagree	2. Disagree	3. Neither agree or disagree	4. Agree	5. Strongly agree

C (To focus in on digital behaviour)

15. Do you use (or have you used) any websites or smartphone/tablet/in-car apps to locate charging facilities, or to schedule charging, remotely monitor your car’s state of charge, route optimisation etc., i.e. Nissan’s Carwings, Leafspy, Polar Instant, mapping from your local network provider or websites such as Zap-Map? Apps such as ChargeBump for communicating with other EV drivers? Any open-source databases, i.e. OpenChargeMap, or resources such as Plugsurfing?
15a. (if no) Can you tell me why these aren’t of interest to you?

15b. (if yes) Are such tools of practical use and assistance to you in journey-planning and managing your vehicle's range and charging? Can you tell me more? What are the best/most useful apps you've used?

16. Do you participate in any EV web forums, discussion groups or Facebook pages, identify as an EV driver on Twitter or use hashtags such as #ukcharge, for example?
16a. (if no) Can you tell me why this isn't of interest to you?
16b. (if yes) What benefits do you get from this?

17. Do you use any other transport-related apps, such as those for train timetables, hailing taxis, cycling routes, booking car-share vehicles? Any other energy-saving or carbon-saving apps or calculators? (if yes) Which ones? Can you tell me more?

18. Please indicate how you feel about this statement: "I find apps and digital resources important and of interest to me as an electric vehicle driver"

1. Strongly disagree	2. Disagree	3. Neither agree or disagree	4. Agree	5. Strongly agree

19. Please indicate how you feel about this statement: "I find social media important and of interest to me as an electric vehicle driver"

1. Strongly disagree	2. Disagree	3. Neither agree or disagree	4. Agree	5. Strongly agree

20. Do you have any further comments and suggestions about tools, information sources or other things which could either make your life easier as an EV driver, or that you think would encourage more people to drive EVs? (What sort of info would you like to be able to access, and how?)

Appendix ii: Group email to recruit interviewees

From: Rob Hull
Sent: Friday, July 31, 2015 12:17:50 PM (UTC) Dublin, Edinburgh, Lisbon, London
Cc: Alkhalisi A.F.
Subject: Electric car research

Hello,

Thank you for your feedback on your electric car in the 2015 Which? Cars Survey, and for indicating that you would be prepared to provide further information on your experiences with your vehicle.
As an electric car driver you are still very much a motoring minority, and as such researchers are very keen to hear from you.

One of our regular Which? Cars freelance contributors, Farah Alkhalisi, is currently undertaking an independent PhD research project in the Transportation Research Group, Southampton University. She is looking for electric vehicle drivers willing to be interviewed about their battery-charging and journey-planning. These interviews (by phone or Skype) take 20-30 minutes and would be anonymous (meaning that any comments you might make, would not be attributable to you personally, and the research would be written up in a way so that no one individual could be identified).

If you would like to take part in this research and share your experiences of living with your electric vehicle, please contact Farah at F.Alkhalisi@southampton.ac.uk

More details about this research can also be found at Farah's personal blog:
https://drivingtothefuture.wordpress.com/electric-vehicle-drivers-im-looking-for-interviewees/

This is not a Which?-affiliated or sponsored project; it is for academic publication only, and data and personal information will not be shared between the two pieces of research. Participation in this further research is therefore voluntary.

Regards

Rob

--

Rob Hull

Senior Researcher

Which?

Appendix iii: Participant information sheet

Participant Information Sheet

Study Title: Electric vehicle drivers and their use of digital media

Researcher: Farah Alkhalisi **Ethics number**: 10640

Please read this information carefully before deciding to take part in this research. If you are happy to participate you will be asked to sign a consent form.

What is the research for?

This research project is about driving, owning or operating electric vehicles. I am a PhD candidate in the Transportation Research Group (TRG), in the Faculty of Engineering and the Environment, University of Southampton and this research will form the basis of my doctoral thesis. This research is not for, nor sponsored by, a car company, energy supplier or any other commercial entity.

Why have I been chosen?

You have been approached as a driver, owner or operator of an electric vehicle. Your participation is appreciated and will contribute to an understanding of the future for electric vehicles and electromobility in the UK.

What will taking part involve?

Participants will be interviewed once, either in person or via telephone or Skype, with the questions and related conversation to take an estimated 20-30 minutes. The interview will be audio-recorded and then transcribed.

A small number of volunteer participants will be appreciated for follow-up interviewing at a later date to talk about how their experience of electric vehicles may have changed over time.

Will my participation be confidential?

Your personal details will remain confidential and you will not be quoted by name or identifying details in any submitted or published research, reports, journal papers or presentations.

Name of participant (print name)…………………………………………………

Signature of participant……………………………………………………………..

Date………………………………………………………………………………………

Appendix iv: Consent form

CONSENT FORM (*27/02/15 v1*)

Study title: Electric vehicle drivers and their use of digital media

Researcher name: Farah Alkhalisi
Study reference:
Ethics reference: 10640

Please initial the box(es) if you agree with the statement(s):

I have read and understood the information sheet (27/02/15 v1) and have had the opportunity to ask questions about the study.

I agree to take part in this research project and agree for my data to be used for the purpose of this study.

I understand that the interview will be audio-recorded and then transcribed (words written down).

I understand my participation is voluntary and I may withdraw at any time without my legal rights being affected.

I would be willing to take part in a similar follow-up interview at a later date and consent to providing contact details.

Data Protection
I understand that information collected about me during my participation in this study will be stored on a password protected computer and that this information will only be used for the purpose of this study. All files containing any personal data will be made anonymous.

Name of participant (print name)..

Signature of participant...

Date...

Appendix v: Data analysis taxonomy

A: Demographic information and motivation

1. Age, gender, occupation, location

a. 0. Unknown 1. 35 or less; 2. 36-50; 3. 51-69; 4. 70+

b. 0. Male; 1. Female

c. 0. Undisclosed; 1. Retired; 2. self-employed/company owner or director; 3. engineer/IT/skilled technical; 4. other professional; 5. Other non-professional; 6. Other

d. 0. Not disclosed/unclear; 1. Rural; 2. Suburban; 3. Urban

2. What electric vehicle do you drive?

a. 0. All-electric; 1. Range-extended electric

b. 0. Undisclosed; 1. Nissan Leaf; 2. BMW i3 Rex; 3. BMW i3 EV; 4. Renault Zoe; 5. Vauxhall Ampera; 6. Tesla Model S; 7. Tesla Roadster; 8. Mitsubishi i-MiEV; 9. Peugeot iOn; 10. Citroen C-Zero; 11. Renault Twizy; 12. Volkswagen e-Up!; 13. Smart Fortwo ed; 14. Renault Fluence; 15. Other

3. How long have you been driving an EV?

0. Undisclosed/unclear; 1. Less than a year; 2. One or two years; 3. Three years or more

4. Do you have another vehicle in your household or that you can use?

0. No; 1. Yes

5. What's your usual weekly mileage and type of usage?

a. 0. Undisclosed/unclear; 1. Always low; 2. Typically low with occasional longer trips; 3. Medium-to-high (200+ miles)

b. 0. Undisclosed; 1. Personal/leisure use; 2. Commuting to workplace; 3. Business/work-related use; 4. In multi-modal journey context; 5. Other

6. Why did you initially decide to buy/drive an electric vehicle?

0. Undisclosed; 1. Fitted lifestyle/needs; 2. Interested in technology; 3. Financial advantages/money-saving; 4. Environmental concerns; 5. Wanted something different; 6.

Image/professional profile; 7. Did/took part in successful trial; 8. Driving ease/experience; 9. Other

7. Have your reasons/motivations changed since; new/different aspects now important?

0. No/as expected; 1. Liked driving experience; 2. More interested in eco/enviro issues; 3. Became more interested in energy-saving; 4. Have changed driving style; 5. Have changed travel behaviour; 6. More engaged with tech; 7. Struck by cost savings; 8. Liking convenience; 9. Other

8. "*I am happy and satisfied with my overall electric vehicle experience so far" [1-5]*

B: Charging routines & behaviour, perceptions/opinions on infrastructure

9. Where do you mostly charge your EV?

a. 0. Undisclosed; 1. Mostly/always at home; 2. Mostly/always public facilities; 3. Combination of private/public; 4. Workplace; 5. Other

b. (Use or have used) – 0. Domestic 13-amp socket; 1. Home wallbox/dedicated charger; 2. Workplace charging; 3. Motorway rapid/fast-chargers; 4. IKEA or other public-access rapid/fast-chargers; 5. On-street slow-chargers; 6. Destination slow-chargers; 7. Dealership facilities or Tesla Superchargers (marque-specific); 8. Other

10a. What do you think about the current UK national recharging infrastructure? Is it adequate for your needs?

a. 0. No; 1. Yes

b. (Would like…) 0. Nothing else needed; 1. More motorway/trunk road rapid-chargers; 2. More destination chargers; 3. More of all types; 4. Reliability/compatibility more a concern; 5. Specific geographical locations; 6. Other/preference not specified

11. Have you ever run out of battery charge/got in a tight spot when out & about?

0. No; 1. Yes

12. *"I find the UK's national public EV recharging infrastructure adequate" [1-5]*

13. Has your journey planning changed since you've been driving an EV?

a. 0. No; 1. Yes

b. 0. No change; 1. Think about range/distance; 2. Think about/change route; 3. Prepare battery-charging; 4. Research charging facilities; 5. Now take other mode of transport/multi-modal journey for some trips; 6. Other

14. "Since starting to drive an electric vehicle, I have had to adapt the way that I plan my journeys" [1-5]

C: Digital behaviour

15. "Do you use or have you used any websites, apps…"

a. 0. No; 1. Used them at first but don't need to now; 2. Only very occasionally/in critical situation; 3. Frequently; 4. Most journeys/feel reliant

b. 0. Never use anything; 1. Websites; 2. Smartphone or tablet apps; 3. Tools for mapping, route-planning, charger locations; 4. Scheduling/monitoring vehicle charge; 5. Remote control of vehicle i.e. pre-heating; 6. In-car and/or charger interfaces; 7. Other

16. Do you participate in any EV web forums, discussion groups, identify as an EV user on Twitter… [social media]?

a. 0. Never; 1. Did at first and/or when planning purchase; 2. Only very occasionally, i.e. when I have a specific question; 3. On a regular basis; 4. Frequently

b. 0. Nothing; 1. General forums i.e. Speak EV; 2. Model-specific forums/platforms; 3. Contributing information/helping others; 4. Advocacy and activism, association membership; 5. Contributing to open-source/crowdsourced data/projects; 6. Building own apps or tools; 7. Blogging, making YouTube videos or similar; 8. Twitter; 9. Only as a reader/observer; 10. Non-digital social activity, i.e. meet-ups; 11. Other/not specified

17. Do you use any other transport-related apps? Energy- or carbon-saving apps? Domestic energy monitors?

0. Nothing; 1. Public/active transport, walking or cycling apps/journey-planning tools; 2. Energy- or carbon-saving apps; 3. Have home domestic energy monitor i.e. Nest or Hive; 4. Don't use digital monitors but keep a close eye on energy consumption via meter/watching bills; 5. Other

18. "I find apps and digital resources important and of interest to me as an electric vehicle driver" [1-5]

19. "I find social media important and of interest to me as an electric vehicle driver" [1-5]

20. [Any other business, other themes raised across all questions]

a. 0. No other energy/eco tech; 1. Have solar panels, wind turbines, ground-source heat pump, rainwater harvesting, or other domestic sustainable tech; 2. Interested in other domestic tech i.e. energy storage; 3. Concerns about grid, supply and demand

b. 0. Never schedule or optimise charging; 1. Charge overnight, i.e. on Economy 7;
2. Coordinate charging with home generation i.e. solar when possible; 3. On renewable tariff or with renewables supplier; 4. Other charge strategy

c. 'Would also like' – 0. Have what they need; 1. Integrated payment/access for public charging; 2. Common standards for charging/connectors; 3. Definitive mapping/databases of chargers; 4. Real-time information on charger reliability/availability; 5. More sophisticated range calculations and routing; 6. More information on battery degradation and health; 7. More detailed data on energy/electricity use/running costs; 8. Communicate with other EV drivers over charger access; 9. Pre-booking charging facilities; 10. Other/more info generally

d. [preferred means of getting information/data] 0. In-car interfaces/integrated into sat nav; 1. Smartphone/tablet apps; 2. Websites for desktop/laptop; 3. Text/SMS or e-mail; 4. Social media; 5. Traditional i.e. physical signage; 6. Other; 7. Not specified

Appendix vi: Typology of Electric Vehicle Driving

The Typology represents qualitative narrative from personal interviews with individual electric vehicle drivers [n=88]. Considerations, choices, decisions, actions, activities and behaviour as reported by the participants in this particular sample have been categorised and synthesised to express specific and discrete elements of electric vehicle journey-making. It is not necessarily a definitive list of all electric vehicle driver behaviour – but could be supplemented and expanded upon in further research.

1 Pre-journey

1.1 Journeys of any length (within or beyond vehicle battery range)

1.1.1 Pre-journey considerations and route planning

Consider mileage to destination, return journey or whole round trip
Consider nature of the journey, i.e. load-carrying needs
Look at paper maps and road atlas
Plot mileage using AA or RAC route planners, Google Maps or similar
Plot mileage using TomTom, Garmin or sat nav in car
Choose the shortest or most direct route to destination
Plan a different route into nearby town or for regular journey to work out most energy-efficient, including at different times of day
Consider whether journey/errand can be combined with another later/next day/at another time
Plot most efficient route between different stops or tasks
Choose and plan 'gentler' route to optimise energy efficiency
Choose and plan route avoiding steep hills, even if it takes longer

Choose to go cross-country to travel at lower speeds, rather than use motorway
Plan around the journey taking longer due to driving more slowly
Plan journey with miles 'in hand' in case of detours, delays or diversions
Check weather forecasts, consider how conditions may affect battery range
Check temperature, consider how this may affect battery range
No pre-planning of journey, known to be well within range (may never go out of car's range anyway)

1.1.2 Determining whether to take EV at all

Choose to take ICE car if journey or round trip is beyond battery range
Choose to take ICE car if journey or round trip is over personal threshold of [psychological] range comfort
Choose to take ICE car rather than EV rather than charge away from home, i.e. to avoid 'hassle'
Choose to take ICE car if no convenient or suitable charging facilities en route or at destination
Choose to take ICE car as no suitable charging facilities within range of home anyway
Choose to take ICE car rather than carry large, expensive charging cable and adaptor
Choose to take ICE car due to time constraints, i.e. prospect of charging stops or downtime
Choose to take (larger) ICE car for load-carrying reasons, i.e. if carrying more than three passengers, luggage, or need to tow trailer

Choose to take other household vehicle (i.e. SUV) if going over rough, bumpy rural roads, i.e. due to low ground clearance of EV, need for off-road ability
Choose to take ICE car due to wanting to drive faster on motorway
Choose to take ICE car if it's very hot/cold and journey or round trip is pushing limits of range (concerns over energy use)
Choose to take EV rather than ICE car on a journey that may involve traffic queues and stop-start driving (i.e. it's more relaxing, more energy-efficient)
Choose to take (small) EV rather than large ICE family car if no need to carry children, pushchairs or large luggage

1.1.3 Determining EV vs other transport modes

Choose to take train or other mode if journey is beyond battery range, full stop
Choose to take train or other transport mode rather than charge away from home
Choose to take train or other transport mode due to lack of convenient charging facilities en route or at destination
Choose to take train or other transport mode due to time constraints, i.e. charging stops and downtime
Choose to make multi-modal journey based on distance and charging availability, i.e. leaving car charging at park-and-ride facility, driving to station
Choose to drive rather than use public transport, if free or advantageous parking for EVs (i.e. at a charging point)
Choose to drive rather than use public transport, if charging offered at destination
Choose to drive rather than use public transport, if journey now cheaper than in petrol/diesel car
Choose to drive rather than use public transport, as now feeling less guilty
Choose to use car for short journey previously done on foot/bicycle, as now feeling less guilty
Choose to use car for short journey previously done on foot/bicycle, as no need to try and save money on petrol/diesel any more

1.1.4 Pre-journey charging

Consider whether a charge is needed before departing on next trip/journey
Check battery charge levels via in-car or charger interface
Check battery charge levels via smartphone or tablet app
Check battery charge levels via iWatch, Pebble, smartwatch app or similar
Decide whether to charge to 80% or 100% overnight or in advance, set charger accordingly
Bear in mind possibility of unexpected extra mileage or detours, charge accordingly
Consider whether to charge at home, or take advantage of free chargers at destination
Consider whether enough range to get to a free charger at destination, or need to charge/top-up at home before leaving
Set charger to charge off-peak or for full charge in time for departure
Reset charge timer if setting out earlier than usual the next day
Rely on automatic charger timing and settings unless outside usual routine
Charge and leave journey till next day/later in the day, if journey not urgent and it's going to be sunny (household with solar panels)
Plug in or switch on charger manually if car not already suitably charged
Use smartphone app to remotely start charging and/or monitor charging progress, if car not already suitably charged
Use Pebble, iWatch or similar to remotely start charging and/or monitor charging progress, if car not already suitably charged
No planning or scheduling of charging, always keep car fully charged
Research available chargers at destination or on intended route, even if unlikely to need them – 'just in case'

1.2 Journeys beyond battery range or involving (non-essential) charging

1.2.1 Considering charging options

Consider whether to rapid-charge on route, or if charging available at destination
Consider length of stay at destination, and whether to slow-charge there
Consider availability of private charging, i.e. at family/friends' houses, client offices
Consider whether to stop to charge on outbound or return trip, if one stop needed
Consider return journey and whether a further charge will be needed

1.2.2 Locating charging facilities and checking charger status

1.2.2.1 Searching and identifying

Do a Google search for chargers
Use Google Maps to check charger locations
Research charger availability and status online or via app using Zap-Map/National Chargepoint Registry or similar
Research charger availability and status via local council or local authority, Source London or similar websites
Research charger availability and status using individual service provider websites or apps, i.e. CYC, Polar, Ecotricity
Research charger availability and status via car maker's own website or app
Check out open-source resources i.e. Plugshare or OpenChargeMap for 'shared' chargers at private houses or local businesses
Ask other EV drivers via social media for any advice/suggestions on charging when planning new or long journey

1.2.2.2 Updating and maintaining knowledge

Update existing knowledge on charger availability and status, i.e. new facilities installed on intended known route or around destination
Consult and update own spreadsheet, Google Doc, Google Maps map or similar personal record of charging locations (i.e. including locations and postcodes, connector types, network providers or access types)
Check own self-developed app (i.e. aggregating feeds from network operators) for charger status on intended route
Update and refresh any apps used
Use app (i.e. BMW i3 app) to 'send to car' charger postcodes from Google Maps as new destinations for the in-car sat nav
Manually enter charger postcodes as 'points of interest' on sat nav
Look at OS map and mark charger locations in pencil
Maintain and update paper list or reference document to take in car

1.2.2.3 Checking of specific charger availability and status

Check with owners of hotels or holiday cottages as to whether charging will be possible, and if so, how to pay for the electricity
Call or email destination to check that charger is working
Call or email service/network providers to check that chargers are working
Check emails for any relevant information from mailing lists signed up to (i.e. Ecotricity)
Look at EV online forums, Twitter or other social media for news on any updates to/problems with charger networks

Choose to take ICE car instead, having found no convenient or feasible charging facility
Make other travel plans, having found no convenient or feasible charging facility
Choose to take ICE car if charging availability looks risky, i.e. uncertain charger status
Choose to take train or other mode, if charging availability looks risky
Check out park-and-ride facilities or splitting journey mode, if charging availability looks risky

1.2.3 Checking charger compatibility and access

Check charger and connector types for compatibility with car, using above reference sources
Make sure of having all necessary RFID tags or network cards to access public chargers; join any networks as necessary
Research weeks ahead of driving abroad, i.e. Rep. of Ireland, France, Holland; request any network cards or RFID tags needed for access to foreign chargers
Download any apps needed for access to new or different national/international charger networks
Pack any needed adaptor cables, connectors, portable equipment (i.e. Nissan Leaf's 'brick')

1.2.4 Adapting journeys and destinations with reference to charging

Choose route according to charger availability, i.e. at motorway services
Plan journey breaks or lunch stops around charging needs and availability
Develop a back-up plan, alternative stop or alternative route in case a charger is occupied/out of action
Plan a detour or to go out of the way, if this enables using a charger previously experienced to be functioning and easy to access
Decide which town to go shopping in, based on on-street/public car park charger availability/price
Plan shopping trip destinations to retail parks or specific retailers (i.e. IKEA) based on charging availability/price
Choose to visit leisure destinations based on charger availability (or price)
Choose to visit or stop at National Trust property, specifically because they have chargers in key out-of-the-way destinations
Identify charging facilities at unusual places, i.e. local businesses, sports centres or village car parks, when travelling cross-country in rural areas
Identify charging facilities in previously unvisited industrial places, i.e. industrial estates, harbours, agricultural facilities
Plan charging at car dealerships for supplying brand (i.e. Nissan, Tesla, BMW)
Plan route or stop around likelihood of charger being blocked, in use or broken, based on previous experience or feedback from other EV drivers
Plan to stay overnight rather than risk long late-night journey home (i.e. with ref to uncertain charger availability/status, lack of out-of-hours support)
Book hotels or holiday cottages based on charging availability

1.2.5 Considering charging time

Estimate charging downtime depending on speed/type of charger
Plan journey and charging stop(s) around diary or tasks for the day
Plan around the journey taking longer due to charging downtime
Schedule any meetings or appointments to allow for charging stops on route
Build in flexibility to schedule if possible to allow for charging issues, i.e. having to wait for charger or detour to find working charger
Use website or app i.e. Google Maps to see whether a multi-modal journey is quicker and easier, given charging downtime

1.2.6 Considering charging cost

Check out charging fees at destination or on route, including additional parking fees

Plan to charge at free or cheapest facility wherever possible
Cost out journey to see if parking plus charging fees still make driving the cheapest option

1.2.7 Further pre-departure checks, activities and decisions

Use app (i.e. Nissan Carwings, or third-party, i.e. Leafspy, Leaflink) to check charge level a few hours before departure, to allow time for extra top-up
Use app to remotely check state of charge and range to see if a top-up at public rapid-charger is needed, and thus earlier departure (i.e. if no home charging facilities)
Pick up and act upon any low-charge alerts from remote monitoring app
Check apps and/or in-car interface for any further updates to charger status just before set-off
Check social media, i.e. Ecotricity Twitter feed, for further updates to charger status
Decide to take ICE car instead, having found out that charging facility is out of action
Decide to take train or other transport mode, having found out that charging facility is out of action
Make other travel plans, having found out that charging facility is out of action
Defer journey/trip, having found out that charging facility is out of action
Use app to pre-heat or pre-cool car before departure
Use app to pre-heat or pre-cool car while still plugged in, specifically to save battery power when underway
Don’t plan until departure, but get into car and fire up the sat nav
Don’t plan until departure, but check apps for updates when setting off
No pre-planning, all rapid-chargers known on regular routes
No pre-planning, familiar with charging facilities at all regular destinations
Don’t bother to check anything, confident that there will be plenty of chances to charge on the way or at destination

1.3 Additional activities specific to Tesla Model S drivers

Take car to nearest Supercharger the night before if heading off very early
Plan shopping trip around Supercharger availability
Check intended routes first of all for Supercharger availability/status, and then other networks
No pre-planning needed at all, unless expecting to go over 250 miles
No pre-planning at all, assume there will be a Supercharger within reach
No pre-planning, all Superchargers previously used are stored as destinations in the sat nav and new ones within range are automatically identified

1.4 Additional activities specific to RE-EV drivers (i.e. BMW i3 REx, Vauxhall Ampera)

Plan to do as much mileage in electric mode as possible, but not stop to recharge
Plan to use electricity for whole journey if possible, even if it means stopping to recharge
Top up with petrol (as don’t tend to keep full tank normally, in order to save weight)
Consider where to switch between electric and petrol modes, to optimise efficiency and/or emissions
No pre-planning, will just use petrol engine if electric range runs out

2 Journey

2.1 At departure

Double-check state of charge before start-up
Read Carwings statistics or similar on start-up
Double-check charger availability and/or status when leaving
Set out earlier than would have done in ICE car, to allow for charging issues i.e. charger already occupied upon arrival
Set trip meter to zero when departing, for quick and easy calculation on distance for return journey
Drive straight to nearest rapid-charger or Supercharger if insufficient range or running low (no home charging)
Drive straight to nearby rapid-charger if going out at short notice and car doesn't have sufficient range/not time to charge up using slow home charger

2.2 While driving

2.2.1 Checks and calculations

Keep eye on in-car sat nav, TomTom, Garmin or similar to track remaining journey mileage
Keep in mind distance already done, and distance remaining
Make mental calculations as to remaining battery range
Keep track of range by deducting from 'optimistic' in-car calculation
Think about weather and temperature, and how this may affect range
Minimise use of heater and air conditioning to conserve battery range
Wear coat and hat in winter to minimise use of heater!
Think about use of wipers and lights, and how this may affect range
Think about steep hills (upward) and how these may affect range
Think about steep hills (downward) and effect on regenerative braking
Be anxious about range if there are diversions or road closures
Be comfortable about 'low battery' warning if within a certain known threshold from home
Don't look at range indicator on most journeys, familiar with car's limits

2.2.2 Changes to driving style/driving experience

Drive more slowly than when in ICE car
Be more aware in general about speed
Stick to 60-65mph on motorway
Set speed limiters or active cruise control to keep at lower speeds
Try to drive more smoothly
Accelerate and brake more gently when possible
Drive to maximise regenerative braking
Slow down by lifting off throttle rather than braking, when possible
Slow down much earlier before junctions or traffic light
'Slipstream' behind large lorries when on the motorway
Try to stay within in 'eco zone' on dashboard indicator
Adjust driving style according to remaining range or journey demands
Drive in different modes to test differences in energy consumption
Drive to 'beat' own records for efficiency and range
Be generally much more aware of energy usage than when in ICE car
Be more likely to talk with passengers than in ICE car, due to quietness

Turn radio off to enjoy the quiet driving experience
Be more aware of other road users, i.e. pedestrians, cyclists, horse riders, due to quietness of EV
Appreciate not having to stop at a petrol station, or fill up with 'smelly' petrol or diesel
Drive faster if have a full range, or if only going short-distance
Enjoy rapid acceleration from standstill/low speed
Drive faster and accelerate more now not paying for petrol (as stated by Tesla Roadster owner)!

2.2.3 Driving style, specific to RE-EV drivers

Drive knowing that petrol engine will kick in if battery range runs low
Be conscious of where to use electric and where to use petrol power
'Save' battery power for use in town or during stop-start traffic
Be conscious of automatic switching between electric and petrol power to understand energy usage and efficiency
Drive to 'beat' own record for electric-mode mileage before engine kicks in

2.2.4 Routing and range

Try different route variations to check mileage and energy efficiency
Take extra care to avoid getting lost and adding mileage to journey
Use Waze app or similar to find free-flowing traffic route, to smooth out route and optimise efficiency

2.3 Charging away from home

2.3.1 Dynamic checking of chargers

Be aware of where chargers are in relation to route, 'just in case'
Look out for new chargers and charging facilities when out and about, for future reference
Specifically check charger and connecter types spotted while out and about, for future reference
Check status of next/desired charging point while on route/mid-journey, in time to allow for detour, using app or in-car interface
Check status of desired chargers when a few miles away, i.e. to work out which car park to head for, using app or in-car interface
Check status of rapid-chargers regularly on motorway trips, i.e. to work out whether to stop earlier if intended stop has charger out of action, using app or in-car interface
Use in-car browser to search 'on the fly' for Superchargers [Tesla Model S]
Use in-car mapping and routing to chargers while en route [Tesla Model S]

2.3.2 Charging stops

2.3.2.1 Public slow charging

Park and leave car at slow public charging point, i.e. on-street, municipal car park
Park and leave car at slow public charging point at transport hub or connection, i.e. train station
Park and leave car at slow destination charger, i.e. at supermarket or retail centre, while shopping or doing routine household tasks
Park and leave car at slow charger at leisure destination i.e. National Trust property or RHS gardens, sports centre
Park and leave car at slow charger even if a charge isn't really needed, to take advantage of free electricity and/or parking
Park and leave car at slow charger even if a charge isn't really needed, to use handy parking space
Park and leave car at slow charger even if a charge isn't really needed, to show that public facilities are being used, or to increase visibility/awareness of electric vehicles

Park and leave car to charge at park-and-ride, continuing regular journey or commute by other means (i.e. foot, folding bicycle)

2.3.2.2 Private charging (usually slow)

Charge using installed equipment at house of friends/family
Charge using extension cable and domestic socket at house of friends/family, or similar
Charge at own workplace using installed car-charging equipment
Charge at reserved, private or restricted-access slow charging point, i.e. contract parking, private business car park
Charge using extension cable and standard 13amp socket at own workplace
Charge at other workplaces visited, i.e. for client meetings, using installed equipment
Charge using extension cable and standard socket when visiting clients or similar
Charge using installed equipment at private leisure destination (fixed location; i.e. golf club, gym, hotel)
Charge using extension cable and standard socket at private leisure destination (i.e. sailing club, riding stables)
Charge using auxiliary power source or generator at outdoors event or temporary work site (varied locations, i.e. music festivals, sports events, building sites)
Charge at campsites when on holiday or travelling cross-country, i.e. on long trips abroad
Charge at private facilities owned by strangers, found via open-source sharing app or social media

2.3.2.3 Charging at public fast- or rapid-chargers

Decide to stop at rapid-charger even if not really needed, 'just to test it out'
Stop at fast- or rapid-charger on route, i.e. motorway services
Go out of way to fast- or rapid-charger in non-destination location i.e. business park, dockland
Use fast- or rapid-charger at destination i.e. IKEA, retail park, at arrival or prior to departure

2.3.3 While car is charging

Stay in car or leave only briefly, i.e. to get coffee or use toilet
Have coffee, snack or meal while car is charging
Take part in leisure activity, i.e. shopping, cinema, golf, gym
Take part in work-related activity, i.e. meeting, client visit, getting on with work in café or business lounge
Look at route and charging options for onward journey
Check phone app for any charging network/charger status updates
Check social media for any charging network/charger status updates
Check phone app to monitor charging progress, when desired level reached
Check Pebble, iWatch or similar to monitor charging
Pick up automatic email or alert via charging app when desired charging level is reached
Be conscious that other EV drivers may need charger, and check/look back regularly to see if anyone else is waiting
Use ChargeBump app to communicate with other EV drivers over charger access and needs
Move car on and repark if have enough charge to complete journey, if message received via ChargeBump that someone else needs charger
Leave note on windscreen with mobile number, in case anyone else needs to charge more urgently
Upload photo of charger and any useful information, i.e. on finding location or access, to open-source database or social media/web

2.4 Dynamic decisions and actions

Use public charger if ‘caught short’ or plans change and need unexpected top-up
Stop quite randomly on long leisure trips as and when spotting a charger, to keep car topped up
Stop earlier on route than actually needed, if/ in case later charging point is inoperable/inaccessible
If running lower on range than anticipated – or if traffic is bad - use park-and-ride and leave car charging
If running lower on range than anticipated but have sufficient energy to get home again, use park and ride but don’t leave car charging
If running lower on range than anticipated, divert to nearby known charger
If running lower on range than expected, shorten journey, series of trips or defer errands
Drive very slowly (if safe to do so) to eke out final few miles of range if running lower than expected
Coast downhill to a charger or home, having run out of battery range!
Push car last few yards to a charger or into home/work driveway or parking space, having run out of charge
Call AA, RAC or similar for tow-truck ride home or to working charger

2.5 Public charger access and payment

Use RFID network card or tag to access charging point/pay for charging
Use network members’ app to access charging point/pay for charging
Use PAYG app to access charging point/pay for charging
Make contactless debit card payment (latest equipment; from summer 2018)

2.6 Inoperable or inaccessible charging point

2.6.1 Issues arising

Find charger is out of action due to technical issue
Find charger has been deliberately damaged or vandalised
Find charger has not been reset or previous charge ‘ended’ for new vehicle to start
Find charger is inaccessible outside of business hours
Find charger is blocked by ICE vehicle
Find charger is blocked by other fully-charged EV or PHEV left parked
Finding charger already in use and likely long wait/queue to access it
Find charger access is blocked or inaccessible due to other issue, i.e. supermarket delivery lorries unloading
Unable to find charging equipment at all at a location, i.e. if fitted in obscure position
Be unable to operate charger due to poor mobile reception for app
Be unable to operate charger due to not having right RFID card or tag (i.e. changed to different network operator since last usage)

2.6.2 In event of issues…

Call emergency helpline for remote technical support, i.e. ‘unlocking’ or resetting charger
Report issue to network provider or chargepoint operator via phone
Report issue to network provider or chargepoint operator via email
Notify network provider or chargepoint operator via social media
Wait in a queue for other working charger at same site
Decide whether range is sufficient to make it home

Decide whether to risk continuing journey to destination
Decide to try again on return journey instead, if sufficient charge to do so
Negotiate to have ICE cars moved for access to charger, i.e. requesting announcement in supermarket, requesting service station staff to repark their own cars, asking at nearby local businesses
Use motorway service road/request access to motorway service road to cross to charger at the other side of a motorway
Drive on to next motorway service station with a rapid-charger
Divert off motorway to another known charger in the area, i.e. at IKEA
Divert off motorway to another known charger, i.e. slow-charger in supermarket car park
Stop for lunch or coffee in a different place than planned, to use another rapid-charger
Divert to friends, family members or business associates nearby for top-up charge to complete onward journey or get home
Look for alternative charger using sat nav or in-car system
Look for alternative charger using Google Maps or smartphone browser
Look for alternative charger using chargepoint mapping app
Look for alternative private charging solution, i.e. using Plugshare app or similar, or via social media
Share news of technical issue via social media, i.e. using Twitter hashtag #ukcharge
Complain about or shame drivers blocking chargers, i.e. using Twitter hashtag #IvebeenICED
Contribute to real-time or crowdsourced updates on charger status
Call AA, RAC or other breakdown service provider for tow-truck ride home or to working charger

2.7 Further planned stops or routine habits

Plug in at public fast- or rapid-charger near work if going on somewhere else before going home
Stop for quick top-up at rapid-charger on way home if running low on range
Stop at rapid-charger on way home if going out again later or early next day

3 Post-journey

3.1 Recharging – back home

Plug car in to recharge straight away upon return
Plug car in to recharge later, charge to be activated via automatic timer
Plug car in to recharge later, charge to be activated via remote app
Check weather forecasts to decide when to recharge (i.e. to synch with solar panels or wind generation)
Look at weather apps to decide when to recharge
Plug car in to top up, but with a view to fully-recharging at (free) public charger later
Reset charge timer according to next day’s plans
Reset charge levels (i.e. 80% or 100%) according to next day’s plans
Leave car unplugged if sufficient range left for next day’s planned usage

3.2 Recharging – no private facilities

Park at or near home, not charging
Park on-street at public charger

Park off-street at shared charging facility (i.e. within housing development)
Make additional trip later (i.e. after peak demand times) to fast- or rapid-charge, i.e. at nearby IKEA, Tesla Supercharger
Make additional trip later to find on-street slow-charger
Move and repark car again later once charged
Don't recharge post-journey, but plan to charge when setting out on next trip
Don't recharge post-journey, have sufficient range for next trip or to reach convenient charging facility i.e. at workplace or service station en route

3.3 Post-journey analysis

Check mileage travelled and consider battery range achieved
Think about range achieved and factors which may have affected it
Look at in-car stats on trip indicator to further understand driving efficiency
Regularly monitor battery health to check for cell degradation
Download journey data or check data-logger (i.e. for EVStatus, FleetKarma)
Upload data to EVStatus or other crowd-sourced project
Compare data (i.e. on range or energy efficiency) with other drivers via app i.e. Carwings, Leafspy (anonymous)
Input data (i.e. on range, energy efficiency or electricity costs) to own private spreadsheet, self-developed app or similar
Input and share data with other known drivers via GoogleDoc or similar
Input and share data with other known drivers via self-developed app
Make calculations i.e. cost comparison with ICE car, % of renewable energy used
Feed data into own app under development
Share and discuss data with other drivers via web forum or social media
Share and discuss other information, i.e. on charger status, handy observations from journey, with other drivers via web forum or social media
Note successful charging to open-source databases, i.e. OpenCharge Map, or social media/web forums
Share or upload other useful information, i.e. pictures to help find new charging points, to crowd-sourced resources, i.e. OpenCharge Map
Privately update friends and other EV users on new charging facilities spotted, charger status, i.e. via email, text
Feedback of information, observations to EV user group, association, campaign body
Feedback of information, observations to service provider, i.e. complain about malfunctioning charging points to network operator, blocked charging spaces to car park operator