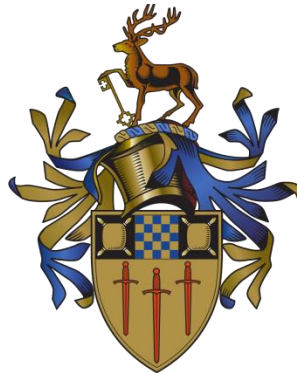


# **THE TRANSITION TO ELECTRIC VEHICLE FLEETS: AN E-MOBILITY SERVICES APPROACH**

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## **Abstract**

Electric vehicles have been identified as a key technology to decarbonise road transport which accounts for approximately a quarter of the UK's greenhouse gas end-user emissions (DECC, 2014). The diffusion of electric vehicles requires a transformation across a large spectrum of societal and economic dimensions. Using research and data over the study period from 2011 to late 2015, this research examines the pathways for transition from today's personal transport mix to one focused on electric vehicles, the research identifies path dependencies and lock-in of the internal combustion engine that results in sustained usage patterns. The relationship between transition pathways, path dependencies, technology lock-in and e-mobility has been under-researched.

Commercial urban fleets and car clubs were identified as key market opportunities for electric vehicles. Total Cost of Ownership studies and in-depth interviews with industry experts were conducted to identify existing transition barriers for the adoption of electric vehicles within these applications. Established path dependencies of the internal combustion engine and consequent technology lock-in were found to stem from an inter-dependant and reinforcing technology system of roads, service stations, parking facilities and societal status. In order to achieve integrated transport services –and EVs as part of it - alternative business models are to redefine humankind's relationship with the car through systemic innovation and competitive finance models.

The multi-level perspective was used to determine the dynamics of change for fleets towards electric vehicles, and the roles of different stakeholder types were explored through the 'action space' of government, civil society, market and governance logics. The results indicate that the diffusion of niche technologies and business models are establishing individual pathways within the two markets. It is evident within the fleet and car club markets that an 'innovator logic' is competing within the action space to unlock EVs through technology innovation that extends beyond the transitional role of hybrids. However, fundamental to each market is the parallel role of government to invest in R&D and motivation crowding to remove lock-in and destabilise the existing regime.

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## **Statement of originality**

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## **Executive Summary**

### Background

The transport sector accounts for 22% of the world's total carbon dioxide emissions, contributing substantively to climate change (IEA, 2012). Over 50% of the transport sector's emissions are the result of the combustion of petroleum-based products such as gasoline in internal combustion engines (Environmental Protection Agency, 2015). Within the UK, the transport sector is responsible for approximately a quarter (23%) of greenhouse gas end-user emissions (DECC, 2014). In order for the UK to meet targets from the Climate Change Act (2008) that stipulates an 80% reduction in emissions from 1990 levels by 2050, road transport needs to be decarbonised (CCC, 2015b).

Policy makers have identified electric vehicles (EVs) as a key technology towards that target, due to the benefits of zero emissions in the use phase and the consequent reduction in air pollutants, as well as the carbon dioxide emission advantages that will come as the electricity supply industry decarbonises. Motivation crowding has been employed to encourage the uptake of EVs and installation of charging infrastructure. However EVs have yet to become established within the automotive sector and remain below forecasts set by industry and academia in 2011 with the launch of a 'new generation' of EVs (McKinsey, 2014). Despite this, the EV market has grown from very small numbers, gaining momentum slowly as a disruptive technology.

The slow uptake is arguably due to the success and dominance of the internal combustion engine (ICE); there are a number of path dependencies surrounding industry structure, vehicle architecture and driver expectations. Vehicles are part of an inter-dependant technology system along with roads, service stations, parking facilities and a social status system that are all dependent and mutually reinforcing. It is questioned the extent to which this has caused technology lock-in within the industry or within individual sectors, preventing the uptake of EVs. The integration of EVs requires an extensive transformation across a large spectrum of societal dimensions including policy, behavioural change, fiscal models and technology dissemination. As a niche market a range of factors will determine the rate of EV sales in the UK, this includes consumer acceptance, oil prices, battery technology and infrastructure (OLEV, 2011).

This research has identified fleets and car clubs as key markets for EV utilisation. Fleets offer substantial opportunities for EVs as vehicles tend to have high utilisation rates, centralised parking facilities and managed, known activities (PikeResearch, 2010). This leads to specific and predictable charging requirements that theoretically make the integration of EVs more economic and generally attractive. Furthermore, fleet procurement is based on total cost of ownership which arguably removes financial

barriers of high purchase price. Despite this, there are evidently barriers preventing the adoption of EVs; these transitions barriers deserve further exploration.

Car clubs have the opportunity to change city mobility for both businesses and citizens, using service based business models. Car club vehicles inherently do short distances within defined locations and with regular downtime, therefore using EVs within this application can remove technology lock-in that is centred on range anxiety, high purchase price and charging. However utilising EVs within car clubs challenges the fundamental culture surrounding the automobile, (i) ownership, and (ii) gasoline vehicles. It is questioned how the embedded characteristics of the automotive industry can be challenged to establish a service based circular economy.

### Objectives

The research aims to investigate the transition barriers of EVs and explore the dominant path dependencies of ICE vehicles. Focusing on the fleet and car club markets, this requires an exploration of market conditions, stakeholder engagement and the diffusion of niche technologies. It intends to identify the impact of technological lock-in on the EV market and evaluate market techniques employed to increase EV usage. The role of EVs within mobility services will be explored to identify additional opportunities to decarbonise transport and challenge the existing reliance on privately owned ICE vehicles. The relationship between transition pathways, path dependencies, technology lock-in and e-mobility had largely been under-researched. This research is a synthesis of these models to identify transition pathways that the EV market can adopt to sustain growth within the fleet and car club markets.

The following are the objectives of the research:

- i. Investigate the transition barriers of EVs and explore the dominant path dependencies of ICE vehicles
- ii. Clarify whether path dependency threatens EV adoption and analyse technology lock-in EVs are experiencing within the UK
- iii. Explore the concepts of service based mobility models and the role of EVs within those
- iv. Evaluate market techniques implemented by Government to encourage EVs and the impact on the market

In order to achieve these objectives, three research questions have been created with a number of sub questions.

Research questions	Sub questions
What change is required for fleets to transition to EVs?	<ul style="list-style-type: none"> <li>• What are the drivers and barriers of EV fleet adoption?</li> <li>• How does the total cost of ownership of an EV compare to that of ICE vehicle?</li> <li>• What challenges can be overcome through behavioural change rather than technological developments or regulative enforcement?</li> </ul>
To what extent is technology lock-in restricting the EV market?	<ul style="list-style-type: none"> <li>• What are the dominant path dependent characteristics within the automotive industry that challenge the utilisation of EVs and EV charging?</li> <li>• To what extent has motivation crowding been a successful technique for EV adoption?</li> </ul>
What is the role of EVs towards the pathway to a ‘mobility-as-a-service’ model?	<ul style="list-style-type: none"> <li>• What car club business models exist?</li> <li>• What are the path dependent characteristics within society that challenge electric car clubs?</li> <li>• What are the drivers and barriers to electric car clubs in urban environments?</li> <li>• To what extent can the challenges be overcome with policy?</li> </ul>

Addressing these research questions will help determine key elements for transition pathways to tackle technology lock-in and path dependencies of the automotive sector, for a sustainable and competitive EV value proposition for commercial applications.

### Methodology

In order to achieve the research objectives and expand upon existing literature, an exploratory approach was taken across two markets (i) fleets and (ii) car clubs, within the period from 2011 to late 2015. Existing transitions theory was applied to the niche technology of EVs entering the structured automotive regime. However, the specific market conditions that establish embedded path dependencies and technology lock-in needed further investigation. Due to the lack of existing theory on the transition to EVs specifically, a deep exploration was required to gather extensive and in-depth data that could then be used to create normative results to direct market developments. Therefore interviews were conducted providing cultural, personal and business insight that would be unattainable using other methodologies.

The research took a considered approach to gathering data on the niche technology, choosing to create three fleet case studies. The fleets were chosen for investigation based on the diversity between characteristics of sectors, operations, vehicle procurement and EV experience. Considering the transition

to EVs across a diverse mix of fleets operating in different sectors identifies the extent to which EVs are locked-out and the similarities in the challenges of EV adoption. The case studies explore procurement of vehicles, the company fleet strategy, employee reaction to vehicle and technology change, charging considerations and future projections of the fleet's activities and transition to low carbon vehicles. Interviews were conducted across a range of employees, including key decision makers, managers and, where possible, drivers who had experienced a transformation in vehicle technology. It was important to interview a range of employees that were involved with the company's fleet and that were positioned across the business at different levels to ensure triangulation, reliability and objectivity to the results.

Due to lack of existing evidence and the infancy of car clubs within the UK it was necessary to obtain a broad view of market dynamics and an in-depth understanding of actors within this space. Therefore interviews were conducted with three key stakeholders in relatively mature organisations within the niche market. It was necessary to have contribution from experts in the field that had attained experience of the market growing, developing and challenging the existing regime. Furthermore due to the exploratory nature of the questions regarding transition barriers and existing and future policies, it was necessary for those interviewed to have a holistic view of their operations within the wider context; therefore it was evident the interviewees would need to be senior management.

In both the fleet and car club interviews a semi-structured approach with open-ended questions was used due to the exploratory nature as well as flexibility to encourage the embedded knowledge of interviewees to be shared. Interviews were conducted by telephone (except one) for the convenience of the interviewee whilst efforts to gain a level of rapport and flexibility were equally important (Bryman, 2008). Interviews were recorded either using computer software or a Dictaphone to allow for uninterrupted conversation and reliability of data recording. In analysing the interviews, content analysis was used in the broad sense that inferences were made through "objectivity and systematically identifying specified characteristics of messages" (Holsti, 1969 p.14). This approach enabled similar concepts within the text to be identified as well as consistent relationships and individualities specific to a certain environment. Further it was useful in identifying trends and patterns which are occurring, particularly if they are incremental and have little immediate impact (Stemler, 2014).

The limitations of interviews were considered along with alternative data gathering methodologies, however due to the research emphasis on current market dynamics and the implications of those on future transitions, it was fundamental to obtain current data, regardless of the probability that the interviewees opinions will change in time. The interviews were supported by contributing methodologies including case studies and examples of market actors. These methodologies were incorporated in to the research to

further support empirical evidence and demonstrate existing forces on the regime. European examples of business models and national policies were referenced as a comparative tool.

Commercial procurement of vehicles i.e. fleets, focuses on the total cost of ownership (TCO). As a fundamental component of the fleet's decision matrix, its analysis is imperative to the transition to EVs. Therefore TCO studies analysed three alternative business models (i) outright purchase, (ii) contract hire, (iii) as a company car. This demonstrated the financial options and implications of fleet procurement under predefined conditions. Four vehicles were compared to represent a range of vehicle technologies, including an ICE, HEV, PEV and a PEV with a leased battery. As a consequence it is possible to identify the most cost effective vehicle technology within each scenario, as well as the possible economic barriers of AFVs in contrast to an ICE vehicle.

In addition to a generic TCO from a national perspective, a London centric TCO analysis was performed. This was to explore the value proposition of EVs within urban environments; it is argued EVs are well suited to city-use due to complimentary drive cycles, regenerative braking and a higher proportion of publically accessible charging points. Consequently there are a number of incentives within London to promote EV uptake, most significantly, free access to the congestion charge zone. Analysis was conducted across the three (previously stated) business models as well as the addition of a private hire scenario as explored within the case studies.

This research used the multi-level perspective where appropriate to identify specific characteristics of the EV market that are complex and implicate multiple actors. The transition to EVs is based on the interaction between competing logics upon the action space; therefore the multi-level perspective was applied to the case study examples to explore structural change across these dynamics (Geels, 2011). This explores more broadly the process of environmental and system innovation.

The combination of qualitative and quantitative research was fundamental to achieve the research objectives, and supports the reliability through triangulation (Patton, 2002). It enabled the analysis of which transition barriers could be overcome through behavioural change, technological developments, economic stimulus or regulative enforcement. Furthermore the methodologies were deemed most applicable to establish the existing lock-in and identify a necessary support to achieve a transition pathway for optimum EV integration within the two markets. Due to the dynamism of the EV market, the research field continually developed along with market evolution, thus requiring the need for longitudinal immersion to achieve a holistic perspective.

## Results

This research has established that the automotive industry is fundamentally built upon path dependant characteristics and has embedded and strong preconceived notions of vehicle design and specification suited to customers' expectations. Evidence from the case studies suggests that Foxon's three existing logics are insufficient in explaining the transition to EVs as the process requires technology transfer, implicating organisational, economic, social and cultural factors in order to challenge the incumbent market actors. The EV market is following the transformation path and technological substitution whereby innovative activities are responding to moderate landscape pressures; thus developed niche-innovations are entering the system and destabilising the regime. Consequently it is the 'innovator logic' that will stimulate traction across the market, governance and civil society logics in response to technological change. The innovator logic is responsible for the existing uptake of EVs within fleets and will continue to drive the market until critical mass is achieved by the market logic to sustain investment, without the support from the government logic.

The research found four key challenges to the transition to EVs within commercial applications, (i) range, (ii) TCO, (iii) charging infrastructure and (iv) scepticism. The TCO studies highlighted the possible implications of alternative business models on the economic case, however this requires a shift to alternative business models that are currently challenging ownership. The niche technology remains largely uncompetitive within multiple scenarios explored due to the high purchase price and depreciation rates of alternatively fuelled vehicles (AFVs). This is particularly challenging for the fleet market due to the short ownership cycles of vehicles and importance of residual values.

As a consequence, the TCO is locking-in ICEs and reinforcing the barriers to market entry through a lack of confidence in the new technology by insurers and fleet providers. The analysis suggests that within the UK EVs are not a 'rational' business decision, unless early adopters of the market can continue to exploit the extended value of PR and kudos. It is proposed that if intangible benefits or additional value could be included within the TCO analysis it would be possible for EVs to be economically more competitive in a shorter time frame.

Market perceptions of EVs prove to be a barrier to behavioural change as the market is faced with scepticism of legacy and reliability. This is due to the limited range which has not been eradicated through the publicly accessible charging infrastructure. The reinforcing nature of technology lock-in is limiting the available market to EVs resulting in niche applications that can benefit from the available grants and incentives. Through the exploration of technology diffusion in the fleet and car club markets,

it is evident that EVs are infiltrating the two markets along individual pathways, with no evidence of a dominant actor.

Regarding fleet applications the research suggested the government logic had been a key catalyst in unlocking ICE vehicle dominance within the market through the use of incentives and regulations relating to emissions. Such measures put pressure on the existing regime providing an incentive for adoption, thus resulting in the transformation path developing to technological substitution (Mazur et al, 2014, Geels et al, 2007). However, the financial opportunities and TCO of an EV still do not offer significant gains to outweigh the transition barriers of range, reliability and market scepticism. For adoption of EVs to increase in the fleet market, it is considered that additional policy measures need to broaden the feasibility of operating EVs. Alternatively, the market logic needs to compete more heavily on providing alternative ownership models such as battery leasing that can substantially reduce the TCO.

The case studies highlighted the importance of senior management sponsorship for the successful transition to EVs. Thus suggesting the action space is dominated by the innovator logic that is reliant upon the extrinsic value of EVs alongside a willingness to adapt behaviours and operations in order to gain momentum.

It was found that the e-car club market can alter the transportation mix whilst also improving air quality and reducing emissions and congestion. However, the results suggest there are a number of challenges to overcome for a transition to a use-oriented service within an industry heavily associated with status and flexibility. Since the influx of investment from auto manufacturers into the car club market the transition to mobility services is being led from the market logic. The balance needs to be readdressed with additional support from policy makers to ensure the possible environmental benefits for cities are reaped by society.

The research suggests the e-car club market requires cross collaboration from national government, local authorities and car club operators to ensure further progress is made, specifically in terms of interoperability. Broadening e-car club's application and removing the existing barriers of parking, charging infrastructure and multiple operating platforms, will enhance the integration of the private and public transport sectors to offer complimentary services. Furthermore, the developing demands on service, user transparency and fluency across modes suggest that car clubs could be used to complement public transport and create an alternative to private car ownership.



## Conclusions

The relationship between transition pathways, path dependencies, technology lock-in and e-mobility had been under-researched; this research synthesises these models. Having explored two suitable markets that also offer substantial opportunities to decarbonise the road network, it is evident that the four logics competing on the action space are interdependent and that across the two markets the niche technology does not exploit or depend on a dominant actor. The research makes it explicitly clear that for a niche technology to gain momentum and attain investment from the market logic, the government logic must take a parallel role of incentives and research and development.

Government incentives have been key catalysts in unlocking EVs, the TCO analysis highlights the importance of the Plug-in Car Grant to the feasibility of EVs. Existing policies have focused on providing incentives to the consumer market to increase EV uptake, whilst relying on private investment to install charging infrastructure that is publically accessible. Strategically, incentives should be targeted towards fleets to manifest confidence in the general populous via employment and infiltrate the vehicles through the second hand car market. Regardless of the benefactor group it is important that changes within the government logic are managed with sensitivity to avoid market actors withdrawing from the action space.

The research has shown that EVs have an exceptionally challenging value proposition that on the surface is not immediately convincing. Case study examples are challenging the path dependencies of traditional diesel led sectors but admit the challenges of EVs are too great in the present regime, therefore hybrid vehicles are used as a transitional technology. The regime is confined by path dependencies that lock-out EVs through the network of refuelling stations, sunk technological costs, range and price. The option value of flexibility and freedom is largely under-estimated within the automotive industry, whilst an emphasis on brand, reputation, status and reliability are prioritised. However this research has identified the significance of flexibility to commercial-urban applications and the resistance to restrict versatility of operations. In scenarios whereby EVs are applicable, the market requires innovator actors to build show case examples that can be replicated until sufficient confidence ultimately amends the balance of technologies across the regime.

Research has identified that within the UK there is a culture aligned to vehicle ownership and social status that resists mobility services. This is intensified by a number of transition barriers surrounding the provision of charging infrastructure and access to parking bays. Redefining the car as a mobility service provider requires systemic innovation that can challenge the existing regime incumbents which are market orientated rather than focused on society and technological capabilities. A greater emphasis is

required on the application of EVs in scenarios and environments that enables the lock-in of ICEs to be removed. This relies on higher order learning of stakeholders, particularly by auto manufacturers and energy suppliers that are threatened by the transition. Currently the market logic and civil society logic are stimulating the demand, but there is a distinct need for the innovator logic to enter the market to provide alternatives to mainstream manufacturers, enhancing flexibility and interoperability.

This research proposes a number of recommendations for both the fleet market and the car club market to further develop the transition to EVs. The recommendations for each market are targeted to specific logics that require stimulation in the action space for EVs to achieve technological substitution. The research suggests there is a need for strong and sustained investment in the fleet market by the government logic, with the introduction of a socio-economic approach and greater focus on using motivation crowding for EVs in fleet applications. E-mobility services is a niche market which requires funding, policy and legislation to support the transition to a services approach. In order to optimise the potential opportunities that could alter city transport the government logic needs to devolve powers to city mayors to create integrated and complimentary transport systems that can enable the market logic to enhance the value proposition with truly flexible models. Within both the fleet and car club market there is a need for education and marketing of EVs that should be delivered by the government and market logics combined to remove scepticism within civil society.

Further research on the innovator logic is required to explore the role of technology innovation across the complete EV market and the impact more broadly on the diffusion of niche technologies. This will identify dynamics of competing logics upon a niche innovation within the action space. Additionally future research should consider the market potential of e-mobility services that relies on the 'readiness' of stakeholder adoption and the rate product service systems (PSSs) will fundamentally alter the system.

## **Abbreviations**

AFV - Alternative fuelled vehicle

E-REV - Extended range electric vehicle

HEV - Hybrid electric vehicle

ICE - Internal combustion engine

MaaS - Mobility-as-a-Service

OEM – Original equipment manufacturer

OLEV – Office for Low Emission Vehicles

PEV - Pure electric vehicle

PHEV - Plug-in hybrid electric vehicle

TCO – Total Cost of Ownership

TOC – Total Operating Cost

ULEV – Ultra low emission vehicle - vehicles with fully electric powertrains and cars/vans with tail pipe emissions below 75 g/km

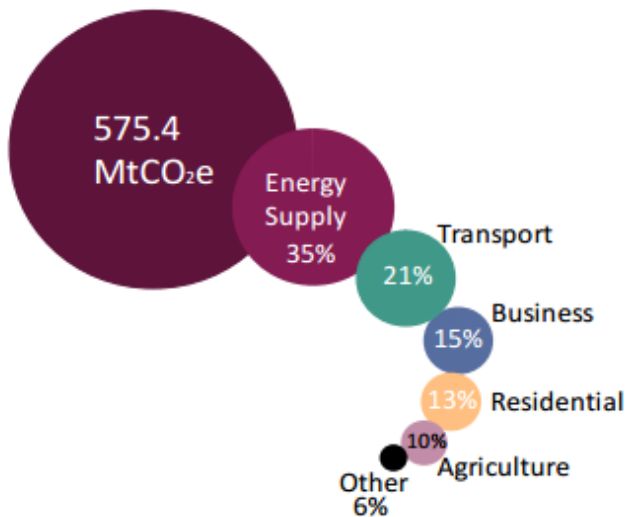
*“If EVs are to be the agents of change that allow a significant reduction in CO<sub>2</sub> emissions, it is likely to be in an environment that is different from that which has evolved symbiotically with the internal combustion engine over the last century” (RAENG, 2010 p.12)*

## The Transition to Electric Vehicle Fleets: An E-Mobility Services Approach

### 1. Introduction

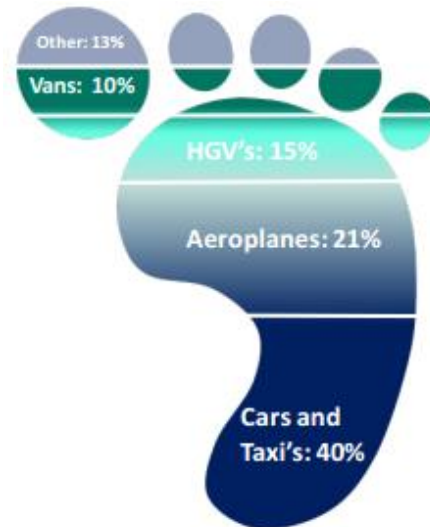
Transportation is a key component of global trade, national and regional economics and quality of life (PwC, 2014b). The sector moves people and goods by road, rail, air and sea using a range of vehicle and technology types. The sector is inherently sensitive to the price of oil and significantly damages the environment across both the manufacturing and use phases. The transport sector accounts for 22% of the world's total carbon dioxide emissions, contributing to the effects of climate change (IEA, 2012a). Over 50% of the transport sector's emissions are the result of the combustion of petroleum-based products such as gasoline in internal combustion engines (Environmental Protection Agency, 2015). Similar to global statistics, the UK's transport emissions accounted for 21% (118MtCO<sub>2</sub>e) of total greenhouse gas emissions in 2012 (DfT, 2014). Of this road transport is the largest contributor, with cars and taxis accounting for 40% (DfT, 2014).

Figure 1: UK GHG emissions, 2012



Source: DfT, 2014

Figure 2: UK GHG emissions by transport mode, 2012



Source: DfT, 2014

Consequently the transport sector provides both challenges and opportunities for the UK's Climate Change Act, requiring an 80% reduction in emissions from 1990 levels by 2050 (CCC, 2015b). This UK target "represents an appropriate contribution to global emission reductions consistent with limiting global temperature rise to as little as possible above 2°C" to minimise climate change impacts (CCC, 2015b, p. 1).

As a high contributor to greenhouse gas emissions the sector, and specifically petroleum based road transport, need to be decarbonised substantially. It is questioned how can a transition in the automotive sector be achieved? Should reliance be on alternative vehicle technology, driver behaviour or usage patterns to decarbonise the road network? Electric vehicles (EVs) have been identified as a promising vehicle technology in the short term to decarbonise road transport due to the ability to roll out a network of vehicles and infrastructure rapidly. To optimise the potential of EVs two markets have been identified (i) fleets, and (ii) car clubs. These markets are the central premise as they are perceived as early adopters of EVs that can maximise business value and potential, of the vehicles and charging infrastructure due to route predictability, high vehicle utilisation rates and centralised parking facilities.

Using the multi-level perspective to explore the dynamics acting upon the transition pathway, it is questioned whether these markets are 'ready' for EVs and what is driving or preventing the procurement of EVs? The opportunities and barriers of EVs within these markets will be discussed at length in the following chapters. The market perception of EVs focuses on high costs, limited range and lack of infrastructure, to what extent is this reality within commercial applications?

### 1.1. Project Aims

This research is focused on the utilisation of EVs within two broad markets; the fleet market and the car club market. Both markets have motivations to electrify vehicles, requiring an extensive transformation across a large spectrum of societal dimensions including policy, behavioural change, fiscal models and technology dissemination. EVs are part of an inter-dependant technology system along with roads, service stations, parking facilities and a social status system that are all dependent and mutually reinforcing.

Due to the success and dominance of the internal combustion engine (ICE), EVs are inhibited by the current industry structure and vehicle architecture. EVs have to manage path dependencies, intensified by sunk technological costs alongside driver expectations of vehicle design, safety and cost. As a result changes in power train technology will need to be introduced gradually; this highlights the individual pathway of the automotive industry compared to other industries. Industries such as telecommunications are more likely to have a high rate of creative destruction, this being key to innovation and entrepreneurship. In contrast in the automotive industry change is initiated by the manufacturers and legislation rather than customers dictating product evolution. This is largely a consequence of government's reliance on the economic contribution from auto manufacturers to gross domestic product, along with the technological complexities found along the supply chain.

This research will investigate transitions that the EV market requires to sustain growth within the fleet and car club markets. Consequentially, it shall explore the existing market dynamics to identify the necessary action by various actors to tackle technology lock-in and path dependencies of the automotive sector and enhance the EV value proposition for commercial applications. Therefore this research will consider the requirement of policy, user behaviour, fiscal models and commercial applicability. The theories underpinning these objectives will be explored in detail in Chapter 3.

The following are the objectives of the research:

- v. Investigate the transition barriers to EVs and explore the dominant path dependencies of ICE vehicles
- vi. Clarify whether path dependency threatens EV adoption and analyse technology lock-in EVs are experiencing within the UK
- vii. Explore the concepts of service based mobility models and the role of EVs within those
- viii. Evaluate market techniques implemented by Government to encourage EVs and the impact on the market

In order to draw conclusions on these objectives, three research questions have been created with a number of sub questions.

## 1.2. Research questions

The following research questions, stemming from the objectives, have been formed to analyse the challenges that the EV market are faced with. Addressing these research questions it aims to understand the barriers preventing adoption of EVs and requirements to market acceptance with specific focus on fleets and car clubs.

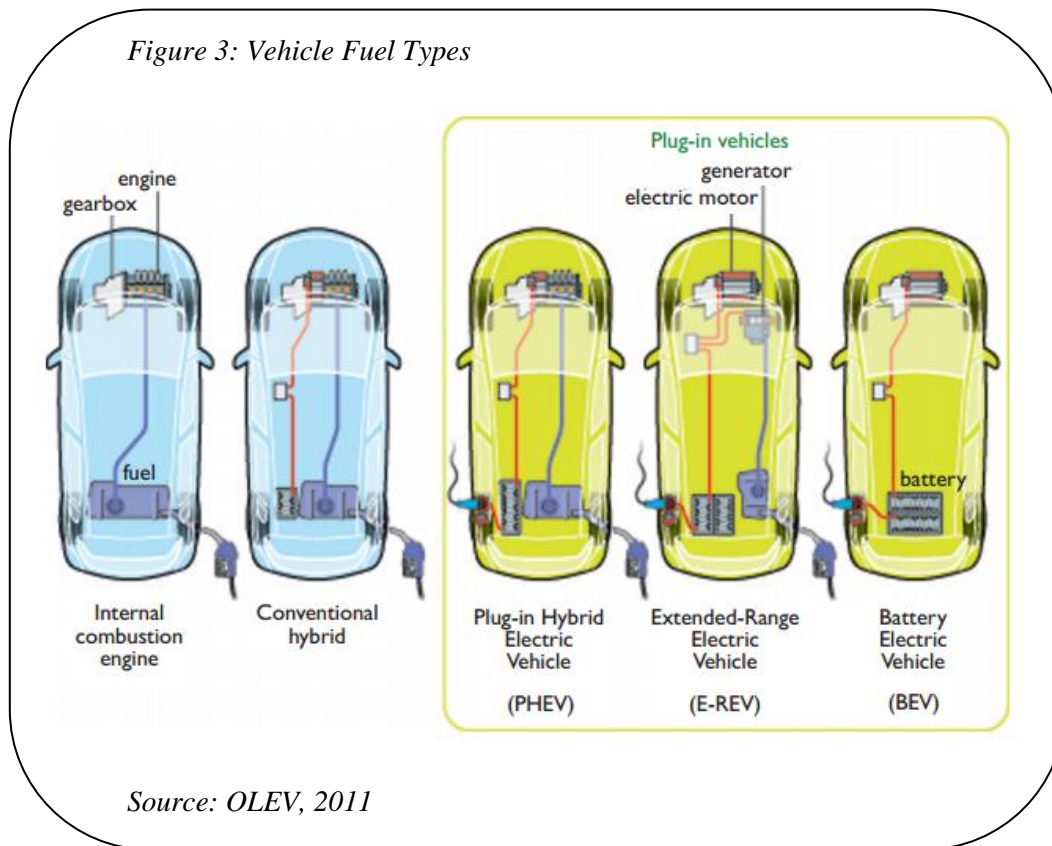
Research questions	Sub questions
What change is required for fleets to transition to EVs?	<ul style="list-style-type: none"> <li>• What are the drivers and barriers of EV fleet adoption?</li> <li>• How does the total cost of ownership of an EV compare to that of ICE vehicle?</li> <li>• What challenges can be overcome through behavioural change rather than technological developments or regulative enforcement?</li> </ul>
To what extent is technology lock-in restricting the EV market?	<ul style="list-style-type: none"> <li>• What are the dominant path dependent characteristics within the automotive industry that challenge the utilisation of EVs and EV charging?</li> <li>• To what extent has motivation crowding been a successful technique for EV adoption?</li> </ul>
What is the role of EVs towards the pathway to a 'mobility-as-a-service' model?	<ul style="list-style-type: none"> <li>• What car club business models exist?</li> <li>• What are the path dependent characteristics within society that challenge electric car clubs?</li> <li>• What are the drivers and barriers to electric car clubs in urban environments?</li> <li>• To what extent can the challenges be overcome with policy?</li> </ul>

### 1.3. Scope

The term 'electric vehicle' can encompass a wide spectrum of vehicles that are "powered in part or in full by a battery that can be directly plugged in to the mains" (SMMT, 2011a, p. 5). For the purpose of this research, it will include pure electric vehicles (PEV), plug-in hybrid electric vehicles (PHEV) and extended-range electric vehicles (E-REV) due to the direct withdrawal of electricity from the national grid. Whereas hybrid electric vehicle (HEV) technology will not be investigated to the same extent within the research project as HEVs generate electricity through regenerative braking, and therefore do not require behavioural change or charging infrastructure solutions.



Figure 3: Vehicle Fuel Types



Source: OLEV, 2011

However HEVs will be used as a reference point of alternative fuelled vehicle (AFV) stakeholder behaviour, as it will demonstrate market and societal response to the diffusion of a new technology over the early stages of the product lifecycle. It is questioned whether HEVs represent a transitional technology between ICEs and EVs that can heighten awareness of AFVs without the need for behavioural change? This is an important element to consider as well as the possibility that the pathway of HEVs could be mirrored by the diffusion of EVs, however to explore this in great depth is out of the project scope.

This research assumes EV technology is the fundamental pathway to decarbonisation of road transport, therefore this research does not consider the viability of EVs or alternative technologies as a means to achieve this. The research will focus on the UK automotive sector and UK EV market; therefore evidence collected will be UK centric and recommendations will be specific for the UK markets of commercial fleets transitioning to EVs. Case study examples of e-mobility solutions from European cities will be incorporated to identify success factors and contributing policies that are in contrast to the UK. It will be explored whether such market techniques should be replicated in the UK.

The research will consider the role of OEMs in the automotive industry as the major agent determining the overall design, manufacture and marketing of EVs. The research will not explore the tiered supply chain as Tier 1 suppliers and beyond are removed from the immediate market governance and have less direct impact on the customer.

The literature study and data collected from primary and secondary sources will be dated from 1942 to 2015. This time span is important to note in regards to EV market data as it ceases prior to thesis submission.

#### 1.4. Reader's Guide & Thesis structure

The Engineering Doctorate portfolio consists of two volumes. Volume 1 is a dissertation that presents a thesis for examination. The thesis comprises of results, analyses and discussions that were developed and refined during the project, and in some instances disseminated in conference presentations and proceedings. Below provides a guide to Volume 1:

Executive Summary - page x-xviii	
•Summary of the research objectives, findings and conclusions	
Chapter 1 - Introduction - page 1-9	
•Introduction to transport sector and EV market. Defines project objectives, research questions and scope	
Chapter 2 - Background - page 10- 29	
•Background review of current EV market and contextualises the project	
Chapter 3 - Literature Review - page 30 - 60	
•Body of knowledge compiled and critique of literature	
Chapter 4 - Methodology - page 61 - 79	
•Development of analysis methodology	
Chapter 5 - Results - page 80 - 116	
•Presents total cost of ownership analysis, case studies and interviews	
Chapter 6 - Discussion - page 117 - 144	
•Analysis of results and links between results and literature. Addresses research objectives and research questions	
Chapter 7 - Conclusions & Recommendations - page 145 - 156	
•Reviews research findings alongside research objectives and makes final recommendations for the EV market across different stakeholder groups and future research	

Volume 2 contains progress reports written during the research project, a conference paper published in WIT Transactions on Ecology and the Environment and a journal paper published in Journal of Contemporary Management. The progress reports chart the research's development and do not provide additional evidence to that addressed within the thesis; the salient points are included within Volume 1.

A paper has been accepted for publication by the Journal of Contemporary Management, Volume 5, Issue No 4 2016, pp. 53-67:

Gould, E; Wehrmeyer, W; Leach, M (2016) *Transition pathways of commercial-urban fleet electrification in the UK.*

A double peer reviewed conference paper, presented at the 10<sup>th</sup> International Conference on Urban Regeneration and Sustainability: Sustainable City has been published on the WIT Press e-library:

Gould, E; Wehrmeyer, W; Leach, M (2015) *Transition Pathways of E-mobility Services*. WIT Press: Transactions on Ecology and the Environment, 194 pp. 349 - 359

Additionally, four presentations were made at international conferences, these were:

- (i) Identifying Opportunities for Electric Vehicles. University Global Partnership Network Interdisciplinary Doctoral Seminar on Climate Change. VCU Rice Centre for Environmental Sciences. Virginia, USA. September 2012
- (ii) Charging Infrastructure for Electric Vehicles – Identify and develop business opportunities within target sectors. Sustainability for Engineering & Energy Systems Engineering Doctorate Annual Conference. University of Surrey, England. June 2013
- (iii) Transition pathways of commercial-urban fleet electrification. The Fifth Annual Asian Conference on Sustainability, Energy and the Environment 2015. Kobe, Japan. June 2015
- (iv) Transition Pathways of e-Mobility Services. 10th International Conference on Urban Regeneration and Sustainability: Sustainable City. Universidad Pontificia Bolivariana, Medellin, Colombia. September 2015

### 1.5. The Engineering Doctorate

The Engineering Doctorate in Sustainability in Engineering and Energy Systems is sponsored by the Engineering & Physical Sciences Research Council (EPSRC), the University of Surrey and Schneider Electric.

As the industrial sponsor the Research Engineer has spent four years within Schneider Electric, a global specialist in energy management specialising in electrical distribution and automation management. Schneider Electric entered the electric vehicle charging infrastructure market in 2010 offering residential (3kW-11kW), commercial (11kW-22kW) and rapid charging infrastructure (50kW DC). Back office management and billing solutions are additional services that are tailored per project. The Research Engineer has been based within this Business Unit from 2011 – 2015, conducting research and providing market intelligence to the team.

Electric vehicle charging infrastructure has been a key priority for Schneider Electric, particularly in developed markets across Western Europe. Due to the embryonic stage of the EV market, the company strategy has had to be dynamic both in terms of the product portfolio and the marketing approach. With

revenues of \$31billion in 2014, the sheer size of Schneider Electric and the company structure has proved challenging for the EVlink range to compete on price, innovation and speed against start-up enterprises.

Over the past four years Schneider Electric has targeted a range of customers including fleet providers, auto manufacturers, retail chains and municipalities. The Research Engineer has been involved with various projects, and conducted research to support and direct the business strategy.

## 2. Background

This Chapter will contextualise the project, providing a background review of the EV market and the contributing market forces on the diffusion of the technology. It will explore the existing challenges associated to the automotive industry and the possible opportunity of EVs within commercial applications. Particular focus will be attributed to the fleet market and mobility services in order to scope the existing transition barriers preventing greater utilisation of EVs.

### 2.1. Introduction

Climate change poses significant threats to the earth's sustainability; caused mainly by carbon dioxide emissions the effects of global warming are irreversible. Responding to climate change is likely to require a shift from fossil fuel use to renewable energy sources and improvements in energy efficiency (Rowling, 2015). Both mitigation and adaption is required by countries to reduce greenhouse gas emissions and achieve targets to the internationally agreed limit of a maximum 2°C increase in global temperatures. The UK has committed to an 80% reduction of greenhouse gases by 2050 on the 1990 baseline levels in the UK Climate Change Act (CCC, 2015a). There is a degree of urgency to decarbonise as currently the UK has achieved 29% reduction below the base year since 2008 however the 4th Carbon Budget stipulates a 50% reduction by 2025 (CCC, 2015b).

The transport sector in the UK is responsible for approximately a quarter (23%) of greenhouse gas end-user emissions (DECC, 2014). This is predominantly carbon dioxide from road transport which is accountable to the internal combustion engine (ICE) and closely linked to the amount of fuel used (DECC, 2014). The transport sector demands over 50% of overall UK oil consumption that intrinsically causes high levels of emissions and results in the sector to be extremely vulnerable to the effects of global supply constraints and price shocks (ITPOES, 2010). More specifically, road transport in the UK contributes 90% of domestic transport emissions; the fastest growing contributor to climate change in the country (OLEV, 2011). Therefore it is imperative that methods of transportation and humanities relationship with mobility are addressed to reduce the carbon intensity of the sector and for the UK to meet the legally binding carbon targets (Department for Regional Development, 2010).

In 2009 European regulation set binding targets to reduce the CO<sub>2</sub> emissions of new cars (EC Regulation No. 443/2009) (DfT, 2015a). The regulation stipulates (DfT, 2015a):

- The target is for an overall European fleet average of 130g/km of CO<sub>2</sub> emissions by 2015 (phase in from 2012). In order to meet this average, manufacturers are set a specific emissions target to meet, based on the types of vehicles sold in any given year. This allows a broad range of vehicles

to remain on sale with manufacturers deciding where they make improvements to ensure compliance

- The 'type' of vehicle is currently determined by its mass. Manufacturers that sell predominately heavier cars will have a higher grams of CO<sub>2</sub>/km target
- There are different arrangements for manufacturers that produce very small numbers of cars in any year, so as to protect the diversity of the market
- There is a further target for improvement from 2021, set at 95g CO<sub>2</sub>/km (95% fleet phase in from 2020)

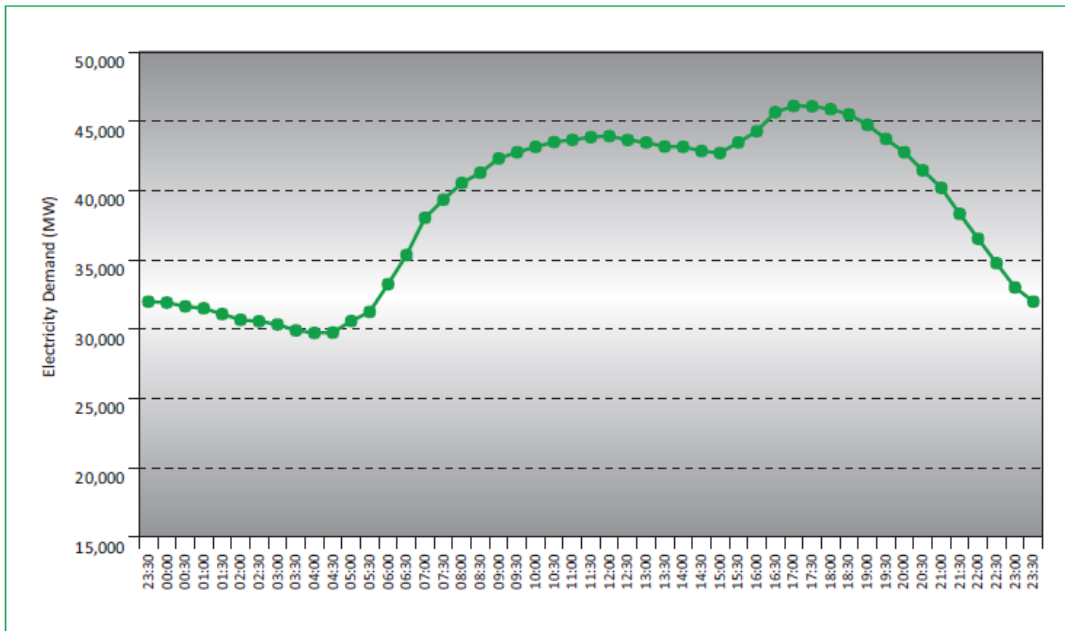
Presently there is a lack of consensus in the market on which vehicle mode offers the performance demands as well as low levels of carbon emissions. With 52% of all new cars sold in Europe running on diesel, it suggests the recent trend of drivers favouring efficient diesels rather than petrol fuelled vehicles (Fidelity, 2011). However, a further lack of clarity regarding vehicle performance was introduced in 2015 when Volkswagen were exposed having installed software in approximately 11 million diesel vehicles (Hotton, 2015). This software adapted the vehicle's performance during testing in order for carbon dioxide emissions to be reduced and limits to be met (Hotton, 2015). This revelation has introduced a degree of scepticism for customers around auto manufacturers and the efficiencies of diesel vehicles; therefore a diminishing diesel market may be witnessed across the globe in coming years. Nevertheless, the ICE defines humankind's perception of automobiles heightened by the vested interests within the industry that encourage resistance to new vehicles modes.

There are immediate opportunities of a paradigm shift within the automotive sector to AFVs in order to decarbonise. A key option identified by the sector and policy makers has been the electrification of transport, this has gained considerable attention and therefore deserves further research on the feasibility of EVs within certain scenarios (OLEV, 2013).

Research shows that EVs are more energy efficient than an ICE vehicle within the use phase, with 75% efficiency compared to the 20% efficiency of ICE (WWF, 2011). This is the benefit of EV drivetrain technology that uses an electric motor and electricity storage. EVs present the opportunity to reduce extensive fossil fuel use by 80% for the purpose of meeting vehicle motive power requirements by 2030 (AEA Group, 2009) (WWF, 2011). This has further benefits for "energy security by diversifying the energy sources used in the transport sector, and reducing tailpipe emissions of air quality pollutants" (AEA Group, 2009, p. 3). Moreover, there is potential for the UK to save up to £8.5 billion per year by 2030 in avoided fuel imports (WWF, 2011).

However there are challenges in transitioning to EVs as it could disrupt existing transportation networks across the UK thus being detrimental to a wide range of businesses that rely on ‘just-in-time’ business models based on highly integrated transport systems (ITPOES, 2010). There are concerns that EVs could cause various energy system challenges including harmonic disturbance in the electricity supply and peak electricity demand. However, EVs have the ability to balance the electricity supply system positively if the majority of vehicles are charged overnight, the consistency of energy demanded will flatten the existing peaks and troughs illustrated in Figure 4.

*Figure 4: Average daily electricity demand for UK*



*Source: OLEV, 2011*

In order to manage the new source of energy demand of EV charging and best manipulate charging behaviour (whilst offering an attractive solution to customers), companies are offering a range of different commercial models that will co-exist. These include, a parking-plus model, pay-as-you-go models, subscription based models, mobile phone tariff-style models and follow-me tariffs by which the electricity used at public charge points is attributed to the driver’s domestic electricity bill. Each model will require management via back-office systems to differentiate payment and provide the necessary software to complete the transaction. The behaviour of charging is largely unknown and could have considerable consequences on energy supplies, driver behaviour and vehicle use.



Although EVs are deemed by regulators as zero emitting due to no tail pipe emissions, there are environmental concerns regarding the overall impact of an EV from 'well-to-wheel' and beyond. Critiques argue that EVs emit more carbon than that of an ICE vehicle due to the manufacturing process and the current UK electricity generation mix (RAENG, 2010). However, McKinsey (2009) predicts that if the market develops sufficiently by 2017 the UK will reach a point at which vehicle electrification can be justified for well-to-wheel carbon abatement (Covington, 2011). It is suggested that if the entire global passenger vehicle fleet was electrified by 2030 it would be likely that well-to-wheel carbon emissions from fleets would reduce by up to 85% compared to the baseline of no action being taken (McKinsey, 2009). This highlights that need for further research as whilst some studies suggest major potential benefits of lower carbon emissions of EVs, others remain more sceptical. Certainly, as more renewable sources of electricity contribute and decarbonise the national grid the less environmentally damaging EVs will be over the lifetime of the vehicle.

## 2.2. Electric vehicle market

In the early nineteenth century Michael Faraday demonstrated the principles of electric motors and generators, this led to the first experimental EVs to appear in the UK, USA and the Netherlands (Hoyer, 2008). The 'golden age' of EVs from the late 1800s to early 1900s saw EVs dominate the vehicle market, competing with steam powered and gasoline cars. However over the following century there was a decline in popularity of EV technology as gasoline vehicles improved and the limitations of range and speed prevented EVs from competing, thus resulting in un-sustained market share within mainstream transportation (AEA Group, 2009).

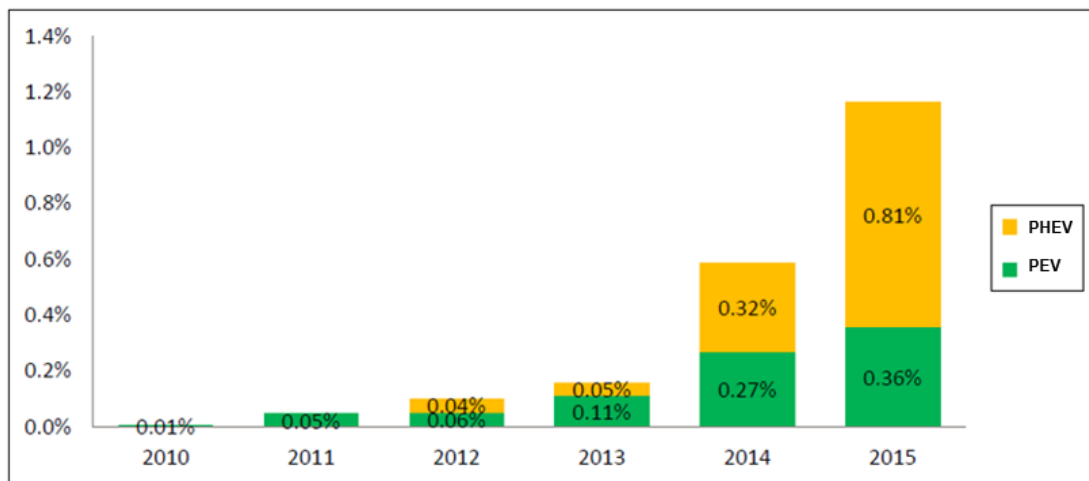
However, by the twenty first century, climate change was rapidly rising on the political agenda, with particularly focus on carbon dioxide emissions. This led to renewed innovations and investment in EV technology and policy support, offering significant strength to provide vehicle technology and engineering capabilities (BERR & DfT, 2008). As a niche market a range of factors will determine the rate of EV sales in the UK, this includes consumer acceptance, oil prices, battery technology and infrastructure (OLEV, 2011). Are these factors currently contributing to the uptake of EVs or is there a lack of stimulus encouraging adoption?

As competition among EV manufacturers and manufacturing increases, it will assist in removing the existing high barriers to market entry and begin to challenge the ICE. As a result, greater competition will make it more difficult to differentiate products, vehicle life will increase and the need to service and maintain will decrease. However due to the stringent 2020 CO<sub>2</sub> targets under the European New Car CO<sub>2</sub>

Regulation technological advancements within ICE vehicles are proving to be fiercely competitive with PEVs (OLEV, 2011).

Over the four years this research has been conducted, 2011-2015, the number of EV models on the market has increased by a factor of seven, with 30 PEV and PHEV models now available. As of December 2015 there were approximately 47,690 ultra low emission vehicles (ULEV) in the UK that have been bought using the Plug-in Car Grant (discussed in Section 2.2.1) and 8,787 charging points at 3,378 locations (Lane, 2015). Figure 5 shows the relatively rapid increase in market share for PEVs and PHEVs over a five year period, but more importantly, their comparatively small market share within the automotive industry. In 2014, the UK EV market was comparable to the US, France and Germany (OLEV, 2015).

Figure 5: Market Share of BEVs and PHEVs



Source: SMMT, 2010 – 2015

As expected within an emerging market, the number of companies providing charging infrastructure solutions has risen rapidly. Currently there are ten direct suppliers of charging infrastructure in the UK, all of which provide a range of charging infrastructure and extra services such as billing. In November 2013, the European Parliament endorsed a Directive that required the UK to have 70,000 charging points by 2020 (Peixe, 2013). However by the following year the EU retracted and stated governments must endeavour to install an appropriate number of charging points accessible by the public (Wirgman, 2014a). Withdrawing the Directive was arguably due to the realisation that the EV market was gaining market share at a slower rate than previously anticipated. However it is unlikely the withdrawal will have had

significant impact on individual nation's low carbon delivery plans, stipulating targets of charging infrastructure.

At present, the UK EV market has reached pioneers of the technology; further support from the Government in terms of education and financial stimulus is required before the market can be self-sustaining and sufficiently competitive. Despite the slow uptake of EVs, the technology will become much more desirable in future years as the UK electricity mix incorporates more low carbon energy.

#### 2.2.1. Government investment: OLEV

The UK Government have committed over £600million to 2020 to support the uptake of plug-in vehicles in the UK. There is available funding support for charge points at homes, on street and at public sector estates. Managed by the Office for Low Emission Vehicles (OLEV), a cross governmental team composed of the Department for Transport, Department for Business, Innovation & Skills and Department of Energy & Climate Change, they are tasked to remove barriers to the uptake of EVs. Funding is reviewed annually with the latest announcement of grant extension in December 2015; policy measures include

- £15m is available to continue the Electric Vehicle Homecharge Scheme, supporting EV drivers to charge at home. EV buyers receive a 75% grant up to an initial maximum of £700 towards the installation of a chargepoint
- £8m is available to support public infrastructure across the UK. 75% grants will support on street residential, public sector estate, train station car park and rapid and destination charging
- £15m of funding from the Highways Agency will deliver rapid charging across the Strategic Road Network and also offer funding to local authorities and NHS trusts to provide charging points on their property and town and city streets
- £9m will be utilised in the period to address key strategic issues including maintenance, interoperability and accessibility which will ensure the UK continues to build a world class charging network

Demonstration of the Government support is seen through further policies; in January 2011 the introduction of the Plug-in Car Grant of up to £5,000 (or 25%) against the purchase price has helped to reduce the high initial capital investment. The grant was due to expire in March 2012 however it has been extended to 2017, or until a prescribed number of vehicles have been sold. In February 2012 the introduction of the Plug-in Van Grant in which eligible vans are subsidised up to £8,000 (or 20%) widens the opportunities for EVs within light commercial fleets.

The UK Government is tackling transport emissions with a technology neutral approach, therefore businesses or private consumers with cars with tailpipe emissions of 75gCO<sub>2</sub>/km or less thus including PEV, PHEV and hydrogen-fuelled cars are all potentially eligible for the grant (DECC, 2011). The 2016 revised Plug-in Car Grant categorising vehicles based on CO<sub>2</sub> emissions and range was enforced in March 2016. The categories are:

- Category 1 – CO<sub>2</sub> emissions of less than 50g/km and a zero emission range of at least 70 miles, eligible for subsidy of £4,500
- Category 2 – CO<sub>2</sub> emissions of less than 50g/km and a zero emission range between 10 and 69 miles, eligible for subsidy of £2,500
- Category 3 – CO<sub>2</sub> emissions of 50 to 75g/km and a zero emission range of at least 20 miles 3, eligible for subsidy of £2,500

Further exemption and discounts for EV owners are available including (DfT, 2015b):

- Fuel Duty exemption
- Vehicle Excise Duty exemption
- Enhanced Capital Allowance
- Lowest rate of Benefit in Kind /company car tax
- Congestion Charge exemption in London
- Free/reduced price parking

Additionally, in 2020 the Ultra Low Emission Zone (ULEZ) will be introduced to improve air quality in central London in the attempt to comply with European Union legal limits for concentrations of pollutants (TfL, 2015c). The ULEZ standards are based on ‘Euro standards’ that define limits of exhaust emissions for new vehicles. Vehicles which do not comply can alternatively pay a daily charge to enter the ULEZ, similar to the congestion charge zone. However as PEVs “do not have a conventional engine and are not subject to Euro emission standards [they] are not subject to the ULEZ standard” (TfL, 2015c, p. 25) . This could be very significant, operationally and financially, to businesses operating within ULEZ.

There is further investment in developing the broader EV market, there has been approximately £66m in low carbon vehicle research, development and demonstration projects. This along with £74m allocated to Local Authorities and the Technology Strategy Board to fund low carbon projects, instils confidence within the market and enhances the relationship of car manufacturers, power companies, Regional Development Agencies, councils and academic institutions (Europa, 2011) (Automotive Council UK, 2010).

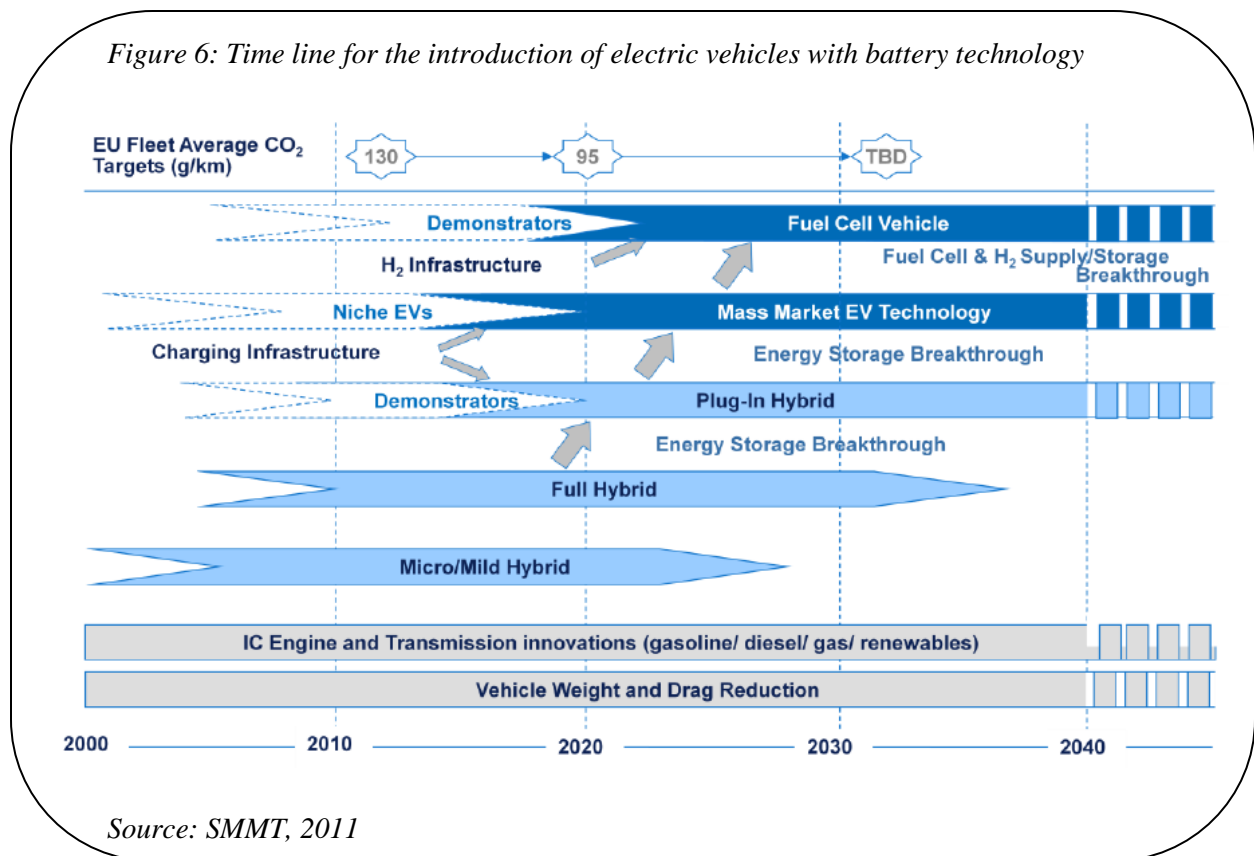
In 2011 OLEV funding launched the Plugged-in Places (PiP) scheme alongside local consortia's of businesses and public sector partners in eight locations across the UK (OLEV, 2011). As the key mechanism of increasing infrastructure, it created 'pockets' of EVs across the UK that relied on publically accessible infrastructure. Consequently the PiP scheme did not encourage interoperability across the UK, thus making it difficult for EV owners to use the vehicles nationally. The charging infrastructure and back office management of charging was (and remains) not homogeneous, therefore EV owners need membership to multiple schemes if travelling across regions. Additional funding was announced in 2015 for the Go Ultra Low City Scheme which follows a similar strategy to the PiP scheme. Four cities across the country were awarded £40 million to implement initiatives to support the take-up of EVs (DfT, 2016a).

This lack of interoperability remains a challenge for EV drivers today; however alongside targeted city schemes there is a developing network of pay-as-you-go charging infrastructure due to renewed Government regulation and standardisation of charging infrastructure technology. Fundamentally, the UK's lack of a national EV infrastructure framework heightens the potential barriers to market for EVs which is directly juxtaposed to an existing and well established gasoline infrastructure network (petrol stations) for ICEs which offers open access throughout the UK. Does public charging infrastructure pose as a significant threat to the take up of EVs? This will be considered in regards to commercial applications, in Chapter 5.

The available grants and incentives surrounding EVs are in theory supposed to encourage drivers to adopt the new technology. In some instances in which utilisation is particularly suited to an EV and the additional incentives are applicable, such factors would be integral to the procurement decision. However in order for the EV market to develop across the entire industry, it could be argued that government investment should result in EVs having cost parity with ICE vehicles. To achieve a monetary balance Government would be required to provide sufficiently high subsidies, such as a waiver on VAT on new EV registrations. Absorbing the 20% VAT would have a dramatic impact upon the total cost of ownership and would clearly highlight the Government's support. However such high subsidies are unsustainable in the long term and could be detrimental to the market and stakeholders. Alternatively, Government could internalise the cost of carbon to society, correcting market failure to form a low carbon economy. This will be addressed in Chapter 5 with an analysis of the financial case of EVs compared to ICEs in a number of scenarios, and will further explore the transition barriers to EV take-up.

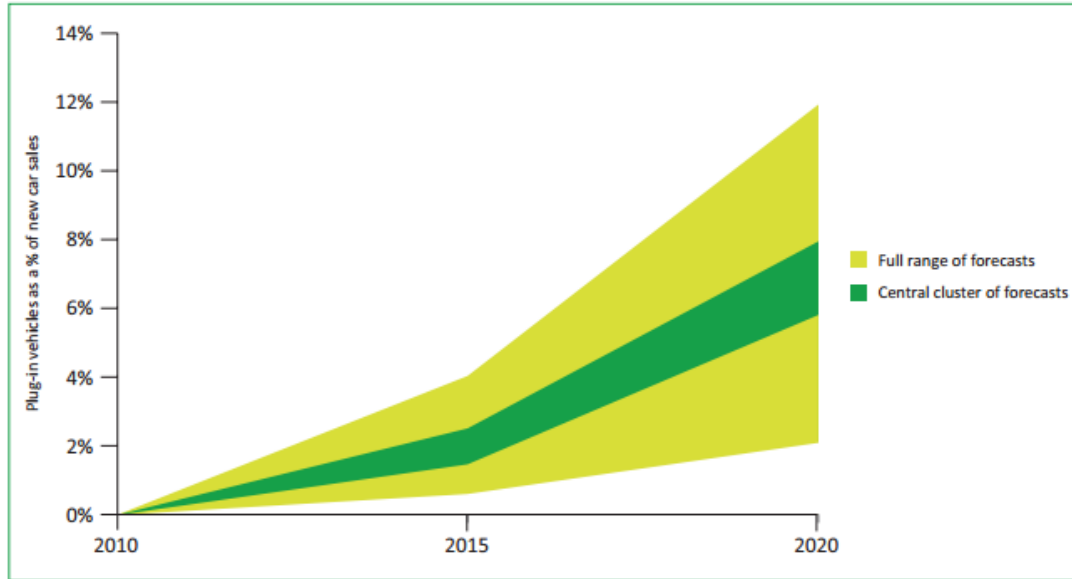
2.2.2.EV Forecasts

Due to the nature of a new market there is substantial investment into manufacturing and research and development. This clearly requires a level of speculation on the growth of market share over time and the return on investment. Figure 6 suggests a possible scenario of new technologies including EVs over the next three decades. It suggests that although ICEs are likely to remain in the market, it is predicted that over time the integration of EVs will become more prevalent. The continued use of ICE would occur naturally, regardless of which technology dominates the automotive sector due to the existing vehicle stock globally. The graph suggests the future market is concentrated upon reducing carbon emissions and that an encompassing approach of all vehicle types will be required to reach the emission targets.



Over the duration of the project (2011 – 2015) there has been a wide range of projections, as seen in Figure 7.

Figure 7: Plug-in vehicle uptake forecasts for 2010 – 2020



Source: OLEV, 2011 (Graph based on selected plug-in vehicle uptake forecasts by Arup -Cenex, BCG, Berger, Cheuvreux, Deutsche Bank, Frost & Sullivan and McKinsey)

Comparing the actual sales in 2014 to the midpoint projection, there were 2,476,435 new AFVs registered in the UK of which 14,498 were plug-in. This equates to 0.6% of overall new car sales which would align to the lowest forecast in Figure 7. This indicates there are clearly significant transition barriers to the adoption of EVs that the higher forecasts did not deem to be as influential on the market as has been experienced. The low adoption of EVs deserves further exploration to identify the challenges that are stifling market growth.

Although the EV market has a very small market share, the rate of growth has increased in recent years. The Chief Executive of SMMT stated that 2014

*“...was particularly strong for alternatively-fuelled vehicles as increased choice, coupled with a growing desire for reduced costs and greater efficiency, resulted in a quadrupling of plug-in car registrations over 2013. With a variety of new plug-in models expected in 2015, this area of the market will continue to grow significantly”* (Hawes, 2015, p. 1).

In 2015 there were 2,476,435 new AFVs registered in the UK, with 28,188 of those eligible for the Plug-In Car Grant. As suspected with a rise of available vehicles along with uncertainty regarding the longevity of government subsidies, it resulted in a surge of plug-in car sales equating to 94% increase on the previous year.

Despite the significant growth in the EV market, it is relatively very small within the automotive sector. However, one scenario argues that at least 1.7 million EVs will be necessary by 2020 and 6.4 million by 2030 for the UK's climate change targets to be met (WWF, 2011). This would equate to 6% of all cars in the UK being EVs by 2020 and 18% in 2030 (WWF, 2011). For this to be possible it relies on how manufacturers "trade off control over differentiating technology against scale and flexibility in the short to medium term" (BCG, 2010, p. 11). Whilst currently vehicle and cell manufacturers form an alliance to dominate the market, this is suggested to continue until technologies improve and batteries become a commodity. At this point traditional relationships between manufacturers and consumers will resume and the scale of production and sales will regain importance (BCG, 2010). Despite this, countries such as Norway are already achieving high EV sales due to their tax regime which de-incentivises ICEs. This begs the question, should a carrot or stick approach to taxation be utilised to achieve a transition?

### 2.3. Fleet market

A fleet is a group of vehicles owned or leased by a business, government agency or organisation. The fleet market comprised of 14 million fleet vehicles in 2011 and was valued at approximately £17 billion a year, with new vehicle registrations equating to £106,491,424 (Maslen, 2011). Large fleets will spend up to £3 billion a year on vehicles and fleet services (Maslen, 2011). Fleet vehicles comprise of over 50% of all new vehicles sold in the UK and has steadily increased over recent years (SMMT, 2012).

Within any fleet a strategic process is undergone to procure, integrate and manage the vehicles required to deliver the necessary service, this includes (DfT, 2010):

- Understanding the required service level
- Understanding any pressure that may affect the fleet service
- Reviewing the assets and employees that are necessary to deliver the service
- Developing an integrated system of management to optimise service delivery
- Managing, monitoring, reviewing the service to ensure maximum efficiency and compatibility with developing needs



The management of fleet vehicles provides knowledge on the operational and technological requirements that are necessary to optimise efficiencies. This is advantageous when considering appropriate vehicle technologies; this will be further discussed in Section 2.3.5.

### 2.3.1. Public sector fleets

Fleet vehicles within the public sector are extremely diverse, ranging from local policing to refuse collection thus resulting in considerably different influencers to procurement (DfT, 2010). However, due to the vast number of vehicles within the public sector there may be opportunities to combine purchasing power of individual departments to reduce costs (DfT, 2010). Public sector fleets often operate under various financial, environmental and social policy constraints that can be either internal or external to the government department (DfT, 2010). Public sector fleets will often possess the following characteristics:

- Vehicles driven by staff, not trained drivers
- Vehicles are procured for specific operations with limited opportunity for utility diversification
- Low average annual mileage due to use within specific geographical areas
- Vehicles are kept in service for longer than average

A key motivator for the public sector to manage their fleet operations efficiently is the opportunity to meet wider social obligations and policy objectives.

### 2.3.2. Private commercial fleet

A fleet of ten or more vehicles that function within business operations qualifies as a commercial fleet (Entrepreneur, 2015). Private commercial fleets consist of a broad range of vehicle types, specifications and modes, determined by the operational activity, fleet manager or employee. The market was heavily affected during the recent recession as commercial fleets are an expensive overhead that can be managed according to business demand. However, since 2012 the commercial vehicle market has expanded with 60% of fleets increasing the number of operational vehicles (Lex Autolease, 2014). Over 80% of commercial fleets are deemed to be Business Critical, whereby they are central to operations (Lex Autolease, 2014).

The vehicles are financed through a range of ownership models and operations are increasingly reliant on outsourced support i.e. telematics (Lex Autolease, 2014). The use of telematic systems within the commercial fleet sector is rapidly increasing; it enables fleet managers to monitor the location of vehicles, the driver's behaviour and receive real-time information. Therefore telematics can be used as a mechanism to "improve business efficiencies, ensure legislative compliance and cut costs", whilst also

enhancing driver safety (The Fleet Industry Advisory Group, 2014, p. 2). ALD Automotive (2012) suggest telematics could result in significant savings for commercial fleets:

- Fuel savings of up to 20% through better driving
- A 15% saving on overtime claims due to better mileage records
- Productivity increases of up to 15% due to improved journey scheduling
- Improved customer relations with more accurate response times and call scheduling
- Insurance premium savings of up to 30% with drivers involved in fewer crashes as a result of practising ‘smarter driving’
- A greater likelihood of vehicle recovery in the event of theft
- Reduced operating costs with vehicles serviced on schedule and less aggressive driving
- Increased awareness of general risks that could impair business or personal performance or safety, and lead to unforeseen costs or vehicle downtime
- Potential reduction in penalty notices and speeding fines

Furthermore, commercial fleets benefit from incorporating environmental policies for PR value and potentially tax relief. The environmental impact of commercial fleets needs to be assessed alongside the effects on the total cost of ownership, this being based on fuel consumption, emissions and regulations.

### 2.3.3. Grey fleet

Grey fleets are vehicles that are owned by employees but are used for business purposes, substantial numbers are found both within the public and private sectors. Within the UK the number of grey fleet vehicles is not known as it is not uncommon for organisations to be unaware of how many reside within their own fleet (Briers, 2010). Lex Autolease estimate there are approximately “14 million cars in the grey fleet, with 9 million of these used for work purposes on a regular basis” (2014, p. 6). Grey fleet vehicles remove the expense of purchase and maintenance; however there are multiple reasons why a business would wish to limit their grey fleet use.

Firstly, due to the Health & Safety at Work Act 1974 employers are required to ensure the welfare of the employees which includes driving for work purposes regardless of vehicle ownership (BVRLA, 2015). The additional resources required to do so make it a less attractive option. Secondly, it is likely that grey fleet vehicles will significantly contribute to a fleet’s carbon emissions due to age and efficiency. Thirdly, mileage re-imburement rates tend to be considerably higher than alternative modes of transport, for example 10 million miles at an average speed of 40mph would take approximately 250,000 hours and

cost £3.8 million, such figures could be dramatically decreased through alternative transport modes e.g. trains (BVRLA, 2015).

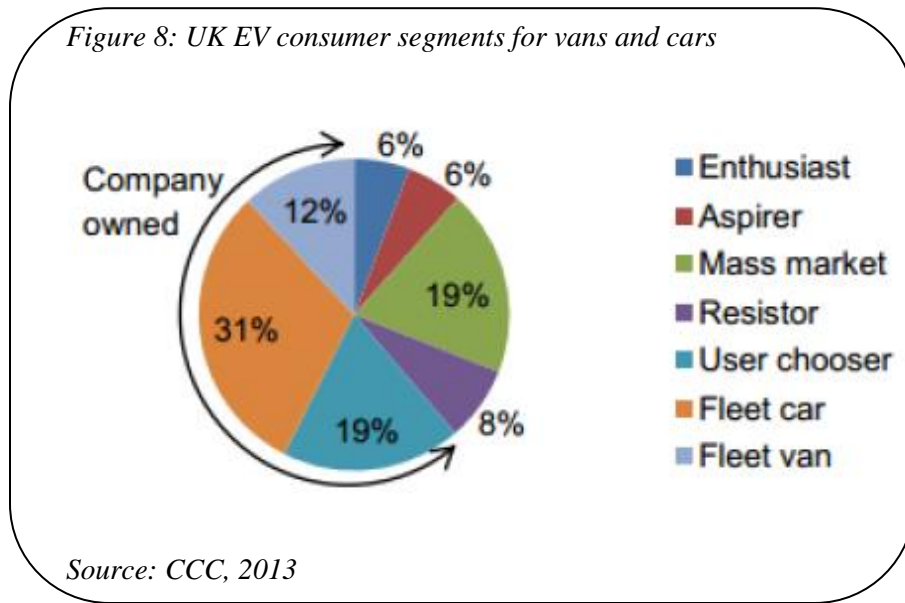
#### 2.3.4. Vehicle rental & leasing

The vehicle rental and leasing industry is valued at approximately £8billion, employing 32,000 people across 2,935 businesses (IBIS, 2011). The industry provides a range of vehicles for businesses and private individuals determined by the needs of customers (SAB, 2014). Car rental is considered the largest segment within the market and amounted to 38% of market revenue in 2011-2012 (IBIS, 2011). Car rentals are typically for less than a month, whereas leases will be for over a year (SAB, 2014). Car rental companies have the opportunity to influence consumer demand for low emission vehicles through providing the option on the fleet and customers using the vehicles for extended periods.

#### 2.3.5. Fleet EV opportunities

The fleet market in its entirety is predominantly fuelled by diesel but could have a significant impact on the EV market if it were to electrify a proportion of vehicles. This could have secondary benefits as a significant number of private individual's would have exposure to EVs through their contact with fleet vehicles and may consider EVs for personal use. This process has been shown in trials to be a significant way of changing public opinion and reducing perceived risk to an individual of purchasing an alternative technology (Cenex, 2011b). A study of 3,000 UK car buyers identified distinct market groups of new private car buyers (as seen in Figure 8), these segmentations are discussed further in Chapter 6 (CCC, 2013). The diagram however shows 50% of all EV sales are attributed to fleets, with nearly a third purely cars, although still relatively very small in overall car sales it highlights the interest and applicability of EVs within the fleet market.

Figure 8: UK EV consumer segments for vans and cars



Fleets present a very promising opportunity for EVs for a number of reasons:

- The majority of commercial fleets have similar characteristics including high utilisation rates, centralised parking facilities and managed known activities (Pike Research, 2010). These factors are significant for the business case as it enables strategic management of charging and operations, allowing for a quicker return on investment
- Fleets are expected to have specific and predictable charging requirements derived from their drive cycle, destinations, time schedules and fleet size. This enables route and vehicle optimisation which can be supported by telematics
- The concentration of buying power associated to fleets and the relatively small number of influential decision makers within the industry (Electrification Coalition, 2010). This results in targeted policies, economies of scale in the set-up and greater consideration for user preferences

#### 2.3.5.1. 'Sweet spots'

The benefit of a fleet is that the concentration of vehicles allows a fleet manager to analyse where an EV could best be utilised. Within the current market there are certain scenarios that EVs can immediately outperform an ICE vehicle through either costs or efficiency, hailed as a 'sweet spot' opportunity. At present there is a narrow area in which the operational barriers are overcome and EVs work particularly well, this is often a light commercial vehicle within a city travelling under 100 miles per day; for example:

- Royal Mail – 60 miles per day typical usage, predictable stops

- Sainsbury – 100 miles per day, unpredictable stops
- DHL city courier – 70 miles per day, unpredictable stops
- Council pool car – 50 miles, unpredictable stops

Such drive cycles are ideal for EVs due to the low mileage per day and the ability to charge if required when the vehicle stops. Predictable stops are an advantage as the fleet manager would be able to forecast when and where the vehicle could charge. However with fleet operations below 100 miles, an EV would be able to perform the day's objectives and be charged out of business hours. However EVs are not always suited to a business's operation and if forced to go beyond the realms of current EV capabilities it would result in a more expensive and less efficient vehicle. In such instances bad publicity ultimately follows which may be extremely damaging for the EV market.

To enhance EV integration, vehicles should not be immediately procured at the same specification as existing ICEs within the fleet but drive cycles, battery capacity and route optimisation need to be considered. In most scenarios it would be possible to alter the operational requirements of a fleet to reduce the distance that a vehicle travels to do the services it needs to through linking activities together. It is suggested the operational requirements of a fleet enables an average of 20% of the vehicles to be electrified, however if total operations of a fleet are analysed then it is possible to achieve approximately a 40% reduction in energy or fuel consumption (Haycock, 2011). Therefore fleets managers should analyse their operations and capability to utilise EVs as introducing the vehicles to their drivers will be considerably easier if the transformation 'fits'.

#### 2.3.6. Conclusions on fleets

The fleet market encompasses a broad range of vehicle types, mode and operations, used within a plethora of other markets. The potential to decarbonise the fleet market is extensive, currently the technology gaining most attention is the EV due to the proposed transitional suitability. It is suggested that within 'sweet spots' there is the opportunity to make substantial efficiency gains transitioning to EVs. This questions why the uptake of EVs is still relatively low; do 'sweet spots' exist only in niche applications or are fleets simply not 'ready' to adopt EVs? Further research needs to be conducted to explore the drivers and barriers of fleets adopting EVs and the lock-in ICEs appear to be experiencing within commercial applications. To what extent is increased utilisation of EVs reliant on technological developments, a change of culture or economic and regulative enforcement? These fundamental issues of fleet transitions will be explored in the following chapters of the thesis.

## 2.4. Mobility services

Urbanisation is accelerating at an unprecedented rate, today 50% of the world's population live in cities with 1.5 million additional people migrating every week (PwC, 2014a). As all city systems, mobility is heavily affected by this; mobility can be described “as the ability of people and goods to move around an area, and in doing so to access the essential facilities, communities and other destinations that are required to support a decent quality of life and a buoyant economy. Mobility incorporates the transport infrastructure and services that facilitate these interactions” (Arup, 2014, p. 4). The impact on mobility alongside the developing demands on service, frequency, user transparency and fluency across modes are encouraging new business models to be created with alternative service provisions.

In Britain the average car is parked at home for 80% of the time, parked elsewhere for 16% of the time and in use for only 4% of the time (RAC, 2012). This indicates the significant potential for an alternative ownership model for private individuals; consequently it would remove ownership costs, remove a considerable proportion of vehicles off the road and increase parking availability. Over the next decade it is likely that transport solutions will develop to become a more integrated system within cities, composed by various modes of transport and alternative ownership models. This along with a more diverse energy mix managed by demand response, ‘Mobility-as-a-Service’ (MaaS) could significantly alter the city scope across the energy and transport platform.

The concept of mobility is dramatically changing; evidence suggests that MaaS will become integral to society providing alternatives to car ownership (KPMG, 2013). This could be through a range of services, such as car sharing or car clubs, which will widen the mobility solution. Ben Plowden, Director of Strategy and Planning for Surface Transport at Transport for London, said (2014, p. 1): “there is a very significant challenge facing London's roads. 30 million trips are made every day and 80 per cent of those are on the roads...so we have to respond and find some way of dealing with that. Car sharing is a very important part of that jigsaw puzzle”. Car club services will incorporate mobile apps for payment and location-aided services, thus ensuring ease of use and functionality (KPMG, 2013). However, will mobility services increase congestion and discourage travellers from using public transport?

This research identifies car clubs as a substantial opportunity for the EV market. Using EVs within such applications can remove many of the barriers to EVs, including range anxiety, high purchase price, total cost of ownership and charging. This is a considerable opportunity to decarbonise transport, especially within cities that could have multiple vehicle pick-up and drop-off locations. However utilising EVs within car clubs challenges the fundamental culture surrounding the automobile, (i) ownership, and (ii)

gasoline vehicles. These are embedded characteristics of the automotive industry, how can these be challenged in order to establish a service based economy?

#### 2.4.1. Car clubs

ICT has dramatically enhanced the transport system enabling new business models so drivers do not have to own their own vehicles, alongside the introduction of mobility services. The use of real time data and smart phones enables car clubs to not only be an alternative to car ownership but to best serve certain journeys for those taking public transport.

Car sharing membership grew fivefold between 2006 and 2012 globally equating to 1.8 million drivers. London currently has approximately 140,000 car club members, the second highest number of any city in the world and forecasts suggest that could increase to 800,000 by 2020 (Thomas, 2015). There has been further investment in the capital with Bolloré and BMW-Sixt DriveNow having both recently entered (Car2Go exited in 2014). The market potential is large, there is expected to be a 14% rise in population in the next decade that could equate to 350,000 more privately owned cars at current ownership levels (Fergusson, 2014). This is in addition to the 2.6 million vehicles that are already within the city. For London to address this, the concept of mobility needs to be fundamentally challenged to reinstate the equilibrium between congestion and pollution with cyclists, pedestrians and drivers.

The majority of car club vehicles are ICEs, with only 43,544 vehicles used globally in 2013 being electric, proportionally disparate to the number of members (Fairley, 2013). However this highlights the opportunity e-car clubs have to accelerate EV deployment and increase exposure. Electric car clubs have been increasing in numbers across the world; this is whereby members have access to a fleet of EVs for planned or spontaneous journeys. E-car clubs are primarily in cities due to the high population density, localised demand and the compatible user drive cycle of low mileage. Furthermore within cities, vehicle ownership is not an essential asset for the majority of citizens due to accessible public transport and the relative expense of car ownership. Therefore e-car clubs offer an affordable alternative to car ownership that can be used in conjunction with public transport services.

Figure 9 highlights the leading electric car sharing clubs that range in business models:

*Figure 9: Electric Car Sharing Leaders*

Program	Primary vehicle/range	Fleet size/location
Bolloré Autolib	Bluecar/200 km	1800/Paris
Daimler Car2Go	Smart For two EV/140 km	1000/six cities
Citroën Multicity	Mitsubishi i-MiEV*/150 km	350/Berlin
BMW-Sixt DriveNow	BMW ActiveE/140 km	130/three cities

\* Rebranded as Citroën C-Zero

*Source: Fairley, 2013*

There are a plethora of benefits for customers and operators to optimise EVs within car clubs these include; low fuel costs, unique selling point, environmentally conscious and the available Government incentives. The extent to which these benefits impact the diffusion of EVs within car clubs will be explored at greater depth. Similarly, it must be considered, what are the challenges of e-car clubs and why are they not gaining momentum within the market?

#### 2.4.2. Conclusions on mobility sharing

Mobility services is a growing market, challenging the population's disposition to own underutilised assets and instead optimise alternative business models alongside public transport. However, are travellers and businesses prepared to transition to a service based transport system? The combination of mobility services and EVs introduces a new dynamic to the relationship of operators and users, varying between business models employed. This research will consider the role of EVs within mobility services, and therefore explore the drivers and barriers of e-car clubs to identify required support for a transition pathway in a largely unregulated market.



## 2.5. Conclusions

The background review contextualises the research, highlighting the importance and urgency for a low carbon transition within the automotive sector. It is evident that regulators and industry are responding most aggressively with the arrival of a ‘new generation’ of EVs. The opportunities are extensive within the markets identified; both the fleet market and within mobility services, the road transport system in the UK could be significantly altered through the adoption of EVs. However EV sales remain relatively low, with market perceptions of the technology arguably restricting the potential growth. Moreover, at present the EV market is heavily stimulated by Government investment but is this market technique of motivation crowding creating a competitive environment, or can we learn from cities overseas? This research will explore the transition barriers within these markets and ask the extent to which ICE lock-in threatens EV adoption. This question extends to consider the lock-in of private ownership and the transition barriers to alternative business models that allow for a more flexible approach to mobility.

### 3. Literature Review

Given the research objectives and questions, the fundamental issues of technology change will be reviewed using socio-technical theory to explore the influence of competing market factors on the diffusion of EVs. There is a long standing history of socio-technical theory that explores the “linkages between elements necessary to fulfil societal functions” (Geels, 2004, p. 900). This research will focus on the diffusion and use of EV technology within the automotive industry, analysing and adapting a number of models that are situated under the socio-technical umbrella. The literature on technology lock-in and path dependant characteristics will be explored to establish the impact on transition barriers. This will assist in determining the necessary support the EV market requires to remove lock-in and path dependencies. As well as the exploration of proposed future technology developments that would significantly alter the pathway of EVs, therefore it is necessary to consider these in the broader context of the industry.

The relationship between transition pathways, path dependencies, technology lock-in and e-mobility has been under-researched. This chapter will explore these theories in the context of EVs and critically assess the existing literature across these research fields. There are existing research gaps regarding the characteristics and usage of EVs within commercial applications, along with the current motivations and effectiveness of incentives. Frameworks that can contribute to the core analysis of this research will be reviewed and applied to the market of fleets and mobility services. The Chapter will identify gaps and uncertainties within the literature that deserves further exploration in order to meet the research objectives.

#### 3.1. Theories of technical change

##### 3.1.1. Path dependency

Path dependency plays a vital role in determining what products/services come to market and how they infiltrate and compete with existing market actors. Path dependency refers to “a dynamic theory assuming that initial events can increasingly restrain present and future choices” (Koch, et al., 2009, p. 67). Ahman et al (2007) further explains the embedded characteristics from previous and existing markets govern new innovations, determining the route, speed and success of a new entrant to a market. Path dependencies are “generally seen as a barrier to change, but ... also a precondition for change” (Ahman et al, 2007 p.7). Therefore to understand the EV market and the diffusion of technology in fleets and car clubs it is essential to have an appreciation of the path dependencies that are inherent to the automotive sector.

The car market has very strong path dependent characteristics that have become ingrained within society since the production of the motor car in the 1900s (Cowan & Hulten, 1996) (Schot, 1994). Path dependencies of the automotive sector are stimulated through the mutually reinforcing social system of road transport encompassing infrastructure, service stations and roads. These contribute to the culture of road transport by which drivers are susceptible to and have engrained behaviour as a result. Pasaoglu (2014) argues personal mobility has been entrenched in Europe's economy since the introduction of mass motorisation, over which time the "automotive mobility system [has developed] profound regime stability" (Well & Nieuwenhuis, 2012, p. 1681). Consequently path dependencies of cars include the design, specification, price and the sunk technological costs of ICE technology (Ahman et al, 2007). Nieuwenhuis et al (2006, p. 13) consider the industry to be "almost paralysed by its own structural conditions" and it is arguably these inherent conditions that are preventing the utilisation of AFVs, despite attempts to unlock ICE dominance with the use of government policies. Higgins et al (2012) proposes that consumer decisions to purchase EVs are "influenced by several complex criteria such as costs/benefits, performance, appeal/status, risk, psychographics, and demographics" (Higgins, et al., 2012, p. 1399). These criteria largely stipulate all purchase decisions; regarding EVs these criteria are certainly limiting adoption. However are these criteria applicable to commercial fleets? Anable et al (2014) highlights there is limited evidence of the motivations of vehicle choice within fleet procurement, although research indicates weight is given to total cost of ownership and vehicle reliability. Although Anable et al (2014) deems this as restricted insight in to fleet behaviour, it clearly indicates the fundamental concerns of fleet procurement are closely linked to business operating costs and the return on investment. Therefore this suggests a heightened need to ensure EVs are equally comparable to ICEs on cost and performance. This research will further investigate the decision criteria of the fleet and car club markets and analyse the total cost of ownership of an EV. It will then be considered if these factors are restricting the uptake of EVs and how the barriers could be overcome.

Due to the high costs to market entry in the automotive industry which stem primarily from sunk technology costs of the ICE, there is a relatively slow rate of creative destruction whereby EVs can revolutionise the market by replacing the existing technologies through the process of innovation (Schumpeter, 1942). It is considered that technologies entering a new market can be 'sustaining' or 'disruptive' based on the performance of existing products (Christensen, 1997). Sustaining technologies "improve the performance of established products...that mainstream customers in major markets have historically valued", such technologies reinforce the dominant operating system. In contrast, disruptive technologies "bring to market a very different value proposition than had been available previously" (Christensen, 1997, p. 8). Although in most scenarios disruptive technologies are cheaper and more

convenient, Christensen argues these innovations will undergo transition failure due to poor product performance (Christensen, 1997). Therefore, is the automotive sector primarily focused on the development of sustaining technologies due to their aversion to risk that is inherent with EVs as a disruptive technology?

Path dependencies play an important role on innovation and entrepreneurship and are often fuelled by low cost of entry, low unit costs and flexible and broad channels of supply. Entrepreneurship within the EV market has been pivotal in overcoming path dependencies, utilising a unique value proposition. Tesla for example emphasised “the superior advantages of EVs in the shape of high-performance luxury EVs” (Bohnsacka, et al., 2014, p. 298). Entrepreneurial firms are more flexible in coming to market with alternative business models that can exploit the existing landscape, more specifically regulatory change (Sosna, et al., 2010) (Demil & Lecocq, 2010). Bohnsack et al (2014) explore Tesla’s route to market, which highlights Government support as an important enabler of the company’s success. As an entrepreneurial firm Tesla are able to manipulate contingent events such as the 2012 update to the Corporate Average Fuel Economy (CAFE) standards. The standard incentivises auto manufacturers to improve fuel economy of their vehicle portfolio, credits are used to incentivise or penalise accordingly. It was reported that since 2008, Tesla has earned \$534 million from the sale of environmental credits to other auto manufacturers that “either don’t produce electric cars or have made a strategic decision to buy credits and cap their own sales of such vehicles” (Hirsch, 2015, p. 1). Consequently, Tesla’s motivations to continue lobbying the US Government for tighter emission standards could be questioned beyond extrinsic environmental values.

Although it is clear that entrepreneurs stimulate innovation and market incumbents, it is important to consider their role within the broader regime alongside large multinationals, Government and society. Ahman et al (2007) suggest entrepreneurial characteristics have significant implications on the role of government and use of policy mechanisms in supporting technology and market developments. Therefore it is questionable whether path dependencies stimulate the use of motivation crowding or if the market techniques employed are due to landscape pressures. This research will explore the challenges that government policy tries to tackle and the effectiveness for the fleet and car club markets.

Drivers expect vehicles to have similar capabilities based on the ICE, this includes a range of 300+ miles with regular access to refuelling stations that on average takes seven minutes to complete the transaction. This relationship between the driver and vehicle is entwined within a social system that proves particularly challenging for EVs to compete within. To overcome path dependencies it is necessary for each individual to adapt to new market conditions whilst the vast majority still operate ICEs and are

targeted by external factors such as advertising to reinforce path dependencies. Cowen et al (1996 p.3) argues that auto manufacturers have established “economic-technical problems that have blocked the realisation of the economic benefits” of EVs due to existing manufacturing processes and designs. These costs are passed on to the consumer and are limiting the EV market from gaining momentum. This introduces the concept of lock-in (discussed in Section 3.1.2) that represents the outcome of path dependency and is equally challenging to eliminate.

Existing literature explains the significance of path dependency on new innovations; however it fails to consider the extent to which niche and mainstream technologies can comparatively compete within a new market. EVs are entering a well established industry that is dominated by path dependencies of the ICE, it is these characteristics of lock-in that are limiting EV uptake. This research will explore the extent path dependencies are restricting the transition to EV fleets, e-car clubs and the use of charging infrastructure.

### 3.1.2.Lock-in

A lock-in situation is a self-reinforcing mechanism within a dominant practice. It indicates that a process has become path dependent with rigid and inefficient outcomes, being difficult to replace with an alternative mode. There is evidence of lock-in within the automotive industry as market maturity has led to “a society, economy and culture tightly bound to ICE” (Koch et al, 2009 p5). This research questions how this can be challenged to allow EVs to be utilised to a greater extent along with the introduction of alternative business models.

As established, the ICE has become the benchmark technology for car travel, locking-in a correlation between specification, purchase price and efficiency (miles per gallon). The Department for Trade and Industry (2008) argue that the key challenge for auto manufacturers is to align technology, product and business performance alongside customer value and financial constraints. This creates transition barriers within the automotive industry that are underpinned by the requirement to optimise technology whilst under limited market conditions. As a result technology lock-in is established, reinforced by societal demands and expectations of vehicle specification and cost. Therefore the diffusion of AFVs has to address these challenges by either meeting, exceeding or altering these demands. This is particularly challenging due to the path dependencies of sunk technological costs; Vooren et al (2012) suggests this is especially relevant with infrastructure-dependent vehicles which rely heavily on investment.

A greater level of investment is required for an EV compared to an ICE, both financially for the vehicle and the charging infrastructure, as well as psychological investment to change ‘refuelling’ behaviour. However, if an individual has a personal aspiration to use an EV the perceived level of investment

diminishes. Nevertheless, unlocking vehicle technology for the mass market requires humankind's perspective of undesirable change to be adequately challenged, using a collective methodology of economic, societal and technological change management models. This highlights the entwined and reinforcing relationship between lock-in and path dependency that dictates market behaviour.

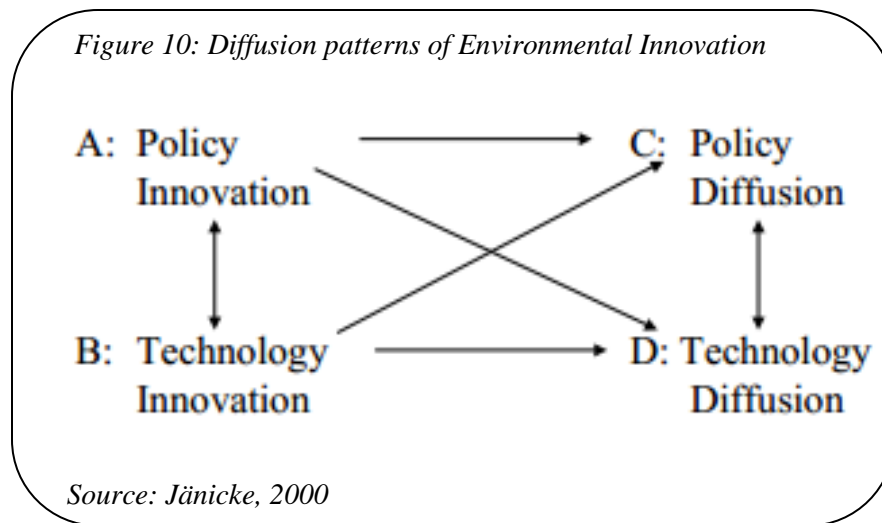
To understand the transition from the ICE to AFVs requires consideration of historical events and market conditions. Since the 20th century, the car has been the dominant form of transportation, whilst adapting to many challenges both economically and technologically (Epprecht, et al., 2014). Over the last 125 years ICEs have dominated the market, the technology has become entrenched within society and as a result there has been very limited competition for the ICE from alternative power trains. Perkins (2003, p. 1) suggests this is central to the concept of technological lock-in, in which "technologies and technological systems follow specific paths that are difficult and costly to escape", thus forming path dependencies that create lock-in. Vooren et al (2012) describes technology lock-in as the impact on the market and standard for future designs from a dominant technology. The definitions demonstrate the close relationship between path dependency and lock-in, referring to the impact of previous systems on the existing market. However, the key aspect this research considers is the restriction lock-in places on new innovations entering a market i.e. EVs in the automotive sector.

Lock-in is defined most broadly in pure technology terms but it is useful to consider lock-in by social and cultural factors. Socially, ICEs are locked-in by expectations of range and allegiance to status and brand; as a result EVs are locked-out by not conforming to predefined conditions. Furthermore Banister (2008, p. 73) suggests that due to an increased emphasis on the speed of travel it has outweighed the cost, therefore "local public transport, cycle and walking have become less attractive, and this in turn has resulted in the greater use of the car". This assimilation with the automobile leads Epprecht et al (2014) to argue the barriers are not overcome by technological innovation and regulation independently but require a combined approach within market specific conditions. This is fundamental for niche innovations to challenge lock-in and destabilise the dominant technology. This research further considers the role of stakeholders to establish a route to market using applicable tools that can stimulate creative destructive. This can be witnessed in the EV market with the use of incentives; however this research will question if financial stimulus is necessary or sufficient to encourage take up and if it is currently targeting the 'best' audience.

Vooren et al (2012) suggests there are 3 stages for infrastructure-dependent vehicles to enter mass market, starting from a position of lock-in; (i) a technology-push from Government in which variety is stimulated through aligning regulation and financial support for research & development, (ii) Government influence

in bringing the technology to the market through large scale pilot projects, (iii) consumer adoption which ultimately determines technology substitution, dependent on price and consumer fit. Vooren's theory suggests the role of the Government is important for the longevity of new technologies as it "can affect the probability (and speed) of the technological substitution process" and it is at this point when innovations can fail (Vooren, et al., 2012, p. 114).

Vooren et al (2012) suggest that the plug-in vehicle market is led by the government and responded to by the market and society, which then fundamentally removes lock-in. The first stage Vooren et al (2012) identifies the parallel role of government to stimulate investment alongside research and development. Evidentially, the sustained investment from government is required to establish an EV market that can challenge scepticism manifested from ICE lock-in to a point at which sufficient market share is attained to compete independently. The UK EV market relies heavily on Government stimulus and will continue to do so until lock-in is less prevalent. This research will further explore the dominant actors within the fleet and car club markets that are determining the rate of traction for EV utilisation.



Jänicke (2000) emphasises that the relationship between technology and policy is extensive and varied, as displayed by Figure 10. This is evidently true for any alternative technology entering a market, and can therefore be applied to the EV market specifically. This research considers the UK Government are taking the "Technological initiative (B – A – C – D): An existing environmental technology induces a political innovation whose diffusion in turn encourages the diffusion of the technology" (Jacob & Jänicke, 2006, p. 10). Government is able to use the electrification of transport to contribute to climate change targets through the gradual reduction in carbon emissions aligned to the incentives for low emission vehicles. This is aided by other nations having proven the technical and political feasibility of EVs. It

could therefore be argued that commercial applications are following a diffusion of “Political priming (A – B – D – C): A national environmental policy leads to technological innovations whose diffusion in turn encourages diffusion of the political innovation” (Jacob & Jänicke, 2006, p. 11). However, due to the indirect nature of the existing policies on fleets and car clubs, there is a degree of “Autonomous technological development (B – D): An innovation in environmental technology is successfully diffused without political influence” (Jacob & Jänicke, 2006, p. 11). This suggests there are perceived additional benefits of the technology innovation which challenge lock-in of the ICE.

For over three decades ecological modernisation has been applied to the relationship between environmental innovation and policy. The concept “encompasses all measures to foster eco-innovation and to support the diffusion of the [technology-based] innovations” (Jänicke, 2008, p. 557). Jänicke proposes ecological modernisation “has by far the largest potential to achieve environmental improvements”, especially when a marketable solution exists to an environmental or political problem (Jänicke, 2008, p. 557). The effectiveness of the innovation is based upon its rate of diffusion, classified by two levels; incremental and radical. Incremental innovations introduce ‘cleaner technologies’ but remain within niche markets, whereas radical innovations are new ‘clean technologies’ that improve some or all phases of a product’s life cycle (Jacob & Jänicke, 2006). Kemp (1997) argues for innovations to be sustained within the market a transition from incremental to radical innovation is required alongside the resolution of an ecological challenge. Applying the theory of ecological modernisation to the EV market, it is reasonable to consider EVs as an incremental innovation that is still constrained within the niche market. As discussed in Section 3.1.1, the new generation of EVs stem from the ICE and the evolution of the hybrid, therefore the technology is incrementally entering the automotive industry without the rate of diffusion to challenge the existing lock-in.

This research, as defined in the research questions, will investigate the motivations and barriers for utilising EVs within fleets and car clubs to determine:

- (i) What are the factors that lock technology in?
- (ii) How significant are these factors?
- (iii) What can be done to change these factors?

This will assist in establishing the extent to which EVs are locked-out of the automotive industry within the markets explored. It is clear that technology lock-in does not depend exclusively on technology and can introduce socially embedded path dependencies. The implications of a mutually reinforcing structure dominating vehicle manufacturing and procurement has restricted opportunities to decarbonise and



enhance efficiencies. This deserves further research to determine the transition pathway that can be pursued to overcome ICE dominance within the two markets.

### 3.1.3. Transition Pathways

EVs have been identified by policy makers as a key technology to decarbonise road transport. However, incorporating EVs within the UK's vehicle fleet requires "a shift from one socio-technical system to another i.e. a system innovation" (Geels, 2005, p. 682). This research aims to explore the market developments required to achieve a system innovation and identify the dominant actors within the transition pathway.

A transition pathway is an analytical framework developed to examine a transition process and considers the key dynamics (Geels, 2011). Foxon et al (2013) suggest that a transition requires fundamental changes in market concepts through governance, social practices and business models that have been developed upon past and present technological systems. This is extremely relevant to the EV market due to the established path dependency and lock-in as previously discussed. A transition to EVs is an extremely dynamic process as it extends beyond innovating and competing technologies. Introducing a new technology in this vein is much more likely to achieve long term impacts on the market through creative destruction (Schumpeter, 1942).

Struben et al (2008, p. 3) suggests transitioning within the automotive sector is extremely difficult due "a wide range of powerful positive feedback processes that confer substantial advantage to the incumbent ICE technology". The barriers to market are high due to the lock-in and path dependencies associated with large R&D costs, expensive and co-dependent technologies and substantial cost of market entry within an oligopoly. Epprecht et al (2014) proposes that the transition relies heavily on the bidirectional relationship between users and technology with influence from factors such as price, availability and convenience. This relationship is extremely sensitive in the context of EVs, therefore to encourage technology diffusion the market could benefit from the use of mechanisms to: remove market entry barriers, remove technology lock-in factors and focus on non-technical factors that prevent transitioning. These transition barriers are the core challenges that fundamentally prevent a transition to EVs. This research will establish recommendations across stakeholder groups to remove these transition barriers.

Transition polices often rely on understanding previous transitions to determine the appropriate policies for particular stages or element of the pathway i.e. social, economic, political. However due to the relative infancy of the EV market, Mazur et al (2015) highlights that policies have been influenced from experience with alternative technologies i.e. photovoltaic. This is a likely eventuality where by an

assimilation is formed between the diffusion of new ('green') technologies. The policies in place today are appropriate for the early stages of the market, attempting to encourage EV uptake through monetary incentives. However Sierzechula et al (2014) questions whether the Government will continue the subsidies until EVs are able to compete with ICEs and sustain market share independently. This thinking assumes that the current norms and aspiration of vehicles emissions stays constant, and therefore the auto manufacturers continue to produce zero emission cars. Nonetheless it is vital Government are sensitive to market conditions as well as indirect economies when incentives are removed, as to minimise risks of market instability and/or failure.

Transition pathways are influenced by a complex dynamic of economic, legal, social and technology concepts. There is a need to consider these market concepts further to establish the necessary changes that will lead to a transition pathway for the electrification of fleets and car clubs. The existing approach of motivation crowding will be analysed to consider its impact on transition pathways of multiple stakeholders.

#### 3.1.3.1. Multi-level perspective

The multi-level perspective (MLP) of transition pathways argues transitions are a result of interactions between processes at three levels (Geels & Schot, 2007):

- (i) Niche-innovations that build internal momentum through learning processes, support and price and performance improvements
- (ii) Changes at the landscape level creating pressure on the regime
- (iii) Destabilisation of the regime creating opportunities for niche-innovations

The transition to EVs is influenced by a broad and extensive range of factors; literature has yet to explore these in the context of the multi-level perspective. Geels (2011, p. 27) explains that niche-innovations are 'protected spaces' which could be small market niches "where users have special demands and are willing to support emerging innovations". Niche actors provide new products or services which offer radical innovations that could complement or replace the existing regime (Geels, 2011). If these niche innovations gain momentum and create system change that challenges lock-in, a transition can occur. Secondly, the landscape level is the wider context which influences both the regime and the niche dynamics. Geels (2011 p28.) suggest this includes "demographical trends, political ideologies, societal values, and macro-economic patterns". The landscape level is difficult to influence and can be slow to respond to challenges. Thirdly, Geels (2011 p.27) explains the socio-technical regime "refers to the semi-coherent set of rules that orient and coordinate the activities of the social groups that reproduce the

various elements of socio-technical systems". It is this that generates the stability of the existing regime; this is similarly proposed by Vooren's theory of diffusion (discussed in Section 3.3) which stipulates technology substitution relies on consumer adoption.

The regimes' internal dynamics generate fluctuations, this interaction can lead to a breakthrough in mainstream markets and existing regimes allowing competition to gain market share (Geels, 2004). At the landscape level, the transport sector is changing due to the pressure from climate change targets, resulting in behavioural and political changes (Geels, 2004). Geels (2004) argues the greater the instability of the sector the more likely an innovation can enter the mass market and compete with the existing system, influencing the wider landscape. This highlights the barrier to greater utilisation of EVs as the automotive industry is relatively stable with few negative externalities that consumers challenge. How can the EV market orchestrate a shift inorganically across an established regime?

The MLP emphasises the requirement of a technological niche for regime change to occur, whilst appreciating it acts as an independent dynamic within a greater concept. There are four pathways within the MLP:

- (i) Transformation – Moderate landscape pressure leading to the need for a change in the regime. Niche technologies are unable to optimise the landscape developments; but regime actors are able to adopt symbiotic elements of niche technologies
- (ii) De-alignment and re-alignment – Landscape pressure are quick and diverse leading to regime actors to lose faith in current technology. Niche technologies have not developed sufficiently to be a replacement, therefore competition persists until one niche technology gains momentum and replaces the regime
- (iii) Technological substitution – Niche technology has developed fully but remains niche due to a powerful regime. A sudden shock of landscape pressures destabilises the regime enabling the niche technology to gain momentum
- (iv) Reconfiguration – As in the transformation pathway, symbiotic elements of niche technologies are adopted in response to landscape pressures. However in this pathway, subsequent adoptions change the architecture of the system leading to technical changes, user perception, user practices and search heuristics.

The EV market is not following one of these pathways independently, but has components of the transformation, de-alignment and re-alignment and technological substitution pathways. Due to climate change targets and tightening regulations on toxic emissions the automotive industry needs to be decarbonised, although confidence remains in ICE technology with continual improvements in efficiency,

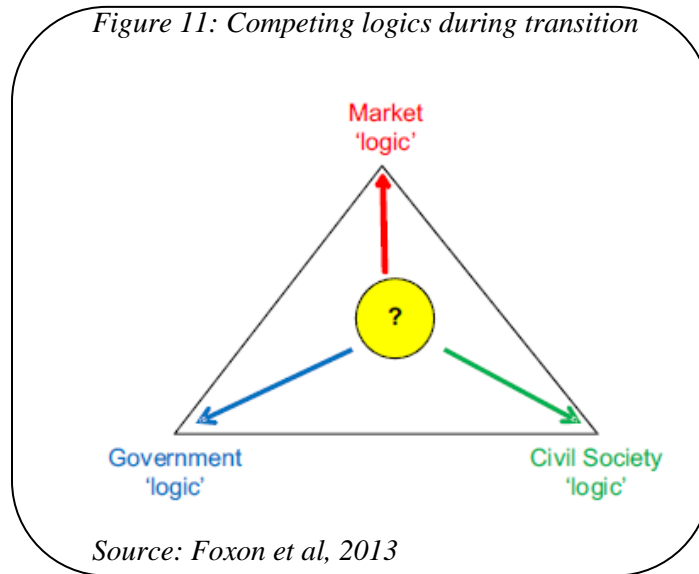
EVs have been identified as a key technology solution. However due to the powerful regime of ICEs, EVs have been unable to gain sufficient momentum to optimise landscape developments and destabilise the market.

Cowan et al (1996 p.3) suggest the dynamics of political, economic and technical decisions develop within the economy thus establishing “economic-technical problems [of manufacturing processes and design] that have blocked the realisation of the economic benefits” of EVs. Applying Struben et al (2008) to the complex challenge suggests diverse approaches are required to stimulate the sustained transition to EVs along with an understanding of the dynamic implications and reinforced feedbacks. Therefore within the automotive industry consideration needs to be assigned to the mutually reinforcing transport system encompassing vehicles, infrastructure, service stations and roads.

Arguably the MLP fails to consider all stakeholders relationships across the three levels, this is largely due to the multi-dimensional and multi-faceted nature of system innovation (Hall, 2003). Despite this criticism MLP can identify specific and dominant characteristics that implicate multiple actors. The transition to EVs is based on the interaction between competing logics, therefore this research will use the MLP as a tool to explore the diffusion of EV and explore structural change across these dynamics. This will more broadly explore the process of environmental innovation and system innovation.

#### 3.1.3.2. Competing logics

Foxon argues that “transition pathways arise through the dynamic interaction of technological and social factors at and between different levels, mediated by the actions of actors within an action space” (Foxon, 2013, p. 1). Foxon’s exploration of transition pathways is based upon three core competing logics and the dominant actors of governance (Figure 11). This suggests that the concept within the action space is influenced by pressures from government, society and the market, and that this action space will have been comprised through past transition pathways and will influence future regimes.



Placing EVs within the action space, it is possible to examine the current transition pathway that EVs are being integrated through and the roles of each logic. The government logic is competing heavily in the action space through the use of monetary incentives, this is primarily targeted at private individuals in order to increase the uptake of EVs. The extent to which motivation crowding is used by the government logic needs to be managed sensitively to ensure the market is sustainable once incentives are removed. The market logic has the auto manufacturers holding a dominant position; the manufacturers will influence Government frameworks but ultimately Government will specify systemic goals and structures. It then enables Government to retract and the auto manufacturers to maximise market opportunities to ensure they remain the “principal coordination mechanism” (Foxon, 2013, p. 7). The auto manufacturers are currently in a strong position and thus hold a certain level of responsibility (alongside Government) to educate customers on the environmental benefits of EVs, with the aim to heighten climate change awareness.

In contrast, the civil society logic takes a decentralised approach at a more local level, encouraged by local authorities and citizen groups to develop micro-grids that make towns less dependent upon national services. The transition to EVs can be witnessed in transition towns across the UK through car clubs, infrastructure and shared ownership, with the aim to reduce a community’s carbon and fuel use. However, in the main the civil society logic is not taking an active role in the transition to EVs. This is arguably due to the consumers’ perception of EVs, formed from path dependencies and lock-in. Humankind’s perception of undesirable change acutely impacts the pathway of new technology. Arguably this standpoint that EVs are less desirable is affirming ICE use and preventing the transition to

EVs. However, according to Griskevicius & Tybur (2009) AFVs are challenging traditional status allegiance with luxury vehicles despite the sacrifice of performance

Previous “scale of learning economies, technical compatibility and industrial networks” is considered to dictate how the world develops technologically (Ahman et al, 2007 p.1). The RAENG (2010, p. 12) states “if EVs are to be the agents of change that allow a significant reduction in CO<sub>2</sub> emissions, it is likely to be in an environment that is different from that which has evolved symbiotically with the internal combustion engine over the last century”. This seems to be integral to the future of a low carbon world as although the premise of transport is that it consumes fuel, creative destruction can challenge this as AFVs present an opportunity to positively alter the energy mix; this however requires social norms to modernise (Schumpeter, 1942). At present the EV market is at a critical point relying on social norms to challenge the existing fuel of the UK’s transport network. If the civil society logic were to be dominant, whereby citizens take a leading role in the low carbon transition, it would be relatively easier for EVs to challenge ICEs as people would be more receptive to change behaviours due to personal aspirations. Alternatively in a market or government led future it is arguable that there would need to be greater incentives to encourage change. Struben (2006) explore the behavioural dynamics of consumers’ willingness to try alternative technologies and the impact of their experience. It is established that the “intimate interdependencies between consumer choice and the evolution of the technology” still exists despite social exposure to AFVs (Struben et al, 2008 p.5). Evidence suggests trials are an extremely effective method to overcome negative market perceptions and change attitudes that could impact driver behaviour and vehicles procurement (Cenex, 2011b).

Vergragt et al (2007, p. 1104) suggest Government have “a significant role in promoting change: by stimulating technological innovation through regulations, incentives and subsidies, by investing in the infrastructure, by providing leadership, and by organising and supporting a debate with a focus on the system as a whole”. Government incentives and regulations relating to emissions have been key catalysts in beginning to unlock ICE vehicle dominance within the market. This has led to Government having a substantial involvement in the system integration of EVs. Although the UK Government state they are technology neutral in terms of emission reduction in vehicles, they are currently investing most heavily in to EVs. By 2025 the UK Government alone will invest over £150bn in low and ultra-low carbon vehicle technologies to ensure the UK is at the global forefront of the development, demonstration, manufacture and use of ultra-low carbon vehicles (SMMT, 2011b). Government have implemented mechanisms across multi-level stakeholder groups, such as the available grants and incentives for drivers, local councils, auto manufacturers and businesses to procure EVs and the necessary infrastructure. Market

techniques such as these can often result in short lived system innovations that do not result in technology substitution, therefore this research will consider the impact of motivation crowding on the EV market.

The three competing logics are a tool to explore stakeholder dominance within a particular sector. It can be used as a dynamic analysis of changing markets and to consider the relationships between actors.

Foxon introduced the three logics to identify which stakeholder dominates governance within the energy sector. This research proposes the logics can be adapted to the automotive sector to identify how each logic impacts the transition to EVs. However within the EV market there are a number of small technology developers that have been largely responsible for innovation but are not taken in to account within Foxon's existing model. Due to the focus on technology and innovation within the transition to EVs the three logics are arguably insufficient in explaining the process of the system innovation. There are such fundamental differences between the incumbent market actors (e.g. gasoline suppliers compared to EV charging equipment suppliers) that differentiation between market actors and innovators is warranted (Gould, et al., 2016).

The EV market relies heavily on the investment and promotion of niche players that approach the low carbon transition using innovative techniques. These niche actors are commercial entities that sit outside of the market incumbent actors. This is largely due to the size or financial impetus of these organisations despite the realised or potential impact on the market. Therefore a fourth logic is proposed, the innovator logic. This is a technology innovation led governance pathway in which niche actors respond rapidly to market needs. Although the innovator logic may have relatively small market share, the actors have significant influence on the action space. A key example of a niche actor within the innovator logic is Tesla, the manufacture's entrepreneurial and innovative route to market has demonstrated the potential of radical innovation on a stable market. This research draws attention to the role of the innovator logic within the EV market that has been responsible for significant progress of the niche technology. The logic was identified through practical conceptual work and exploration of the market, highlighting the additional pressure upon the action space from the original Foxon model. The research will consider the innovator logic in the context of EV utilisation in fleets and car clubs.

#### 3.1.4. Motivation Crowding

Currently the EV market is heavily stimulated by the use of government incentives and grants for both the vehicles and the installation of charging infrastructure. In recent years charging infrastructure grants have moved away from targeting businesses and fleets towards a focus on residential customers. Therefore this research considers the role of motivation crowding and explores the impact it has had on the fleet and car

club markets to date. The effectiveness of motivation crowding eradicating lock-in will be evaluated through the case study examples, TCO and the remaining transition barriers that prevent EV uptake.

There is extensive work on the role economic incentives can play on environmental and urban issues to minimise externalities (Oberholzer-Gee & Weck-Hannemann, 2002). It is generally considered within the literature that “charging people something for the external costs of congestion and environmental damage will be more efficient than not charging them” (Goodwin, 1995, p. 149). However there is substantial literature on ‘The Hidden Cost of Reward’ (Lepper & Greene, 1978) that argues providing a financial incentive for an activity has indirect negative consequences (Frey & Stutzer, 2001). Using a price mechanism does not necessarily increase supply/demand despite the foundations of economic theory and price effect.

Economic theory does not differentiate between external and internal origins of motivations. It is argued that intrinsic motivators drive and reward the person from performing the activity itself and provide greater and more sustained interaction, rather than simply providing a financial reward. Intrinsic motivations are much more challenging to influence due to individuality and path dependencies. Within the UK there is explicit use of price mechanism such as; road tax, the London congestion charge and tolls roads such as the M6, demonstrating “successful demand regulation” (CEDR, 2009, p. 3). Vine et al (2014) highlights the opinion of transport planners and network operators who argue that road pricing is a useful mechanism to manage travel demand. However, Dacko & Spalteholz (2014, p. 230) suggests coercion policies should be considered carefully to avoid change resistance from drivers as “consumers tend to react more positively to incentive mechanisms than to push initiatives”, especially when they based on “ecological rather [than] a pure fiscal rationale”.

Another market technique employed by Government is motivation crowding to incentivise certain behaviours such as EV use. Frey et al (2001 p.1) explains motivation crowding as a theory that considers extrinsic and intrinsic motivations, suggesting “that external intervention via monetary incentives or fine may undermine, and under different identifiable conditions strengthen, intrinsic motivation”. Frey (1997) suggests motivation crowding is flexible across a spectrum of extrinsic and intrinsic motivations that can be accounted for by either a change in preference, a change in the actor’s perception or the perception of the task or the task environment. This has clearly been the Government’s approach to stimulate EV sales, with the use of both tangible and intangible benefits of EV ownership. However would it be more effective to dis-incentives ICEs through taxation, or take a combined approach of EV incentives and ICE penalties to dramatically encourage a transition?



External incentives can encourage intrinsic motivations to be acted upon if aligned to one another but if in opposition, external intervention can undermine intrinsic motivations and reduce outcome actions. In the instance that policy employs price regulation ‘crowding out’ can result in “an unintended effect of a policy that frustrates the intended beneficial outcomes of it” (Bergh, 2013, p. 15). Bergh (2013 p.15) suggest this has been the case for environmental policies that have undermined intrinsic motivations consequentially having a lower “net effect on behaviour than a-priori expected”. Therefore it is essential to determine the impact of external intervention prior to implementation to minimise risk and prevent undesired effects.

In the UK motivation crowding has been utilised to provide incentives for consumers who purchase an EV and/or charging infrastructure in residential applications, public estates or railway stations. This provides a financial saving of £5,000/£8,000 for an electric car/van, and 75% subsidy for the provision of charging. In doing so, the Government have been appealing to extrinsic motivations to encourage uptake of alternative fuel technologies. Vergragt et al (2007, p. 1104) argue that governments have a significant role in promoting change, especially regarding niche technologies, “through regulations, incentives and subsidies”. However, the use of monetary incentives is arguably creating false market conditions which are being manipulated by stakeholders exploiting the system.

Frey & Gallus (2014) argue that having a fiscal reward for an action can cause actors who are motivated by intrinsic incentives to be negatively affected as their involvement and personal value are materialised. As a result effort diminishes and those early adopters/early majority could be deterred to embrace as intended. Furthermore Wolf et al (2015) suggests for large scale adoption of a new technology policy needs to focus on the demand-side based on consumers’ needs, values and social norms. Wolf et al (2014 p.2) says that an “exclusive zone for EVs in the city would accelerate the early-phase diffusion of EVs more effectively than financial incentives only”. This approach has been taken to an extent in London with EVs being exempt from the congestion charge zone and in some areas free parking. A prime example where additional benefits have been very successful in encouraging EV uptake is Norway; these include access to bus lanes, free toll roads, free charging and free access to ferries. This highlights that in the main, rewards of both economic and/or ‘privilege’ influence people’s behaviour, hence why governments often utilise motivation crowding to direct populations to certain activities, such as renewable technology.

The research will consider the use of motivation crowding to support and direct the transition to EVs, analysing the current requirement from competing logics for additional incentives. It will question the

extent to which motivation crowding can influence individual sectors to challenge path dependencies and will identify the impact of motivation crowding on the case study examples.

### 3.2. Alternative business models

Transitioning to a functional ‘experience’ economy is where by profitability is based on the provision of services to meet essential human needs rather than on material production and consumption (Jackson, 1996). Within the automotive industry, mobility services have the “potential to move along the servicing continuum between vehicle ownership, through the currently available methods of sharing, to passenger transport in particular city contexts” (Akyelken, et al., 2015, p. 3). Mont (2002), Fioruzzi (1996) and Vergragt et al (2007, p. 1105) agree that this requires new business models to be formed by the manufacturer to the provision of services, thus diversifying the market and complimenting the penetration of new products whilst “fundamental[ly] rethinking the entire system of personal mobility”. However this area of research is under-researched, therefore a synthesis of alternative business models will be formed to identify gaps in the existing knowledge.

Urban mobility will adapt to landscape pressures resulting in gradual political and economic changes; however the transport sector is relatively stable and therefore more difficult for an innovation to compete with the existing system (Geels, 2004). It is suggested by Brown et al (2003) that there are two scenarios regarding a collective change, either the innovation is widely adopted or the innovation is more slowly diffused through society until it reaches a critical mass. This links with the transition pathways strategies of socio-technical systems which can be categorised into (i) the adaptation of a dominant system or (ii) the attempt to take over the dominant position (Marletto, 2014).

When an innovation is increasingly adopted and becomes the dominant system (creative destruction) through gradual changes supported by a coalition of actors it tends to be along an established transition pathway. The alternative is forced dominance which can create unstructured transition strategies and unaligned forces (Marletto, 2014). Currently e-mobility services are gradually entering the market, this is due to lock-in of societal and cultural norms surrounding ownership models and the demand for flexibility and freedom to travel. Anable et al (2014) cite work that suggests the desire to travel long distances is due to the association of vehicle ownership with freedom. This embedded characteristic requires stimulus from the government logic to encourage behaviour change towards use-orientated services. However, the reasons for the lock-in are largely unknown and will be explored further through case studies in order to understand the existing transition barriers.

Augenstein (2014, p. 11) states that e-mobility is a “systemic challenge of organising mobility differently in the future – however, the involved actors each view the mobility system from their distinct perspectives”. From the perspective of auto manufacturers the challenge is focused on the car and the additional services that they can provide, the energy providers are concerned about the threat to the energy supply and the public transport sector views future transport systems as fitting within the existing system (Augenstein, 2014). Consequently the broad implications e-mobility has upon stakeholders needs to be considered further in exploring the transition pathway and how the use of regulation can encourage multi-modal transport.

Due to extensive lock-in of ownership models, mobility services within the innovator logic are acting in ‘coalition’ to the dominant system of ICEs within the market logic. Marletto (2014, p. 174) suggests the use of e-mobility services introduces both a change in business model and vehicle technology which will “simultaneously weaken the dominant position of the ‘individual car’ system, and support alternative transition pathways”. Alongside this, policies to incentivise car sharing for those in the life-cycle of the product/service will be required to challenge the path dependencies and lock-in of the internal combustion owned vehicle. Marletto (2004) argues there needs to be a multilevel and multidimensional policy for integrated urban transport by which EVs can play a secondary role. This is fundamental to development and success of the e-mobility market and what is currently lacking. Roy (2000) suggests regulations and other measures such as tax incentives are necessary to ensure e-mobility schemes are viable. However, the difficulty is deciphering the extent to which motivation crowding is relied upon to influence and change behaviours.

Orsato (2006) and Tukker (2004, p. 251) argue that customers are “willing to pay more [for mobility services] than would be justified on the basis of ‘rational’ calculation”. This is arguably due to intangible added value i.e. vehicle choice and the ecological differentiation. Schemes such as car sharing are gaining momentum and can considerably reduce car ownership and car mileage, positively impacting congestion, air pollution and emissions. However, as there is only a limited network that supports e-mobility, further investment in infrastructure is required by city operators. Roy (2000) suggests that the use of public transport is increased as a result of lower car ownership thus intensifying peak demand on public transport. Considering this, Vine (2014, p. 3) explains that introducing car sharing requires a “new value proposition...and new ways of interaction with the public sector” compared to traditional transactions. This research will explore the existing value proposition of e-mobility services across a number of business models, this will identify the drivers and barriers to MaaS and the extent to car ownership is locked-in.

### 3.2.1. Product-service systems

Sustainability of the automobile industry requires behavioural and system-level changes (Wells & Nieuwenhuis, 2001). There is an emphasis on a product-service system (PSS) which has been defined as, “a marketable set of products and services capable of jointly fulfilling a user’s need” (Goedkoop, et al., 1999, p. 18). Mont (2002, p. 240) further explains PSS as “a system of products, services, supporting networks and infrastructure that is designed to be: competitive, satisfy customer needs and have a lower environmental impact than traditional business models”. PSS requires higher order learning based on a fundamental shift in culture, resources and behaviour in order to overcome the psychological barriers, whether it is in companies or the general populous. In the product-service segment of the automotive industry the most adaptable and innovative products are the additional services such as the assistance services and location-aided apps. Tukker (2004) suggests these are particularly important in mobility solutions and add value through customer experience, building unique relationships and customer loyalty.

Mont (2001) suggests companies follow a five step process to develop a PSS: (i) initial review of existing activities, (ii) marketing analysis, (iii) feasibility analysis, (iv) implementation, and (v) continuous system development. These should be in accordance to economic, social and environmental sustainability criteria determined by the company. Williams (2006, p. 179) explains this methodology “identifies critical success factors, such as consumer perception of trust in the function provider, constant feedback concerning system function, changing customer needs [and] necessary changes in the system”. This requires “close integration of all actors within the life-cycle of a product-service” (Mont, 2002, p. 242).

Mont (2002) identifies three PSS approaches that can be introduced through e-mobility services, (i) the sale of the use of the product instead of the product itself, (ii) the change to a leasing society and (iii) the change in consumer attitudes from sales to service orientation. These approaches highlight the fundamental issues of transitioning from ownership to service models. It requires a greater level of responsibility from the producer or service provider for the product’s life cycle, and requires greater customer involvement to use and operate the service. In order to achieve a transition to a service based model, three uncertainties have to be overcome, (i) the readiness of companies to adopt, (ii) the readiness of consumers to adopt, and (iii) the environmental implications (Mont, 2002). These three uncertainties could equally be applied to the readiness of companies and employees adopting EVs within fleet applications, and the environmental implications on their operational emissions. Due to the small size of the EV market, can it be assumed that companies and consumers are not ready to adopt? This research considers (i) and (ii) as fundamental requirements to a transition to EVs, therefore these factors will be addressed in the empirical research.

Arguably the three approaches could be explained through the competing logics; the sale of the use of the product represents the shifting market logic, the change to a leasing society is stimulated through both the market and government logic and the change in consumer attitudes stems from within the civil society logic. For a transition to PSSs the three logics must be active and collaborative in order for the niche innovation to gain sufficient momentum, this could explain the slow diffusion of PSSs within the automotive sector. This research will explore the existing dynamics of the logics and consider the role of an innovator logic upon the action space of e-mobility, thus questioning its impact on take up.

PSSs can be classified in to three main categories (i) product-orientated services (ii) use-oriented services and (iii) result-orientated services. Williams (2007) explains product-oriented services maintains a focus on the product but the provider will also sell services required during the use phase, this could include a maintenance contract, extended warranty or the provision of spare parts. A results-oriented service uses the product to derive payment from the use of the product, either predetermined or unspecified (Williams, 2007). However this research focuses on use-orientated services, by which the products remain central to the offer and are managed by a service provider, whilst the utility is provided as an output service unit for the desired level of use (Mont, 2002) (Williams, 2007). In doing so alternative profitable revenue streams can be identified and considerable changes in behaviour and culture can be achieved (Williams, 2007).

Ehrenfeld (2001) introduces five key evaluative criteria to assess the contribution of an initiative towards the innovation at the system level in the automotive industry: (i) evidence of 'higher-order' learning amongst stakeholders, (ii) changes in infrastructure and institutional practice, (iii) changes in vehicle design, manufacture and end-of-life management, (iv) changes in vehicle ownership structure, (v) changes in modes of producer-user interactions. Although all five criteria are applicable to introducing and managing EVs in cities, e-mobility services relates directly to (iv) and (v) categories. These changes in market structure have begun to contribute to the system innovation towards mobility services.

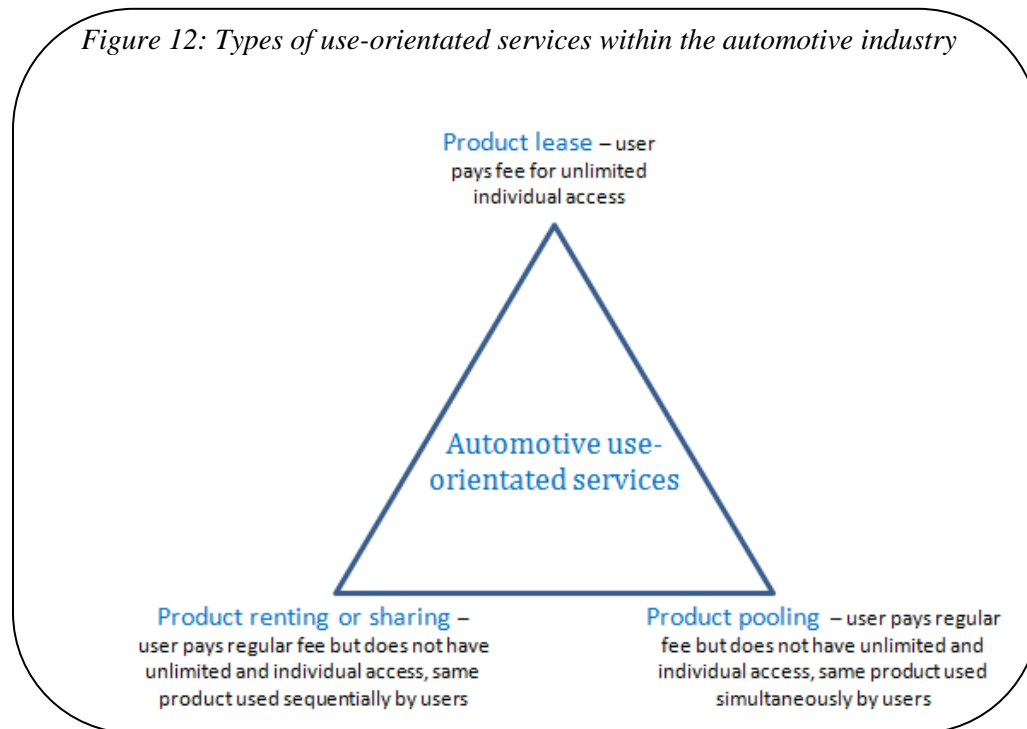
However it remains a niche offering that requires further stakeholder engagement and higher-order learning regarding the broader implications of ICE ownership. Ehrenfeld (2001) indicates that changing the product concept eases the system transition; therefore it could be argued that using EVs in services such as car clubs will encourage drivers to adopt the service rather than if it were internal combustion engine vehicles (Williams, 2007).

PSSs introduce alternative business models that could provide opportunities for the use of niche technologies and remove lock-in associated with ICEs. This research will focus on use-orientated services due to the potential to fundamentally shift the existing ownership culture to a services system.

This requires significant change within society and the existing system that operates within ICE structures.

### 3.2.2. Use-oriented services

Use-oriented mobility services increase efficiency of private transport in cities, for example “one vehicle can service around 15 times more users daily than a privately owned vehicle” (Weiller, 2012, p. 3). As seen in Figure 12, there are three main use-orientated services within the automotive industry. These can be used independently to each other and other forms of transport, or can be in used in conjunction, with a multitude of mobility services.



The three business models will approach transition barriers individually through a dominant logic – market logic. However further exploration is required to establish which user-orientated service best overcomes technology lock-in.

#### 3.2.1.1. Product lease

Vehicle leasing is growing in popularity both by companies and private users as a means to finance vehicle purchase. There are two forms of leasing (i) traditional use and return, and (ii) eco-leasing whereby the product is returned and re-leased or disassembled and re-used as raw materials. Eco-leasing has not developed to the same extent as traditional leasing; primarily because the vehicle is not purchased

and there is no lease to buy incentive for the customer (AIGT, 2002). However Whitfield (2003) highlights the potential to reduce material costs and materials going to landfill is high using eco-leasing.

Leasing could be argued to be an intermediary phase between ownership and vehicle sharing. It shifts behaviour from owning assets to a pay-as-you-go model, whilst having unlimited and individual access. Williams (2007, p. 1099) suggests that “leasing has become the most important means of financing purchases” within the automotive sector, for example in Germany 25% of all cars are leased.

There are a number of examples of leasing models but the majority offer a range of vehicles to fit the personal or professional needs of the customers. A mobility offer from BMWi 360° offers a range of services including mobility solutions; for those customers with an EV they can hire an appropriate vehicle for extended journeys beyond the range of an electric car (BMW, 2015). This is an encompassing approach to transport as it encourages ‘green’ behaviour where possible but the convenience of distance, speed and/or size for specific journeys. This is an effective service model to remove technology lock-in surrounding range-anxiety by removing the perceived level of compromise by reinstating the option value.

#### 3.2.1.2. Product renting or sharing

There is a growing number of vehicle rental or sharing schemes that offer access to a variety of vehicles to suit customers’ needs as required. In such instances the provider will retain ownership of the vehicle and is often responsible for maintenance and repair; the user pays a regular fee but does not have unlimited and individual access. This model is used by corporations as a means to lower their overhead costs, by providing employees leased cars rather than long term company cars. There are a number of vehicle renting or sharing across the globe that account for 1,788,000 car sharing members that have access to 43,500 cars (Marletto, 2014).

The Roads Task Force report (2013) identified car clubs as a key mechanism to reduce “overall car dependence by making access to cars more flexible, thereby reducing pressure on road space and encouraging sustainable transport” (Akyelken, et al., 2015, p. 39). Akyelken et al (2015, p. 8) argue that “the complex nature of vehicle sharing, mainly in terms of space-time and ownership, means that a range of important actors need to be considered when drawing the system boundaries of moving away from private car ownership through car...sharing systems”. This highlights the necessary inclusion of a broad range of stakeholders in order to transition to sustainable transport.

Firnkorn (2012) suggests there is an equal demand from both auto manufacturers and cities to further progress the car sharing market. Cities with high congestion can benefit from car sharing through

reduced privately owned vehicles that are used by the majority of owners inefficiently (Firnorn, 2012). Whilst auto manufacturers can implement car sharing as a differentiator of products and services that enhances the brand and identifies new business opportunities (Orsato, 2006). To maximise the potential efficiencies in transportation and the environmental implications of air pollution associated to road transport, Whiteman (2011) suggest EVs can be optimised in car clubs to reduce the emissions during the use phase. EVs extend the opportunities of car clubs; using AFVs can benefit the operator and municipality by reducing emissions and air pollution, improving air quality and decreasing running costs. Furthermore a network of shared EVs provides a large data source for auto manufacturers of practical usage that could assist in developing the next generation of vehicles (Firnorn, 2012).

Car clubs are the biggest opportunity for e-mobility services to overcome transition barriers within cities as the business models could be integrated within an intermodal mobility system. However, there is limited research on the diffusion of EVs within car clubs. Therefore the role of EVs within mobility services will be explored, this will identify the existing transition barriers and the necessary support to mainstream the concept.

#### 3.2.1.3. Product pooling

Vehicle pooling is similar to that of vehicle renting but the car is used simultaneously by the user rather than sequentially. This requires considerably less investment than car leasing/sharing with the need for fewer vehicles (Tukker, 2004). There are two distinct client bases, the public and members often in a workplace environment. Product pooling offers less scope for e-mobility services due to the additional barrier of shared transport, and therefore will not be explored to any great detail within this research.

### 3.3. Fleet Behaviour

The majority of commercial fleets have very similar characteristics including high utilisation rates, centralised parking/charging facilities as well as local and predictable routes, such behaviours are ideal for EV use and can assist faster payback (Pike Research, 2010). Fleets possessing managed and pre-defined activities are considered by the Electrification Coalition as “among the more important characteristics that could facilitate uptake of grid-enabled vehicles in fleet applications” (Electrification Coalition, 2010, p. 59) (Centre for Automotive Research, 2011). This is due to the ability to forecast the utility of the vehicle and optimise the capabilities of the vehicle with specific reference to charging requirements derived from their drive cycle, destinations, time schedules and fleet size. Markel (2010) emphasises that this would maximise the vehicle efficiency as well as reducing the psychological fear of



running out of battery capacity with no accessibility to charging infrastructure, this apprehension is known as ‘range anxiety’.

Briers (2010) and Anable et al (2014) suggest there is a surprising lack of knowledge across fleets upon their own operations, for instance average CO<sub>2</sub> emissions, annual mileage and fleet budgets are not always known characteristics. This implies there is significant potential to develop the fleet market, especially considering the available telematics software that can aid the collection of such information. The lack of fleet data does not only prohibit the efficiency of a ‘traditional’ fleet but the integration and optimisation of EVs. This highlights the need for education regarding both the importance of vehicle management as well as the opportunity of EVs. It is suggested the operational requirements of a fleet enables an average of 20% of the vehicles to be electrified, however if total operations of a fleet are analysed and the utility of the vehicle is adapted it is possible to achieve a minimum average of 40% reduction in energy or fuel consumption (MacAndrew, 2011). A key motivation for EV procurement is the low running costs which is argued by Hutchins et al (2013) to be more important than the high purchase price as it protects them against future fuel price increases (OLEV, 2015). Nonetheless OLEV (2015, p. 48) stipulate that the “total cost of ownership appears to be an important factor in organisational decision-making”. Therefore the motivations of EV procurement within fleets will be explored within this research alongside further analysis of the financial implications.

More broadly speaking, Whiteman (2011) suggests that company strategies and therefore fleet activity is largely influenced from surrounding environments at a local level. Multi-nationals will likely adapt to climate change initiatives to suit specific locations and operations; however it is possible the company’s country of origin will be reflected in the approach taken, for instance the technology used or the speed of diffusion (Kolk, 2008). Therefore fleets operating in a multiple countries will have diverse strategies due to national policies and local priorities and pressures, however senior management will have a general influence on operations and development of the fleet.

It is fundamental to understand the characteristics of fleet behaviour in order to identify transition barriers of EV utilisation. There is a relatively small body of research that considers the application of EVs within fleets, therefore this research will expand upon the opportunity of electrification and identify the motivations and barriers to EV uptake. This will be based on case study research and will result in recommendations for fleets and supporting policy to challenge lock-in within this market.

### 3.4. Future technologies

There are a number of technological developments within the EV market that could significantly alter the transition pathway of EVs, therefore it is necessary to consider these in the broader context of the industry. Four key opportunities have been identified within the literature that could affect the fleet and car club markets, therefore requiring some exploration.

#### 3.4.1. Battery Swapping

Battery swapping is considered an opportunity to address the current limitations of battery capacity, this would “allow vehicles to be recharged with comparable speed to refuelling an ICE vehicle” through replacing a discharged battery with a charged one (OLEV, 2011 p.46). The International Energy Agency (2011) consider battery swapping to increase the number of fleet applications EVs could be integrated within whilst decreasing the cost of the battery through decoupling battery costs from the cost of the vehicle. Fleet vehicles would be suitable for battery swapping as fleet managers do not tend to value choice to the same extent as an individual who is sensitive to comprise. Furthermore battery swapping requires the battery to be leased thus having the benefit of reducing the high initial cost as well as availability to technological improvements (Sarker, et al., 2013). Neubauer & Pesaran (2011) highlight battery swapping can capture additional value through resale of batteries that no longer meets EV specifications, this could reap large returns due to satisfying others energy storage requirements.

Although battery switching stations could overcome a plethora of challenges EV fleets and e-car clubs face, Becker et al (2009) believe the concept is currently flawed due to the lack of battery standardisation. Furthermore the fundamental principal of battery swapping is to extend the range of an EV in the quickest possible time, this is not challenging technological lock-in of ICEs but embedding it further. Fleets and car clubs have the opportunity to adjust operations and tariffs to optimise the ‘limited’ range. Ingenia (2010) questions where the funding and capital expenditure would originate from to successfully deploy a national infrastructure scheme. Additionally battery swapping would require a controlled environment for the physical act of swapping the battery to take place, this would very likely contribute to the cost of the vehicle further and heighten technology lock-in. Regarding niche technologies the balance between convenience and price would have to be considered, this would be heavily influenced by political motivations to become less fuel reliant and more sustainable. If these geo-political factors were prioritised it is likely the government logic would compete heavily within the action space through regulation and subsidies.

### 3.4.2. Vehicle-to-grid

Vehicle-to-grid (V2G) enables energy stored within a vehicles battery to be used by the electric distribution network. Ralston & Nigro (2011) explain how V2G would assist in regulating the imbalance of supply and demand through enabling EVs to act as dispersed storage units serving as spinning reserves. It is discussed that V2G could help mitigate demand issues as it “synergistically uses power capacity...to reconcile the complementary needs of the driver and grid manager” (Schill, 2010) (Kempton & Tomic, 2005, p. 280). Tomic & Kempton (2007) argues that fleets are an ideal opportunity to drive the V2G market due to centralised charging depots, scheduled operations and need for ancillary services. A report published by Ricardo and National Grid argued UK businesses could save 18% on recharging costs through V2G with zero investment (National Grid & Ricardo, 2011)

However V2G technology could be restricted by the current capacity of the battery and plug circuit as well as the relatively limited experience of battery life and battery performance operating within vehicles (Letendre, et al., 2006) (DeForest, et al., 2009). Further research and pilot test are required as ultimately V2G is widely speculative and many of the characteristics and implications remain unknown.

Furthermore it is suggested that there may be less expensive methods to achieve the same ancillary service.

The Head of Engineering at BT (Poston, 2011) argues the opportunity of V2G could not only provide important ancillary services, peaking power, and even energy storage but it could also minimise the costs of a business. Kamboj et al (2010) suggest that 90% of a vehicles life is parked therefore if this time the vehicle was replenishing the grid it would be possible to retrieve revenue and minimise fuel costs further. Furthermore, V2G could offer a range of possibilities for charging EVs, the grid could determine a framework of when each vehicle is charged taking into account both availability of power and also transformer capacities (Wright, 2011).

Although currently there are no vehicle manufacturers producing vehicles capable of V2G, the technology to make this possible is being developed (MacAndrew, 2011). This development will have large ramifications on various UK and international markets and open a plethora of opportunities.

### 3.4.3. Second life

Research classifies ‘end of life’ when the battery reaches 80% capacity, therefore an EV with a 100 mile range would only achieve an average range of 80 miles on one charge (Hutt, 2011). National statistics presents the average daily mileage as 25 miles in total and an average of 8.6 miles per trip. Therefore a battery at ‘end of life’ still holds the capacity of over three times the average daily mileage, this suggests

the battery would be more than capable of completing the vast majority of the populations journeys (Hutt, 2011). It is logical that the second hand market should develop as EVs are integrated within society and consumers have become comfortable with the technology. With a second hand market fleet managers could reduce the TCO through the opportunity of keeping a vehicle for a longer period of time, as the 'end of life' battery could be sold to offset the expense of a new battery. Catherine Hutt (2011), the former Business Development Manager at the Society of Motor Manufacturers and Traders argues the concept of batteries being used for energy storage is the third or fourth stage of battery use after its capabilities have been maximised within automotive. Hutt (2011) emphasises that at the point in which batteries are experiencing 0% capacity the components could be stripped and reused or recycled, thus highlighting various business model opportunities. As expertise of battery recycling enhances the second hand value of EVs will be underpinned, encouraging a more competitive TCO and eventually exponential growth within the market (Haycock, 2011).

Massachusetts Institute of Technology (2011) proposes opportunities can be reaped through utilising the battery once the capacity to power a vehicle has degraded. Witkin (2011) suggest as battery lifespan extends beyond EV use it will maintain a level of value. The capacity of the battery to store energy after EV use is debated, however ranging from 50% to 80% capacity there are various second life uses including backup power for homes and offices, transmission support and storage for intermittent renewable electricity supplies (Cready, et al., 2003) (Electrification Coalition, 2010). This would help drive residual values of the battery higher and improve economic efficiency of the vehicle. The National Renewable Energy Laboratory (2010) argues that second life use can reduce the purchase price of an EV by offsetting the cost of the battery. However, the Electrification Coalition (2010) highlights that batteries will experience strong competition from alternative energy sources for second life applications.

As vehicle use and charge rates have led industry to speculate over battery lifespan, it is thought that further exploration of this could limit the second life market due to a reduction of excess battery capacity that fits EV consumer needs (Williams & Lipman, 2011). Furthermore, research highlights battery leasing models decouple the lifespan of the battery from the lifespan of the vehicle, reducing the high initial cost and the need for a second life market (BCG, 2010). Currently literature on the future of second life battery use is contradictory but it can be concluded that as the volume of degraded batteries increases, the market for second life use will develop and it will become evident the extent of which they can be utilised.

#### 3.4.4. Right-sizing

To address the market barrier of high initial investment, literature highlights through a thorough examination of a specific fleet “underused vehicles can be shared with another operating division in order to optimise their use or be removed from the fleet completely” (City of Prince George, 2011, p. 9). This could benefit the business through greater efficiency, decreasing operating costs and reducing greenhouse gas emissions (City of Prince George, 2011). Additional opportunities are discussed by the Department for Business, Enterprise and Regulatory Reform (2008) regarding battery optimisation as 93% of journeys do not use the entire capacity of the battery; certain fleets that regularly travel short distance have an opportunity to right-size the battery. The Electrification Coalition (2010 p.57) argue this would minimise excess capacity and lower the high purchase price through “reducing the material, manufacturing, and logistics costs of large-format batteries”.

It has been suggested by manufacturers that in fact battery right-sizing can be customised for various mile ranges (Electrification Coalition, 2010). Gartner & Wheelock (2009) suggest that right-sizing the battery packs would provide even more flexibility in the design phase due to considerably more space in the bonnet; this would consequently lighten the vehicle and enhance efficiency. Literature recognises this opportunity relies on the ability of battery manufacturers to be flexible in battery design and for the market to positively respond (Electrification Coalition, 2010).

Smith Electric Vehicles argues that “if a fleet has 100 routes it would likely equate to 50 standard route sizes and 50 will be different sizes, different lengths, different ranges” (MacAndrew, 2011, pers. comms). This highlights the opportunity to right-size the battery to fit the un-standardised routes and tailor battery capacity to certain operations. It is argued that the opportunity of right-sizing the battery is ideal for fleet use especially in city centres as the capacity of the battery is not always necessary, therefore it would be an added benefit associated to the business case (Haycock, 2011). Right-sizing could result in large cost savings on the initial capital investment and would enable ownership cost parity with an ICE or hybrid vehicle to be achieved much quicker (Hutt, 2011). Although this would assist in removing barriers associated to costs it would likely heighten barriers regarding restricted range and the lack of flexibility and freedom. This would only be a relevant concern in certain applications where the vehicle is used privately or for unspecified journeys travelling varied distances.

#### 3.4.5. Conclusions on future technologies

It is arguable that the additional opportunities discussed are necessary for technology lock-in to be challenged and the business case of EVs to be truly viable. As the competitiveness of the EV total cost of

ownership is debated (largely due to the high purchase price), sources of additional finance are key if EVs are going to overcome path dependencies of the ICE. For instance, revenue from V2G could balance the TCO sufficiently that the market would not be reliant on the rise of fuel prices for electrification of transport to be competitive.

Additionally, if battery technology significantly improved the battery could be manipulated to benefit from energy efficiency. This combined with off peak charging and corporate rates of electricity suggest the cost advantages EVs could provide are considerable (BACC, 2015). Alternatively, battery swapping and/or rapid charging would allow EVs to suit a great deal more applications and provide businesses with a more versatile vehicle that would able both the risk and the costs to be spread across the business. These opportunities are considered possible by the market logic, however the timescale remains unidentified and it is speculated whether the opportunities will materialise.

### 3.5. Conclusions

From the literature it is evident that vehicles are part of an interdependent technology system along with roads, service stations, parking facilities and a social status system. As a result the ICE is locked-in with reinforcing path dependencies that avert technology substitution and stifles incremental innovation to transition to the radical diffusion of EVs. Therefore the diffusion of EVs requires an extensive transformation across a plethora of societal dimensions to disrupt the stable market. Research identifies the significant role of Government in challenging the embedded path dependencies and lock-in within the automotive industry, and promoting change towards low emission vehicles. As the market is starting from a position of lock-in, it is being led by a technology push from Government where by regulation and financial support is aligned enabling auto manufacturers to sufficiently penetrate the market. Government acting as the dominant logic in the market has given emphasis to the use of incentives to influence consumer behaviours and technology adoption. However the incentives are focused on selling EVs in the broader sense, the lack of subsidies for businesses result in low adoption and integration of the technology within operations. Based on the policy review the fleet market is lacking direct support to transition to EVs despite the significant opportunity to stimulate prolonged investment and unlock the incumbent ICE technology, thus redefining mobility solutions. Therefore this research will further explore the role of motivation crowding and the extent to which it could remove or diminish technology lock-in.

An innovator logic has been introduced to represent a key stakeholder group that influences and determines governance within the sector that is currently poorly captured within Foxon's three logic model. This is due to the focus on innovation and technology that is being stimulated from niche actors and is shaping the market. The proposition of this fourth logic, and its applicability to the EV market

needs to be analysed further using the MLP to highlight dynamics of change. The impact of the innovator logic upon technology lock-in will be considered within the fleet and car club market and the extent to which it dominates the action space.

There are extensive barriers to EVs developing in the existing regime due to significant investment in ICE sustaining technologies over the last century. Arguably the combination of investment and the value consumers hold to private car ownership has caused EVs to remain niche with minimal disruptive impact. However due to climate change commitments there is significant pressure on the regime to transition to EVs in more applications and alter the asset culture prevalent in the UK. Consequently there has been (relatively) substantial investment in the niche technology by both auto manufacturers and the Government that has begun to introduce alternative business models of vehicle ownership. Moving to a true product service system will require a paradigm shift in provider-user interactions in order to overcome the uncertainties within the market and ensure companies and consumers are ready to adopt.

Clearly there are knowledge gaps regarding the opportunities alternative business models have to alter the transport sector and the diffusion of EV technology within those. However it needs to be established how the actors can stimulate the market to generate momentum sufficient for change across the regime. This research will question whether mobility services can be used to break out of ICE path dependencies, and the role of motivation crowding to overcome barriers of ownership models.

Both the fleet market and the car club market have suitable characteristics to adopt EVs and could benefit from utilising EVs and the associated technologies. However it is evident that “currently the adaptability of the mobility system is low and that the EV niche is captured by regime incumbents, indicating that a true mobility transition is not yet taking off” (Bakker, 2014, p. 4). The challenges of technology lock-in and path dependent characteristics will provoke the discussion to understand the existing barriers and the pathways that can achieve a transition.

The technological possibilities for the battery sector and the integration of vehicles on the grid is an important dimension to consider for the EV market, as at the early stages of the market it is heavily influenced by developments in technology and the degree of competition. Although these future opportunities do not directly implicate the existing business opportunities of EVs within fleets and/or car clubs, they could significantly alter the value proposition and should therefore be considered within future works.

The literature review has provided the basis of discussion within the field of transition pathways, specifically regarding the utilisation of EVs within fleets and car clubs. The opportunity for these

markets to utilise EVs is extensive but there is a lack of knowledge surrounding the transition barriers and appropriate transition pathway. This topic has largely been under-researched; combining the literature with the results in Chapter 5 will provide a stimulating discussion in Chapter 6. This will address the research objectives and answer the research questions that broadly intend to investigate the transition barriers of EVs within commercial applications, and evaluate the market techniques implemented to build momentum.



## 4. Methodology

The research project was carried out between 2011 to 2015 during which time the automotive industry and EV market continuously evolved, and has so since the research was completed. This chapter will discuss the development of the methodologies used for the research. This will address the approach to primary research, seek to justify its implementation and critically review the research's reliability and limitations.

### 4.1. Research development

The research aims to investigate transition barriers of EVs and explore the dominant path dependencies of ICE vehicles. It intends to identify the impact of technological lock-in on the EV market and evaluate market techniques employed to increase EV usage. The role of EVs within mobility services will be explored to identify additional opportunities to decarbonise transport and adjust the existing reliance on privately owned ICE vehicles. Consideration will be given to the role of OEMs, entrepreneurs and technological innovator as primary enablers to unlock ICEs and establish EVs within the mass market through value creation.

Chapter 2 identified two key markets within the automotive sector that EVs have an opportunity to infiltrate (i) fleets, and (ii) mobility services, specifically car clubs. Therefore the research questions (in Section 1.2) are focused on the transitions of these markets and the contributing factors to the success or failure of EV adoption. The foundation of this research was established from the literature review (Chapter 3) that explored transitions theory alongside the exploration of the fleet, car club and EV markets. This provided the underpinning knowledge on the current scenario, how it has developed in recent years and where gaps remain.

As the research was conducted within Schneider Electric there was an extended period of engaged scholarship, whereby a vernacular assessment of the key issues surrounding EVs and mobility services was conducted. The commercial environment enabled there to be a collaboration between theoretical models and practitioner experience. This is often unachievable in academic research due to diffused relationships and influence, consequently the practical application of academia is often criticised (Rynes, et al., 2001) (Ven & Johnson, 2006). However, during the researcher's immersion within the EV market there was an ongoing process of informal industry consultations with a broad range of stakeholders. This contributed to a thorough understanding of the complex social issue of transport electrification and alternative business models within the period 2011 - 2015 (Van De Ven, 2007). Obtaining this exposure to the industry and experiencing the culture within fleets and car clubs enabled the most suitable

methodologies to be identified. In addition to conducting the research, the researcher held responsibility for Schneider Electric's relationship with the OLEV. This involved lobbying, providing technical guidance and ensuring company compliance with charging infrastructure specifications. This provided longitudinal understanding of the political landscape and governance surrounding incentives and national infrastructure projects, thus helping to shape the empirical research and understand the context in which it was conducted within.

An exploratory approach was taken in conducting this research, using where appropriate the multi-level perspective (MLP), as the challenges surrounding the transition to EVs within commercial applications have been under-researched. Existing transitions theory can however be applied to the niche technology of EVs entering the structured automotive regime. It is however, the specific market conditions surrounding the Government incentives and embedded path dependencies that impact upon the EV market that need further exploration. In order to conduct this research a range of methodologies could be used. Consideration was given to conducting large scale questionnaires to a number of fleets and car clubs to gather a broad consensus of the existing drivers and barriers of EV utilisation. However using questionnaires would arguably supply rather limited and shallow data that "may not capture the entire sample desired for the study" (Schensul, 1999, p. 194).

This determined the need to conduct interviews in order to gather extensive and in-depth data that could then be used to create normative results to direct market developments. Due to the lack of existing theory on the transition to EVs specifically, individual interviews were deemed appropriate as they can inform a wide range of research questions that would otherwise not have been plausible (DiCicco-Bloom & Crabtree, 2006). Furthermore interviews allow key informants to be identified in order to provide expert elicitation that cannot be guaranteed through the use of questionnaires. It can be ensured that the interviewees are "fairly homogenous and share critical similarities related to the research question" (DiCicco-Bloom & Crabtree, 2006, p. 317). Therefore interviews were favoured to allow for in-depth analysis in to cultural and business forces necessary to investigate the challenges of EVs. This can then contribute to the broader knowledge of transitions theory with greater significance.

Consequently interviews were conducted for both areas of the research in order to achieve a greater understanding of the individual markets and contribute to knowledge on transition pathways of niche innovations. Further analysis of the use of interviews is conducted in Section 4.3.2 and Section 4.4.2. The interviews were supported by contributing methodologies including case studies and examples of market actors. These methodologies were incorporated in to the research to further support empirical evidence and demonstrate existing forces on the regime. European examples of business models and

national policies are referenced as a comparative tool. Combining these methodologies allows proposal of recommendations to develop both market segments across appropriate stakeholder types.

Commercial procurement of vehicles i.e. fleets, focuses on the total cost of ownership (discussed in detail in Chapter 5). As the total of ownership (TCO) is so instrumental in the decision matrix for fleet procurement, its analysis is imperative to the transition to EVs, as identified in the research questions. It is therefore an essential component of this research to compare the financial implications of an EV to an ICE vehicle.

*Table 1: Research methodologies*

<b>Research questions</b>	<b>Methodology</b>
What change is required for fleets to transition to EVs?	<ul style="list-style-type: none"> <li>• Literature review</li> <li>• Industry discussions</li> <li>• Interviews</li> <li>• TCO analysis</li> <li>• Case studies</li> </ul>
To what extent is technological lock-in restricting the EV market?	<ul style="list-style-type: none"> <li>• Literature review</li> <li>• Industry discussions</li> <li>• Interviews</li> <li>• Policy analysis</li> </ul>
What is the role of electric vehicles towards the pathway to a 'mobility-as-a-service' model?	<ul style="list-style-type: none"> <li>• Literature review</li> <li>• Industry discussions</li> <li>• Examples</li> <li>• Interviews</li> </ul>

The research took a considered approach to gathering data on niche technology, choosing businesses within different sectors and with varying scales of EV adoption to explore. Alternatively conducting research within one specific sector i.e. private hire, the results would be restricted within a topic that already has very limited theoretical analysis. The following sections will elaborate on these methodologies (as seen in the Table 1), and further justify their implementation.

## 4.2. Methodologies

Due to the two distinct markets explored a range of methodologies were employed to ensure a comprehensive exploration was achieved in understanding the transition pathways of EVs, and the contributing factors of path dependencies and lock-in. This section outlines and reviews the individual studies that were deemed most appropriate in addressing the research questions.

### 4.2.1. Total Cost of Ownership

Fleet managers are driven by costs that are accountable to vehicles operating for the business; therefore when considering the procurement of new vehicles an assessment of the relative costs is conducted. This is known as a total cost of ownership (TCO) analysis which provides valuable information based on the relevant funding model. Vehicle procurement within fleets is focused on the TCO and the vehicle specification for the operation. Therefore when considering EVs, it is necessary for them to compete with traditional ICEs. This is unless a strategic decision, normally from senior management, is made to procure alternative vehicle types for other motivations.

TCO is a “methodology and philosophy which looks beyond the price of a purchase to include many other purchase related costs” (Ellram, 1995, p. 4). It is a financial assessment of the direct and indirect costs associated to the ownership or management of a system (NewZealandGovernment, 2003). The TCO of a car includes the purchase price, the expenses incurred through its use, such as repairs, insurance and fuel as well as the depreciation cost and residual value. Depending on the vehicles use it is necessary to consider contract finance, national insurance contribution and/or benefit in kind. Furthermore, alternative technologies may require additional infrastructure, but available incentives and grants would also need to be taken in to account.

Fleet managers use a TCO model to financially assess vehicles normally on a four-year cycle (Haycock, 2011). This enables the fleet to optimise costs and create benchmarks for vehicle replacement. For many companies costs associated to their fleet will be the largest expenditure and therefore deserve thorough exploration. However certain fleet attributes cannot be easily quantified such as driver behaviour, driving style and vehicle suitability, despite these factors potentially having a large quantitative impact.

#### 4.2.1.1. Vehicle Comparison

In order to understand the feasibility of EVs from a fleet perspective and the comparative cost to ICEs a TCO was undertaken. This compared:

- Ford Focus 1.6 TDCi 115PS Titanium X
- Toyota Prius T-Spirit 1.8
- Nissan Leaf
- Renault Zoe

These vehicles were compared as they represent a range of vehicle technologies, including an ICE, HEV, PEV and PEV with a leased battery. The Ford Focus acts as the conventional benchmark within the TCO to identify the possible economic barriers of AFVs in contrast to an ICE vehicle. Furthermore the four vehicles were chosen to provide an overview of vehicles within similar classes with equal performance. Consequently, the results will allow for extensive analysis without bias towards a particular vehicle technology. The TCO was performed prior to the launch of the Renault Zoe, therefore the figures were based on assumptions, with the running costs and depreciation rate aligned to that of the Nissan Leaf. This was considered appropriate as both vehicles are PEVs and compete in the same vehicle class.

#### 4.2.1.2. Framework

The TCO analysed three alternative business models (i) outright purchase, (ii) contract hire and (iii) a vehicle as a company car. A fourth component was incorporated, the addition of charging infrastructure which can be applicable to any of the three business models identified. The range of scenarios are applicable to fleets throughout the UK, there is no bias towards regions such as the Plugged-in Places which could alter the conditions of the TCO for EVs. The scenarios were analysed to investigate the financial options and implications to fleet procurement. As a consequence it is possible to identify the most cost effective method of procuring vehicles and which technology has the lowest pence per mile, under predefined conditions.

To complete the TCO certain conditions were set based on typical features and costs associated with vehicle ownership and necessary accessories. These were identified through literature, automotive expert analysis, longitudinal immersion and industry discussions in 2012. These were:

- The cost of insurance was based on a 35-year-old male, business professional with no previous claims, 2yr no claim bonus and no license infringements (CAP, 2012c)
- One entry to central London per month (TfL, 2012)
- Fuel/Electricity is based on manufacturers claimed vehicle consumption using AA (2012) average UK fuel prices and British Gas (2012) UK average standard rate electricity, £0.1345kWh
- Depreciation figures based on CAP (2012b) values

- Expected residual value for 15,000 miles & 20,000 miles assumed at an additional 5% & 10% respectively of the 10,000 miles figure
- One Schneider Electric EVlink wall mounted charger installed (sourced via industrial placement)
- Access to public charging infrastructure network based on UK average subscription charge (sourced via longitudinal immersion)
- Contract hire based on 10,000 miles per annum on a non-maintained contract (CAP, 2012a)
- Company car hire scheme attributes 20% tax to the company (EST, 2012a)
- The Renault Zoe has a leased battery which therefore assumes a monthly contribution (based on Renault's (2012) average Battery Hire Pricing model)

Schneider Electric was used as the cost base for residential charging as the researcher could ascertain the average cost for the equipment and installation at a property with off street parking. As explained within Section 1.5 and Section 4.1, the researcher was involved in the commercial activity of the infrastructure provider, therefore using costs validated through engaged scholarship was considered more reliable than collating quotes from competitors.

#### 4.2.1.3. London Framework

It has been suggested that EVs have significant potential to be utilised within sub-urban and rural environments, where there are “inflexible, inconvenient or entirely absent” transport nodes (Newman, et al., 2014, p. 320). However, EV technology is currently being targeted towards urban environments by Government, this is due to relatively short mileages, regular charging points and congestion and therefore regenerative braking. Additionally, multiple UK cities have introduced EV incentives for centrally located parking and charging, therefore it is likely that EVs will be more prevalent in urban areas. These factors could favourably implicate the TCO for fleets adopting EVs and therefore a city centric TCO is explored.

London was chosen as the UK city to explore as currently London has the highest concentration of EVs within the UK and has a number of Government schemes supporting the uptake of EVs specifically within the region. As a global cosmopolitan city with considerable investment and economic resource it is often identified as a first-mover towards technology adoption, whereas other UK cities often replicate technology diffusion/policy initiatives once they have been proven successful.

Therefore a London centric TCO was conducted to explore the financial implications of the available incentives within the capital in 2012. Similarly to Section 4.2.1.2 certain conditions were set based on typical features and costs associated with vehicle ownership within London. These were identified

through literature, automotive expert analysis, longitudinal immersion and industry discussions. The conditions set were:

- The cost of insurance was based on a 35-year-old male, business professional with no previous claims, 2yr no claim bonus and no license infringements (CAP, 2012c)
- Unlimited access to London's congestion charge zone, 252 consecutive days (TfL, 2012)
- Fuel/Electricity is based on manufacturers claimed vehicle consumption using AA (2012) average UK fuel prices and British Gas (2012) UK average standard rate electricity, £0.1345kWh
- Depreciation figures based on CAP (2012b) values
- Expected residual value for 15,000 miles & 20,000 miles assumed at an additional 5% & 10% respectively of the 10,000 miles figure
- One Schneider Electric EVlink wall mounted charger installed (sourced via industrial placement)
- Access to Source London (2012) charging network
- Contract hire based on 10,000 miles per annum on a non-maintained contract (CAP, 2012a)
- Company car hire scheme attributes 20% tax to the company (EST, 2012a)
- The Renault Zoe has a leased battery which therefore assumes a monthly contribution (based on Renault's (2012) average Battery Hire Pricing model)

In addition, a TCO analysis was conducted on the premise of a private hire firm operating within London. This scenario assumed the London centric conditions, with the addition of the legal requirements for operating a private hire firm, as stipulated by Transport for London (2014a):

- Operator's licence based on no restriction on the number of licensed private hire vehicles
- At least one 'operating centre' in London
- The vehicles are owned by the private hire firm
- Drivers are self-insured and pay for fuel

The TCO analysis of the private hire scenario does not include the revenue stream generated by renting the vehicles to drivers. This is largely because it does not allow for a true comparison of the TCO of vehicles within this application, but also as this data is not known due to the lack of PEV disseminated within private hire firms.

#### 4.2.2. Conclusions

TCO is a very important and useful methodology for financial comparison, being used by fleet managers it identifies competitive finance models and vehicle types. The TCO analysis will be examined in the

Results (Chapter 5) and contribute to the Discussion in Chapter 6. It will assist in understanding the transition barriers of EVs and indicate to path dependencies of ICEs.

### 4.3. Fleets

In order to investigate the drivers and barriers of EV fleet adoption and understand the challenges associated with EV technology and/or fleet behaviour, a thorough exploration was conducted on three fleets thus forming case studies. This provides an evidence base of the extent to which UK fleets contribute to the transition to EVs. Throughout the case studies, path dependency and technology lock-in has been considered, using the MLP as a tool to identify the dynamics of change.

#### 4.3.1. Case Studies

Case study research is the “desire to derive an up-close or otherwise in-depth understanding of a single or small number of ‘cases’, set in their real-world contexts. The closeness aims to produce an invaluable and deep understanding—that is, an insightful appreciation of the ‘cases’—hopefully resulting in new learning about real-world behaviour and its meaning” (Yin, 2011, p. 4). Due to the descriptive and exploratory nature of the research questions, it is pertinent to use case studies as a methodology to provide “rich description or ... insightful explanations” (Yin, 2011, p. 5). Furthermore, by conducting the study within its operating context, the case study method favours the collection of data in natural settings, compared with relying on “derived” data such as questionnaires (Bromley, 1986, p. 23).

Case studies of three fleets operating in urban environments were selected due to the suggested ‘fit’ with EVs, this is due to the range, regenerative braking in traffic and greater number of public charging infrastructure. Case study research on decisions and actions within urban initiatives help to reveal how actors, in this case fleet owners and operators, influence the transition to a new dynamic and the impact on innovation (Whiteman, et al., 2011). The three fleets within the study are:

- TNT Express Services UK & Ireland - the UK's leading business-to-business express delivery operator
- Schneider Electric UK & Ireland - an energy management ‘blue chip’ technology company
- Green Tomato Cars - a London based environmentally conscious private hire service

These three fleets were chosen for investigation based on the diversity between characteristics of sectors, operations, vehicle procurement and AFV experience. It was speculated that as a consequence three strategic intents for EV adoption would be identified, thus contributing to the exploration on motivations of transitions. Considering the transition to EVs across a diverse mix of fleets operating in different



sectors identifies the extent to which EVs are locked-out and identifies similarities in the challenges of EV adoption. The case studies explore procurement of vehicles, the company fleet strategy, employee reaction to vehicle and technology change, charging considerations and future projections of the fleet's activities and transition to low carbon vehicles.

#### 4.3.2. Interviews

Interviews were chosen as the qualitative research method as the most likely means of attaining the necessary information and experiences required to address the research questions (Polit & Beck, 2008). The major alternative to interviews would have been to disseminate questionnaires to a broad range of fleet operators. This was not considered a viable option because firstly, the data gathered by questionnaires has less reliability than of an interview as there is no guarantee who completed the questionnaire and under what conditions. Secondly, a questionnaire lacks the flexibility of an interview where by the interviewer can delve for further information on points of interest. This was essential for this research as the field of transition pathways, specific to EVs, is largely under-research and therefore requires deeper exploration compared to a broader more superficial study established by questionnaires. Finally, the interviewer was able to build a strong rapport with the three fleets which significantly assisted in gathering data of a sensitive nature. This was fundamental to the interviews as a good rapport between the interviewer and interviewee ensures co-operation and participation where by the interviewee will guide and teach the interviewer on the topic (Spradley, 1979).

The "corporate interview method is particularly appropriate in periods of economic and social change that challenge traditional analytical categories and theoretical principles" (Schoenbergera, 1991, p. 180). This is particularly relevant to the introduction of new technologies responding to legislation associated to climate change, as alongside the transformative change of vehicle type it has broader social implications.

Interviews were conducted with the three fleets across a range of employees, this included key decision makers, managers and, where possible, drivers who experienced a transformation in vehicle technology. It was important to interview a range of employees that were involved with the company's fleet, who were positioned across the business at different levels to ensure triangulation, reliability and objectivity to the results. The interviewees can be categorised as senior management, fleet management or drivers. Therefore all had had different interactions with EVs (within one fleet), whether through analysis, procurement, driving or founding the strategy to utilise EVs. This ensured that each case study formed explored the broad implications of transitioning to EVs.

Below is the list of interviewees from the specified companies:

- Schneider Electric
  - Fleet Manager
  - Business Development Director, EV Infrastructure
  - Driver
- TNT
  - Global Program Manager Sustainability
  - National Engineering Manager
- Green Tomato Cars
  - Vice President
  - Marketing Manager
  - Driver

The interviews were conducted to identify the drivers and barriers of EV fleet adoption and understand the perceptions and behaviours surrounding EVs. Therefore questions asked the strategic intent and extent of EV use, the associated targets, the challenges and barriers experienced and the integration strategies. A semi-structured approach was employed “on the basis of a loose structure consisting of open ended questions that define the area to be explored, at least initially, and from which the interviewer or interviewee may diverge in order to pursue an idea in more detail” (Britten, 1995, p. 251).

This approach, semi-structured with open-ended questions, was used to achieve a level of comparability between the fleets as well as flexibility to encourage the embedded knowledge of fleet managers and fleet specific behaviours to be incorporated within the research. The contribution from practitioners strengthens the data and its analysis. The “open-ended corporate interview as a qualitative research method is proposed as a valuable component of an evidentiary strategy...It is argued to be more sensitive than other survey methods to historical, institutional, and strategic complexity” (Schoenbergera, 1991, p. 180). The goal is to understand the company’s observed behaviour “in the context of other other considerations such as the firm’s competitive strategy, relationship to its markets [and] product technology” (Schoenbergera, 1991, p. 180). This methodology provides a good foundation to form hypotheses about business behaviours regarding “conflicting and shifting strategic logic and historical contingencies that underline corporate decisions” (Schoenbergera, 1991, p. 181). This is fundamental in understanding the path dependencies of ICE vehicles and the associated lock-in within fleets.

Britten makes reference to Patton's suggestion of six types of questions that can be used within an interview: "those based on behaviour or experience, on opinion or value, on feeling, on knowledge, and on sensory experience and those asking about demographic or background details" (Britten, 1995, p. 252). Within the interviews conducted for this research all six types have been exercised, this is to encourage a detailed and broad conversation and therefore good insight and analysis. Below highlights a number of the interview questions:

Senior management	Fleet manager	Driver
How has the fleet developed over the last five years?	To what specification are vehicles procured?	What vehicles have you driven in your time with company?
To what extent does senior management influence vehicle procurement?	To date what experience have you had with electric vehicles?	Do you currently manage the fuelling of the vehicle?
What has been your experience of alternative fuelled vehicles within the fleet?	To what extent do you think EVs could be successfully utilised within the fleet? What challenges do you expect?	Do you think an electric vehicle would fulfil the requirements of the job? Why?
What challenges do you expect to experience with electric vehicles?	What changes will you implement to help the acceptance of electric vehicles?	Would you be happy to drive and charge an EV day to day?
What charging requirements have been considered?	Will drivers be given training? Will there be a monitory in-use period?	What barriers would you predict if TNT had electric vehicles for your job?
What would you predict for the fleet over the next five years?	What charging requirements have been considered? How would this be implemented?	Do you think EVs will be embraced by the company? Why?

#### 4.3.2.1. Data Recording

Interviews were conducted by telephone for convenience of the interviewee whilst also gaining a level of rapport and flexibility (Bryman, 2008). Interviews were recorded either using computer software or a Dictaphone. This was to allow for uninterrupted conversation and reliability of data recording, as alternatively writing notes at the time of, or after, the interview can significantly "interfere with the process of interviewing" and the reliability of information (Britten, 1995, p. 253). Also, conducting the interviews via telephone meant interviewees were less concerned with being recorded as they could not see the recording equipment. The recordings were then transcribed to text for analysis and comparison.

#### 4.3.3. Analysis

This qualitative research is inductive; ensuring the nature of the relationship between theory and research is analysed and highlights core strategies to fleet operations (Bryman, 2008). In analysing the interviews content analysis was used in the broad sense that inferences were made through “objectivity and systematically identifying specified characteristics of messages” (Holsti, 1969, p. 14). This approach identifies similar concepts within the text, relationships that are consistent and those individualities specific to a certain environment. Content analysis is useful in identifying trends and patterns which are occurring, particularly if they are incremental and have little immediate impact (Stemler, 2014). In this respect, reference to such matters may not achieve recognisable attention but inferences may be made across a number of interviews. Content analysis can therefore monitor the shift in expert or public opinion that contributes to a transition in social or culture movements.

More specifically, due to the case study approach summative content analysis was applied to compare the content and interpretation of the underlying context of each fleet (Hsieh & Shannon, 2005). Summative content analysis is an effective methodology to study the phenomenon of interest, in this instance in real world examples of EV utilisation in fleets (Babbie, 1992). The approach is a mechanism to demonstrate credibility and consistency of evidence within a single fleet and across multiple fleets (Weber, 1990).

The case studies enabled the creation of a short questionnaire for fleets of company cars, service providers and transportation trucks within urban environments. The purpose of these questions were to identify the key challenge that a fleet is likely to experience when integrating EVs in to an existing ICE fleet, and provide recommendations to overcome those. In completing the questionnaire it requires the participant to consider the fleet’s main motivations for utilising EVs, where the demand originated and the rate at which EVs will be implemented. The intention was that the questionnaire is completed by employees who have an understanding of the company’s strategy and fleet requirements. An assumption was defined prior to constructing the questionnaire, that the fleet involved had already justified the finance/business case of EVs. Although the recommendation will likely alter the feasibility equation for the fleet, it is secondary to the 'economics' being a key challenge.

#### 4.3.4. Conclusions on fleet methods

The methodology of recorded interviews was most appropriate to address the research questions within a field that is largely under-researched. The results of the interviews are explored to address the research questions and understand the challenges associated with EVs within fleets. Additionally, they indicate factors that can be overcome through behavioural change rather than technological developments or

regulative enforcement. Finally it highlights the existing lock-in that is in place and indicate to a suitable transition pathway for optimum EV integration.

#### 4.4. E-Car Clubs

E-car clubs were identified in Chapter 2 as a major opportunity for the diffusion of EVs due largely to the business models and operating environments. Therefore the methodologies employed need to support the analysis of transition pathways of e-car clubs within urban areas; this encompasses the exploration of path dependencies of mobility services and the lock-in of car ownership.

In order to establish the opportunity EVs have to extend the pathway to mobility services, an analysis of the existing market was performed. This created examples of e-car clubs and the various business models that are currently operating. Following this, interviews were conducted with a range of stakeholders to understand the drivers and barriers to e-car clubs and the necessary action required to transition to a service based mobility approach.

##### 4.4.1. Interviews

Interviews were conducted with three stakeholders of the car club market to gain further insight and attain expert elicitation on the e-car club market. Due to lack of existing evidence and the infancy of car clubs within the UK it was necessary to obtain an in-depth understanding of actors within this space, rather than abundant sources supplying superficial data with little reliability. Therefore the case study approach was employed to depict existing drivers and barriers of EVs being used within this context. This will provide “rich description or ... insightful explanations” that is required to understand the extent to which the challenges can be overcome by policy (Yin, 2011, p. 5). The interviews enabled a wider appreciation for the two dimensional challenge of transitioning to mobility services and interdependently, EVs. This would not have been achievable through questionnaires due to the restricted interaction and communication with the respondents. Below lists the interviews which took place:

- DriveNow UK
  - Director
- E-Car Club Ltd
  - Founder & Development Director
- Car Plus – National Accreditation Body for Car Clubs
  - Car Club Development Manager / Assistant Director

These stakeholder organisations were chosen due to their relative maturity within the embryonic market. It was necessary to have contribution from experts in the field that had attained experience of the market growing, developing and challenging the existing regime. Due to the exploratory nature of the questions regarding transition barriers and existing and future policies, it was necessary for those interviewed to have a holistic view of their operations within the wider context; therefore it was evident the interviewees would need to be senior management.

It was important to develop rapport with the interviewees to ensure maximum information was shared. This requires building a positive relationship throughout the initial stages of organising the interview as well as during the interview (DiCicco-Bloom & Crabtree, 2006). Spradley (1979) explains there are generally four stages of rapport between an interviewer and interviewee, these include apprehension, exploration, co-operation and participation. These stages are not necessarily incremental but develop as the relationship/interview does. However the optimum is to achieve ‘participation’ reflecting the greatest level of rapport where by the interviewee guides and teaches the interviewer. On several occasions ‘participation’ was achieved and led to a very successful interview.

The interviews were structured around “several key questions that help to define the areas to be explored, but also [to] allow the interviewer or interviewee to diverge in order to pursue an idea or response in more detail” (Gill, et al., 2008, p. 291). Below are the questions which the interviews were centred on:

- (i) What are the common challenges of car clubs across the UK, and why?
- (ii) What do you suggest slows the uptake of car clubs?
- (iii) For increased car club use and electric car club use, what do you think needs to be addressed?
- (iv) In what respect do you think electric car clubs can be used for businesses?
- (v) To what extent do city and/or local authorities recognise the need to move to a service based transport model?
- (vi) How do you perceive the business model developing as mobility is more widely used as a service?
- (vii) To what extent do you think current transport policy is encouraging an integrated approach?

The questions were semi-structured and open-ended (following the success of the fleet interviews) to allow for adaptability of the context and a degree of flexibility and flow of the conversation. The flexibility of this approach, “allows for the discovery or elaboration of information that is important to participants but may not have previously been thought of as pertinent by the research team” (Gill, et al., 2008, p. 291). This would not have been achieved by other methods such as questionnaires, nor would

the detail and depth of material be collected that would suffice for comparison and contrast using content analysis.

#### 4.4.1.1. Data Recording

Similar to that of the fleet research, interviews were conducted by telephone for convenience and greater objectivity (Bryman, 2008). They were recorded with a Dictaphone and transcribed to text, thus ensuring reliability. However, one interview was conducted in person due to the close proximity in office location. This enabled a more personable approach with the ability witness social cues such as, voice and body language (Opdenakker, 2006). However, as the interviewee is an expert in the field, social cues were less important to witness (Emans, 1986). Notes were taken throughout the interview whilst encouraging a flow of conversation to avoid significant time delay between questions (Opdenakker, 2006). The purpose of this was to ensure the interviewee responded more spontaneously to the question, without extensive reflection (Opdenakker, 2006).

#### 4.4.2. Conclusions on car club methods

Again these methodologies were employed to best satisfy the research objectives. The car club examples and the interviews conducted will address the role of EVs towards the pathway of a 'mobility-as-a-service model'. The results will determine the recommendations of transitioning to a multi-modal service system, but more specifically, to a greater utilisation of EVs.

### 4.5. Methodology considerations

Following qualitative and quantitative research methods, it is necessary to consider the limitations, bias and reliability of this research. This can then be taken in to account when assessing the results in Chapter 5 and the consequent conclusions.

#### 4.5.1. Limitations

The way in which this research has been conducted has inherent limitations; interviews are based upon opinions and attitudes that can change over a short period of time but can also be manipulated by certain environments and/or company cultures that can result in bias (Golafshani, 2003). Therefore the interviews capture a precise picture of the employee, the company and the market, at the given time. The responses given can also be dependent on the relationship or rapport between the interviewer and interviewee, whether it is negative or positive to the results, it cannot necessarily be replicated if the interview were performed by someone else (Golafshani, 2003) (DiCicco-Bloom & Crabtree, 2006).

Alternatively, using questionnaires would remove the relationship dynamics, relying purely on the sample, template and questions. However questionnaires still capture opinions at a precise moment with limited explanations in an uncontrolled environment.

Secondly, transcribing recorded interviews can result in a degree of interpretation (Poland, 2002). This is due to the conversation structure, style, use of quotations and figures, which all require an element of analysis to ensure it is transcribed correctly. In order to overcome these challenges the recording was listened to whilst reading the transcribed material to ensure accuracy (DiCicco-Bloom & Crabtree, 2006).

An additional limitation within this research is the focus on UK case studies and examples; this lacks the ability to make global generalisations for the transition pathways of EVs due to varying policy and legislative frameworks. However, case studies provide the necessary depth required to analyse the existing transition barriers and market forces due to the lack of existing evidence. Additionally, European examples have been provided to contextualise the UK's positioning and approach to EVs. Furthermore, as the research is specific to the UK it is possible to relate the findings to the transition pathways of other alternative technologies within the country.

Finally, although the TCO is a beneficial financial tool to assess the costs associated to ownership, "it is aimed purely at keeping down costs, and not at contributing to the success of the business" (ITSM, 2002, p. 1). It is questionable whether this is an effective method of analysis when considering EVs, as new technology is often less financially competitive. The TCO does not consider the environmental, health or PR benefits of EVs which contribute significantly to their value. However, as TCO is a very common tool for fleet managers to compare vehicles, it was important for the study to include it as a comparative tool to understand the lock-in of ICEs within a fleet context.

#### 4.5.2. Ensuring reliability and validity

Patton (2002) states that reliability and validity are two factors that are fundamental to qualitative research and should be considered when designing a study, analysing results and judging the quality. This assists in reducing the impact of limitations and therefore strengthens the research.

Joppe (2000, p. 1) defines reliability as: "*the extent to which results are consistent over time and an accurate representation of the total population under study is referred to as reliability and if the results of a study can be reproduced under a similar methodology, then the research instrument is considered to be reliable*". Considering this definition in light of the methodologies this research has employed, it is arguable that the results will be reliable and unbiased, to a degree. The interviews of both fleets and car clubs were conducted with a range of stakeholders to ensure that a broad population was represented.



Furthermore, the fleets were chosen across a number of industries to be relevant to a wider audience as well as to identify common challenges and motivations (Noble & Smith, 2005).

However as previously discussed within the Limitations (Section 4.5.1), interviews are dependent on opinions, attitudes and rapport; all of which are sensitive to the environment and relationships at a given time (Golafshani, 2003). Although this provides a dynamic and comprehensive insight in to the given market, interviews represent only a limited sample of behaviour which could lead to inconsistencies if the results were collected again (Algina & Crocker, 1986). Regardless of the methodology employed to explore the diffusion of new technologies it is very likely that the data collected would be un-replicable due to rapid changes of market forces within the early stages of optimisation.

It is suggested that the use of both qualitative (interviews) and quantitative (TCO) methodologies supports the reliability using the method of triangulation (Patton, 2002). This “strengthens a study by combining...several kinds of methods or data, including using both quantitative and qualitative approaches” (Patton, 2002, p. 247). However, the need for consistency of results when replicating research is questioned as a core aspect of reliability by a number of qualitative researchers. Instead precision, credibility and transferability are argued to be more important (Glesne & Peshkin, 1992) (Hoepfl, 1997) (Winter, 2000). Following this paradigm of qualitative research enhances the findings of this study to a greater degree due to the nature of methodologies used. The results collected in both qualitative and quantitative formats have been accounted accurately, the techniques employed are transferable to other studies and those interviewed are experts within their field.

Considering validity, “there is not a single, fixed or universal concept” and it is described by a wide range of terms (Golafshani, 2003, p. 602). One definition explains: “validity determines whether the research truly measures that which it was intended to measure or how truthful the research results are” (Joppe, 2000, p. 1). Therefore this research used the most appropriate methodologies to best achieve the objectives. The research aims were clearly of a qualitative and exploratory nature, therefore interviews seemed most fitting to identify how path dependency and lock-in of ICEs can be overcome to enable greater adoption of EVs. It was evident that expert elicitation was applicable for such an investigation, which could then be supported by quantitative research as a means to triangulate the findings.

#### 4.5.3. Research ethics

Throughout this research, University ethics were complied with and a general practice of decorum was followed. There are a number of specific ethical requirements for interviews that include; (i) reducing the risk of unanticipated harm; (ii) protecting the interviewee’s information; (iii) effectively informing

interviewees about the nature of the study, and (iv) reducing the risk of exploitation (DiCicco-Bloom & Crabtree, 2006).

Therefore following such ethical considerations, it was confirmed with the interviewees at the end of each interview whether all information could be shared with a wider audience or if elements were required to be confidential. This was particularly important within a semi-structured interview as the interviewee was encouraged to divulge, therefore confirming the sensitivity of information ensured the interviewee did not consider themselves to be at jeopardy professionally or personally. Similarly it was confirmed whether the interviewees wanted to remain anonymous.

Additionally, concerns regarding the stress induced upon the interviewee before, during or after the interview were managed accordingly. In organising and fermenting the interview the interviewee was provided with an overview of the research topic and the areas for discussion. Furthermore the interviewee was reassured throughout the process, with no pressure to conduct the interview if they felt uncomfortable. After the interview had taken place the interviewee was asked if they were satisfied with their responses and experience of the interview, with the option to withdrawal from the study.

In regards to recording interviews, interviewees were informed of the purpose of recording and asked for their consent. Furthermore due to a degree of unknown progression of the research/results, it was agreed with interviewees that secondary interviews may be necessary for further exploration or clarification.

#### 4.6. Conclusions

In this chapter the research design has been presented, exploring the use of interviews and case studies in order to address the research questions. The methodology, its validation and the ethics involved are discussed and demonstrate the strength of the research.

Due to the exploratory nature of the research questions the methodologies assigned to analyse the transition pathways of e-mobility were largely qualitative. The use of interviews provided the necessary depth to the information through further elaboration of expert elicitation. Using existing examples within the market to identify business models, path dependencies and lock-in provides evidence to question the diffusion of EVs within the UK and the supporting policies. In addition to this a TCO analysis was performed to further triangulate the data collected and identify specific transition barriers to EV adoption in commercial applications.

Overall, extensive consideration was given to the methodologies that are most appropriate to the research objectives. The foundations of these are structured to contribute sound knowledge to the body of literature and decipher the most applicable transition pathway for EVs within the current landscape.

## 5. Results

In the following Chapter the results of this research will be presented and analysed. The research can be divided into three phases which stem from the research questions, (i) total cost of ownership analysis, (ii) the electrification of commercial-urban fleets, and (iii) the electrification of car clubs. The objective of this research is to identify the transition barriers of EVs within these applications and determine the dominant path dependencies and lock-in that challenge increased utilisation. It will explore the necessary change to achieve a transition and the extent to which EVs are restricted in these markets, this will be explored through interviews, case studies and examples along with a number of TCO studies across different scenarios.

### 5.1. Total Cost of Ownership

It has been established that fleet operators use TCO analysis to establish the direct and indirect costs of a vehicle, dependent on a fleet's pressures the TCO will determine the vehicles procured. Therefore it is important to consider the competitiveness of EVs comparatively to ICEs to identify possible economic barriers to transitions and establish the necessary changes in market conditions. TCO studies on EVs are likely to be varied in results as there are a number of assumptions inherent to the new market and unknowns of a second hand market. As discussed in Chapter 4, the conditions of the TCO were set based on typical features identified through literature, industry experts and industry discussions.

#### 5.1.1. Analysis

EVs have a comparatively high purchase price in contrast to ICEs due to the high costs of battery technology which is likely to limit the extent “the share of battery-powered vehicles will grow” within the automotive industry (McCall, 2011, p. 1). For private individuals the high purchase price is a barrier to uptake, however fleet procurement being focused on the TCO it is less prohibiting, as other costs associated to the ownership of an EV i.e. fuel, are substantially lower than an ICE. To explore this, a TCO study was conducted comparing the following vehicles:

- Ford Focus 1.6 TDCi 115PS Titanium X
- Toyota Prius T-Spirit 1.8
- Nissan Leaf
- Renault Zoe

Table 2: Total cost of ownership comparison on an EV basis, outright purchase

Data gathered, 2012

TCO (GBP £)	Ford Focus 1.6	Toyota Prius	Nissan Leaf	Renault Zoe (battery leased)
Catalogue price	21,595	24,870	29,990	20,000
Discount	0	0	5,000	5,000
Additional costs of accessories	1500	1188.58	0	0
Total investment needed to purchase	23,095	26,059	24,990	15,000
£ per month				
Servicing / maintenance	29	28	25	25
Insurance	81	76	69	69
VED	2	0	0	0
Congestion charge	120	120	0	0
Fuel	80	70	31	31
Subscription to charging network	0	0	0.8	0.8
Battery leasing	0	0	0	70
Total mandatory costs	312	294	125.8	195.8
Depreciation cost per month	375	424	427	256
Depreciation cost per year	4,500	5,088	5,124	3,075
Depreciation cost over 3 years	13,500	15,264	15,372	9,225
Expected residual value @ 10,000, 3yrs	9,595	10,795	9,618	5,775
Expected residual value @ 15,000, 3yrs	9,106	10,009	8,369	5,025
Expected residual value @ 20,000, 3 yrs	7,952	8,706	7,120	4,275
<b>TOTAL COSTS over 3 years</b>	<b>24732</b>	<b>25848</b>	<b>19902</b>	<b>16275</b>
<b>TOTAL COSTS per annum</b>	<b>8244</b>	<b>8616</b>	<b>6634</b>	<b>5425</b>
<b>Pence per mile</b>	<b>1.42</b>	<b>1.60</b>	<b>1.58</b>	<b>0.98</b>
<b>Pence per mile (15,000 miles)</b>	<b>1.00</b>	<b>1.13</b>	<b>1.15</b>	<b>0.71</b>
<b>Pence per mile (20,000 miles)</b>	<b>0.82</b>	<b>0.92</b>	<b>0.93</b>	<b>0.58</b>

Dataset:

- The cost of insurance was based on a 35-year-old male, business professional with no previous claims, 2yr no claim bonus and no license infringements (CAP, 2012c)
- One entry to central London per month (TfL, 2012)
- Fuel/Electricity is based on manufacturers claimed vehicle consumption using AA (2012) average UK fuel prices and British Gas (2012) UK average standard rate electricity, £0.1345kWh
- Depreciation figures based on CAP (2012b) values
- Expected residual value for 15,000 miles & 20,000 miles assumed at an additional 5% & 10% respectively of the 10,000 miles figure
- Access to public charging infrastructure network based on UK average subscription charge
- The Renault Zoe has a leased battery which therefore assumes a monthly contribution (based on Renault's (2012) average Battery Hire Pricing model)

#### 5.1.1.1. Initial capital costs

The TCO analysis highlights the significant impact the Plug-in Car Grant (£5,000) paid by the Government has on the purchase price of the PEVs. As a result of the grant the PEV demands a lower capital investment than the HEV, providing a financial stimulus to extend adoption from the transitional technology of HEVs to PEVs. Despite the grant the Nissan Leaf does not reach cost parity with the competitively priced ICE (Ford Focus), however it competes with a high specification as standard. This includes a colour LCD satellite navigation system, automatic headlights and wipers, cruise control, steering wheel controls, intelligent key entry system, LED lamps, rear view camera, USB/iPod/aux connection, Bluetooth with voice, AVSP and Eco mode. Such features are not considered standard on many ICE vehicles, including the Ford Focus, this is often neglected in financial assessments. In the case of Renault's model of battery leasing, whereby the vehicles is owned but the battery is leased, it reduces the high initial purchase price and makes the vehicle the most affordable option.

#### 5.1.1.2. Monthly cost

The TCO highlights the economic benefits of PEVs during the use phase, with lower maintenance, insurance and fuel costs compared to the ICE and HEV. The PEV battery leasing model requires monthly payments to rent the battery, this requires higher disposable income and results in the Zoe being the most expensive PEV per month in the TCO analysis (Accenture, 2010). Therefore the vehicle procurer has to determine which payment model is more viable based on a monthly budget rather than an annual contribution. Leasing components of a vehicle requires a shift in culture for individuals/companies from outright asset ownership to an alternative ownership model based on the provision of service. The challenges of this transition will be explored further in Chapter 6 to establish the transition barriers of adopting e-mobility services and the path dependencies embedded within society that prevent greater uptake.

Both the ICE and HEV are subject to the cost of one entry to London congestion charge zone (EVs are exempt) per month thus negatively impacting economic competitiveness. One entry to central London was assumed to avoid bias towards either vehicle technology or assumption of operating location. However, the commercial-urban fleets that were involved within this research were entering central London daily. It is questioned, how would daily access to central London alter the TCO of ICE vehicles? Furthermore, due to the exemption for vehicles that emit 75g/km or less of CO<sub>2</sub> and meet the Euro 5 standard for air quality, to what extent would EVs be repositioned within the TCO (TfL, 2015b)? To address these questions a London centric TCO analysis has been conducted in Section 5.1.3 for further evaluation of the financial implications of utilising EVs in central London.

#### 5.1.1.3. Pence per mile

The TCO clearly shows higher mileage results in greater efficiencies, purely on return on investment and regardless of the vehicle technology. The pence per mile is substantially lower for the Renault Zoe due to the low monthly costs and purchase price; but interestingly the Ford Focus competes heavily against the Nissan and Toyota on a pence per mile basis due to the lower purchase price and depreciation cost. Therefore considering the operating costs of the vehicles it is apparent that the Renault Zoe, leasing the battery, is most competitive. However it is questionable whether fleet operators would consider the AFV technology a risk compared to the competitive and traditional ICE Ford Focus.

#### 5.1.1.4. Lifetime costs

The TCO analysis shows total costs of the PEVs (Zoe and Leaf respectively) are lower than of the ICE and HEV. This is due to the lower monthly costs of these vehicles, as a greater proportion of the overall costs. However, it is evident from the TCO analysis the PEVs are expected to have greater depreciation values as a percentage of the initial investment. It is calculated that both PEVs will lose between 62 – 72% of the purchase value, after 3 years of ownership at the specified mileages. In comparison the ICE and HEV are expected to be valued 58 – 67% below the purchase value, under the same conditions. Therefore considering vehicle procurement on a replacement cycle scheme, as fleets operate, it is likely the ICE or HEV would be favoured on this basis. This is despite the HEV possessing the highest total cost of ownership due to the combined high purchase price and high running costs.

It is imperative to consider the costs of charging infrastructure when analysing the lifetime costs for EVs. In Table 2 subscription to a charging network was included, however a fleet would likely need regular access to at least one charging point. Table 3 introduces this additional cost to the analysis.

Table 3: Total cost of ownership comparison on an EV basis, with charging infrastructure.

Data gathered, 2012

TCO (GBP £)	Ford Focus 1.6	Toyota Prius	Nissan Leaf	Renault Zoe (battery leased)
Catalogue price	21,595	24,870	29,990	20,000
Discount	0	0	5,000	5,000
Additional costs of accessories	1500	1188.58	0	0
Total investment needed to purchase	23,095	26,059	24,990	15,000
£ per month				
Servicing / maintenance	29	28	25	25
Insurance	81	76	69	69
VED	2	0	0	0
Congestion charge	120	120	0	0
Fuel	80	70	31	31
Subscription to charging network	0	0	0.8	0.8
Battery leasing	0	0	0	70
Total mandatory costs	312	294	125.8	195.8
Depreciation cost per month	375	424	427	256
Depreciation cost per year	4,500	5,088	5,124	3,075
Depreciation cost over 3 years	13,500	15,264	15,372	9,225
Expected residual value @ 10,000, 3yrs	9,595	10,795	9,618	5,775
Expected residual value @ 15,000, 3yrs	9,106	10,009	8,369	5,025
Expected residual value @ 20,000, 3 yrs	7,952	8,706	7,120	4,275
Additional cost: Infrastructure	0	0	700	700
<b>TOTAL COSTS per annum</b>	<b>8244</b>	<b>8616</b>	<b>7334</b>	<b>6125</b>
<b>Pence per mile</b>	<b>1.42</b>	<b>1.60</b>	<b>1.65</b>	<b>1.05</b>
<b>Pence per mile (15,000 miles)</b>	<b>1.00</b>	<b>1.13</b>	<b>1.20</b>	<b>0.76</b>
<b>Pence per mile (20,000 miles)</b>	<b>0.82</b>	<b>0.92</b>	<b>0.97</b>	<b>0.61</b>

Dataset:

- The cost of insurance was based on a 35-year-old male, business professional with no previous claims, 2yr no claim bonus and no license infringements (CAP, 2012c)
- One entry to central London per month (TfL, 2012)
- Fuel/Electricity is based on manufacturers claimed vehicle consumption using AA (2012) average UK fuel prices and British Gas (2012) UK average standard rate electricity, £0.1345kWh
- Depreciation figures based on CAP (2012b) values
- Expected residual value for 15,000 miles & 20,000 miles assumed at an additional 5% & 10% respectively of the 10,000 miles figure
- One Schneider Electric EVlink wall mounted charger installed
- Access to public charging infrastructure network based on UK average subscription charge
- The Renault Zoe has a leased battery which therefore assumes a monthly contribution (based on Renault's (2012) average Battery Hire Pricing model)



Table 3 highlights that incorporating charging infrastructure in to the TCO analysis significantly heightens the financial burden of EVs. The Renault Zoe remains most competitive due to the low purchase price but the Nissan Leaf is now the most expensive vehicle to operate per mile. Whilst the ICE and HEV are unaffected, these vehicles still possess the greatest costs per annum.

Furthermore the charging infrastructure specified is a 3kW – 11kW wall mounted charger that would on average charge a vehicle between 4 – 6 hours. This would be appropriate for a fleet with a 100 mile drive cycle per day, with the downtime available to recharge. Alternatively if the fleet operated 24/7 there would need to be multiple PEVs on rotation to account for charging downtime. The TCO has not considered the installation of higher kW rated charging infrastructure as the costs are highly variable due to available power capacity and cabling. However, clearly higher costs of charging infrastructure would substantially increase the TCO of an EV and therefore enhance the viability of the ICE and HEV.

#### 5.1.2. Alternative finance

A large proportion of fleets would not purchase vehicles outright but would lease vehicles for a predetermined length of time with a tailored package to meet business requirements. Consequently, the TCO analysis has been extended to consider this finance model, as seen in Table 4.

Table 4: Total cost of ownership comparison on an EV basis, contract hire

Data gathered, 2012

TCO (GBP £)	Ford Focus 1.6	Toyota Prius	Nissan Leaf	Renault Zoe (battery leased)
Catalogue price	21,595	24,870	29,990	20,000
Discount	0	0	5,000	5,000
Additional costs of accessories	1500	1188.58	0	0
Total investment needed to purchase	23,095	26,059	24,990	15,000
£ per month				
Servicing / maintenance	29	28	25	25
Insurance	81	76	69	69
VED	2	0	0	0
Congestion charge	120	120	0	0
Fuel	80	70	31	31
Subscription to charging network	0	0	0.8	0.8
Battery leasing	0	0	0	70
Total mandatory costs	312	294	125.8	195.8
Depreciation cost per month	375	424	427	256
Depreciation cost per year	4,500	5,088	5,124	3,075
Depreciation cost over 3 years	13,500	15,264	15,372	9,225
Expected residual value @ 10,000, 3yrs	9,595	10,795	9,618	5,775
Expected residual value @ 15,000, 3yrs	9,106	10,009	8,369	5,025
Expected residual value @ 20,000, 3 yrs	7,952	8,706	7,120	4,275
Infrastructure	0	0	700	700
Contract hire finance	261	332	355	355
National insurance contributions	30	26	0	0
Total additional costs	291	358	355	355
<b>TOTAL COSTS over 3 years</b>	<b>35208</b>	<b>38736</b>	<b>33382</b>	<b>29755</b>
<b>TOTAL COSTS per annum</b>	<b>11736</b>	<b>12912</b>	<b>11594</b>	<b>10385</b>
<b>Pence per mile</b>	<b>1.77</b>	<b>2.03</b>	<b>2.08</b>	<b>1.47</b>
<b>Pence per mile (15,000 miles)</b>	<b>1.23</b>	<b>1.42</b>	<b>1.48</b>	<b>1.04</b>
<b>Pence per mile (20,000 miles)</b>	<b>0.99</b>	<b>1.14</b>	<b>1.18</b>	<b>0.83</b>

Dataset:

- The cost of insurance was based on a 35-year-old male, business professional with no previous claims, 2yr no claim bonus and no license infringements (CAP, 2012c)
- One entry to central London per month (TfL, 2012)
- Fuel/Electricity is based on manufacturers claimed vehicle consumption using AA (2012) average UK fuel prices and British Gas (2012) UK average standard rate electricity, £0.1345kWh
- Depreciation figures based on CAP (2012b) values
- Expected residual value for 15,000 miles & 20,000 miles assumed at an additional 5% & 10% respectively of the 10,000 miles figure
- One Schneider Electric EVlink wall mounted charger installed
- Access to public charging infrastructure network based on UK average subscription charge
- Contract hire based on 10,000 miles per annum on a non-maintained contract (CAP, 2012a)

- The Renault Zoe has a leased battery which therefore assumes a monthly contribution (based on Renault's (2012) average Battery Hire Pricing model)

A key outcome from the contract hire finance model is that although the Renault Zoe and Ford Focus remain most competitive to operate, the price to have vehicles contracted results in higher costs of ownership and mileage. Again the Renault Zoe has the lowest total costs due to the low purchase price, but interestingly the other three vehicles compete closely. The Nissan Leaf remains the least competitive due to the combined and relatively high purchase price, contract finance model and the requirement for charging infrastructure.

This analysis would advise fleet operators leasing vehicles to procure the Renault Zoe, followed by the Ford Focus. The competitiveness of the Renault is due to the substantially low purchase price supported by the leased battery. It is therefore a question of traditional vehicle technology competitively priced versus PEV technology that is economically advantageous.

Table 5 below explores the TCO of these vehicles in a company car scenario, this introduces additional costs of Benefit in Kind taxes to the ICE and HEV which EVs are currently exempt from. Consequently the PEVs have the lowest total costs of ownership but it is again the Zoe that offers the cheapest pence per mile.

Table 5: Total cost of ownership comparison on an EV basis, company car

Data gathered, 2012

TCO (GBP £)	Costs based on the EV framework			
	Ford Focus 1.6	Toyota Prius	Nissan Leaf	Renault Zoe (battery leased)
Catalogue price	21,595	24,870	29,990	20,000
Discount	0	0	5,000	5,000
Additional costs of accessories	1500	1188.58	0	0
<b>Total investment needed to purchase</b>	<b>23,095</b>	<b>26,059</b>	<b>24,990</b>	<b>15,000</b>
<b>£ per month</b>				
Servicing / maintenance	29	28	25	25
Insurance	81	76	69	69
VED	2	0	0	0
Congestion charge	120	120	0	0
Fuel	80	70	31	31
Subscription to charging network	0	0	0.8	0.8
Battery leasing	0	0	0	70
<b>Total mandatory costs</b>	<b>312</b>	<b>294</b>	<b>125.8</b>	<b>195.8</b>
Depreciation cost per month	375	424	427	256
Depreciation cost per year	4,500	5,088	5,124	3,075
Depreciation cost over 3 years	13,500	15,264	15,372	9,225
Expected residual value @ 10,000, 3yrs	9,595	10,795	9,618	5,775
Expected residual value @ 15,000, 3yrs	9,106	10,009	8,369	5,025
Expected residual value @ 20,000, 3 yrs	7,952	8,706	7,120	4,275
Infrastructure	0	0	700	700
<b>As a company car:</b>				
Benefit in Kind personal tax	47	40	0	0
Benefit in Kind personal fuel tax	41	31	0	0
<b>Total additional costs</b>	<b>88</b>	<b>71</b>	<b>0</b>	<b>0</b>
<b>TOTAL COSTS over 3 years</b>	<b>27900</b>	<b>28404</b>	<b>20602</b>	<b>16975</b>
<b>TOTAL COSTS per annum</b>	<b>9300</b>	<b>9468</b>	<b>7334</b>	<b>6125</b>
<b>Pence per mile</b>	<b>1.53</b>	<b>1.68</b>	<b>1.65</b>	<b>1.05</b>
<b>Pence per mile (15,000 miles)</b>	<b>1.07</b>	<b>1.19</b>	<b>1.20</b>	<b>0.76</b>
<b>Pence per mile (20,000 miles)</b>	<b>0.87</b>	<b>0.97</b>	<b>0.97</b>	<b>0.61</b>

Dataset:

- The cost of insurance was based on a 35-year-old male, business professional with no previous claims, 2yr no claim bonus and no license infringements (CAP, 2012c)
- One entry to central London per month (TfL, 2012)
- Fuel/Electricity is based on manufacturers claimed vehicle consumption using AA (2012) average UK fuel prices and British Gas (2012) UK average standard rate electricity, £0.1345kWh
- Depreciation figures based on CAP (2012b) values
- Expected residual value for 15,000 miles & 20,000 miles assumed at an additional 5% & 10% respectively of the 10,000 miles figure
- One Schneider Electric EVlink wall mounted charger installed
- Access to public charging infrastructure network based on UK average subscription charge

- Company car hire scheme attributes 20% tax to the company (EST, 2012a)
- The Renault Zoe has a leased battery which therefore assumes a monthly contribution (based on Renault's (2012) average Battery Hire Pricing model)

Interestingly, although the Toyota Prius has the highest purchase price within the TCO analysis and in each scenario is attributed the highest total costs; it is only in the company car scenario at 10,000 miles that it supplies the highest pence per mile. In the other finance models the low depreciation cost (compared to the EVs) along with the no requirement for charging infrastructure results in the high purchase price and monthly costs to be absorbed and remain more competitive than the Nissan Leaf. However the introduction of additional taxes whilst the EVs are exempt results in an additional 63p per mile compared to the Renault Zoe at 10,000 miles. Despite this, the overall TCO results for the HEV compared to the Nissan Leaf, suggests that HEVs could act as a 'bridging technology' until alternative ownership models (such as battery leasing) are adopted by customers, thus enabling EVs to compete economically.

#### 5.1.3. London centric TCO analysis

There are multiple advantages to operating EVs within urban areas as discussed in Chapters 2 and 3. These include high population density, localised demand and compatible user drive cycles. Additionally there are localised grants and incentives in regards to parking, charging and tax exceptions in the aim to promote EV use and therefore improve air and noise pollution. From a national and global perspective London's road transport network is a key opportunity to electrify. However, is it feasible for a London fleet to operate EVs rather than ICEs?

Table 6 analyses the London centric TCO of the four vehicles procured by the three finance models, (i) outright purchase, (ii) contract hire and (iii) as a company car and considers the cost of charging infrastructure. The analysis assumes the fleet will subscribe to the London network of charging infrastructure, install one wall mounted charger and enter the congestion charge zone daily. It is still arguable that a fleet would require a higher specification of charging infrastructure but within London it is possible to utilise a network of over 1,300 public charge points.

The additional cost of the congestion charge significantly increases the total ownership costs by £2688 annually. This is only applicable to the ICE and HEV as EVs are exempt from the charge. However, interestingly the order of competitiveness between the vehicles does not change, only the disparity between the figures. Generally the EVs are more competitive and the ICE and HEV are less so than originally portrayed. The Renault Zoe benefits most substantially from the London centric analysis as the

vehicle remains most competitive in all scenarios. It is questioned, why are EVs not exploited for inner London operations to a greater extent?

Table 6: Total cost of ownership comparison on an EV basis, London centric

Data gathered, 2012

TCO	Ford Focus 1.6	Toyota Prius	Nissan Leaf	Renault Zoe (battery leased)
Catalogue price	21,595	24,870	29,990	£20,000
Discount	0	0	5,000	5,000
Additional costs of accessories	1500	1188.58	0	0
Total investment needed to purchase	23,095	26,059	24,990	15,000
£ per month				
Servicing / maintenance	29	28	25	25
Insurance	81	76	69	69
VED	2	0	0	0
Congestion charge	241.5	241.5	0	0
Fuel	80	70	31	31
Subscription to charging network	0	0	0.8	0.8
Battery leasing	0	0	0	70
Total mandatory costs	433.5	415.5	125.8	195.8
Depreciation cost per month	375	424	427	256
Depreciation cost per year	4,500	5,088	5,124	3,075
Depreciation cost over 3 years	13,500	15,264	15,372	9,225
Expected residual value @ 10,000, 3yrs	9,595	10,795	9,618	5,775
Expected residual value @ 15,000, 3yrs	9,106	10,009	8,369	5,025
Expected residual value @ 20,000, 3 yrs	7,952	8,706	7,120	4,275
<b>TOTAL COSTS over 3 years</b>	<b>29106</b>	<b>30222</b>	<b>19902</b>	<b>16275</b>
<b>TOTAL COSTS per annum</b>	<b>9702</b>	<b>10074</b>	<b>6634</b>	<b>5425</b>
<b>Pence per mile</b>	<b>1.44</b>	<b>1.61</b>	<b>1.58</b>	<b>0.98</b>
<b>Pence per mile (15,000 miles)</b>	<b>1.00</b>	<b>1.14</b>	<b>1.15</b>	<b>0.71</b>
<b>Pence per mile (20,000 miles)</b>	<b>0.82</b>	<b>0.93</b>	<b>0.93</b>	<b>0.58</b>
Infrastructure	0	0	700	700
<b>TOTAL COSTS per annum</b>	<b>9702</b>	<b>10074</b>	<b>7334</b>	<b>6125</b>
<b>Pence per mile</b>	<b>1.44</b>	<b>1.61</b>	<b>1.65</b>	<b>1.05</b>
<b>Pence per mile (15,000 miles)</b>	<b>1.00</b>	<b>1.14</b>	<b>1.20</b>	<b>0.76</b>
<b>Pence per mile (20,000 miles)</b>	<b>0.82</b>	<b>0.93</b>	<b>0.97</b>	<b>0.61</b>
For contract hire per month per vehicle:				
Contract hire finance	261	332	355	355
National insurance contributions	30	26	0	0
Total additional costs	291	358	355	355
<b>TOTAL COSTS over 3 years</b>	<b>39582</b>	<b>43110</b>	<b>33382</b>	<b>29755</b>
<b>TOTAL COSTS per annum</b>	<b>13194</b>	<b>14370</b>	<b>11594</b>	<b>10385</b>
<b>Pence per mile</b>	<b>1.79</b>	<b>2.04</b>	<b>2.08</b>	<b>1.47</b>
<b>Pence per mile (15,000 miles)</b>	<b>1.24</b>	<b>1.42</b>	<b>1.48</b>	<b>1.04</b>
<b>Pence per mile (20,000 miles)</b>	<b>1.00</b>	<b>1.14</b>	<b>1.18</b>	<b>0.83</b>
As a company car:				
Benefit in Kind personal tax	47	40	0	0
Benefit in Kind personal fuel tax	41	31	0	0
Total additional costs	88	71	0	0
<b>TOTAL COSTS over 3 years</b>	<b>32274</b>	<b>32778</b>	<b>20602</b>	<b>16975</b>
<b>TOTAL COSTS per annum</b>	<b>10758</b>	<b>10926</b>	<b>7334</b>	<b>6125</b>
<b>Pence per mile</b>	<b>1.54</b>	<b>1.69</b>	<b>1.65</b>	<b>1.05</b>
<b>Pence per mile (15,000 miles)</b>	<b>1.07</b>	<b>1.20</b>	<b>1.20</b>	<b>0.76</b>
<b>Pence per mile (20,000 miles)</b>	<b>0.87</b>	<b>0.97</b>	<b>0.97</b>	<b>0.61</b>

Dataset:

- The cost of insurance was based on a 35-year-old male, business professional with no previous claims, 2yr no claim bonus and no license infringements (CAP, 2012c)
- Unlimited access to London's congestion charge zone, 252 consecutive days (TfL, 2012)
- Fuel/Electricity is based on manufacturers claimed vehicle consumption using AA (2012) average UK fuel prices and British Gas (2012) UK average standard rate electricity, £0.1345kWh
- Depreciation figures based on CAP (2012b) values
- Expected residual value for 15,000 miles & 20,000 miles assumed at an additional 5% & 10% respectively of the 10,000 miles figure
- One Schneider Electric EVlink wall mounted charger installed (sourced via industrial placement)
- Access to Source London (2012) charging network
- Contract hire based on 10,000 miles per annum on a non-maintained contract (CAP, 2012a)
- Company car hire scheme attributes 20% tax to the company (EST, 2012a)
- The Renault Zoe has a leased battery which therefore assumes a monthly contribution (based on Renault's (2012) average Battery Hire Pricing model)

#### 5.1.3.1. London centric TCO analysis, private hire

As part of the study exploring the transition to EVs within private hire fleets, the case study Green Tomato Cars is London centric. Private hire vehicles are “exempt from paying the congestion charge when actively licensed with ‘London Taxi and Private Hire’, the exemption...only applies when undertaking private hire bookings” (TfL, 2015b, p. 1). This exemption is applicable to all vehicle technologies and therefore presents alternative findings of the London scenario for this application. Table 7 analyses the impact of no congestion upon the four vehicle types, whilst including the additional costs of private hire licensing.



Table 7: Total cost of ownership comparison on an EV basis, London centric private hire

Data gathered, 2012

TCO (GBP £)	Costs based on the EV framework			
	Ford Focus 1.6	Toyota Prius	Nissan Leaf	Renault Zoe (battery leased)
Catalogue price	21,595	24,870	29,990	20000
Discount	0	0	5,000	5,000
Additional costs of accessories	1500	1188.58	0	0
Total investment needed to purchase	23,095	26,059	24,990	15,000
£ per month				
Servicing / maintenance	29	28	25	25
VED	2	0	0	0
Congestion charge	0	0	0	0
Subscription to charging network	0	0	0.8	0.8
Battery leasing	0	0	0	70
Total mandatory costs	31	28	25.8	95.8
Depreciation cost per month	375	424	427	256
Depreciation cost per year	4,500	5,088	5,124	3,075
Depreciation cost over 3 years	13,500	15,264	15,372	9,225
Infrastructure	0	0	700	700
Private hire operator license application fee	838	838	838	838
Private hire operator license fee per year	397.6	397.6	397.6	397.6
Private hire vehicle license application fee	65	65	65	65
Private hire vehicle license fee per year	35	35	35	35
Total additional costs	1336	1336	1336	1336
<b>TOTAL COSTS over 3 years</b>	<b>31093</b>	<b>32749</b>	<b>33479</b>	<b>29852</b>
<b>TOTAL COSTS per annum</b>	<b>5305</b>	<b>5857</b>	<b>6567</b>	<b>5358</b>

Dataset:

- Unlimited access to London's congestion charge zone, 252 consecutive days (TfL, 2012)
- Depreciation figures based on CAP (2012b) values
- Expected residual value for 15,000 miles & 20,000 miles assumed at an additional 5% & 10% respectively of the 10,000 miles figure
- One Schneider Electric EVlink wall mounted charger installed (sourced via industrial placement)
- Access to Source London (2012) charging network
- The Renault Zoe has a leased battery which therefore assumes a monthly contribution (based on Renault's (2012) average Battery Hire Pricing model)
- Operator's licence based on no restriction on the number of licensed private hire vehicles
- At least one 'operating centre' in London
- The vehicles are owned by the private hire firm
- Drivers are self-insured and pay for fuel

The analysis suggests that for a private hire firm the most economic vehicle over a three period is the battery leased PEV, despite comparatively high monthly costs attributed to the battery, the low initial investment results in low total costs. However it is questionable if a private hire firm would adopt this ownership model due to the use of vehicles by contracted drivers and the terms of warranty. On the contrary, the Nissan Leaf is most expensive absorbing an £10,000 in to the equation. Removing the cost of fuel and insurance (financed by the driver) further improves the TCO for the ICE and HEV, whilst PEVs do not benefit from congestion charge exemption. This results in the Ford Focus being the most competitive per annum. Therefore it is questionable whether under traditional forms of ownership if a private hire fleet have any motivation to adopt PEVs beyond a unique selling point. Arguably for a private hire fleet minimised downtime and extended ranges are invariably important; therefore should Government incentivise private hire fleets to operate PEVs to maximise improvements in air and noise pollution within a 'dirty' fleet?

#### 5.1.4. Conclusions on TCO

The TCO compares a range of vehicle technologies including ICE, HEV, PEV and a PEV with a leased battery. It demonstrates the importance of considering the direct and indirect costs of ownership and the exercise of conducting a financial comparison. The lack of market confidence and sunk technology costs of ICE vehicles holds significance to the depreciation and residual values of PEVs. This is particularly challenging for the fleet market due to the short ownership cycles of vehicles, thus heavily dependent on the resale value (Electrification Coalition, 2010). As a consequence it is locking-in ICEs and reinforcing the barriers to market entry through a lack of confidence in the new technology by insurance and fleet providers. The TCO analysis demonstrates the low depreciation rates of the ICE and HEV maintains the competitiveness and thus further reinforces the lock-in of ICEs. The analysis highlights the current significance of Government incentives; the Plug-in Car Grant and congestion charge exemption improves the competitiveness of EVs, which otherwise would be largely diminished.

Exploring different finance models that would be employed by fleets highlights the impact on vehicle competitiveness. Battery leasing suggests that new ownership models can be cost effective across a range of operations by removing upfront costs and introducing a leasing mechanism. This approach is arguably more likely to succeed within commercial applications than with private individuals due to the existing relationship fleet operators have with alternative ownership models such as contract hire. However for a wide spread adoption of EVs it is imperative that path dependencies of ICEs are challenged to broaden the availability to AFVs and shift the culture of outright ownership to service based models. These

findings will contribute to the research objectives that aim to investigate the transition barriers of EVs and explore their role within mobility services, this will be further discussed in Chapter 6.

## 5.2. Fleets

A number of interviews were carried out with three commercial-urban fleets to identify the existing path dependencies that are restricting an organic transition to greater EV utilisation. It was explored what changes are necessary to increase the uptake of EVs and how these can be achieved. Additionally, a study was conducted between Schneider Electric, Energy Saving Trust and EDF which took place alongside the research interviews, to investigate the transition barriers of a London based fleet of company cars. The results will be elaborated upon within the following section.

### 5.2.1. Schneider Electric

Schneider Electric is an energy management company providing automation, control, electrical distribution and installation systems. Schneider Electric has approximately 200,000 employees globally, of which 7,000 are based in the UK & Ireland. There are 1,200 vehicles in the UK company car fleet varying broadly in specification, but only 2 AFVs.

In the company car scheme, employees are graded depending on their role and the number of miles driven which decides if and what car the employee is entitled to and at what contribution rate (Schneider-Electric, 2013a, pers. comms). Drivers can choose vehicles up to 25% above their allowance with the majority of drivers trading up rather than down. Drivers must exert “10,000 miles per annum or be out of the office more than 3 days per week....[those] employees driving under 2,000 miles per annum receive a cash allowance” as it is not cost effective to provide them with a car (Schneider-Electric, 2013a, pers. comms). The company reimburses the driver one pence per mile based on +15% of the mpg, this encourages better driver behaviour to enhance efficiency and increase miles per gallon (Schneider-Electric, 2013a, pers. comms).

Schneider Electric funds the vehicles through Hitachi Capital, as a taxable benefit “the Benefit in Kind is now based on the combination of the P11D and CO<sub>2</sub> emissions of the vehicle” (Schneider-Electric, 2013a, pers. comms). The employees pay the Benefit in Kind to the HM Revenue & Customs. This “step change is quite dramatic as the driver’s choice of vehicle can now be based around the efficiency of the vehicle rather than based on maximising the fixed Benefit in Kind, regardless of the CO<sub>2</sub> level” (Schneider-Electric, 2013a, pers. comms.). Vehicle choice is capped at 160gCO<sub>2</sub>/km, this is still relatively high compared to many other company car fleets. Schneider Electric are “aware that Government are to

enforce more stringent limits in the future” but the company are more reactive than proactive in order to maintain employee expectations of company car allowance (Schneider-Electric, 2013a, pers. comms.).

There seems to be little motivation to adapt the company car policy to incorporate EVs at present. While “the P11D is still expensive on EVs it will not be a competitive option for employees, regardless of whether EVs are on Hitachi Capital’s vehicle portfolio” (Schneider-Electric, 2013a, pers. comms).

Economics is very important for employees in monthly costs, residual values and the emissions bracket of the vehicle due to option-to-buy at the end of the four-year contract (Schneider-Electric, 2013a, pers. comms). The low cost of electricity is not a particular draw to the employee as the company reimburses company mileage, removing a key incentive of EVs.

The key challenge to Schneider Electric is likely to be “driver acceptance for the use of vehicles for private mileage” (Schneider-Electric, 2013a, pers. comms). This is due to range restrictions, thus reinforcing the path dependencies that restrict EV use. Even if the contribution each month for an EV was considerably lower than an ICE, it is thought employees would not sacrifice flexibility and the practicality of the vehicle, suggesting technological lock-in (Schneider-Electric, 2013a, pers. comms).

The sales person interviewed was based between London and Telford, the driver admits his driving style varies between the two locations due to the respective inner city roads and motorways. In Telford the driver averages 250 miles per day, therefore he suspects an EV would not be suitable and he fears for a lack of charging infrastructure in the region. However for the role in London, where approximately 100 miles per day are travelled, it “would be beneficial in terms of the free congestion charge as sometimes [the driver] would take a detour to miss the congestion charge zone”, increasing mileage and travel time (Schneider-Electric, 2013b, pers. comms). Additionally, the driver highlighted the suitability of EVs in London as “there is so much traffic in London that unless...driving on the M25...[the driver is] forced to drive slowly, always stop, starting” (Schneider-Electric, 2013b, pers. comms). Due to regenerative braking this style of intermittent driving is very economic for EV drivers and could extend the available range before needing to charge.

The driver interviewed also highlighted the restrictions it would introduce in his personal life as he uses the car for private mileage. Although the employee suggested it could be “managed by planning journeys and charging at home”, it is something that both the employees and company would have to consider (Schneider-Electric, 2013b, pers. comms). At the time of this interview, the company (or HM Revenue & Customs) had not established a method or fuel reimbursement rate which would be inherently different to the traditional rate for an ICE. This combined with the question of payment for charging infrastructure at

home and/or whilst travelling, are challenges that a company car fleet need to overcome to ensure employees feel confident in specifying an EV as choice.

Additionally, it is clear that within Schneider Electric “badge consciousness and psychological kudos with its customers” is important to employees (Schneider-Electric, 2013c, pers. comms). This emotive dimension surrounding status is established within the ‘civil society logic’ and exploited by the ‘market logic’, this results in a co-dependent relationship of supply and demand of ‘desirable’ vehicles (Foxon, 2013) (Griskevicius & Tybur, 2009). It is thus challenging for a company to initiate cultural change and destabilise the internal regime by introducing AFV technology. This transition barrier suggests a broader requirement for a paradigm shift in vehicle status allegiance that requires a niche innovation pathway, driven by the ‘innovator’ logic.

#### 5.2.1.1. Plugged-in Fleet Initiative

Schneider Electric analysed the financial and operational viability of EVs in their own company car fleet. This analysis was done in conjunction with Energy Saving Trust, EDF Energy and Route Monkey, funded by Transport for London and the Department for Transport. The analysis was based on 49 company cars based in London due to the opportunity city driving provides EVs with shorter distances and regular regenerative braking. Figure 13 separates the fleet by fuel type:

*Figure 13: Schneider Electric’s London fleet*

Fuel Type	Number	%
Diesel	36	73%
Petrol	12	24%
Hybrid	1	2%
EVs	0	0%
<b>Total</b>	<b>49</b>	<b>100%</b>

*Source: EST, 2013*

Of these 49 vehicles, there are currently no PEVs. This is arguably due to the lack of integration of EVs within the policy, there has not been a designated scheme created with independent reimbursement rates

nor is there a communication strategy to encourage employee engagement. Consequently, there is limited awareness amongst employees, who have not received communication regarding the availability of EVs or clearly, the financial implications of reimbursement and charging. Therefore it is not surprising the lack of take up of EVs.

Nonetheless, of these vehicles the average business mileage is 14,042 and total mileage including private mileage is 18,755. It is evident from the TCO studies in Section 5.1 that as mileage increases, the vehicles become cheaper to operate on a pence per mile basis. However within the company car scenario, private mileage is unaccountable to the company and funded privately by employees. Nonetheless due to the low operating costs of PEVs the mileage is not particularly influential compared to the high indirect costs of ownership. The analysis considered the monthly and whole life costs for both the company and the employee. It compares a BMW 320d Modern Auto which is a popular car on the fleet with a Vauxhall Ampera Electron, a premium PHEV with an extended range of 300 miles.

The analysis revealed:

*“At the prestige end of the choice range, the financial analysis shows that although the list price of a car like the Vauxhall Ampera or Chevrolet Volt is well above a prestige economical diesel like a BMW 320d, the lease rates of the cars are relatively similar but if it was just based on lease rental alone, the EVs may erroneously be ruled out as marginally more expensive. However, once the taxation costs are considered, there are considerable financial savings to both Schneider and their drivers of selecting an EV alternative” (EST, 2012b, p. 3).*

Figure 14: Financial comparison of BMW 3 Series and Vauxhall Ampera

Model	320d Modern Automatic	Ampera Electron	Difference
Engine Type	Turbo Diesel	Electric + Petrol	
P11d List Price	£31,490	£37,195	£5,705
NEDC CO <sub>2</sub> (g/km)	118	27	91
NEDC MPG	62.8	-	
Forecast MPG – (less 15%)	54.6	40	14.6
Number of Months	48	48	
Annual Miles <sup>1</sup>	15,000	15,000	
Assumed Tax Rate (%)	40	40	
Fuel £ / litre (ex-VAT)	£1.18	£1.12	0.06
Electricity Cost (peak/low rate)	N/A	14.39 / 5.20	
Total NIC Class 1A	£3,390	£1,951	£1,439
Total business fuel	£3,929	£4,261	£332
Fuel + Class 1A NIC	£7,319	£6,212	£1,107
Lifetime Lease Cost	£21,954	£22,447	£493
Whole Life Costs	£29,273	£28,659	£614
Pence per mile	48.79	47.77	

Source: EST, 2013

The Ampera is cost effective for both the employer and the employee; this is largely due to tax savings and the cost of fuelling the vehicle, despite a higher P11D. Although the analysis put forward a business case for the Ampera to replace the BMW 3 Series, it is very unlikely Schneider Electric employees will begin adopting these vehicles as it is a price sensitive decision and the contribution required by employees each month would still remain high due to the lower residual values. For EVs to achieve greater adoption the company would need to strongly communicate the Benefit in Kind benefits of driving a hybrid or EV.

#### 5.2.1.2. Conclusions

Despite possible cost savings for both Schneider Electric and their employees it is evident from the interviews that Schneider Electric does not currently intend to adapt their company car policy to

encourage EV use. Due to the strong sales ethos in the company, company cars seem to be a sensitive employee benefit with embedded significance placed on vehicle specification and brand. Consequently, rather than Schneider Electric trying to challenge this lock-in and install new behaviours, the company currently do not extend their commitment beyond the legislation set by Government.

The lack of communication from senior management and consequently low awareness amongst employees regarding a transition to AFVs within the fleet that operates within an energy management company is surprising. It would be beneficial for the company to electrify a substantial proportion of the fleet, not only to reduce their carbon footprint but as a marketing ploy to create a show case example that would generate attention and (potentially) business.

Arguably the lack of commitment demonstrated by Schneider Electric is a reflection on weak government policy regarding the environmental impact of company car fleets. Should Government enforce a transition to AFVs within fleet applications with more stringent regulations regarding the carbon emissions per kilometre? Without this enforced, is it too big a challenge for fleets to transition to EVs, especially when the act of travelling (i.e. private hire) is not the main premise of the business? The Plugged-in Fleets Initiative supports the theory that urban environments provide suitable conditions for EVs; it does not however consider opportunities for EVs to address the lack of public transport in rural and sub-urban environments where car reliance is greater than within cities (Newman, et al., 2014). Nonetheless, it is recommended that fleets utilise EVs within ‘sweet spots’ where the vehicles will provide greatest return on investment and minimal behavioural change by the driver.

The relationship demonstrated by Schneider Electric employee’s and the brand and specification of an automobile is a considerable transition barrier to EVs. The market perception of EVs (discussed further in Chapter 6, Section 6.1.1.1) is based on scepticism of legacy and reliability. This requires a behaviour change based on awareness and experience. However is this attitude extended to the general populous, and therefore the explanation for the overall low uptake of EVs?

### 5.2.2.TNT

TNT is a parcel delivery company to the UK, Europe and beyond. Within the UK, they own 4,743 vehicles, including tractor units, rigid trucks, semi trailers and cars across 134 operating locations (TNT, 2013a, pers. comms). This research focused on the 1,398 rigid 7.5 tonne trucks that on average travel 56,000km per annum, used for UK local deliver and collection (TNT, 2013a, pers. comms).

In 2006 the Board of Directors instructed the fleet managers to procure EVs to contribute to the zero emission targets of the company (TNT, 2013b, pers. comms). After trials TNT “procured fifty 7.5 Smith



Electric trucks with sodium nickel batteries...[Due to unreliability,] in 2010 ten were converted to lithium ion batteries despite the conversion costs being greater than a diesel equivalent” (TNT, 2013a, pers. comms).

TNT experienced two key challenges:

- The limited range of the vehicles introduced inflexibility and further requirement for logistical planning
- The “increased unladen weight that affects the payload due to the weight of the battery, meaning less weight can be carried, requiring more planning on which loads can go in which vehicle” (TNT, 2013a, pers. comms)

Both challenges affect the core business of TNT and the efficiency of operations. TNT did not intend to make these vehicles more economical to run but “to be cost neutral with a diesel vehicle over a 5 year life span” (TNT, 2013a, pers. comms). However, it was evident by the third year that that did not prove to be the case due to the unreliability and the subsequent conversion costs. Due to the unreliability of the EVs, drivers were resistant to use the vehicles and would “always choose the diesel if available” (TNT, 2013a, pers. comms). This slowed the return on investment as “for most of the time the trucks were sat in the depot” (TNT, 2013a, pers. comms). Despite this, TNT considered the “procurement as a moderate success but cost prohibitive” (TNT, 2013a, pers. comms). As a result, in 2013 all of the vehicles were returned to the manufacturer and TNT awaits the development of new vehicle technology.

TNT states that if the reliability of the new vehicles is proven then it is likely “TNT will procure more from Smith’s as there are limited manufacturers of electric trucks” (TNT, 2013a, pers. comms). TNT’s National Fleet Engineer predicts that TNT will focus on EVs in the foreseeable future with the use of telematics. TNT, being mainly based in city centres, believes “EVs will be the future of mobility and [predicts that] ICEs will be prohibited from entering cities” (TNT, 2013b, pers. comms).

TNT wishes to “be compliant with future Government legislation and in fact lead the way by using different technologies in operation today” (TNT, 2013a, pers. comms). As TNT is a dominant agent within the industry with such a well-established brand, it heightens the pressure to be first movers at the forefront of regulation (TNT, 2013b, pers. comms). As a large company with stringent CO<sub>2</sub> targets, TNT have the budget to absorb the expense and potential challenges in order to discover the ‘sweet spots’ of rewards, including fuel savings and PR value (TNT, 2013a, pers. comms).

Regarding hybrids, TNT have previously trialled prototypes for various auto manufacturers. TNT found these vehicles “much easier to run due to the available petrol tank but in densely populated urban areas

there was greater demand for efficiency than braking regeneration” (TNT, 2013a, pers. comms). Although the “fuel saving was between 16-18% the hybrids were performing relatively low mileage and therefore the savings were not significant” (TNT, 2013a, pers. comms). TNT performed a total cost of ownership analysis that revealed the hybrids would need to be in operation for 13 years to be cost neutral with a diesel (TNT, 2013a, pers. comms). As the replacement cycle for TNT is 5 years, these vehicles are not feasible within this cost model.

Unfortunately for TNT, the electric truck market is not as advanced technologically as is required for full integration within the fleet. There is more focus on efficient diesels due to EU regulations (i.e. Euro 6 Regulation (EC) No 715/2007 (Europa, 2015), than the ‘innovator logic’ for EVs. The case shows the lack of economic stability of EVs to support technology lock-in, whereas the discussion to pursue hybrid vans is arguably an expression of the strength of path dependency as a guide for technology innovation. This indicates the strength of the ‘government logic’ on the automotive sector at a landscape level compared to that of niche-innovations.

#### 5.2.2.1. Conclusions

Due to TNT’s global strategic targets to be zero emitting by 2020, the fleet have been able to decarbonise to some extent. However this transition has been limited by technology and has therefore been detrimental in challenging employee’s preconceptions of EVs. This demonstrates transition barriers aligned to technology lock-in and market perceptions that are restricting the diffusion of EVs. Nonetheless, the environmental motivations to utilise EVs has led TNT to begin challenging lock-in within the courier industry, despite it being cost prohibitive. This demonstrates the importance of sponsorship and support from senior management to transition to a niche technology. In order to sustain change within an organisation’s regime, when it fundamentally challenges the function of the business and the profitability, it is necessary that the initiative demonstrates a greater contribution that leaders can identify value in.

This can be witnessed on a grander scale by Government’s investment in to AFVs, and specifically EVs, thus broadly demonstrating their commitment to low carbon transport. However, for both governments and organisations it is imperative that all levels of the community (citizens and employees) identify with the need to transition and are aware of and comfortable with the technology. Without community engagement the regime cannot be destabilised to create opportunities for the niche innovation. The fundamental question is, what will cause destabilisation of the incumbent ICE to occur to allow EVs to enter mass market? Are market techniques employed by Government such as motivation crowding building sufficient momentum to remove technology lock-in?

### 5.2.3. Green Tomato Cars

Green Tomato Cars offer “an environmentally friendly private hire minicab service in London for corporate accounts and one off bookings” (Green Tomato Car, 2014, p. 1). The business model aims to demonstrate that a ‘green’ business can be commercially successful within a competitive market with AFVs mainstream rather than niche (GTC, 2013b, pers. comms). Within the fleet there are 410 vehicles; 8 bio-diesel people carriers, 6 bio-diesel executive cars (run on 30% vegetable oil) and 396 hybrid cars. All of which do an average of 120-150 miles per day mainly within central London (GTC, 2013a, pers. comms).

GTC trialled two Renault Fluence’s on the fleet in 2012 for six months. These vehicles had an effective, actual range of 60 miles (Renault states 99 miles) and were charged nightly without the ability to rapid charge (GTC, 2013a, pers. comms). As a result “the vehicles could only be used for half a day and were limited to certain journeys...with greater attention on the destination rather than the pick-up point” (GTC, 2013a, pers. comms). However it was “logistically difficult to manage and was not commercially viable” (GTC, 2013a, pers. comms). Ultimately “the Fluence did not have the range to be a viable component part of a fleet of an established private hire company” (GTC, 2013a, pers. comms). This highlights the fundamental issue of using a vehicle with a restricted range within a sector that relies on flexible travel. This does not infer range anxiety as a transition barrier as the fleet operators are prepared to plan around the ‘limitations’, but the battery capacity introduces operational restrictions that have economic impact.

A driver at GTC who has trialled various EVs, bio-diesel vehicles and hybrid vehicles, stated the pure EV’s “range was very limiting, although it was suitable for city driving, motorways proved challenging” (GTC, 2013c, pers. comms). The Driver did not think that EVs were suitable for a taxi provider if it were a driver’s sole vehicle. This is due to the battery capacity as “the working hours can be long and you would not be able to earn money whilst the car is charging” (GTC, 2013c, pers. comms). The necessary downtime of the vehicle while charging introduces a fundamental challenge for EVs to be applicable for private hire firms. As a result driver’s working hours would be largely dictated by the requirement to charge and the availability to charging infrastructure.

GTC found two main barriers against a wider use of EVs:

- Charging infrastructure – despite profiling the drivers to best suit the vehicles, the cars will still need to be charged every day (compared to once/twice a week for the Prius)

- Winning over the stakeholders – “a compelling argument is necessary for new technology and requires a change in behaviour and a level of confidence that the vehicles will work operationally and be a good business decision” (GTC, 2013a, pers. comms)

These two challenges highlight the technological unsuitability of existing EVs for a private hire fleet, but these are also very relevant to the general market of EVs.

Strategically, GTC see themselves as a pioneering brand and consequently feel “they have a responsibility to be test beds of new technology” (GTC, 2013a, pers. comms). This ‘innovator logic’ approach, indicates as to why GTC did not wait until an EV taxi was brought to market but focused on vehicles that already offered a less polluting solution. When the management are forward thinking in this way it begins to eliminate technological lock-in in the market and begins to entrench new behaviours in society, thus giving the market the opportunity to gain momentum and learn from operational problems.

#### 5.2.3.1. Conclusions

The interviews conducted with GTC highlights the strength of the company’s existing business model, to use hybrids as a flexible bridging technology and EVs as a unique selling point aligned to innovative progress (GTC, 2013b, pers. comms). The motivation to transition to EVs is being driven from senior management, however for a business that has to manage their relationship with drivers, private customers and corporate customers, it is evident that winning over stakeholders is paramount to the success of incorporating EVs. This relies heavily on the reliability and desirability of the vehicles, these characteristics will inherently challenge ICE path dependencies and assist in removing technology lock-in. Furthermore, at present there are arguably no direct cost incentives for a private hire firm to operate EVs, therefore it is important that GTC demonstrate added value to customers and exploit themselves as niche actors. This raises the question whether policy incentives should target private hire firms to encourage the adoption of EVs?

GTC’s experience demonstrates the embedded path dependent characteristics of ICE vehicles within the market that instigate the need to have 300+ miles and refuelling within 5 minutes. This is particularly challenging for a private hire firm with unpredictable routes that requires flexibility. GTC have tried to adapt their operations to adopt EVs but currently technology lock-in is preventing successful implementation.

### 5.3. Conclusions

The interviews conducted with the three commercial-fleets highlighted common challenges: the economics, range, vehicle suitability and driver behaviour. These are fundamental elements to the success of removing ICE lock-in and increasing the use of EVs within fleets. The case studies have demonstrated the importance of support from senior management to begin challenging the traditional fleet dynamics and overcome technology lock-in. In the case of Schneider Electric where high level sponsorship lacks, there is clearly little motivation to enforce emission limits below those stipulated by Government.

There are substantial transition barriers to EVs building momentum that could destabilise the regime. A particular challenge highlighted within the cases is the market perception of EVs. The perception remains relatively negative due to reliability issues and social pressures of 'luxury' cars. This requires a cultural shift that will be achieved using a number of market techniques. However, these cases have questioned the existing approach taken by Government to orchestrate a transition to EVs within fleets.

The case studies and those issues they have raised will be analysed and compared more broadly in the context of EV uptake in Chapter 6.

### 5.4. Car Clubs

The opportunity for EVs to penetrate the mobility service sector is vast. The vehicle technology can be optimised to offer a low carbon alternative to travel as well as ownership. This addresses two complex relationships between drivers and their vehicles, but more broadly the issues of sustainability and the transition to a shared economy. Consequently European car club examples and interviews with market stakeholders were identified to explore the role of EVs in the transition to mobility services. This section will explore the results and raise further questions to be discussed in Chapter 6.

#### 5.4.1. DriveNow, Berlin

DriveNow is BMW's carsharing service which operates in five German cities, offering eight BMW models including the PEV, Active E (DriveNow, 2015b). The scheme has various packages that specify payment either per minute or per hour depending on the customers demand. Berlin has 900 cars in and around the S-Bahn ring, twelve of which are PEV (DriveNow, 2015a). The service team refuel/recharge the vehicles but if the tank/battery is low resulting in the driver 'filling up', twenty minutes are granted to the customer's account. This incentive encourages drivers to interact with the vehicle, in the case of the PEV this allows the customer to become more accustomed with the technology. This process of

familiarisation and education through active behaviour unlocks existing path dependencies. This is unless the driver has a poor experience with the PEV and/or charging, thus resulting in heightened technology lock-in for that individual.

DriveNow uses apps to discover vehicles, charging and parking, and the driver's license is used to activate the vehicle rather than having a separate RFID card (DriveNow, 2015b). Making the process streamlined helps overcome many of the transition barriers of EVs and encourages adoption. The use of alternative technologies and application software is fundamental to the niche offering and is appealing to the user demographic. It is reported that 6% of 155,000 members globally did not purchase a new car directly because of DriveNow and that 16% of members deferred buying a new car (Seal-Driver, 2014). This indicates to the opportunity car clubs have to change behaviours, reduce the level of car ownership and reinstate the balance between emissions and air quality using EVs.

#### 5.4.2. AutoLib, Paris

In October 2011 Bolloré successfully trialled 66 Bluecars and 33 rental stations and centres in Paris, this led to the official launch of Autolib' in June 2012 with 250 Bluecars and 250 stations and centres. Today there are approximately 2,000 Bluecars and 4,300 stations and centres within the forty square mile city (Autolib', 2014) (Holland, 2014). Autolib' was the first public service EV plan to be orchestrated in a European city and is suggested to have substituted 22,500 privately owned vehicles, the equivalent of over a hundred million miles per year in an ICE (Autolib', 2014). There are a range of payment models to suit the customer usage requirements including annual subscription for 120 Euros and pay-as-you-go models for 9 Euros per half an hour.

The well established service offers a mobility solution for a broad population that provides flexibility and freedom to travel across the city using a point-to-point business model unlocking the full potential of electric car sharing (Holland, 2014). A point-to-point model limits the user to some extent as the vehicle must be deposited at a specific location. However, as a city known for parking bay shortages, Autolib' provides access to 4,300 parking spaces and charging points in desirable locations provided by the City of Paris. Access to centrally located and limited parking spaces is arguably a key motivation and benefit for Parisians to become members of Autolib'. This strengthens the value proposition of Autolib' by adding value through a desirable benefit that saves the user time and money otherwise spent on parking and finding an available bay. Broadening the inclusive and desirable benefits of car clubs increases the customer base and further diminishes the path dependencies of ownership. Customers are then utilising and operating EVs through ulterior motives but simultaneously technology lock-in is challenged.

Therefore, car club operators and city authorities should consider additional social benefits that are associated and appropriate for specific areas.

Autolib' supplies the vehicles and returns "the city's investment with subscription revenue and a parking space leasing agreement", it was expected this would take seven years but due to high utilisation rates the City's investment will be covered in less than four years (Holland, 2014 p.1) (Goedkoop, et al., 1999). The high utilisation rates of Autolib' demonstrates that drivers are prepared to use AFVs for city travel and that despite a well established public transport network in Paris, car travel remains desirable and/or a more appropriate transport mode for certain journeys. It is reported that the majority of Autolib' users are 25-49, 80% are men and the average distance is less than six miles (Henley, 2014). This is arguably due to a combination of factors including; increased cost of living, better public transport services and availability and acceptance of alternative business models i.e. Autolib'. Does this suggest, within cities there will be a natural trend towards mobility services that are complimented by public transport? Autolib' has normalised EVs in Paris and dramatically altered the transportation mix within the city. The visibility of the vehicles, cost effectiveness and ease of use are all key elements to challenge the embedded technological lock-in of ICEs.

#### 5.4.3. Source London, London

Balloré is replicating Autolib' in London from 2016 using existing charging infrastructure previously managed by a UK Government funded scheme – 'Source London'. Source London was launched in 2010, managed by a consortium of public and private sector organisations, led by Transport for London. However due to a lack of defined ownership and maintenance agreements with the London Boroughs, the network was unreliable and therefore under-utilised. Balloré took ownership of the scheme in 2014 with aims to improve the user experience and develop and expand the network. Charging infrastructure is projected to double to 3,000 by 2018, along with a necessary 4,500 parking bays leased by the London Boroughs.

This will be a considerable shift for London as although there are several car sharing clubs with EVs available, there is not a scheme providing centrally located vehicles on a pay-as-you-go, point-to-point model with associated charging. Therefore the launch of this model will need to be well executed, marketed and managed to encourage citizens to adapt behaviours and remove transition barriers. The scheme aims to be high volume and high frequency with reservations holding for thirty minutes encouraging it to be used on an ad hoc basis to meet both spontaneous and planned journeys. This is a tested model (in Paris) and proves to be well suited for city inhabitants. Furthermore, central London

suffers from limited parking; this can be exploited by Source London as a significant benefit to attract users.

Gaining parking bays on a leasing agreement from 33 Boroughs (including the City of London) is a significant challenge for an operator as each Borough has its own parking requirements and legislation. Car2Go, a car sharing scheme that operated in London ceased operations due to the difficulty experienced working with the various Boroughs. This will require careful consideration by Source London as an integrated approach across the city will be required for a viable scheme that can encourage citizens towards mobility services. Alternatively it will be a restricted local offer for those Boroughs involved, this has been the dominant offer in the UK to date which limits the flexibility and therefore attractiveness of the mobility service.

Car2Go's exit from the market was also reported to be due to the "UK's strong culture and tradition of private vehicle ownership" and the lack of significance assigned to this (BBC, 2014, p. 1). Although this is not unique to Britain and in fact more widespread in countries such as Germany, the pressure to possess material goods is particularly challenging to distil. However younger generations (Generation Y and Z, from 1980 onwards) have begun to adopt alternative business models. This is largely due to the high cost of living and the role of innovation which have created opportunities for product service systems to compete (Vine, et al., 2014). The access to pay-as-you-go private transport with available parking is clearly an attractive proposition for users, however it is questionable whether commercial viability has been reached by operators?

#### 5.4.4.Hertz BilPool, Oslo

Hertz operate a car pooling service across Norway, with Oslo being the primary area with a high concentration of vehicles including PEVs; the Nissan Leaf and Volvo C30 electric. There are two different levels of membership based on hours or kilometres with optional weekend deals (Hertz, 2014). It is an A-A model requiring the car to be returned to the same location after use (Hertz, 2014). This does not provide the same level of flexibility for drivers but guarantees parking availability and charging infrastructure at any given time.

Hertz BilPool also offers corporate membership providing companies with access to vehicles without requiring their own fleet (Hertz, 2014). This removes the need for company cars and/or a leasing agreement preventing asset management, maintenance and high overhead costs. Companies using this model will introduce AFVs to employees that will softly assist in challenging path dependencies of ICE



vehicles. This would have positive feedbacks in further adoption of car clubs and/or EVs in employees' personal lives benefiting the market further.

Despite the strong Government support for EVs in Norway and the success of Tesla amongst other models in Oslo, surprisingly there is not an overwhelming number of e-car clubs in the city (Vidal, 2014). It could be argued this is due to the numerous incentives and subsidies for EVs which have made it extremely attractive to own an EV. Although Norway has successfully challenged technology lock-in through the use of motivation crowding, the policies have not assisted in diminishing congestion but rather increased it. Consequently there is increasing pressure on Norwegian ministers to reduce incentives for EVs. Alternatively funding could be redirected to support schemes to reduce vehicle ownership and increase shared mobility services i.e. e-car clubs (Wirgman, 2014b). This would require additional path dependencies to be challenged regarding ownership models, a transition barrier that would arguably require regulative enforcement following such concentrated promotion of EV procurement. However this would receive significant criticism from EV owners and manufacturers.

#### 5.4.4.1. Conclusions

The European examples of car clubs provided a broad overview of the car club market, highlighting various business models, the level of uptake and the drivers and barriers to car clubs. They indicate the extent to which car clubs are infiltrating society and the uptake from a range of communities. It highlights the importance of user-vehicle interaction beyond driving; encouraging drivers to charge the vehicles breaks down existing ICE lock-in and gets drivers accustomed with EV technology. This has multifaceted benefits, from the business perspective it will further increase EV use within the fleet and therefore increase the rate of return on investment and profitability; from the perspective of EV manufacturers it will heighten the exposure to EVs and may result in fleets or private individuals purchasing additional EVs.

Autolib' in Paris suggests the integration of vehicles and charging managed by one operator in a single scheme enhances the value proposition to customers. This is strengthened by further benefits of access to parking in central city locations, a global urban issue. Should governments introduce further city policies such as the London congestion charge, to encourage car club membership? It is evident that the flexibility of DriveNow's model is gaining momentum across various cities globally – is the flexible business model going to dictate the success of mobility services? This evidence will support the discussion in Chapter 6.

#### 5.4.5. Case studies

Interviews were conducted with industry experts of e-mobility services to identify the role of EVs towards the pathway to a Mobility-as-a-Service (MaaS) approach. It was established in Chapter 2 that car clubs offer a substantial opportunity for EVs due to the operating model and technology ‘fit’. In order to investigate the transition pathways a comprehensive exploration of the existing market is required. This refers to the existing business models and the drivers and barriers determined by path dependencies and lock-in of ICEs and ownership models. The results of the interviews are recorded in the following Sections.

##### 5.4.5.1. E-Car

E-car is “the UK’s first entirely electric pay-per-use car club, designed to provide community members with the convenience and flexibility of a full-sized private car without the high cost of owning one” (E-Car Club, 2015, p. 1). E-Car has a direct partnership with auto manufacturers thus offering an insight in to the approach to service based models. There are three types of offer from auto manufacturers; (i) direct partnership with car sharing operators i.e. Renault, (ii) integration of telematics i.e. Nissan, (iii) provide own solution and offer i.e. BMW DriveNow. E-Car currently exploits (i) and (ii) depending on the specific project, using the Renault Zoe, Nissan Leaf and Renault Kangoo, across two individual business models (E-Car, 2015, pers. comms).

Firstly the ‘home’ business model, targeting specific areas that is bookable via the website or phone, with members using RFID cards to access the vehicles (E-Car, 2015, pers. comms). There are currently 43 vehicles based at designated points across the UK, with 2 more being launched this year. This is an A-A business model requiring the EV to be returned to a specific designated parking bay with either standard or rapid charging infrastructure. Payment is either by the hour or a day rate and includes insurance and breakdown cover, average hourly rate is £6.50 or £50 a day (E-Car, 2015, pers. comms).

The second business model is for ‘businesses’ to provide an “alternative to fleet ownership” (E-Car, 2015, pers. comms). There are a number of finance options including pay-as-you-go, a business account where by blocks of time can be scheduled or hosting an EV. If a business were to host an E-Car, the business would have unlimited access to the vehicle during working hours, but outside those hours the vehicle is available to the public. This reduces the cost to the business but also broadens community engagement.

The E-Car business is split equally between the two business models, although the ‘business’ offer is the key entry to market as it holds less risk and raises greater awareness (E-Car, 2015, pers. comms). E-Car is operating in four locations around the UK using approximately 35 EVs. Northamptonshire County

Council is an example of a 'business' account where by three vehicles are used as a pool car between Council buildings located primarily in Northampton, and then the public have off-peak access.

Aligned to the two different business models, E-Car's experience of users are divided between the two customer bases. E-Car report that business customers travel shorter more frequent journeys but it is variable depending on the bespoke offer (E-Car, 2015, pers. comms). When E-Car are selling the concept to a business of hosting an EV, "the TCO is not considered, neither are extras, being grey fleet. Also they can claim 45p per mile from HM Revenue & Customs so they are making money from over claiming" (E-Car, 2015, pers. comms). However, E-Car's biggest challenge is encouraging behaviour change to achieve a cultural shift towards car sharing (E-Car, 2015, pers. comms). This combined with a utilisation strategy and a high residential density area, is suggested to result in successful deployment (E-Car, 2015, pers. comms).

Although the TCO may not be directly considered, "fleet management are risk averse" that is intensified by limited range, charging infrastructure and employee acceptance (E-Car, 2015, pers. comms). Hence why E-Car provides charging infrastructure, vehicles and manages the back office management. In doing so the "inflection point at which an EV provides return on investment is 13,000 miles" (E-Car, 2015, pers. comms).

Further challenges include "the technology available for billing, charging and membership are across individual software's requiring a number of RFIDs" (E-Car, 2015, pers. comms). There is a technical challenge in forming a single card that can then be used across different networks and can also be integrated with public transport and journey planners (E-Car, 2015, pers. comms). This is being investigated by the Technology Strategy Board to fund incremental projects and demonstrators, rather than national transport strategies (E-Car, 2015, pers. comms). This requires a degree of 'openness' to share back office tools, procurement management could be influenced by the public sector to encourage integration (E-Car, 2015, pers. comms). However until charging networks are interoperable across services and operators the market potential will be limited and adoption will be regional.

E-Car suggests there a number of external challenges within the market that are suppressing the growth of market share. Despite the annual UK growth rate being at 35%, car clubs are not meeting expectations of policy makers, auto manufacturers and the media (E-Car, 2015, pers. comms). This is due to "access to parking bays at appropriate pricing...high insurance premiums...and the lack of awareness of car clubs and EVs" (E-Car, 2015, pers. comms). There are two distinct markets, "London and the rest of the UK; London is only just getting to critical mass, this is required for growth to accelerate" and the UK which is

“dependent upon Local Authority tenders and public sector procurement processes which takes a short term approach due to funding cycles” (E-Car, 2015, pers. comms).

#### 5.4.5.2. Conclusions

E-Car provide an alternative to car ownership for businesses and the public, their joint proposition of ‘hosting’ is a unique business model in the UK and offers substantial benefits to both parties. Providing a complete service that includes the vehicles, charging infrastructure and back office management enables the concept of car sharing and EVs to be considered interdependently. This is fundamental to challenging path dependencies of ownership and creating an attractive alternative that will encourage adoption. However, the market remains restricted by existing technology that fails to incorporate billing, charging and multiple membership networks. Therefore the market is largely reliant on technological developments that require ICT innovation.

#### 5.4.5.3. DriveNow, London

DriveNow is a joint venture between BMW and Sixt, providing zonal car sharing. Within their London operation, launched in 2014, there are 270 BMW and Mini, including 30 pure electric i3 with 8 designated chargers (DriveNow, 2015c, pers. comms). Payment is calculated per minute or by longer packages at a reduced rate; insurance and petrol/electricity is included. Congestion charge however is not included, providing EVs a cost advantage for central London journeys due to exemption.

Traditional car sharing has “approximately 50 customers per car, whereas a flexible model has approximately 150 customers per car” (DriveNow, 2015c, pers. comms). Flexible models allow customers to leave the vehicle anywhere within a specified zone due to prearranged parking conditions with local authorities, therefore pick-up locations are spontaneous. Flexible models are more suitable to a wider population as the vehicles will continuously travel across the zone, whereas point-to-point models are argued to target only affluent areas. In the first six months of operations, DriveNow have accumulated 10,000 customers across 4 Boroughs, equating to 12% of the London market (DriveNow, 2015c, pers. comms). This level of adoption has taken traditional car sharing 10 years to achieve. In terms of EVs there are 30 i3s on the fleet, accounting for 15% of all vehicles. This is targeted to increase by 50%, along with charging infrastructure, by 2018 – 2020 (DriveNow, 2015c, pers. comms).

ICEs have their role within car sharing as “diesel is more efficient over long distances...and petrol has lower NOx which is better for health, but EVs are essential for London” (DriveNow, 2015c, pers. comms). For a successful car sharing operation it is vital that there is open and accessible charging infrastructure available, this is currently lacking within the London (DriveNow, 2015c, pers. comms).

The flexible model reaches a more varied demographic from traditional users due to the roaming nature of vehicles within the model. However, DriveNow customers tend to be male, higher educated with an affinity to technology (DriveNow, 2015c, pers. comms). Within London there is a 25% higher usage of EVs than ICEs, this is presumably due to free congestion charge. In order to “encourage EVs to be taken in to the city and ICEs to be brought out”, ICEs vehicles brought out of the congestion charge zone will not be held liable (DriveNow, 2015c, pers. comms). Further incentives for customers to redistribute vehicles are price sensitive rates.

Common challenges that have been experienced in operating cities are obtaining parking bays, “for success it needs high density, multi centres within the city, high population and high number of cars; in conjunction with good public transport” (DriveNow, 2015c, pers. comms). London has been particularly challenging to acquire parking bays across multiple boroughs due to the multi-authority with 33 boroughs, whilst requiring a contiguous business area for success (DriveNow, 2015c, pers. comms). The “business model needs to be proved through a staggered growth strategy” (DriveNow, 2015c, pers. comms).

DriveNow believe that “experimentation in market evolution is necessary; however it is not conducive to have companies entering and exiting the market...Autolib have said a number of times in the last year that they will be entering the market and have yet to” (DriveNow, 2015c, pers. comms). Furthermore, in an “emerging market it requires big players to act in a way that will encourage trust from officials and local authorities” (DriveNow, 2015c, pers. comms). DriveNow are exploring two expansion strategies, either current areas or launching in new areas, both of which are suggested to be viable (DriveNow, 2015c, pers. comms).

#### 5.4.5.4. Conclusions

The flexible car sharing model is evidently popular, providing a degree of flexibility and focus on one-way travel. However, the restrictions and challenges acquiring parking spaces limits a rapid expansion and remains a transition barrier for car clubs within cities. Customers are using the available EVs to a greater extent than the ICEs, suggesting that London offers a viable environment for e-car clubs to operate. Is their current popularity due to an inquisitive nature to a niche technology or the incentives for EV drivers i.e. free congestion charge?

#### 5.4.5.5. Carplus

Carplus is the national accreditation body for car clubs in the UK, promoting car clubs and shared transport including car clubs, car sharing and taxi sharing (Carplus, 2015a). Carplus was established in

2000 to support and explore alternatives to car use and ownership to reduce congestion and associated environmental, social and health problems (Carplus, 2015a). Carplus provides “technical support, best practice guidance and practical advice to car club operators, community groups, local authorities and transport authorities to assist in setting up and developing car clubs” (Carplus, 2015a, p. 1).

The Assistant Director of Carplus articulates well the current market dynamics, he considers the car club market to be:

*“in a transition currently, moving from a situation where by the car club sector was pioneered by a small number of entrepreneurs who had access to comparatively small amounts of money, to one where the car club sector is now predominately the domain of either large multinationals, car hire companies, OEMs. Growth today has been shaped by access to capital but also to extent by parking spaces within urban areas as well. Growth in the future is less likely to be constrained by that because there will be larger companies putting more money in to car club development”* (Carplus, 2015c, pers. comms).

The Assistant Director of Carplus (2015c, pers. comms) suggests the principal challenge for car clubs operators is to mainstream the concept as it is not necessarily considered as a transport option by consumers or other transport operators. It is suggested mainstreaming the concept will require a combination of strategies that result in greater access to more vehicles in more locations throughout the UK (Carplus, 2015c, pers. comms). Overcoming the challenges requires network developments, marketing and engagement with traditional public transport operators; *so they realise that this is a rapidly growing market and when integrated with [other services] it can be part of a jigsaw of a transport portfolio that can provide a door-to-door alternative to private car ownership and use* (Carplus, 2015c, pers. comms). It is argued that until public transport operators consider car clubs as a complimentary service, the market will be limited and path dependencies of ownership will not be challenged (Carplus, 2015c, pers. comms). Furthermore, car club development relies heavily on being considered as an affordable option for travellers and an alternative to car ownership.

It is considered that the challenges specific to London are very different to those of the UK as a whole, *“London is 83% of the car club market in part due to congestion charge and particular circumstances, it’s a global city and transport is quite constrained. The boroughs and the particularly make-up of London with TfL creates unique challenges within London”* (Carplus, 2015c, pers. comms).

Further challenges lie in obtaining car parking spaces from local authorities. Due to the car clubs in the UK (except one - DriveNow) being back-to-base, it is necessary to secure and maintain dedicated parking (Carplus, 2015c, pers. comms). When EVs are used and charging infrastructure is required at the parking bays it significantly increases the cost of those parking spaces. There are additional *“issues of ownership*

*and location of the charging infrastructure, some local authorities are reluctant to put charging infrastructure on streets which means car club vehicles need to be parked off street. The significant costs with the infrastructure – installation, management and maintenance, are a barrier to car clubs taking up electric vehicles”* (Carplus, 2015c, pers. comms).

The Assistant Director explains a challenge for EVs being used within car clubs is due to the time it takes to charge the vehicles and the implications of that upon the TCO. He explains that although;

*“EV technology is reducing in price, it is not comparable with an ICE...[because] ICEs can be refuelled [by a user] as the normal course of their journey but with an EV the operator takes responsibility of recharging the vehicle, although the user would plug it in, the vehicle isn't being paid for while it's charging whereas it would be with a conventional vehicle which means the downtime is a factor with electric vehicles”* (Carplus, 2015c, pers. comms).

Therefore as an operator considering the TCO of vehicles, EVs are a “more expensive vehicle which is less capable of generating revenue compared to an ICE...this is because it has downtime but also operators aren't sure how much they get for that vehicle when they sell it and that affects fleet renewal and makes operators reluctant to operate electric vehicles” (Carplus, 2015c, pers. comms) This is not the case for OEMs operating car clubs as they are able to operate on a “completely different price structures from traditional car club operators” (Carplus, 2015c, pers. comms).

From an overarching perspective, Carplus (2015c, pers. comms) consider the current Government approach is primarily about selling EVs to public and private sector fleets. Carplus (2015c, pers. comms) argue this is not the most effective strategy as EVs can be far more effective in car clubs due to the non-exhaustive list of users such as; public sector fleets, operators, local authorities and by members of the public. The Assistant Director (2015c, pers. comms) explains car club business models rely on frequent use of the vehicles to achieve a return on investment; therefore densely populated locations are favoured for operations. In order to “sweat the asset” and generate the maximum income from the vehicle, mixed use locations are optimal (Carplus, 2015c, pers. comms). This enables the vehicles to be used by businesses and residential users, whose behaviours compliment each others. Business users tend to use the vehicles during the week day and residential users tend to use the cars in the evenings and weekends (Carplus, 2015c, pers. comms). Therefore Government could “*support [car club operators] to provide EVs to members of the public to use, but that means making available on and off street charging infrastructure and encouraging people to use those cars by dis-incentivising the use of ICEs through the use of taxes and permits”* (Carplus, 2015c, pers. comms).

#### 5.4.5.6. Conclusions

Carplus' overview of the car club sector positively reflects the progress that has taken place over the last decade. Patently, car clubs need to be an affordable means of transport that is able to compliment public transport and business needs. It is questionable whether the challenges of engaging stakeholders, obtaining parking spaces and the feasibility of EVs could be tackled by alternative policies and legislation. These issues will be explored further in Chapter 6.

### 5.5. Conclusions

The results collected from car club stakeholders provide insight in to the dominant path dependencies and lock-in of the automotive industry highlighting the transition barriers to EV use in car clubs. The transition barriers stem from the current culture to own vehicles as a symbol of prosperity, this demands the concept of car sharing to be 'normalised' alongside the introduction of EVs. At a regional level the major challenge is parking regulation, this is currently locking-out e-car clubs from being optimised as a low carbon service within the city transport network.

Paris acts a show case of how this was achieved successfully, taking a city wide approach with an integrated ICT platform. DriveNow is beginning to gain momentum within a much more competitive and regulated London, the flexible business model is resulting in increased car club membership within the city and a higher proportion of those members using EVs. These examples demonstrate how EVs and alternatives to car ownership can break through ICE dominance. Nonetheless, combined and independently, the EV and car club markets remain niche; but what change is necessary for the e-car club market to destabilise the entrenched regime to achieve a low carbon shared economy? These issues will be further explored in Chapter 6 to establish the role and opportunity EVs have to extend the pathway to an electric and service based model of car travel.



## 6. Discussion

This Chapter will explore the transition barriers of EVs in the context of commercial-urban fleets and car clubs, and investigate the extent to which technology lock-in is restricting the market. It will consider path dependencies of the automotive industry and discuss the necessary changes for a transition to fleet electrification and e-mobility services. This Chapter will contribute to knowledge on the opportunity EVs have to extend the pathway to an electric and service based model of car travel.

Following the two markets this research has explored this Chapter will be divided into two sections; (i) fleets, and (ii) car clubs.

### 6.1. Fleets

This section will elaborate upon the existing literature in light of the results collected from the commercial-urban fleet interviews and the TCO analysis. It will explore the drivers and barrier of EV fleet adoption, considering different stakeholders and behaviours, to identify the change required for a transition.

#### 6.1.1. Transition barriers

The interviews with three fleets highlighted a number of drivers and barriers for the integration of EVs and the extent to which technology lock-in is restricting the market. The dominant path dependencies of the automotive industry were considered and the challenge that they propose to fleet electrification. The section below discusses these in the context of commercial-urban operations.

##### 6.1.1.1. Behaviour change

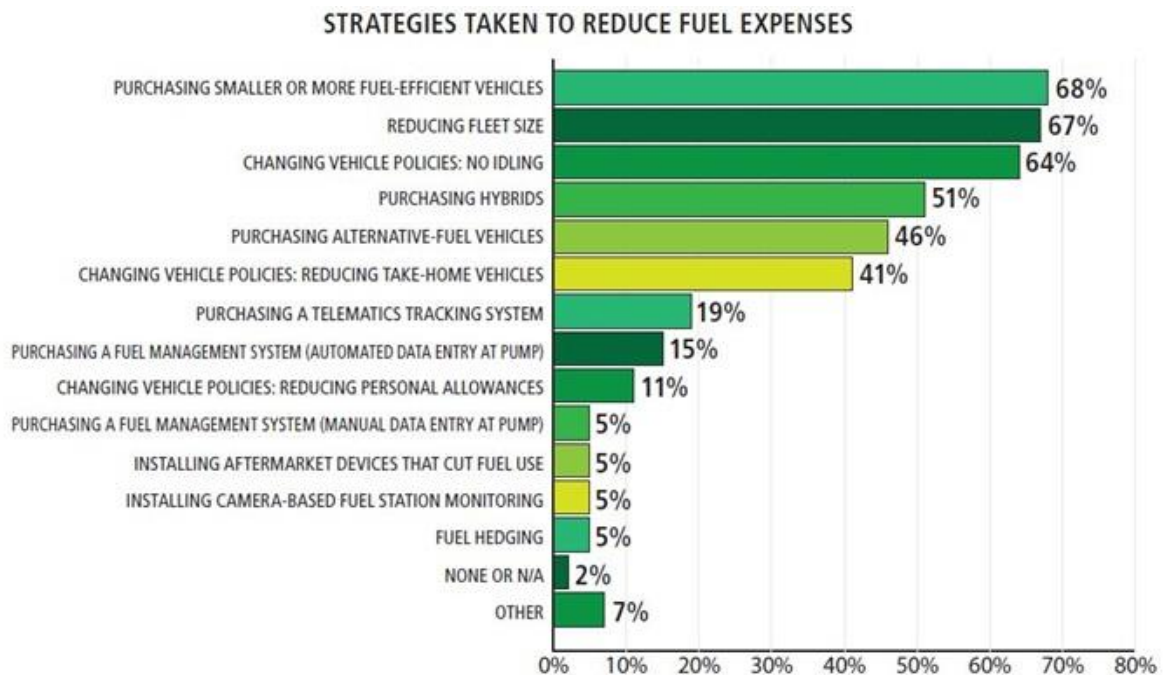
The three fleets involved in the study highlight the importance of managing a variety of driver behaviours regarding their interaction and decisions on vehicle choice. The cases suggest it is centred on preconceived notions of EVs which reinforces lock-in and limits adoption. In the case of TNT, the electric trucks were not optimised due to reliability. This experience could cause positive feedbacks which further embed behaviours and challenge the successful integration of (more reliable) EVs in the future. Schneider Electric's scenario is much more complex; employees are able to choose from a broad portfolio of vehicles for both company and personal mileage. This introduces a wide range of influential and emotive factors including status, company culture and personal requirement i.e. number of seats. Emotive dimensions are much harder for companies to address than purely transactional or functional behaviours, as these are embedded characteristics that have been established over an individual's lifetime and reaffirmed through manufacturers advertising and social pressures. GTC's challenge is functional as

drivers understand the benefits of EVs but there is a misalignment between operational requirements - 150 miles per day, and an EV's capable range on a single charge.

Market perceptions of EVs prove to be a barrier to behavioural change as the market is faced with scepticism of legacy and reliability. This is due to the limited range which has not been eradicated through the publicly accessible charging infrastructure. These path dependent challenges of a new market competing within a very established industry highlights the need for education on EVs to encourage behaviour change. Education is a key component to uptake of EVs within the civil society logic, there is evidence to suggest that drivers have a "very low knowledge base regarding the impacts of low carbon and fuel-efficient vehicles", and unless rectified are less likely to adopt EVs (Lane & Potter, 2007, p. 1088). However, it is questionable, who is responsible for educating society? Arguably greatest success would be achieved by a combined approach from stakeholders in the innovator, market and government logics, thus ensuring complete representation and non-conflicting messaging.

Figure 15 highlights the most common strategy to reduce fuel expenditure is replacing vehicles with more fuel efficient or smaller vehicles (Doa, 2012). This is aligned to existing behaviour of fleet managers and the most natural response to reduce costs. Therefore it can be inferred that fleets are procuring vehicles based on fuel expenditure, rather than taking in to consideration the TCO. Although this would suggest that EVs would be favourable due to the very low operational costs, only 46% of strategies fundamentally change the fleet to incorporate AFVs (Doa, 2012). This is arguably due to the lock-in of the ICE and the perceived difficulty of introducing new vehicle types.

Figure 15: Strategies taken by fleets to reduce fuel expenses



Source: Doa, 2012

A key barrier to behaviour change is that transport use is rooted within cultures, psychology, society and economics (Wells, 2010). This results in attitudinal segmentation whereby distinct market groups can be identified by their approach and reaction to EV innovations, as depicted in Figure 8 (pg.24) (CCC, 2013). Although research indicates there is a reasonable level of willingness to change transport behaviour in the UK, environmentally conscious attitudes are not necessarily reflected in purchasing decisions (DfT, 2011) (European Commission, 2008). A key aspect of electrification of transport is consumer acceptance as within many cultures vehicles are considered as status symbols. However, according to Griskevicius & Tybur (2009) AFVs are challenging traditional status allegiance with luxury vehicles despite the sacrifice of performance. Tesla are a prime example where advances in EV technology are closing the gap between luxury and performance. GTC is maximising this transition, using the bridging technology as a unique selling point within the very competitive, private hire sector.

This highlights the perceived value of using EVs as a PR tool. Schneider Electric has exploited the niche technology for these purposes, funded by the marketing budget to promote and stimulate business. Using EVs as a PR tool will only be effective whilst the technology is niche. However, it is proposed as

environmental concerns have increased within the public, clean technology within business transportation has become of greater importance to industry practitioners (Bae, et al., 2011). Literature suggests that since 2005 there has been an increasing integration of company fleets within CSR strategies as reducing greenhouse gas emissions assists a reputation that may align with sustainability strategies (Lease Plan, 2010). Hutchins et al (2013) and Figenbaum et al (2013) argue that the environmental benefits of EVs are perceived as the most important characteristic as the vehicles can contribute to carbon emission targets. Additionally, Deloitte Car Consulting state that EVs will soon become the dominant vehicle type within fleets, due to the associated positive impact EVs have on market perception and as differentiator to competitors (Leasedrive, 2011) (Hutchins, et al., 2013). In particular it is thought the public sector is motivated to procure EVs to lead by example regarding environmental issues (CCC, 2013). From the interviews conducted with TNT, the strategy to pre-empt legal requirements ahead of competitors is the foundation of their global targets to achieve zero emissions by 2020.

#### 6.1.1.2. Infrastructure

In the current market, charging infrastructure incentives have been formed to stimulate interest across a wide audience and to provide tangible evidence and confidence in the new market. Analysing the Office of Low Emission Vehicle's Electric Vehicle Infrastructure Strategy (2011), the Government suggest the growth of charging infrastructure is reliant on private investment. This places the responsibility on the market logic to dominate the action space despite significant investment from the government logic. However, it is recognised that this could be constrained through lack of finance especially in such stringent economic times and with marginal investment returns; the Electrification Coalition (2010, p.76) suggests smaller "fleet applications may find it difficult to realise a return on investment in a reasonable time period".

As commercial fleets, such as TNT, have predictable and planned journeys, it may be necessary to consider routes alongside a charging strategy. However, public infrastructure will not be guaranteed and within cities or town it is unlikely to be rapid charging. Furthermore, accessing public charging infrastructure would alter the TCO and could result in EVs having lower direct costs, but being less efficient due to increased downtime. This would likely be an unfeasible proposition for fleets to consider. Catherine Hutt, previously the Business Development Manager – Electric Vehicles at Society of Motor Manufacturers and Traders, argues that the majority of fleets perceive the installation of infrastructure as an obstacle to the transformation to electric transportation (Hutt, 2011). However, the initial assumption that the cost of infrastructure can be relatively low for fleets was correct. The approach can be targeted and the location, volume and energy requirement is known. Furthermore, fleets that utilise centralised

depots can benefit from optimised battery management, economies of scale of multiple chargers in individual facilities and the independence from public charging infrastructure.

Fleets such as TNT and GTC that operate on a 24 hour basis may require rapid chargers to gain from efficiency. However if the vehicle is parked overnight or for a significant length of time, more cost effective options are available that will satisfy the drive cycle. The Smith Electric vehicles that TNT have previously used possess on board charging, although this removes the issue of charging infrastructure to a degree (a connection is still required to be plugged into), it requires additional planning on the vehicle capacity and weight of the delivery. This alters business-as-usual and introduces constraints that will negatively impact efficiency.

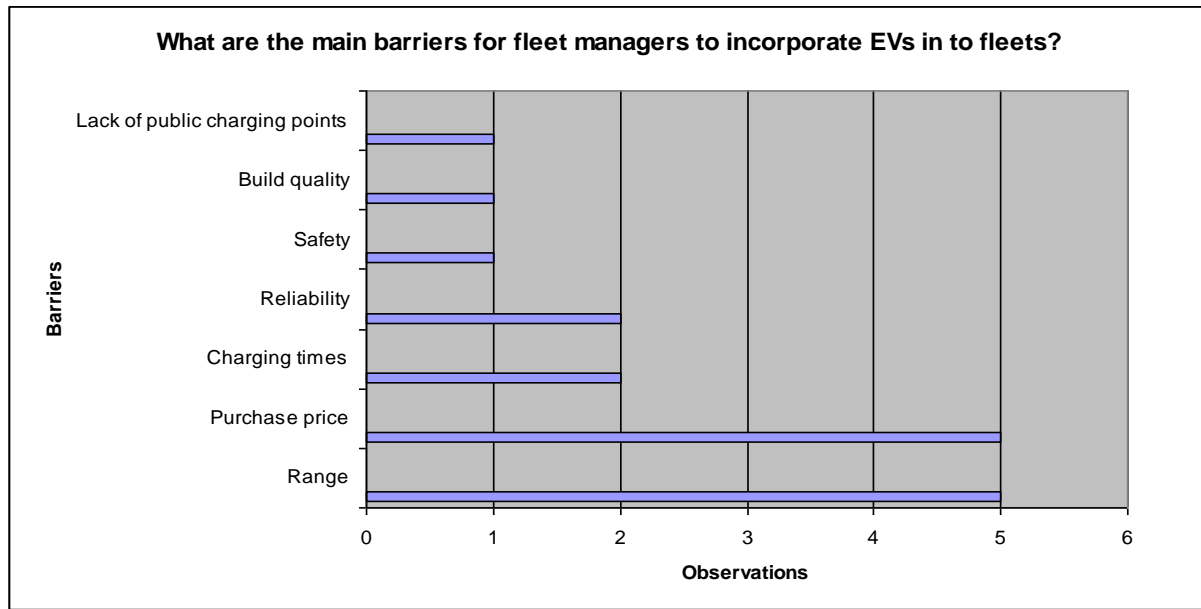
Charging infrastructure is a more difficult task for Schneider Electric, as a company car, charging will be required at employee's homes as well as membership to national charging schemes. Currently this would require additional planning to employee's journeys to ensure charging was available at nearby locations. However, this is only a relevant discussion whilst battery capacity is limited at the price at which they are currently attached to the vehicle.

#### 6.1.1.3. Range

A reinforcing path dependant characteristic that is limiting the PEV market is the reduced range to that of an ICE, resulting in range anxiety and technology lock-in. The technological barrier requires further stimulus on the action space from the innovator logic, as demonstrated by Tesla's 120kW 'supercharge'. Range is argued to be as important as the TCO when considering barriers to adoption due to the possible compromise on operational efficiencies (Anable, et al., 2014) (Hutchins, et al., 2013). This is despite the average trip length in the UK being 7 miles and 6,691 per year (DfT, 2013), yet drivers feel more confident having access to a combustion engine whether that is in conjunction with an electric motor i.e. a hybrid or as an ICE vehicle. As such range anxiety strengthens the relationship between society and the ICE as the vehicle type is considered more reliable and does not require charging management. As a consequence, society in the main remains using the 'safe' technology, despite EVs being "capable of adequately completing their required travel" (Neubauer & Wood, 2014, p. 12). Lock-in as a result of range is evident in all three case studies explored; despite GTC and TNT adapting operations to meet the 'limitations' of an EV, the technology was cost prohibitive due to extended downtime and reliability issues. Whereas Schneider Electric demonstrate behaviours of the regime whereby EVs are locked-out due to demand for extended range and a familiar refuelling network.

Range anxiety is particularly prominent in longer journeys; although these are relatively infrequent drivers expect flexibility and adaptability from their vehicles (CCC, 2013). The ‘option value’ of vehicles is applicable to both fleets and private individuals. Regarding fleets the extended downtime required to recharge an EV travelling an excess of (approximately) 100 miles will have economic implications on the business. Therefore if this poses a likely challenge for a fleet the downtime should be accounted for in the TCO analysis.

Figure 16: UK fleet managers’ barriers to EV implementation



Source: Cenex, 2010

In the UK, to date there are 9,333 publicly accessible charging points installed to 6,700 EVs, thus providing more than one charger per vehicle. The Government target currently sits at 1.5 chargers per EV, regardless of whether they are at homes, workplaces or leisure facilities. When this is compared to the 28.7 million cars licensed in the UK and the 8,000 petrol stations, it equates to one service station fuelling approximately 3,500 cars over a minimum of one fuel cycle.

Table 8 highlights that the current ratio of vehicles to chargers is highly disproportionate to that of ICE vehicles and petrol stations. Understandably the range of an ICE is on average three times greater than that of an EV; however it highlights the innovator logic prioritising infrastructure prior to actual requirement. This reduces range anxiety and assists in unlocking EVs within a positively reinforced market of ICEs and oil conglomerates. However, this approach could be questioned as the 8,000 petrol stations were gradually added to the UK road transport network as vehicle ownership increased.

Furthermore, the approach taken to publically accessible charging infrastructure lacks interoperability amongst charging operators. This has resulted in concentrated areas of EV adoption with restricted zones of travel. Alternatively EV drivers are required to have multiple memberships to charging networks that offer varying tariffs and kW rates of charging, all of which prevents adoption.

*Table 8: Refuelling analysis, 2015*

UK Refuelling network	<b>ICE</b>	<b>EV</b>
<b>Refuelling stations</b>	8,500	9,333
<b>No of vehicles</b>	28,700,000	6,700
<b>Average refuelling time/hours</b>	0.117	2.5
<b>Opening hours</b>	16	24
<b>No of refuelling points per station</b>	8	2
<b>Max No of vehicles refuelled per point per day</b>	137	10
<b>Max No of vehicles refuelled per station per day</b>	1097	19
<b>Max No of vehicles refuelled across all stations per day</b>	9,325,714	179,194
<b>Max refuelling capacity as a % of cars</b>	3249%	267453%

However, membership permitting, the vast number of charging points enables EV drivers to travel the country as ICEs would permit, with more regular refuelling intervals. In the cases of GTC and Schneider Electric, publically available charging would need to be considered by employees both during working and non-working hours. Whereas fleets, such as TNT, would return to a depot so that publically available charging is not as important as journey planning to ensure sufficient mileage for the return journey.

#### 6.1.1.4. Financial analysis

Research conducted in 2010 by the independent Corporate Vehicle Observatory and supported by fleet expert Arval, revealed less than 30% of large UK businesses questioned were planning to incorporate EVs in their fleets whilst 61% were considering hybrids (Maung, 2010). Nearly 60% of participating businesses thought that despite running costs of an EV being lower, the purchase price of the vehicle was too high (NGC, 2010). However, the TCO analysis conducted in Chapter 5 highlights that HEVs do in fact have a higher purchase price and are more expensive to operate over the lifetime of the vehicle. EV competitiveness is further enhanced for fleets operating in central London due to the congestion charge

exemption, which HEVs (and ICEs) do not qualify for. Furthermore, when alternative ownership models are introduced i.e. battery leasing, the TCO dramatically improves against all vehicle modes.

However, to overcome this transition barrier for EVs the Government introduced the Plug-In Car Grant in which electric car buyers are subsidised up to £5,000 (up to 25% of the vehicle cost). The funding has been extended from March 2012 to 2016 and now includes a Plug-In Van Grant, reducing the cost of eligible vans by 20% up to the value of £8,000 (Fleet News, 2012). This research highlights the significance of the Government subsidy for the EV market and the impact it has on the financial case.

This combined with the comparably low fuel and maintenance costs can counter act the high initial purchase price, thus demonstrating the need to investigate the life time costs (Indiana University, 2011). According to Northeast Group, an energy sector research and consulting firm, it is approximately 90% less costly to refuel an EV than an ICE vehicle (Loveday, 2011). Based on cost of fuel for the published range of a Nissan Leaf – 110 miles, an EV with a 24kW battery will cost £2.16 to re-charge compared to the petrol equivalent costing £17.16. The TCO analysis (in Section 5.1) demonstrates the financial benefits of low fuel costs, however the benefit is diminished when a fleet installs private charging infrastructure rather than relying on a public charging network. Incorporating the cost of infrastructure results in the PEV being the most expensive vehicle to operate on a pence per mile basis.

This however excludes the battery leased vehicle as the considerably lower purchase price is reflected throughout the lifetime and running costs. Renault introduced the concept of battery leasing to the UK market in 2014, where by the customer buys the vehicle but lease the battery at approximately £70 a month depending on expected mileage. Although this was contentious at first it is proven to provide lower TCO (as seen in Table 2 - 7), improve the residual value and remove the expense of battery replacement (Accenture, 2010) (Automotive Industry Digest, 2011).

Glass Guide (2011) published that the cost of a Nissan Leaf retains 35% of its value at a utilisation rate of 36,000 miles over three years, equating to 49p per mile. Whereas a vehicle of the same specification but with a leased battery i.e. Renault Zoe, retains 54% of the vehicle value at a cost of 33p per mile and a saving of approximately £6,000 (Glass Guide, 2011). Furthermore Glass Guide (2011) suggest that the overall depreciation costs over three years for the Nissan Leaf at £16,765, a E-REV at £16,570 and a PEV with a leased battery at £8,275. As demonstrated in the TCO analysis (in Chapter 5), leasing the battery results in low purchase price and consequently very competitive TCO. Leasing finance models compliment the majority of fleet operators as vehicles are procured through contract finance, therefore the battery can act as an ‘add on’ component. This eases the transition to EVs and alternative business models are conceptually easier.



A further challenge for fleets is the cost of the vehicle at the point of re-sale. The importance of residual values in fleet procurement is agreed upon within literature and from the case study examples, especially within the new market of EVs. Within the first decade of the 21<sup>st</sup> century the lack of market experience, particularly relating to the long term cycle performance of the battery hindered the EV market (Electrification Coalition, 2010). Due to these unknowns residuals values and TCO studies were largely speculations which created scepticism of the technology. Until 2015 many leasing companies were writing off EVs at the end of a three or four year contract due to the uncertainties of a second hand market (Crowe, 2014). However, as the market has developed with more EV models being manufactured and a higher proportion of market share, there is greater assurance in the second hand market. It is suggested that in many cases the residual value forecasts for EVs are now broadly similar to diesels or at least within a few percent (Nichols, 2015b). This is significant for the EV market and is likely to positively impact the uptake of EVs. Reportedly this is largely due to auto manufacturers “going out of their way to assure and protect early adopters, which is certainly one of the reasons plug-in cars are holding their values so well” (DeMorro, 2015, p. 1). Assurances such as extended warranties would not be necessary when the market is more established and the technology is deeper entrenched within the existing system.

#### 6.1.1.5. Total cost of ownership

The interviews affirmed the importance of TCO analysis for fleets and the significance placed on efficiency and competitiveness. This is the first major obstacle for EVs to overcome before charging infrastructure or behaviour is needed to be considered. The TCO conducted in Chapter 5 indicated the costs associated with four different vehicles over a period of three years in various finance models. Within the studies the PEV with a leased battery was identified as the most cost effective model of ownership across all scenarios. This suggests a shift to leasing and more service based model is paramount to the success of EVs. This is particular important whilst ICE vehicles, such as the Ford Focus remain so competitive in regards to purchase price and residual values.

However, the viability of an EV in terms of cost parity is currently speculated as the TCO model employed for vehicle cost analysis is questioned. The variables within a TCO can be easily influenced and can dramatically alter the result; this is particularly the case for fleet usage as the drive cycle of the vehicle is conditional upon the operation and environment. Furthermore the TCO of a vehicle is very difficult to calculate due a number of unknowns and possible fluctuations such as; fuel price and residual values (OLEV, 2015). Anable et al (2014) and Hutchins et al (2013) propose that this is due to a lack of financial training amongst fleet managers and limited decision-making models and support tools.

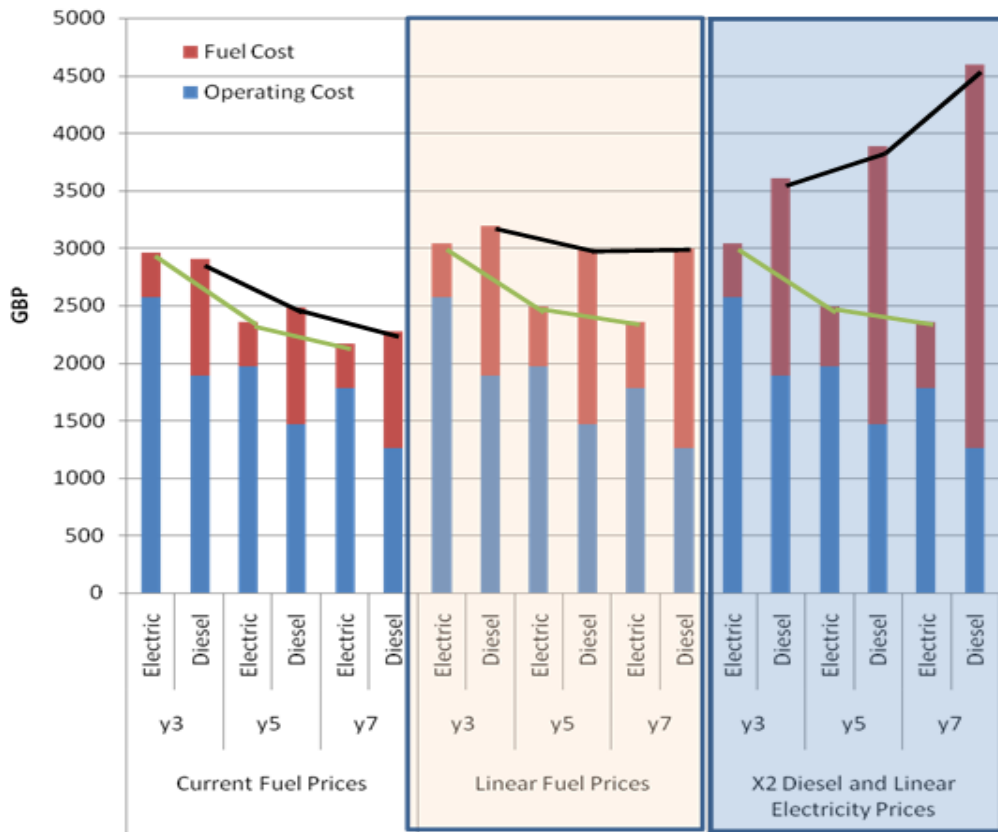
Cenex, a not-for-profit consultancy (supported by the Department for Business, Innovation and Skills) which promotes UK market development and competitiveness in low-carbon transport industry, conducted a study in to the total operating costs (TOC) of a Smart 4-2 coupe Diesel 40kw engine (0.8l) and a Smart ED 4-2 coupe 30kw electric motor; based on the following assumptions:

- Diesel fuel price is based on AA May 2011 fuel price report and is fixed in this analysis
- Electricity costs are a variable in this analysis based on the type of tariff
- Carbon intensity of electricity WTT is based on Defra 2010 average of 617.07gCO<sub>2</sub>/kWh
- The carbon intensity of diesel is taken from the Defra 2010 report
- Diesel vehicle purchase costs include £8,625 for diesel Smart with depreciation to £3,875 over 3 years
- Electric vehicle purchase costs include £20,000 (based on insurance value of new Smart ED) with 40% depreciation over 3 years
- Majority of fleets do not insure their vehicles and will cover the cost of accidents
- Depreciation is taken from Fleet News based on diesel Smart (45% of original value)

Figure 17 highlights the operating costs of possible outcomes within certain scenarios. This is based upon the ‘Assessment and Reliability of Transport Emission Models and Inventory Systems’ Urban drive cycle, consisting of 100% town driving with max speed of 58kph and an average speed of 18kph (Cenex, 2011a). TOC is largely dependent on the price of fuel. If the impact of geo-political changes continues to affect oil prices, the cost parity of an EV is likely to be reached within the near term. The graph highlights that if current diesel and electricity prices prevail to 2018, running an EV will cost more than the Smart Diesel in year 3. However it is apparent that with either linear or non-linear growth in diesel and electricity prices to 2018 it may become cheaper to run an EV in year 3 compared to the efficient Smart Diesel.

Figure 17: Smart analysis of an electric and diesel vehicle

Smart Analysis: 12000 miles



Source: Cenex, 2011

This would suggest that within these scenarios, EVs are currently not a ‘rational’ business decision unless early adopters of the market continue to exploit the extended value of PR and kudos. This can be supported by the TCO analysis (in Section 5.1) that highlights under conventional ownership models (not battery leasing) EVs cannot currently compete with an efficient ICE.

As the market is led by early adopters and levels of production are still low, a premium is paid for the vehicles. However, it is proposed that if intangible benefits or additional value could be included within the TCO analysis it would be possible for EVs to be economically more competitive in a shorter time frame. Alternatively as EVs are a niche technology it is possible the procurement cost can be justified through the marketing/CSR budget. Therefore currently the purchase price may not be a major obstacle

due to the intangible benefits. This was demonstrated in the fleet case studies where both TNT and GTC procured EVs for strategic reasons.

It is questionable whether the relationship between CSR and the media could actually limit the growth of the EV market within fleets. Research highlights the case of Tesco whose UK fleet comprises of over 2000 vehicles, 15 of which were the first Pure-EV delivery vans bought from Modec (CBI, 2011). The transition of 0.75% of Tesco's fleet to EVs attained significant media attention despite 15 EVs having little impact on the broader EV market or total carbon emissions of the company or country. This highlights the necessity to consider the cost benefit analysis of added value through intangible benefits, against the TCO of the vehicles. This was arguably demonstrated in the interview with TNT, as the unreliability of the vehicles and subsequent costs to the business outweighed the PR value associated to sustainability; thus resulting in the vehicles being returned to the manufacturer.

Norway is a prime example where additional benefits of driving an EV can significantly increase the uptake and assist in removing the lock-in of ICEs. In Norway EV drivers have access to bus lanes, free toll roads, free charging, free access to ferries, free parking, no purchase tax and low annual road fee. The policies have resulted in Norway leading the world's EV market, with 18.4% of all new cars registered in the first quarter of 2015 being PEV and 4.5% PHEV (McCarthy, 2015) (Ayre, 2015). Due to the success of Norway's EV tax policies and the level of uptake it has resulted in a tax shortfall of \$267.79 million, whilst actually only achieving a 2.4% transition to EVs of the 2.6 million vehicle fleet of Norway (Ayre, 2015). This research will consider if the UK should adopt a similar approach to motivation crowding to achieve greater EV uptake. The TCO highlighted the current incentives available to UK EV owners improve the financial competitiveness of the vehicles but do not result in a monetary saving. Therefore arguably the Government need to increase the additional benefits to achieve a transition to EVs.

#### 6.1.1.6. Financial incentives

There are various financial opportunities subsidised by the Government that should be highlighted to fleets considering EVs as they can further enhance the economic case of EVs, these include:

- The opportunity for a business to offset their emissions or be able to trade their carbon credits. This will either mean that the business will decrease the value of a payment charge it is given for exceeding its carbon allowance or it will gain a revenue stream determined by the market value of the CO<sub>2</sub> at the point of sale
- Company Car Tax for zero emission vehicles is set at 7% of the list price for 2016-17. Until 2017-18 there will be a differential of four percentage points between the 0-50 and 51-75g/km

CO<sub>2</sub> bands and between the 51-75 and 76-94g/km bands. Thereafter and until 2019-20 this differential will reduce to three percentage points

- Electric cars and vans are exempt from Vehicle Excise Duty. Owners of electric vehicles will therefore save around £130 per year compared to an average conventional petrol or diesel car (VED Band F)
- In 2016-17 and 2017-18, the van benefit charge for zero emission vans will be 20% of the main rate. This will then increase on a tapered basis, reaching parity with the main rate in April 2022
- Businesses are able to claim 100% Enhanced Capital Allowance on electric vehicles in the first year following the purchase. This allows businesses to write off the cost of certain assets against its taxable profits
- Within London, EVs are exempt from the congestion charge, a saving of up to £2,898 a year for fleet vehicles
- The Plugged-in Places locations (London, Milton Keynes, Manchester, Newcastle, East of England, Midlands, Northern Ireland, Scotland) have free/reduced priced parking for EVs. This however is not standardised within the country and can require individual (free) permits to be obtained
- Furthermore the Plugged-in Places have charging facilities attractively priced i.e. In London, £5 is charged for one year of unlimited charging. As a charging option this is unlikely to suffice for fleets but can be used for ‘opportunity’ charging

Additionally fleets should consider the financial opportunity of allowing public access to charging infrastructure installed on the premises of the business. If strategically located both fleet and public vehicles can utilise the chargers throughout the day/night. Businesses could make considerable margins on selling the service, for instance the use of a fast charger for up to 30 minutes could be charged at £10, whilst only costing the business £2.00, providing an 80% profit. Consequently the cost of infrastructure becomes more attractive. Alternatively, it could contribute to a business’s ‘corporate social responsibility’, providing free charging to the public will positively reflect the brand.

#### 6.1.2. Case study analyses

Diverse approaches are required to stimulate the sustained transition to EVs in conjunction with an understanding of the dynamic implications and reinforced feedbacks (Struben & Sterman, 2008). It is reasoned that in order to ensure transformative change, as a basic premise, new vehicle technologies must be economically attractive for market acceptance (Kley, et al., 2011). The Schneider Electric case study suggested this were one of the reasons EVs had not been adopted by employees; the employee’s monthly

contributions would be higher for an EV compared to an ICE as well as the cost of installing charging infrastructure. However, due to senior management sponsorship experienced by TNT and GTC, the transition to EVs was less sensitive on costs but much more focused on technological innovations regarding vehicle range and reliability. These factors are out of the company's realm of control and thus limit the role of the 'innovator logic', relying entirely on market forces to enhance the value proposition of EVs. The low cost benefit of the vehicles may be enticing to small fleets based within cities that can optimise 'sweet spots' of particular drive cycles but this will not enable the niche technology to gain the necessary momentum to unlock EVs and destabilise the regime.

Companies utilising EVs are challenging business and social practices and changing behaviour at work. Considering these dynamics at the multi-level perspective, a company appears to build momentum through niche-innovations, whilst employee behaviour destabilises the regime to make the niche-innovation possible, and social practices create pressure on the existing regime. GTC and TNT are examples of those companies adopting niche-innovations that are trying to justify the business case, building internal momentum through learning processes, support and price and performance improvements. Whereas Schneider Electric represents the existing regime that operate based on a set of rules dictated by landscape pressures. This is arguably due to a number of characteristics aligned to a large organisation such as; entrenched employee expectations, the transition not being led from the 'right' individual/team or the complexity of the unfamiliar (Anable, et al., 2014). Consequently this results in the lock-in of existing practices and technology within the company car fleet.

It is argued that "avoiding undesired lock-ins and creating a beneficial institutional context for sustainable mobility cannot be pursued at the transition path level" (Farla, et al., 2010, p. 1260). Hence a systemic approach should be applied to assess the interdependencies between transition paths, consequently sustainable mobility can be considered in its entirety (Farla et al, 2010). However, as Mazur et al (2015) highlight, there is greater complexity than a systems perspective, innovation theory requires a socio-technical system approach to investigate the impact of transitioning. This is due to the multi-faceted and multi-dimensional nature of a system innovation, hence the limitations of using the multi-level perspective to consider all contributing factors.

The case study evidence suggests that in order to instigate a considerable shift in behaviour and company strategies, the policy field of sustainable innovation and technology should focus on social and environmental benefits (Norberg-Bohn, 1999) (Kemp, 2010). This would reposition the pressure of fleets adopting EVs, moving away from a purely economic analysis to incorporate the added value of air quality, noise pollution and driver safety. Such considerations were accounted for by GTC and TNT

whose prime operations use vehicles at their core business, whereas these factors were not concerns of Schneider Electric's company car fleet that acts as a tool for convenience and employee benefit. It could be argued a new socio-economic approach is required within the existing regime to establish low carbon priorities within all fleets. This could be implemented through introducing a tax for carbon emitting cars, rather than the currently incentivising low emitting vehicles.

The current government logic employing a financial incentives approach appears to have had little influence on the three fleet case studies. Since both GTC and Schneider Electric lease their vehicles, they have been unable to take direct advantage of the Plug-in Car Grant; similarly TNT will not be compliant with the funding due to the size of the vehicles. However it should be possible for fleet managers to see the financial incentives flow through to the decision matrix, and within a company car scenario pass that incentive on to the employees. Furthermore until 2014 all three fleets would have been able to utilise funding for EV charging, this was a significant factor contributing to GTC's business case for EVs. However, in 2014 the 'Chargepoint Scheme' led by OLEV no longer permitted businesses to apply for subsidised charging infrastructure, this had knock-on effects to the TCO of EVs for businesses considering the procurement of EVs.

The scenario faced by EVs today requires challenging the technological lock-in of ICEs, competing on efficiency and specification and removing the associated range-anxiety with current electric drive trains. Both the perceived lack of charging infrastructure and the restricted range of EVs are argued to be key challenges for the adoption of EVs by all three fleets, in particular GTC and TNT.

It is desirable that fleet vehicles will return to a depot as highlighted in the TNT case study. In this instance publically available charging is not as important as journey planning to ensure sufficient mileage for the return journey. However, in the cases of GTC and Schneider Electric, publically available charging would need to be considered both during working and non-working hours. This would need to be supported through the 'civil society logic' as adapting behaviour and driving culture requires a long term strategy at the community/employee level.

As demonstrated by GTC and TNT it is thought hybrid vehicles have a "transitional role...in the sequence of technology adoption" as the vehicles operate within the locked-in range of possibilities (Collantes, 2007, p. 270). The introduction of the HEV Toyota Prius in 1997 increased versatility and flexibility within the market through unlocking the historical market of restricted designs and specifications (Ahman & Nilsson, 2007). This highlights how innovation challenges traditional status allegiance with luxury vehicles despite the preconceived sacrifice of performance (Griskevicius & Tybur, 2009). Despite a slow rate of Prius sales in the early years, the Prius is now the most successful 'green' car in history,

accounting for over half of HEV sales (5 million) in 2012 (Shirouzu, et al., 2013). In 2014 there were over twenty hybrid car models in the market, highlighting the result of manufacturers' innovation and desire to provide the market with their responses to perceived market need as well as the growth in acceptance with drivers both in the commercial and private sectors. The hybrid market could be paralleled to the EV market and used to manage expectations of the rate of vehicle mode acceptance. The EV market remains niche since the launch of 'new generation' EVs in 2011. Considering the rate of diffusion of HEV technology, it is optimistic to consider that EVs could achieve significant market share within a shorter time frame, especially when considering the extension of transition barriers associated to PEVs.

#### 6.1.2.1. Conclusions on case studies

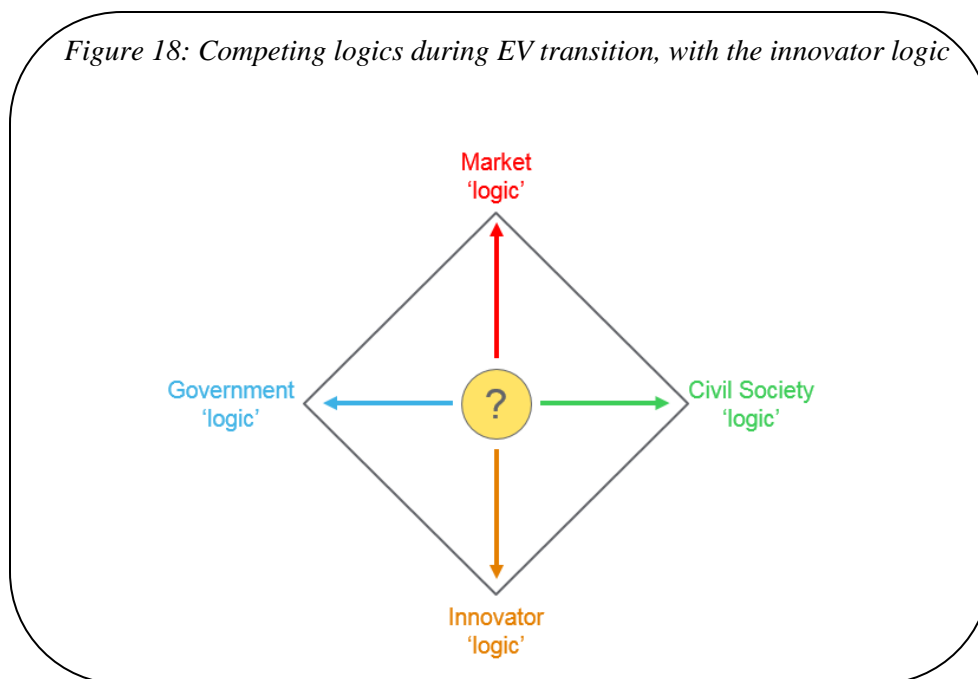
The case studies demonstrate the dynamic relationship between the four logics and the importance of these actors competing upon the action space. However it questions the current role of the government logic as fleets have limited access to EV incentives and grants, this suggests regulative change is necessary to optimise the opportunity of fleet electrification. Today, those fleets that are transitioning to EVs are acting within the innovator logic and are challenging path dependencies and lock-in of ICEs. However the case studies suggest that within commercial-urban environments there are limited scenarios whereby EVs are suitable hence the reliance of the innovator logic.

#### 6.1.3. Innovator logic

The EV market is currently following the transformation path and technological substitution by which the existing regime is being modified and innovative activities are responding to moderate landscape pressures; thus developed niche-innovations are entering the system (Marletto, 2014) (Geels & Schot, 2007). This supports the consideration for the innovator logic (as represented in Figure 18), defined here as the technology innovation led pathway in which niche actors respond rapidly to market needs; in this instance in the EV and EV charging infrastructure markets. The innovator logic will assist in unlocking EVs, destabilising the fleet market across many domains – technological, social, economic, and thus requiring a framework to capture all the transitioning dimensions (Mazur, et al., 2015).



*Figure 18: Competing logics during EV transition, with the innovator logic*



Adapting the competing logic theory from the energy sector to the EV market highlights that the transition of EVs is focused on innovation and technology. Examining the case studies it is evident the three existing logics are insufficient in fully explaining the process of EV utilisation within fleets. Regarding GTC the unsuitability of EVs for a taxi fleet has resulted in the continued use of hybrids, primarily due to the limited range. This indicates the need for further technological innovation of both batteries and charging infrastructure, which cannot be directly stimulated by government, market or civil society logics. An example of an innovator actor addressing this is by the niche manufacturer, Tesla and the 120kW ‘supercharge’. Tesla has demonstrated niche technologies can redefine market barriers even within an established regime. Innovator actors are able to respond to market demands and offer alternatives to mainstream manufacturers who possess high sunk technology costs. However, for the innovator logic to gain momentum and drive the ‘action space’ it relies heavily on the support from the government logic in terms of incentives and grants, therefore the two are mutually reinforcing upon market developments.

In the case of Schneider Electric, the company car fleet will continue to rely on the government logic, reactively rather than proactively. Despite this, there is significant opportunity for the company car fleet to progress along the innovator logic, incentivising employees to adopt the technology where a ‘fit’ exists. Thirdly, TNT’s approach to electrifying 7.5 tonne trucks is an ambitious feat that will require significant advances in technology regarding both the vehicles and the charging, in order to improve reliability and

therefore return on investment. It is likely that the decarbonisation of trucks will be led by the government logic due to EU legislation, and satisfied by manufacturers in the market logic.

From the interviews conducted it was evident that TNT and GTC were examples of 'innovators' of the niche technology trying to adopt operations to suit the available vehicles to their environment and operations. Whereas Schneider Electric demonstrates behaviours and attitudes of the existing regime where by EVs are perceived as undesirable and constrained by range.

Considering these factors, it suggests that the transition from 'conventional' vehicles types to EVs will not merely be "a technological process, but a more general process of technology transfer, in which each technical step requires action or has organisational, economic, social, and cultural implications" (European Commission, 2011, p. 16). This reflects Foxon's theory of 'competing logics' but again infers the requirement of a fourth innovator logic, with more explicit representation accredited to technology innovations. This logic is dominating the action space, unlocking EVs within the fleet market and further destabilising the existing regime.

#### 6.1.4. Conclusions on fleets

It has been established that the automotive industry is fundamentally built upon path dependant characteristics and has embedded and strong preconceived notions of vehicle design and specification suited to customers' expectations. Thus technology lock-in is limiting the available market to EVs resulting in niche applications that can benefit from the available grants and incentives. These applications have to identify specific operations in which the TCO is competitive and the charging infrastructure can manage demand.

The government logic has been a key catalyst in beginning to unlock ICE vehicle dominance within the market through the use of incentives and regulations relating to emissions. There are a number of financial incentives surrounding taxation that are particularly attractive for businesses which have begun to increase competition within the market logic. Such measures put pressure on the existing regime providing an incentive for adoption, thus resulting in the transformation path developing to technological substitution (Mazur, et al., 2015) (Geels & Schot, 2007).

However, the financial opportunities and TCO of an EV still do not offer significant gains to outweigh the transition barriers of range, reliability and market scepticism. Consequently the action space is dominated by the innovator logic that is reliant upon the extrinsic value of EVs alongside a willingness to adapt behaviours and operations in order to gain momentum. Moreover, it is questionable how long the

Government will continue to incentivise EVs and absorb the cost of transiting the countries fleet of vehicles whilst the TCO lacks competitiveness.

## 6.2. Car clubs

This section will discuss the car club market, the drivers and barriers of transitioning to both EVs and a use-oriented service model of car use, rather than ownership. The extent to which these challenges can be overcome by policy will be considered and consequently policy recommendations will be discussed. This will be based on evidence collected and reported in Chapter 5 and the literature discussed in Chapter 3.

### 6.2.1. Opportunity

The opportunity for the car club market to grow is substantial, and therefore so is the opportunity for EVs to operate within car clubs. The interviews conducted indicated the potential for growth of market share within the transport sector. DriveNow obtaining 12% of the London market in six months demonstrates that car club market, particularly in London, is not being fully exploited (DriveNow, 2015c). In cities, the focus on reducing congestion, air pollution and emissions provides a plausible case for car transport to shift to use-oriented services. Furthermore, the use of EVs within car clubs is a niche opportunity to maximise on efficiencies and improve liveable conditions.

Car clubs could benefit the UK through (Fergusson, 2014):

- Reduced number of cars on the road, each car club car replaces at least 14 private cars
- Reduce the volume of traffic and drive fewer miles, for example, users drive seven times fewer short trips (less than five miles) than car owners
- Reduce fleet assets and overheads
- Reduce congestion at peak times, usually only drive outside peak hours
- Reduce demand for parking
- Increase use public transport more, within London users are about twice as likely to use the tube, a train or bike as the average person
- Operate vehicles that tend to have a better environmental performance on a mile for mile basis than the average car on the road, because they are newer and more fuel-efficient
- EVs can offer additional benefits including the reduction in air and noise pollution

These benefits can help reduce significant pressures on existing infrastructure in areas where population and demand for transport and space is increasing. Congestion costs London alone over £4 billion

annually, which is expected to increase by 14% by 2030 (Fergusson, 2014). It is not always possible for networks to reduce travel times or improve capacity but the reliability and resiliency of a city's transportation network should be maintained. This should even be in the case of transportation demand growth and reduced level of resource expenditures for construction of new infrastructure. This can be achieved by adding complementary services to the existing network. Clearly, efficient transportation systems are essential to the economic vitality of any community and congested roads and transit services frustrate these capabilities. In most cities, road corridors and public transport struggle to manage the peak demand, historically peak hours were limited to the working week, however as a result of urbanisation congestion has extended to the weekends. Even within peak demand there is little integration across the systems, however apps such as Google Maps and Citymapper have provided greater transparency and choice of routes and transport modes for travellers.

The developing demands on service, user transparency and fluency across modes suggest that car clubs could be used to complement public transport and create "a door-to-door alternative to private car ownership and use" (Carplus, 2015c, pers. comms). With the use of location aided services and the flexible business models which have been introduced, as well as no necessity to pre book, car clubs will begin to compete with taxi providers. This would require car clubs to be an all inclusive offering, strategically located i.e. railway stations, to encourage use as a 'bridging' transport to other forms of transport or destinations, to redistribute the volume of passengers (Leveque & Moosa, 2013). Autolib' is a good example of this on a large scale and further demonstrates how EVs enhance this opportunity. The low cost of running and maintenance, along with zero emissions in the use phase result in benefits to the city of operation and the inhabitants.

The interviews conducted highlighted opportunity for car clubs in mixed used, high density locations, benefits both businesses and the community. These locations are likely to be in cities or town developments. For businesses it could enable a reduction in company cars, grey fleet and/or operationally vehicles, this however is dependent on the business model employed and the flexibility of vehicle type. For communities it can help to alleviate transport poverty for those who cannot afford to own a vehicle, or where there is distinct lack of public transport in the area or at specific times. Both scenarios require a transition of ownership structure which challenges the British culture of possessing material goods as a status symbol. Although, the stakeholders interviewed suggested this is diminishing in younger generations, whilst the barrier for businesses is the lock-in of governance within existing processes and company ethos (DriveNow, 2015c) (Carplus, 2015c).

### 6.2.2. Transition barriers

There are a number of transition barriers to e-car clubs, combining an alternative business model along with an alternative technology challenges a plethora of embedded path dependencies that is stifling progress.

#### 6.2.2.1. E-Mobility services

The fundamental concept of e-car clubs challenges two intrinsic cultures of UK drivers. Firstly, the transition to EVs requires a degree of trust in the technology (Carplus, 2015c) (GTC, 2013a). The technology lock-in within a car club environment is much lower as the purchase price, infrastructure, residual value and to an extent the operating costs are not considered by the end user. It is purely that the vehicle will function to the same standard as an ICE for a particular journey. The demographics of car clubs users are explained to be young males with an affinity to technology, therefore it is unlikely that scepticism of the technology will be a challenge; however for other users less aligned to alternative technologies this may pose a concern.

The short distances travelled by car club users within cities are on average under 6 miles, extending to 34.9 miles per trip in the UK. This allows EVs to operate within the range of a single charge for a minimum of three customers. As previously discussed, range anxiety exists for EVs in all application due to the path dependant characteristics that have been formed from single journeys of 300+ miles. This has been reinforced by service stations and fuel providers located throughout the UK. This offers flexibility and freedom which has led to the lock-in of ICE technology and the perceived restrictions of EVs. Consequently, it is very important that car club operators manage the charging of EVs as whilst it is a niche offering, car clubs cannot afford to have EVs underutilised due to technical challenges, nor rely on customers to re-charge the vehicles. As DriveNow operate a flexible model it is fundamental that they carefully manage the charging and redistribution of vehicles, this has costs of resource and time that need to be accounted for in the TCO. Without the management of EVs the vehicles are less capable of generating return on investment. This highlights a significant challenge for the transition to EVs for car clubs, particularly those based on a flexible model, as it involves a greater degree of interaction with the vehicles and users of EVs. Both of which involve resource and alternative business models to encourage users, via payment incentives, to charge and locate vehicles in prime locations. Car clubs operating an A-A model such as E-Car Club, do not require the same degree of investment in the management of charging as the vehicle is returned to the designated parking bay with an assigned charging point. Therefore the car club will be required to ensure the charging infrastructure is functioning and the vehicle is charging when parked, performed from a back office IT tool.

From the empirical research it is evident that the second transition barrier to e-mobility services is the concept of no longer owning a vehicle, but relying on a service provider to supply the product i.e. the car, and payment being equated to time and vehicle type. This business model extends beyond that of car rental as membership allows for frequent use with tariffs to suit behaviour and location aided services with multiple pick and drop off locations. This offering mirrors that of a mobile phone contract which has been widely accepted cross generationally by the majority of youths. However due to the significance of the car within society and the psychological synergies that are binding the technology to peoples' asset portfolios, it is debatable whether the car club market could escape the lock-in of ownership and ever be considered as a mass market service.

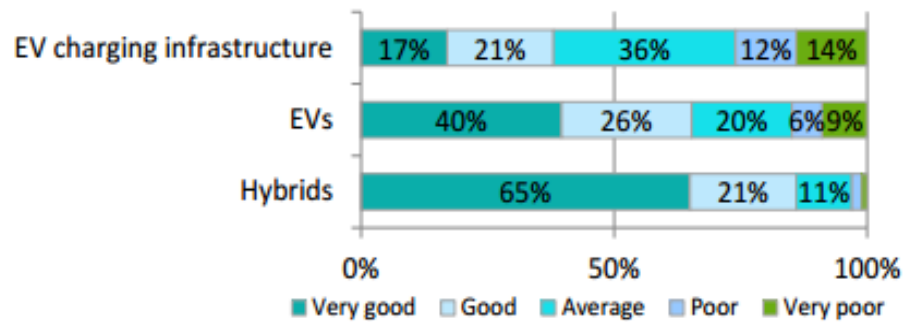
For the concept to be adopted successfully there needs to be a degree of 'higher-order' learning amongst stakeholders; essentially policy makers, transport operators (i.e. public transport bodies) and users (Ehrenfeld, 2001) (Akyelken, et al., 2015). TfL have established a lack of awareness is a fundamental reason car clubs are not considered during the process of vehicle procurement (TfL, 2014c). For critical mass to be achieved and the market to be viable, stakeholders need to assess the opportunities and impact of e-mobility and the complimentary service it can provide to cities and transport networks. This will only be realised when there are significant changes in institutional practices that can support the alternative producer-user interaction (Ehrenfeld, 2001). Support could be provided through behavioural campaigns or financial incentives which have been proven to encourage both consumers and companies to adopt use-oriented services (Mont, 2002). These methods of 'motivation crowding' will be discussed in Section 6.6.

#### 6.2.2.2. Charging infrastructure

For EVs to be successfully deployed in car clubs it is evident that there needs to be a reliable network of charging infrastructure. Without this there is a limit to the extent e-car clubs can operate and expand their customer base without damaging brand and reputation. If this were to be the case, as it currently is within the UK, and the charging infrastructure cannot reliably charge the number of EVs in use the knock-on effects will further lock-out the EV and car club market. The Carplus Annual Survey was completed by over 2,600 round-trip car club users in London, including individual members, corporate members and corporate administrators (Carplus, 2015b). The results revealed 66% of users had travelled by EV, with 62% of those users recording their experience with EV charging infrastructure as average, poor, or very poor (Carplus, 2015b). This is clearly very damaging to the sector and suggests a shift in management responsibility is required from the existing government led schemes to a more commercial application whereby service and maintenance can become a viable business model.

Figure 19: Car club member's experience of using alternative vehicles

### Experience of using an electric or hybrid vehicle



Source: Carplus, 2015

As a new market using niche technologies, it is largely expected that there will be initial challenges across the system. Early adopters of technology are prepared for technological challenges and the inconsistencies that are associated to market infancy (Arthur, 1989). However for e-car clubs to become mass market there needs to be a substantial policy shift to co-ordinate the sale of EVs, installation of charging infrastructure and development planning.

Furthermore, e-car clubs are mainly dependent on existing infrastructure from previous Government funded projects i.e. Plugged-in Places. Largely up until 2015 the infrastructure across the country has been unreliable, and in many cases the technical capabilities have not corresponded to the strategic intent or the location's 'opportunity' potential. This has meant the 'reality' of charging and stakeholder expectations are misaligned, further strengthening the existing path dependencies.

However as the market logic has strengthened with greater investment from auto manufacturers, there is enhanced market confidence and awareness of charging requirements and civil society demands. Consequently a combination of private investment and government funding is beginning to improve the charging network. However for e-car clubs to ensure charging infrastructure is strategically located and available to members, should they be required to have specific and designated chargers that they manage and maintain? Despite the potential to improve the user experience and the reliability of service, it could limit the areas of operation of car clubs even further. As it stands the public charging network can be accessed by anybody registered to use the operating system. This broadens the value proposition for both

car club users and operators, despite requiring users to register for multiple memberships due to the lack of interoperability.

### 6.2.3. London

London is a global city with sustained population growth and severe demands on the existing transport system (TfL, 2015a). The Greater London Authority estimate that by 2031 the population in London will rise over 10 million, the existing transport system is already at maximum capacity in peak hours (TfL, 2015). Therefore car clubs are essential to London's urban mobility solution to ensure there are alternatives to public transport and private car ownership. London is the largest market in Europe for round trip car clubs, with over 155,000 members, demonstrating that a modal shift to use-orientated services has begun. Transport for London supports the car club accreditation programme, with ambitions of 1 million car club members by 2025 (at which point the population is estimated to be 10 million) (TfL, 2015a). Popularity of flexible business models is increasing and further developing the sector and availability to a broader range of users.

However, the interviews conducted and industry discussions suggest there are significant challenges within London for such targets to be achieved. Firstly, London transport is not managed by a single overarching governing body; it is led by Transport for London and the 33 London boroughs (including the City of London). The boroughs are encouraged by TfL to address "car use behaviour through the development of car clubs, installation of electric vehicle spaces and alterations to parking restrictions" within the Local Implementation Plan (TfL, 2014b, p. 16). Consequently regulations for parking, infrastructure and the provisions for car clubs are varied between boroughs due to the socio-economic profiles of each area (DriveNow, 2015c, pers. comms). This makes it particularly challenging for operators to operate across boroughs and maximise business potential (Carplus, 2015c, pers. comms). Car2Go exit from the market is a prime example of the influence the divided boroughs has upon the viability of car clubs. Without gaining permission from each borough the business model is limited to a zonal model; this further strengthens the lock-in of car ownership due to the inflexibility point-to-point travel infers.

Obtaining parking bays for car clubs, and then the installation of charging infrastructure on street, is the fundamental challenge for car club operators in London (DriveNow, 2015c, pers. comms) (Akyelken, et al., 2015). The Director of DriveNow (2015c, pers. comms) explained that for approval from the borough it involves multiple stakeholders i.e. transport planners, parking managers, residents and business, to be consulted throughout the application process. It is then necessary to determine the ownership of charging infrastructure and the continued maintenance of that infrastructure, both of which would have financial



implications. However, it is possible the charging could become a revenue stream for the borough through either the 'location rental' or the service/act of charging. This is an aspect of e-car clubs that has yet to be exploited, but is arguably a likely business model of the future.

Empirical research indicates that from the perspective of an e-car club user, the ideal scenario would be to have a number of operators throughout the city, whose vehicles could function across boroughs with interoperable back office systems to enable users' flexible access. This would be possible to instrument if there was one governing body, as there is in Paris that consequently has the largest single operating car club – Autolib'. However it is apparent that within London the government logic is competing heavily upon the action space from a historical stand point of traditional ownership models and ICE lock-in. This requires a greater drive from the innovator logic to establish technology innovations that can further ease the transition to e-mobility and create demand and momentum within the civil society logic.

#### 6.2.4. Policy recommendations

There are national policies within the UK such as vehicle taxation and EV incentives that influence certain vehicles to be purchased. However, there are currently limited policies and a lack of legislation within the UK that instruct national or local government to support car clubs or the provision of car clubs. This is despite the global awareness that car clubs are instrumental to the integrated urban mobility network. Policy measures are needed to increase social and political acceptability to facilitate implementation of sharing in the mobility sector. Policy needs to avoid contradictory and negative effects in order to decouple the institutional barriers that prevent market growth. Below are a number of policy recommendations to support the transition to use-oriented services within the automotive industry.

Firstly it is essential that there is continued fiscal support for consumers to purchase both EVs and charging infrastructure. However, charging infrastructure grants for businesses and public sector estates needs to be reintroduced, since being removed from OLEV eligibility in 2014, to allow for the market to develop further and in broader application than purely the residential market. As implemented in the London Plan (2015) the requirement to have parking bays and charging infrastructure for EVs amounting to 10% of parking spaces in new retail developments and 20% of parking bays in new residential and employment developments, with equal percentages for the provision of future requirements. A similar requirement should be implemented for e-car clubs at a national level within urban developments and city expansions. This would enhance the infrastructure for e-car clubs, create a better network nationally and increase awareness of alternatives to car ownership, all of which would assist in removing the existing lock-in of both the technology and of ownership.

Secondly, although a national approach cannot be taken in terms of parking regulations, London and Local Authorities should be encouraged to implement a broader consensus for parking bay provision for e-car clubs. Norway is a key example where additional benefits and tax relief have proved to be very successful motivation crowding measures regarding the uptake of EVs. This could be replicated within the UK for e-car clubs, especially in urban environments where parking and congestion are challenges for businesses, residents and visitors. Furthermore, there is an economic and competitive advantage to be attained from demonstrating a successful service transition. Therefore policy guidance should be formed and shared amongst stakeholders to enable a president to be set and for operators to be encouraged to continue deploying vehicles in a zonal model. Public policy should develop and integrate an urban transport system fully integrating public transport and shared cars incorporating pricing, payment systems and infrastructure; rather than taking a paralleled approach (Firkorn, 2012). Furthermore in mixed use developments with both residential properties and businesses, e-car clubs should be a service provision to encourage dual purpose vehicles. Car clubs in these scenarios obtain high exposure and can be used most efficiently.

Thirdly, for e-car clubs to be an attractive and affordable means of travel, operators need to ensure the back office management is interoperable with one another. Currently all charging networks and car clubs are independently coordinated, however to avoid multiple memberships it is advisable to allow users access to a range of schemes through one membership and payment to be taken for activity e.g. the London Oyster card. This is likely to increase use of car clubs as the process would be less complicated removing a number of path dependencies.

Furthermore, it is recommended that e-car club data needs to be integrated alongside other available transport data. Car club location, price and availability should be incorporated into the public transport portfolio to complement the network, not compete. This would suggest an increase of data accessibility between the private and public sector, both in terms of operators and users. Having open data on integrated web portals such as Google Maps and Citymapper would assist in the transition of e-car clubs to a viable modal option and further break down the existing preconceptions of car clubs. There is a demand for this amongst stakeholders but the ownership of data and costs associated with this remains an issue.

Finally as an opportunity to decarbonise the transport sector there needs to be a national policy on education of car clubs and EVs, independently and collectively. Broadly speaking, there is a current lack of understanding of both of these markets highlighting the fundamental challenge of mainstreaming the concept of e-car clubs. There has been a higher degree of marketing for EVs, pushed by the automotive

industry, than the car club market due to the disproportionate level of funding for these sectors. Ensuring drivers, car owners and public transport users are aware that e-car clubs are operating in certain locations will further heighten the demand and encourage a change in behaviour and transport patterns. It is suggested a combined approach to stimulate a modal shift is taken using behaviour incentives alongside marketing campaigns. Behaviour incentives are an effective method to motivate certain activities and life choices that are required within society (Gneezy, et al., 2011). This will have knock on effects for the EV market and more generally the automotive industry in terms of finance models.

#### 6.2.5. Conclusions on e-car clubs

Urbanisation has led to the exploration of transport alternatives and new business models. The e-car club market is one component of the transport jigsaw that offers substantial opportunity to improve air quality, reduce emissions and congestion and more broadly alter the transport mix currently operating. However, there are a number of challenges to overcome for a transition to a use-oriented service within an industry heavily associated to status and flexibility. Since the influx of investment from auto manufacturers the transition to mobility services is being led from the market logic. The balance needs to be readdressed with additional support from policy makers to ensure the possible environmental benefits for cities are reaped by society.

The e-car club sector requires cross collaboration from national government, local authorities and car club operators to ensure further progress is made, specifically in terms of interoperability. Broadening e-car club's application and removing the existing barriers of parking, charging infrastructure and multiple operating platforms, all of which are technically and practically plausible, would enable a quicker and more competitive modal shift that could complement existing services.

### 6.3. Conclusions

This Chapter has investigated the role and opportunity of EVs to decarbonise the UK's road transport network. Having identified two markets of significance (i) commercial-urban fleets and (ii) car clubs, the transition barriers to electrification and the applied market techniques were explored. It is evident that EVs are infiltrating the two markets very differently.

The fleet market is currently dominated by the innovator logic that relies on momentum to be achieved from within companies that have a desire to utilise EVs beyond economic gain. This is complimented by the government logic that stimulates the TCO of an EV through incentives. However, for adoption of EVs to increase in the fleet market, additional policy measures need to be considered to broaden the

feasibility of operating EVs. Alternatively, the market logic needs to compete more heavily on providing alternative ownership models such as battery leasing that can substantially reduce the TCO.

This is contrary to the e-car club market that has witnessed a considerable shift in investment from innovator actors to large multinationals in the market logic. Car clubs are following the market led pathway with the introduction of various business models that are inherently challenged by path dependent characteristics. There is a distinct lack of support from the Government logic, which is fundamental for niche innovations to establish within the existing regime. For a paradigm shift to e-mobility services it is paramount that an interoperable network of charging infrastructure is established. This will remove transition barriers and enhance the integration of the private and public transport sectors to offer complimentary services.

The discussions on the two sectors will form conclusions in Chapter 7, in which the research objectives and questions will be addressed and formalised. The Chapter will also propose recommendations to increase the uptake of EVs in fleets and car clubs, as well as further research.

## 7. Conclusions & Recommendations

The transport sector accounts for 22% of the world's total carbon dioxide emissions, contributing to the effects of climate change (IEA, 2012a). At a national level, the transport sector in the UK is responsible for approximately 23% of greenhouse gas end-user emissions (DECC, 2014). The IPCC (2012) state that reduction in transport emissions is vital to avoid a 2.4 – 6.4 °C increase in 2090 temperatures relative to those in 1990. However the demand for global fuel for transportation is projected to rise by approximately 40% by 2035 (IEA, 2012b). Resulting in part from the continued rise of urbanisation and reliance and demand for personal mobility which has been evident since industrial car manufacturing (Firnkor, 2012).

This indicates the urgency for the transport sector to respond with AFV technology and new business models supported by public policy and a willingness to change by travellers. It is evident that the automotive industry as well as the Government has deemed EVs as an effective vehicle technology to address the challenge of vehicle emissions and air pollutants. There are however concerns regarding the overall environmental impact of EVs from 'well-to-wheel' due to the current UK electricity generation mix. By 2035, it is predicted that the percentage share of electricity generation from fossil fuels will steadily decline from 60% in 2015 to approximately 13% (DECC, 2015). As the grid is gradually being decarbonised, the carbon intensity of EVs from 'well-to-wheel' will reduce and further enhance the opportunity for a reduction in UK road transport emissions and fuel dependency.

Despite significant investment by industry and governments the EV market is not growing at forecasted rates. Therefore the purpose of this research was to investigate transition barriers of EVs and identify path dependencies and lock-in of ICE vehicles that results in sustained usage patterns. It aimed to explore how EVs can overcome existing challenges to encourage new pathways of service based models. The research explored the diffusion of EVs in two markets; (i) fleets, and (ii) car clubs, both of which may provide EVs with substantial opportunities to challenge path dependencies and remove lock-in. Theoretically, within these applications EVs can then attain greater market presence and alter the broader existing regime, facilitating wider uptake.

Despite extensive literature on transition pathways and the multi-level perspective, there is a lack of analysis on the potential transition to EVs and more specifically on e-mobility. Therefore various data gathering methods were used including interviews, total cost of ownership analysis, questionnaires and case study examples, to achieve a deep understanding of the current market. This enabled the research questions and objectives to be answered:

The following are the objectives of the research:

- (i) Investigate the transition barriers of EVs and explore the dominant path dependencies of ICE vehicles
- (ii) Clarify whether path dependency threatens EV adoption and analyse technology lock-in EVs are experiencing within the UK
- (iii) Explore the concepts of service based mobility models and the role of EVs within those
- (iv) Evaluate market techniques implemented by Government to encourage EVs and the impact on the market

These objectives were delivered through the research questions that target specific market uncertainties requiring further analysis.

Research questions	Sub questions
What change is required for fleets to transition to EVs?	<ul style="list-style-type: none"> <li>• What are the drivers and barriers of EV fleet adoption?</li> <li>• How does the total cost of ownership of an EV compare to that of ICE vehicle?</li> <li>• What challenges can be overcome through behavioural change rather than technological developments or regulative enforcement?</li> </ul>
To what extent is technological lock-in restricting the EV market?	<ul style="list-style-type: none"> <li>• What are the dominant path dependent characteristics within the automotive industry that challenge the utilisation of EVs and EV charging?</li> <li>• To what extent has motivation crowding been a successful technique for EV adoption?</li> </ul>
What is the role of EVs towards the pathway to a 'mobility-as-a-service' model?	<ul style="list-style-type: none"> <li>• What car club business models exist?</li> <li>• What are the path dependent characteristics within society that challenge electric car clubs?</li> <li>• What are the drivers and barriers to electric car clubs in urban environments?</li> <li>• To what extent can the challenges be overcome with policy?</li> </ul>

The following sections draw the conclusions from the two phases of research independently, and address the research questions directly.

## 7.1. Fleets

The fleet market is exceptionally diverse operating across different industries, utilising different vehicle types and performing different activities; however the vast size of the market introduces a plethora of opportunities for EVs to be optimised and to gain traction in niches. This research considered fleets of company cars, private hire and courier service to identify the drivers and barriers of EV utilisation and the possible strategies to overcome these.

### 7.1.1. What change is required for fleets to transition to EVs?

For a transition to be achieved within fleets towards the use of EVs, there are a number of changes required. The research has shown that EVs have an exceptionally challenging value proposition that on the surface is not immediately convincing. It is not simply a cost benefit analysis that is required to assess the feasibility of procuring EVs. In order for the niche technology to operate as a successful component of the fleet there are four aspects drawn from the discussion in Chapter 6 that need to be considered. Firstly, a fleet needs to consider if their operations could be executed by an EV in terms of vehicle specification. It is fundamental that the vehicle meets the needs of the business, however as GTC and TNT demonstrated through the innovator logic, operations can be managed to optimise EV use and maximise financial gain. Despite this, technology lock-in within their industries specified extended range and reliability, therefore regardless of the operational changes EVs were unsuitable. Secondly, a TCO analysis should be conducted to assess the financial viability of an EV on the fleet. The research suggests that both 'sweet spots' and additional benefits should be considered within the TCO to identify the economic cost of broader opportunities. GTC and TNT justified the procurement and trial of EVs purely on environmental and PR value, thus responding to the landscape pressures. Thirdly, it is imperative that the company policy incorporates EVs as a choice and communicates the corporate position on fuel reimbursement and/or charging infrastructure. Training and education should consider how to maximise driver acceptance and generate cross business support. Finally, the specification and installation of charging infrastructure can significantly alter the return on investment. Fleets benefit from managed known activities therefore charging infrastructure should be strategically located to minimise downtime. Within the EV TCO study a wall mounted charging point was specified, this would be appropriate for vehicles travelling under 100 miles per day and returning to depot. However, higher kW rated chargers would need to be considered for vehicles exceeding this daily distance which would significantly alter the TCO.

Clearly these elements are fleet specific and in most cases, location and activity specific. If there is an element that has not been addressed by a fleet prior to procurement of an EV, it is unlikely the fleet will

sustain a transition to EVs and inevitably remain locked-in to ICEs. Despite these challenges, those companies that are building momentum through niche-innovations can begin to destabilise the regime and cause sufficient pressure on the landscape to unlock EVs.

The empirical research has shown the importance of cross business support and senior level management engagement in the transition to EVs is exceptionally important. Senior management sponsorship demonstrates to the business the commitment to decarbonise operations through electrification; without this support it is unlikely fleet management will successfully implement a new fleet policy and identify the justification to procure EVs. This is particularly relevant when employees choose their own vehicles e.g. company car as there is a strong emotive influence associated to status, culture and brand. The case study on Schneider Electric highlighted these transition barriers of the civil society logic that are a key reason for lower EV sales than the automotive industry predicted. With the lack of higher order learning surrounding road transport's impact on carbon emissions and climate change, it is plausible that ICE technology will remain locked-in and EVs will not gain the necessary momentum to challenge the regime.

The fleet manager interviews highlighted the importance of using new technologies as a competitive advantage; this is mainly as a unique selling point that can attract PR value and shareholder engagement. The extrinsic motivations of CSR have been largely responsible for the EV activity within the fleet market. Although this is expected with a niche technology it is not sufficient in unlocking EVs. EVs procured for CSR purposes can further embed path dependences as the vehicles will likely be operated inefficiently with little consideration for charging infrastructure, as demonstrated by GTC and TNT.

As a fleet's procurement decisions are based on TCO, apart from in the cases of marketing, it is evidently vital for an EV to be competitively priced with an ICE equivalent. A TCO is sensitive to market conditions and the fleet's environment can be heavily influenced by bias. This bias can be unconscious due to uneducated assumptions on charging requirements or through preconceived notions of EVs encouraged by the incumbent regime. The case studies highlight the need for specialised fleet consultants to fully assess the applicability and feasibility of EVs as alternatively the analysis is (naturally) conducted on the basis of ICE assumptions. Due to the currently high depreciation costs and high purchase price of EVs, the niche technology remains largely uncompetitive within multiple scenarios explored. As the TCO analysis showed, there were significant savings through battery leasing as it removes the risk associated to the vehicle (the battery life) along with the high purchase price, and maximises the low operational costs that EVs possess. However this requires a shift to alternative business models that are currently challenging ownership.



### 7.1.2. To what extent is technological lock-in restricting the EV market?

This research has identified the lock-in of ICE vehicles that is founded on reinforcing path dependencies that prevent technology substitution. Therefore starting from a point of lock-in, the diffusion of EVs requires an extensive transformation across a plethora of societal dimensions. The Government incentives have been key catalysts in unlocking EVs, the TCO analysis highlights the importance of the Plug-in Car Grant to the feasibility of EVs. Existing policy has focused on providing incentives to the consumer market to increase EV uptake, whilst relying on private investment to install charging infrastructure that is publically accessible. Strategically, incentives should have been targeted towards fleets to manifest confidence in the general populous via employment and infiltrate the vehicles through the second hand car market. Regardless of the benefactor group it is important that changes within the government logic are managed with sensitivity to avoid market actors withdrawing from the action space.

The fleet research has identified four key transition barriers, (i) range, (ii) TCO, (iii) charging infrastructure and (iv) scepticism. This highlights the breadth of challenges that are resulting in technology lock-in, as well as the necessity to take a multi-dimensional approach to overcome these barriers. As a result it can be inferred from the research that within the fleet market hybrid technology (HEV, PHEV and E-REV) is the dominant vehicle type acting as a transitional technology. GTC and TNT are companies that are challenging the path dependencies of traditional diesel led sectors but admit the challenges of EVs are too great in the present regime. Consequently, GTC remain using HEVs to distinguish them from the market whilst not requiring any operational adaptations. However, as technology innovations stimulate market competition between manufacturers, confidence in the technology will improve. Furthermore, this momentum will positively influence the residual values of EVs within a second hand market.

The existing regime is confined by path dependencies that more broadly speaking lock-out EVs through the network of refuelling stations, sunk technological costs, range and price. Despite refuelling analysis highlighting that there are considerable more charging points per EV in the UK, compared to petrol stations per ICE, the inter-dependant technology system combined with a social status system that are all dependent and mutually reinforcing results in a scepticism that EVs do not suffice in meeting our daily requirements. The option value of flexibility and freedom is largely under-estimated within the automotive industry of developed nations, whilst an emphasis on brand, reputation, status and reliability are prioritised. However this research has identified the significance of flexibility to commercial-urban applications and the resistance to restrict versatility of operations. In scenarios whereby EVs are

applicable, the market requires innovator actors to build show case examples that can be replicated until sufficient confidence ultimately amends the balance of technologies across the regime.

Consequently it is the ‘innovator logic’ that will stimulate traction across the market, governance and civil society logics in response to technological change. Evidence from the case studies suggests that the three existing logics are insufficient in explaining the transition to EVs as the process requires technology transfer, implicating organisational, economic, social and cultural factors. Greater attention is needed on the role of ‘innovators’ and an innovation-led logic in the low carbon transition in order to represent the technological change of a niche innovation with interdependent dynamics. The innovator logic has been developed in this research as an addition to Foxon’s theory, to emphasise the importance of technology innovation from niche actors within the market. The EV market is following the transformation path and technological substitution whereby innovative activities are responding to moderate landscape pressures; thus developed niche-innovations are entering the system and destabilising the regime. The innovator logic is responsible for the existing uptake of EVs within fleets and will continue to drive the market until critical mass is achieved by the market logic to sustain investment, without the support from the government logic.

## 7.2. E-mobility

At present the car club market is niche and city centric, yet it is growing in popularity amongst policy makers and local governments, as well as amongst those users who have experienced it. This research has explored the role of EVs within car clubs, the existing limitations and recommended policies to achieve a transition to mobility services.

### 7.2.1. What is the role of EVs towards the pathway to a ‘mobility-as-a-service’ model?

Various service models have entered the market in response to the growing demand, it can be concluded that the flexible model, whereby users are restricted to zones rather than parking bays, is gaining momentum due to the ease and diversity that meets users demands. Therefore a diffusion strategy that emphasises flexibility, ease of use and mobility is deemed most suitable within the present market. Regardless of the business model there are a plethora of benefits e-car clubs can provide including the reduction of congestion, air pollution, fleet assets and demand for parking. However the research has highlighted challenges for operators to adopt EVs within car club fleets. This is largely due to the uncompetitive TCO of EVs and the necessary user interaction required to charge the vehicles. As the niche transitions to the regime these challenges will disperse as costs will reduce, battery technology will improve and behaviours will adapt.

From the perspective of the user there are fundamental challenges of e-car clubs that stem from path dependencies of the ICE and the existing ownership models. Transitioning to EVs has been discussed at length; for the e-car club market the fears of range anxiety and reliability are prevalent. The lack of an integrated network of charging infrastructure (to allow for a fully flexible model) is creating higher barriers to market for the operators as well as access for consumers. The research suggests this is due to a lack of technology innovation and collaboration amongst innovator actors regarding back office management. Consequently the government logic should be encouraged to take leadership as a not-for-profit stakeholder that can optimise car club data to manage an integrated travel platform, alongside other forms of transport.

This research has identified that the transition barriers for operators is largely due to the restrictions on parking bays and the consequent limitations on installing strategic located charging infrastructure. This highlights the lack of support from the government logic, the interviews indicated that local government policy makers are very cautious to implement alternative transport models that could affect public transport and therefore operators experience is varied dependent on the city's make-up. Consequently it is evident that the market logic is dominating the action space of e-car clubs with increased investment from large multinationals in 2015.

This research has discovered that the UK culture to possess assets and those assets to be aligned to societal status is a significant transition barrier to car clubs. Although innovator actors have introduced service models, mainly within cities, it is the concept of mobility services that challenges the allegiance to ownership. However due to the existing regime there is a lack of integration between networks and complementary transport systems. If there was greater assimilation of transport modes and live data the market logic could deliver a door-to-door service that would challenge private ownership.

As stated by the Royal Academy of Engineering: "if EVs are to be the agents of change that allow a significant reduction in CO<sub>2</sub> emissions, it is likely to be in an environment that is different from that which has evolved symbiotically with the internal combustion engine over the last century" (2012, p.12). Redefining the car as a mobility service provider presents an alternative environment for the EV to act as a change agent. This requires systemic innovation that can challenge the existing regime incumbents which are market orientated rather than focused on society and technological capabilities. A greater emphasis needs to be permitted to the application of EVs in scenarios and environments that enables the lock-in of ICEs to be removed. This requires higher order learning of stakeholders, particularly by auto manufacturers and energy suppliers that are threatened by the transition.

The research has demonstrated that the opportunity e-car clubs have to reduce costs for businesses are extensive. If certain operations could be replaced by car club vehicles within a fleet, this research suggests the company could benefit from substantial savings whilst also generating revenue from community membership. However this requires a shift in behaviour from fleets and the public to adopt mobility services and make it a viable proposition for both the operator and company.

The issue remains that there is a lack of policy supporting the transition to e-car clubs. Although governments support their use due to the environmental and transport benefits, there is not legislation to address the parking or zonal challenges, nor is there a precedent set from a show case example within the country. Examples in other European cities such as Paris and Berlin demonstrate the importance of one governing body for city transport solutions. The government logic and the use of incentives are exceptionally important in developing a new system of mobility services. Norway has demonstrated the extent motivation crowding techniques and perceived added value can influence procurement decisions in a short period of time. However independent characteristics of cities and existing networks need to be considered as a complex and complete multimodal system.

### 7.3. Contribution to knowledge

The thesis has provided contribution to knowledge across three fundamental areas. Firstly developing a greater understanding of the transition barriers of EVs within two markets (i) fleets and (ii) car clubs. The research has identified the existing technology lock-in that is embedded within the regime and questioned the market techniques employed to destabilise the ICE (Gould, et al., 2016). The research highlights the importance of motivation crowding in order to challenge path dependencies and suggests further incentives are required for a transition to mobility services. The conference paper entitled; ‘Transition Pathways to E-Mobility Services’ explores alternative business models, identifying flexibility, integration and ease of use as fundamental characteristics of the diffusion of car clubs (Gould, et al., 2015). Prior to this research a synthesis of this knowledge was not formed either in academic or industry literature.

Secondly, the research contributes new knowledge on the experience with practical application of EVs within fleets. Thus technological lock-in is limiting the available market to EVs resulting in niche applications that can benefit from the available grants and incentives. Existing literature lacks a comprehensive analysis of the success factors for fleets procuring and utilising EVs. The research identified four key elements that require consideration before the integration of EVs. Based on the transition barriers it highlights (i) charging infrastructure, (ii) economic feasibility, (iii) company policy and (iv) vehicle requirements. The journal paper entitled; ‘Transition Pathways to Commercial-Urban

Fleet Electrification' proposes that addressing these prior to procurement will result in the successful integration of EVs within a commercial-urban fleet (Gould, et al., 2016).

Thirdly, this research has contributed to the theory of transition pathways for the electrification of road transport. The relationship between transition pathways, path dependencies, technology lock-in and e-mobility had been under-researched; this research synthesises these models. Having explored two segments that offer substantial opportunities to decarbonise the road network, it is evident that EVs are following pathways influenced primarily by two competing logics. It is apparent the niche technology does not exploit or depend on a dominant actor within either market. The research demonstrates that Foxon's theory of competing logics based on the UK energy sector is not a sufficient tool to explain the transition to EVs within the automotive industry. Therefore a fourth logic has been proposed to consider the role of technology innovation upon the transition across organisational, economic, social and cultural factors (Gould, et al., 2016). Although the innovator logic is fundamental to each segment explored it is apparent that dominance from competing logics is stimulated by the existing regime. The research makes it explicitly clear that for a niche technology to gain momentum and attain investment from other parts of the market, government support must take a parallel role of incentives and research & development to raise awareness and interoperability.

Further exploration of these contributions to knowledge will be recommended in Section 7.5.

#### 7.4. Recommendations

Drawing on the thesis conclusions there are a number of key recommendations for both the fleet market and the car club market to further develop the transition to EVs. Despite the research analysing the transition of one technology - EVs, the analysis has shown that within the diffusion of the same technology two different pathways are being followed within the sectors explored. Therefore the recommendations for development of each market segment studied will be addressed independently, with specific recommendations for stakeholder groups identified through the competing logics.

Additionally, this research has explored new areas of transitions theory using the multi level perspective to explore the path dependencies and lock-in of ICE vehicles and the dynamics of change. The MLP was a useful tool to consider the market dynamics and dominant characteristics that result in structural change. However, despite the MLP theoretically conceptualising change, it does not provide insight in to functional application. There is further research required on the topic of EV diffusion and mobility services which shall be suggested in Section 7.5.

#### 7.4.1. Fleet market

Concluding from this research there are three key recommendations that would arguably enable the transition to EVs within fleets at a quicker rate of diffusion than at present.

- (i) Government logic - Socio-economic approach – An approach is recommended where a tax is introduced for carbon emitting vehicles as a deterrent to ICEs and second car ownership. This should be implemented rather than the current practice to incentivise EVs with subsidies and grants for charging infrastructure. If this was to be executed it is more likely to positively alter embedded path dependent characteristics of the mass market rather than those individuals who choose to take advantage of the initiative led by OLEV.
- (ii) Government logic - Incentives – It is recommended that incentives should be targeted at fleets instead of private individuals; this is due to the substantial opportunities fleets have to impact both the EV market and mass market through second hand car sales. Secondly fleet operators have the resource to explore available incentives and the motivation and financial footing to exploit the subsidised market. Currently incentives are focused on selling EVs to individuals and small fleets based on market demand that is led by economic viability, however these markets do not possess the necessary scale to transition the automotive market. Furthermore it should be noted that previous charging infrastructure grants available for businesses (up until 2014) stipulated chargers were accessible by the public with pay-as-you-go functionality. These requirements should not be reintroduced alongside the incentive as open-access introduced additional transition barriers of access to land, payment models and risks of restricted fleet access.
- (iii) Market & Government logic - Education – A national education campaign needs to be orchestrated that targets various sectors to devolve the preconceptions of EVs that have been installed by path dependencies. Existing campaigns have not succeeded in gaining momentum or reaching the masses. This needs to be addressed with a greater emphasis on fleets.

These recommendations of strong and sustained actions of the government logic are necessary to ensure EVs are optimised in the fleet market and achieve ‘technological substitution’. Despite the existing significant investment in the EV market, there should be a greater focus on the transition within the fleet market to have consequential positive knock on effects across the regime.

#### 7.4.2.E-mobility services

E-mobility services is currently a niche market which desperately deserves funding, policy and legislation to support the transition to a services approach that can dramatically improve city congestion and air pollution. Below are three recommendations to assist in the development of the market:

- (i) Government logic - City operator – As demonstrated by other European cities, the successful roll out of an e-car club is largely due to those cities having one governing body that determines overall transport policy, parking regulations and charging infrastructure installations. This should be introduced within UK cities to devolve powers to city mayors, thus removing multiple stakeholders at national and local governments that have resulted in a number of differing networks and back office management systems to be operating. As it stands users are members to multiple schemes that are each limited to specific zones and specific parking bays and charging infrastructure, this needs to be addressed to introduce more flexible models and assist in removing lock-in.
- (ii) Innovator logic - Integrated transport – To optimise e-car clubs it is necessary to integrate transport services so car clubs, public transport, walking and cycling can become a door-to-door complementary portfolio. This requires public and private data to be shared so travellers can make informed decisions on transportation modes that can relieve stress on congestion within a city. This would challenge the existing transition barriers to e-mobility services by introducing a ‘one-stop shop’ to travel. With apps such as Google Maps and Citymapper there is greater transparency and choice of routes and public transport modes for travellers; however such tools should incorporate privately funded transport modes.
- (iii) Market & Government logic - Flexible – For a single operator and integrated transport approach to successfully infiltrate e-car clubs, it is vital that e-mobility models are entirely flexible and interoperable. This would remove current restrictions, allowing users to travel as they would with a privately owned vehicle. This would require parking bays and charging infrastructure to be accessible throughout the city. This is demonstrated by Autolib’ which has proven to be the most successful e-car club globally.

E-mobility services have the ability to significantly alter the automotive industry and existing regime which is driven by ownership and status. These recommendations require action from across the competing logics to stimulate traction within civil society; these recommendations should be considered whilst at the early stages of deployment to maximise potential.

### 7.5. Future research

There is a need for further research in this area of transition pathways of EVs and e-mobility services. It remains under-researched despite the growing market and changing regime. Further research should be conducted across four pillars of influence on the market to address existing gaps in the evidence.

Firstly, the innovator logic has been proposed within this research as a technology innovation led pathway. The two segments explored within this research demonstrate the innovator logic acting interdependently forming individual pathways despite common actors. Further research is required to question the role of the innovator logic upon EVs within different segments. This will establish the extent to which technology innovation is driving the entire EV market. Additional research should explore the role of the innovator logic within different niche technology markets to question its broad application. This will identify the necessary balance of competing logics upon a niche innovation that creates momentum within the regime to achieve creative destruction.

Secondly, EVs have a central role within city transport and extensive opportunities within multiple applications, however the technology will only be successful if travellers understand and accept the concept. Therefore further research should be conducted in to ‘readiness’ of travellers to adopt EVs and use-oriented services. Reducing the uncertainties within the market will encourage public and private investment and appropriate motivation crowding. Furthermore understanding the ‘readiness’ to adopt will help to determine the transition pathways and help potential service providers develop the most attractive propositions.

Thirdly, the future of integrated mobility services will consist of a mix of transportation modes and business models. Therefore the trend of auto manufacturers selling the concept of mobility alongside vehicles as a process of creative destructive should be explored. There are a number of auto manufacturers who are actively involved in mobility services, acting in a dominant position within the market logic. Further research could assist in determining the rate product service systems will fundamentally alter the system. This should seek to explore the use of motivation crowding on service behaviours, rather than an incentive for asset procurement. Analysis of Norway’s tax incentives for EV drivers and the implications to the transport system should be used as a case study.

Finally, further research should be conducted on the role ‘big data’ has within the e-mobility market. Optimising live data on a shared platform provides mobility services an extensive opportunity to better manage city travel by dispersing travellers appropriately. This should incorporate the changing market conditions from operators of PSSs to the future of autonomous vehicles.



## Epilogue

The research within this written document was executed between 2011 – 2015, during which time the researcher was based within Schneider Electric. After the completion of the thesis, the analysis and practical application of theoretical models were shared with those organisations involved. The synthesis of the EV market was well received, along with the Recommendations in Section 7.4. The TCO analysis in Chapter 5, stimulated interesting debates with the fleets, in particular surrounding the need for intangible benefits to be quantified within the TCO.

The period of engaged scholarship was exceptionally dynamic due to early market conditions of EVs. On reflection, the four-year research study encapsulated the socio-technical environment of the time, exploring the path dependencies and technological lock-in of EV fleets and the concept of urban mobility services. Throughout this period, the market's primary governing body, OLEV, directed investment to a number of target audiences in response to changes in market dynamics. This research remains relevant to the research field and the commercial environment of EVs, it reflects the system of the time. Since 2015 the EV market has continued to develop very dynamically and a number of relevant changes have occurred. In the following commentary the market progression will be reported to provide an update of the current environment.

The UK new car market experienced 2.3% growth in 2016 with annual registrations of 2.7 million vehicles (SMMT, 2017b). SMMT state that fleets are largely responsible for most of the growth despite a record year of sales within the private market (SMMT, 2017b). Although petrol and diesel vehicles remain the most popular fuel type, “plug-in hybrids and petrol electric hybrids, in particular, experienced significant growth, with demand up 41.9% and 25.1% respectively. Meanwhile, more than 10,000 motorists chose to go fully electric in 2016 – up 3.3% on 2015” (SMMT, 2017b, p. 1). Overall there was a 31.4% increase in new registrations of cars that were eligible for the Plug-In Car Grant, December 2016 year-to-date (SMMT, 2017a). The significant increase in AFVs occurred despite the political and economic uncertainty of the UK. As of January 2017 there were 11,891 charging points at 4,248 locations, approximately a 25% increase since 2015, however it is not possible to determine whether the increase in charging points and AFVs occurred simultaneously or subsequently (ZapMap, 2017).

It is questionable whether the increase in eligible vehicles for the Plug-In Car Grant has increased due to changes in the regulations that categorise vehicles based on CO<sub>2</sub> emissions and range (as stated in Section 2.2.1). The changes to the Grant incentivise EV buyers towards PEVs that can travel over 70 miles, thus employing motivation crowding to remove range anxiety and achieve a cultural shift. The changes to

vehicle eligibility react to the efficiency gains broadly within all auto manufacturers portfolio of vehicles, along with the inclusion of electric motors within premium cars.

There were additional amendments to available OLEV funding during 2016, including:

- The extension of the Plug-In Van Grant to 200 electric vans above 3.5 tonnes
- The Workplace Charging Scheme providing £300 for each socket up to a maximum of 20 across all sites for each application at a registered business, charity, or public sector organisation
- Grants for Local Authorities to procure and install residential on-street charge points for PHEVs

The new Workplace Charging Scheme would most certainly alter the TCO analysis that was conducted in Section 5.1, potentially making EVs more competitive through reducing the cost of infrastructure.

Furthermore, the extension of the Plug-In Van Grant to include heavier vans may encourage TNT to reassess the feasibility to incorporate new lithium-iron EV trucks within their fleet. Therefore it is recommended that future research should consider the impact of the available grants in a number of practical applications. As stated in Section 7.4.1 it was recommended that Government should incentivise businesses to adopt EVs, rather than solely focusing on the residential market. Therefore, it is with satisfaction to report the addition of workplace funding for charging infrastructure.

Further evidence of the UK competing at the forefront of the international transport industry was apparent in the announcement and consultation of the Modern Transport Bill. The Bill is intended to encourage investment in EVs and autonomous vehicles, addressing “three challenges of the growing ULEV sector: the consumer experience of using the infrastructure, the interaction of charging infrastructure with the electricity system, and the future provision of infrastructure” (DfT, 2016b, p. 8). This demonstrates the continued ambition of the UK to be global leaders in the ULEV market and the need to reduce road transport emissions; whilst also recognising the existing challenges surrounding charging infrastructure in the country.

During 2016 there were a number of developments from the UK organisations directly involved within the study; these are listed below:

- Green Tomato Cars: added two Tesla Model S vehicles to the fleet in 2014. With a pure electric range of 250 miles, GTC claim “50,000 miles worth of emissions” have been saved over a two year period (GTC, 2017, p. 1). In the following year, two Toyota Mirai’s were incorporated in to the fleet. GTC were one of the first European customers to adopt the hydrogen fuel cell technology. The vehicles have a range of 300 miles, fuelled by two hydrogen gas tanks, with a conventional battery as a back-up (Toyota, 2015). Evidentially GTC continue to use AFVs as a

USP, despite the poor experience of the Renault Fluence. Utilising AFVs with a higher range has enabled GTC to continually challenge the path dependencies of private hire firms, demonstrating the innovator logic with pioneering technology.

- TNT: deployed 15 specially built electric delivery vehicles in London in June 2014. This followed a successful 18-month trial of six Gnewt Cargo vehicles from TNT Express' London City depot. The new vehicles were tasked with more than 1,000 international deliveries into London each day (TNT, 2014). TNT clearly remained focused on their ambitions to reduce carbon and be environmental leaders within the courier sector, finding a suitable alternative to the unfeasible electric 7.5 tonne Smith Electric trucks.
- Schneider Electric: have revised the company car scheme reducing the emissions limit to 130g/km, in line with 2013 regulations. As previously, the company remain at the upper limit of the capital allowance for business cars. It is expected the national limit will reduce to 110gCO<sub>2</sub>/km within the next two years, at which point Schneider Electric will be legally required to comply. As previously identified Schneider Electric are likely to react to legislation rather than pre-empt changes to the capital allowance; thus appeasing to the psychological kudos within the sales environment, slowly introducing cultural change to the organisation in line with UK law.
- DriveNow, London: there are now 310 BMW and MINI vehicles in an 84 km<sup>2</sup> area across the boroughs of Islington, Hackney, Haringey and the lower half of Waltham Forest in North East London. The fleet includes 41 BMW i3's and 12 designated charging points, this has increased from 30 BMW i3's and 8 chargers in 2015 (DriveNow, 2017). The increase of EVs on the DriveNow fleet indicates a level of success and popularity of the vehicle technology. As stated in Section 5.4.5.3, DriveNow identified two expansion models, the company have chosen to expand within the existing area of North East London rather than enter new regions within the capital. This is arguably the risk averse option, choosing to increase membership in area where the brand is strong and infrastructure is available.
- E-Car Club: in 2015 Europcar Group acquired a majority stake in E-Car Club to strengthen their presence in the mobility market (Europcar, 2015). The acquisition of the disruptor business marked the first exit of a crowdfunded start-up in the market. This demonstrates the continued shift in car club investment from entrepreneurs to large multinationals operating in the market logic. As car clubs cannot currently be considered mainstream, it suggests the investment from market actors is founded on the growth potential of MaaS.
- Source London, Balloré: have experienced significant delays on the expansion projections as stated in Section 5.4.3. Balloré report this is due to contractual challenges with the 33 London Boroughs (including City of London). Cedric Bolloré, the company's director of development,

said "the boroughs are rather independent in their approach and we absolutely need to have the same contract. We must admit that the discussion...are taking a bit more time than we thought... we will be one year or two years behind " (Pitas, 2016, p. 1). Currently there are 19 BlueCity EVs in London, although not all are operational due to technological issues (Pitas, 2016). Balloré are aiming to have 6,000 charge points installed in London by 2020. The persistent challenges experienced by Balloré are exactly those discussed throughout the thesis; regulation of parking bays, the installation of charging infrastructure and the lack of interoperability. These transition barriers have caused both start-up and established car club operators to exit the UK market, for example Car2Go and WhipCar. Arguably for Balloré to achieve their ambitions in London there needs to be stronger collaboration between national government, local authorities and car club operators, as described in Section 6.2.5.

The developments within each of these organisations strengthens the findings of this research. Each company continued on its own pathway that was assessed and explained in Chapters 5 and 6. Although there have been some positive incremental changes, the motivations as well as the barriers echo those reported in 2011-2015. This suggests this research is still very current in the e-mobility debate.

The Go Ultra Low campaign, funded by OLEV, vehicle manufacturers and SMMT "estimates by 2027, electric-powered cars could dominate the market, with over 1.3 million sold per year" (Saarinen, 2016, p. 1). Furthermore, KPMG's Global Automotive Executive Survey reveals that 90% of executives expect EVs to dominate the marketplace by 2025 (William, 2017). Further claims are made that the UK is on track to meet the target that all new cars sold will be electric by 2040, this is substantiated by the rate of existing sales and the expected release of PEVs from most major auto manufacturers (Hudson, 2016). If this is to be achieved there are clearly a number of transition barriers that still need to be overcome through a combined approach of investment, innovation, interoperability and education.

Therefore, although the market remains dynamic and progress in certain areas has been achieved, the research conducted in 2011-2015 continues to be very relevant. The key transition barriers of EVs and MaaS explored within the research remain challenging and although the market share of EVs has increased this is largely within the private market. Consequently the research should not only be used as a reference point of the EV evolution, but (as suggested in Section 7.5) further research should continue to explore the necessary market conditions for greater utilisation of EVs and MaaS.

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