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

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Doctorate of Engineering, Sustainability for Engineering and Energy Systems

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Statement of originality

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

Volume II

This Volume contains six progress reports written during the research project, a 2nd year dissertation, a conference paper published in WIT Transactions on Ecology and the Environment and a journal paper published in Journal of Contemporary Management.

The contents of this Volume are in the following date order:

1) Six month report: Charging Infrastructure for Electric Vehicle Fleets – identify and develop business opportunities within target sectors. April 2012


3) Eighteen month report: Charging Infrastructure for Electric Vehicle Fleets – identify and develop business opportunities within target sectors. April 2013


8) WIT conference paper: Transition Pathways of e-Mobility Services. September 2015

Charging Infrastructure for Electric Vehicle Fleets – identify and develop business opportunities within target sectors.

Six Month Report

Engineering Doctorate

Industrial Doctorate Centre

University of Surrey

April 2012

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Six Month Report

The following report is based on the six month period between October 2011 and March 2012. It will contextualise the project through literature, research questions, a methodology and a proposed timeline.

1. Project description:

Title - 'Charging Infrastructure for electric vehicles – identifying & developing business opportunities within target sectors.'

This research project is focused upon the electric vehicle market and the consequent market for charging infrastructure. Although electric vehicles were the first motorised form of transport, the market has only managed to gain marginal market share over the last century. With tighter regulations amongst the rise of climate change awareness, electric vehicles (EVs) have become a key aspect of transport policies in order to meet carbon reduction targets across the globe. Establishing an EV market is challenging due to the need for extensive transformation across a large spectrum of societal dimensions including policy, behavioural change, fiscal models and technology dissemination. As the market is at a critical point, the following year’s actions by Government, manufactures and consumers are hugely instrumental to the future longevity of the electric vehicle. Over the next four years, the duration of the research project, a path analysis will be undertaken to investigate how the EV market can sustain growth within the industry through tackling existing development blocks of path dependencies and overcome future risks. The researcher is based at Schneider Electric within the UK.

2. Schneider Electric:

Schneider Electric is a global specialist in energy management offering solutions for power and control, critical power, energy efficiency, automation and renewable energies. Since 2010, this has included electric vehicle charging infrastructure across the complete range of applications, 3kw wall chargers, 22kw standard chargers and 50kw fast chargers. Schneider has transformed from a product based company selling through distributors to a product and services company with expertise in energy management. The EV charging solutions suits the new Schneider ethos of energy efficiency and allows both product and advanced services to be offered. During 2010/2011 Schneider have experienced the challenges of a new market in both terms of a regeneration of EVs and the need for regulations; as well as the strategic decision to enter that new market in which new relationships are required with end users, the fleet market and the automotive industry.

3. Terminology:

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, 2011 p.5). Therefore this includes:

- Pure electric vehicles (PEV) - A PEV is a vehicle powered solely by a battery charged from mains electricity, currently PEVs have approximately 100 miles range.
Hybrid electric vehicles (HEV) – A HEV has both a battery and an ICE which are used interchangeably depending upon the speed, engine load and battery charge level. The vehicle automatically selects the power source and charge is maintained by regenerative braking as the vehicle cannot be plugged in. Fuel type varies between vehicles including compressed natural gas, diesel, liquid petroleum gas and petrol.

Plug-in hybrid electric vehicles (PHEV) - A vehicle with a plug-in battery and an internal combustion engine. At present the electric range is about 10 miles, after this has been utilised the vehicle reverts to the benefits of full hybrid capability, utilising both battery power and ICE without range compromise.

Extended-range electric vehicles (E-REV) - A vehicle powered by a battery with an ICE powered generator on board. The vehicle is always electrically driven, the range is typically 40 miles but is extended through an on board generator.

Figure 1: Vehicle types

Source: OLEV, 2011

For the purpose of this research it will include PEV, PHEV and E-REV, this is due to the direct withdrawal of electricity from the national grid (illustrated in Figure 1). HEV technology will not be investigated within the research project as hybrids generate electricity through regenerative braking and therefore do not require a charging infrastructure solution. However HEVs will be used as a reference point of AFV (alternative fuelled vehicle) stakeholder behaviour as it will demonstrate market response to the diffusion of a new technology.

4. **Context:**

This research project will be focused on the UK road transport market that currently contributes 90% of domestic transport emissions (OLEV, 2011). As the fastest growing contributor to climate change methods of transportation need to be challenged in order to satisfy the UK Climate Change Act of a 50%
reduction of greenhouse gases by 2025 on the 1990 baseline levels (European Union, 2009, drdni, 2010). The UK’s current fuel mix is dominated by natural gas and coal resulting in high levels of emissions. This along with the risks of peak oil occurring before 2020 challenges affordability and accessibility of oil supply (UK Energy Research Centre, 2009). This has considerable implications upon the transport sector within Britain as transport demands over 50% of overall UK oil consumption (ITPOES, 2010). UK road transport is therefore particularly vulnerable to the effects of global supply constraints and price shocks, the UK should therefore utilise alternative fuels to separate the transport sector from the trade deficit of importing the single fuel means. It is suggested however that future transport growth will demand oil at a quicker rate and will over compensate for substituted fuel use (ITPOES, 2010). Disruption upon transport networks across the UK could have severe detrimental impacts as a wide range of businesses rely on ‘just-in-time’ business models based on highly integrated transport systems (ITPOES, 2010). This highlights the challenges of transforming to a cleaner energy portfolio and a reduction in fossil fuel use. However there are immediate opportunities for road transport to be decarbonised. Electrification of transport is argued to be a substantial opportunity for the decarbonisation of transport and the most promising in the near term (Electrification Coalition, 2010). It is suggested that EVs are more energy efficient than an internal combustion engine (ICE) vehicle within the use phase, with 75% efficiency compared to the 20% efficiency of ICE (WWF, 2011). Additionally, EVs present the opportunity to reduce extensive fossil fuel use by 80% for the purpose of meeting vehicle motive power requirements by 2030 (AEA, 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, 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 contradictions between academia and industry regarding the life time emissions of an EV. Within industry the vehicles are deemed ‘zero emissions’ as electric vehicles have no tail pipe emissions and therefore from tank-to-wheel are essentially environmentally harmless. However assessing the overall environmental impact of an EV from ‘well-to-wheel’ and beyond; some 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).
Electric vehicles are however expected to cause various challenges to the UK including harmonic disturbance and peak energy demand. However it is suggested that EVs have the ability to balance the national grid positively as long as the majority of vehicles are charged over night, the consistency of energy demanded will stabilise the sine curve illustrated in Figure 2. In order to manage this energy, 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 (with the electricity used at public charge points appearing on the owner’s domestic bill). All of these models will have different implications for how the back-office systems need to operate and what other systems that needs to be interoperable with. This research project will therefore explore how effective the various tariffs are on changing perception and upon charging behaviour.

5. **UK EV market**

In the early nineteenth century Michael Faraday from Britain demonstrated the principles of electric motors and generators, this led to the first experimental EVs to appear in the UK as well as the USA and the Netherlands (Hoyer, 2007). The ‘golden age’ of the electric vehicle, from the late 1800s to early 1900s saw EVs dominate the market but this was not long lived due to the rise of the ICE vehicle. Over the following century EV technology has repeatedly failed to gain market share within mainstream transportation (AEA, 2009). However due to climate change rapidly rising in the political agenda, the EV industry in the UK is increasingly expanding, offering significant strength to provide vehicle technology and engineering capabilities (BERR, 2008). A range of factors will determine the rate at which the EV market develops in the UK, including consumer acceptance, oil prices, battery technology and infrastructure (OLEV, 2011). As competition among the automotive industry rises between EVs and manufacturing increases, economies of scale will help to absorb the high cost of the battery and enable
EVs to reach cost parity with ICEs. However due to the stringent 2020 CO2 targets under the European New Car CO2 Regulation technological advancements within ICE vehicles are proving to be fiercely competitive with PEVs (OLEV, 2011).

At present there are five electric vehicle models available to the UK market, with an expected rise in 2012 to fourteen. There are approximately 1200 EVs in the UK that have been bought using the Plug-in Car Grant (discussed on pg. 5) and approximately seven hundred charging points. The Government target is to install 4,777 chargers across the UK equating to 1.8 public chargers per EV by the end of 2012. As expected within an emerging market the number of companies providing charging infrastructure solutions has risen rapidly. Currently there are ten suppliers of charging infrastructure in the UK all of whom provide a range of charging points and extra services such as billing. Figure 3 suggests a global overview 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. Figure 3 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. From the timeline it can be inferred that the New Automotive Innovation and Growth Team predict that by 2020 average CO2 per fleet will be 95g/km, this therefore does not address individual vehicle averages prohibiting any concrete analysis of fleet vehicle transformation. By 2020 ICE vehicles are expected to be extremely efficient and therefore fleets may be able to consist of diesel vehicles whilst satisfying legal requirements. It could also be argued that full hybrid vehicles are not as progressed within the market as Figure 3 indicates, currently hybrids are utilised by early adopters rather than the majority of drivers.

Figure 3: Time line for the introduction of electric vehicles with battery technology

Source: SMMT, 2011

At present the UK EV market has reached pioneers of the technology who have thus far assisted, alongside Government investment, future longevity of the market. Figure 4 highlights the need for strong governance, as in order to achieve minority adoption sustained incentives and innovative policies are
required. This is currently the stage at which the UK is challenged with and further involvement from the Government will be required until wider adoption is achieved. This will entail education and financial stimulus in order for the market to be self-sustaining and sufficiently competitive. Alternatively a ‘polluter pays’ approach could be enforced to ensure adoption, successful implementation of this strategy can be seen in Norway. Fortunately for the EV market the Government are pressured in to maintaining invested interests as it is argued that at least 1.7 million EVs will be required 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 electric vehicles by 2020 and 18% in 2030 (WWF, 2011). For this to be possible it is argued to rely 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).

Figure 4: Transformation path to road electrification

Demonstration of the Government support is seen through various 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 is has been extended to 2015. 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 EV fleet integration. The UK Government is tackling transport emissions with a technology neutral approach, therefore businesses or private consumers with cars with tailpipe emissions of 75/km or less thus including electric, plug-in hybrid and hydrogen-fuelled cars are all potentially eligible for the grant (DfT, 2011a). This incentive has been pledged to continue for the entirety of the current Parliament’s session, however as manufacturing increases production the cost will decrease and it is questionable whether the government will maintain the incentive support. Further exemption and discounts are available including (DfT, 2011b):

- 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

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 electric vehicle and the additional incentives are applicable, such factors would be integral to the decision matrix. 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. This could be achieved if the Government were to waiver 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.

Despite this, there are significant investments in the electrification of road transport displaying the strong commitment to dramatically alter the transport sector. The European Commission has contributed up to £37m and the UK has directly invested over £500m into multiple initiatives (Europa, 2011, AutomotiveCouncilUK, 2010):

- Nearly £40m attributed to infrastructure support, offering match funding to local consortia of businesses and public sector partners to support the installation of EV recharging infrastructure in eight key locations in the UK (DfT, 2011a). As the key mechanism of increasing infrastructure, the intentions of the ‘Plugged-in places’ is to ease the management of infrastructure as electric vehicles increase within the market. Additionally, data will be retrieved from the charging units about charging behaviour to “provide the necessary evidence base to shape the design of a national system of recharging infrastructure” (DfT, 2011a p.1).
- Investments of approximately £66m in low carbon vehicle research, development and demonstration could suggest an assurance of continued growth within the market (AutomotiveCouncilUK, 2010).
- A collective £74m is allocated to the consortia, authorities and the Technology Strategy Board to deliver low carbon vehicles to consumers and fund bus companies and local authorities to buy new low carbon vehicles. This is with the intention to enhance the relationship of car manufacturers, power companies, Regional Development Agencies, councils and academic institutions (AutomotiveCouncilUK, 2010). This is in addition to the available incentives in the UK that attempt to heighten the competitiveness of an EV compared to that of an ICE.
- Directly addressing the premium cost associated with EVs, £300 million has been invested in the Plug-In Car/Van Grant.

Currently, the way in which the Plugged-in Places scheme is managed does not allow for 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 is not homogeneous, this means if drivers require access to more than one PiP location they will be obliged to register/pay for membership for each
necessary location. The related incentives regarding parking is not uniform for the eight PiP locations nor within the individual locations, for example each London borough (of which there are thirty three) have different regulations dependant on the local council. Not having a simple and national framework that is straightforward for prospective EV drivers to comprehend places extra pressure on the market as the adoption of electric vehicles will appear undesirable. Alternatively, there will become ‘pockets’ of EVs across the UK that rely on publically installed charging infrastructure. This would be detrimental to the market as it would limit the utilisation and production rate of EVs which would weaken the financial opportunities. Therefore this research will investigate the impact the PiP scheme has had upon the market to date and the likely impact on the future.

6. **Areas explored:**

6.1 **Fleet research:**

In the initial stages of this project the research completed was mainly market research of UK fleets. It identified fleets for Schneider Electric to target across key industries including utilities, the public sector and contract hire firms. This was undertaken as Schneider Electric was eager to approach potential customers that have previously not been within Schneider’s client base. This time was spent understanding Schneider’s business, the electric vehicle market and the technology of charging infrastructure. As the researcher had difficulty in defining their role within Schneider Electric as well as the direction of the research, it led to a lack of direction for the research to follow. However as some clarity was formed, the motivations and barriers for fleets to integrate electric vehicles was analysed (Appendix 1).

This was the first major area of research undertaken as Schneider Electric want to gain considerable market share as industry considers the most logical beginning for market transformation to be through commercial fleet procurement. This is because fleet vehicles comprise of over half of all vehicles sold in the UK, this being 973,233 in 2010 (SMMT, 2011). It is predicted that by 2015 there will 1.3 million electric vehicles within UK fleets (PikeResearch, 2011). Although barriers to market penetration do exist in the UK, it is suggested that businesses have an opportunity to take advantage from a plethora of benefits EV fleets could provide. Motivation for adopting electric fleets could vary greatly from the benefits of lower emissions, higher energy efficiency and lower electricity rates or enhanced brand image. Additionally business costs have risen dramatically due to the volatile price of oil which has increased approximately five-fold since 2000 (Cenex, 2010). Oil prices remain elevated and continue to fluctuate with the price of petrol reaching £6 a gallon, however efficiency within ICE vehicles is continuously improving. Competition lies with the electric vehicles as fuel cost per mile travelled is one of the key economic factors differentiating EVs from other technologies, this highlights the advances in battery technologies as more relevant than ever (ElectrificationCoalition, 2010).

Through developing a strong UK electric fleet market it is argued that infrastructure will be created through private investment. If the Government were to mandate i.e. through policy, this infrastructure could form the basis of a new publicly accessible fuel vector infrastructure in the medium term, reducing the burden on public spending. Additionally by encouraging fleet uptake of EVs it could reach a
significant number of private individual’s through their use and contact with fleet vehicles, who may then see the potential for such vehicles in their domestic lives. 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 a ‘new technology’ vehicle. Moreover, the “concentration of buying power associated with fleet operators and fleet management companies represents a significant opportunity to assist the early development of the electric vehicle industry” (ElectrificationCoalition, 2010 p13).

6.2 Total cost of ownership:

Having explored the existing evidence on the wide array of advantages and disadvantages electric vehicles offer, it became apparent a considerable challenge is the high initial capital investment required. This led to a financial analysis to be undertaken as directly comparing the purchase price of an electric vehicle against an ICE vehicle highlights the premium paid for a ‘zero carbon’ vehicle (Figure 7). Despite the Plug-in Car & Van Grant subsidised by the Government, the purchase price still does not reach cost parity with competitively priced ICE vehicles. As a result it is imperative for electric vehicles to be considered over a period of time as comparing total cost of ownership (TCO) is argued to present EVs favourably due to the high petrol/diesel prices incurred with the use of ICE vehicles. TCO comparisons are currently varied in results as assumptions are inherent to the new market and unknowns of a second hand market consequently prohibit concrete residual values. This is considered a significant challenge for the fleet market due to the short ownership of vehicles, averaging three to four years. It is argued the lack of market experience, particularly relating to the long term cycle performance of a battery is hindering market developments (ElectrificationCoalition, 2010).

Additionally, within the current market purchasing decisions of electric vehicles ultimately fall upon comparison between the initial capital investment and known performance indicators of an ICE vehicle. This results in a financial bias towards ICE vehicles as they are considerably less expensive due to the high battery costs associated to EVs. However TCO within the current market fails to consider the high specifications of EVs, the Nissan Leaf for example includes as standard; 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) and therefore contribute an additional cost to the catalogue price of at least £1,500 whilst several ‘extras’ aren’t available on various models.

The TCO analysis (Figure 7) compares a Ford Focus 1.6 TDCi 115PS Titanium X, Toyota Prius T-Spirit 1.8, a Nissan Leaf and a Renault Zoe. The comparison includes these vehicles as they provide an overview of different vehicle types whilst remaining within similar classes with equal performance. The first section of the TCO is based on outright purchase of the vehicle, this is true for the Renault Zoe excluding the battery as the business model is based upon the owner leasing the battery in order to reduce the purchase price. The figures used for the Renault Zoe are based on assumptions as the vehicle is not yet released, therefore the running costs and depreciation rate is valued the same as the Nissan Leaf as both vehicles are PEVs. To complete the TCO certain conditions were set including:
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 (16.01.12)

One entry to central London per month

Fuel/Electricity is based on manufacturers claimed vehicle consumption using AA average UK fuel prices and British Gas UK average standard rate electricity, £0.1345kwh (16.01.12)

Depreciation figures based on CAP values (16.01.12)

Expected residual value for 15,000 miles & 20,000 miles assumed at an additional 5% & 10% respectively of the 10,000 miles figure.

Figure 5: Total cost of ownership comparison on an EV basis

<table>
<thead>
<tr>
<th>TCO</th>
<th>Ford Focus 1.6</th>
<th>Toyota Prius</th>
<th>Nissan Leaf</th>
<th>Renault Zoe (battery leased)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catalogue price</td>
<td>21,595</td>
<td>24,870</td>
<td>29,990</td>
<td>£20,000</td>
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<td>0</td>
<td>5,000</td>
<td>5,000</td>
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<tr>
<td>Additional costs of accessories</td>
<td>1500</td>
<td>1188.58</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total investment needed to purchase</td>
<td>23,095</td>
<td>26,059</td>
<td>24,990</td>
<td>15,000</td>
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<tr>
<td>£ per month</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Servicing / maintenance</td>
<td>29</td>
<td>28</td>
<td>25</td>
<td>25</td>
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<td>31</td>
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<td>10</td>
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<td>Battery leasing</td>
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<td>0</td>
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<td>Total mandatory costs</td>
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<td>375</td>
<td>424</td>
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<td>Depreciation cost per year</td>
<td>4,500</td>
<td>5,088</td>
<td>5,124</td>
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<td>Depreciation cost over 3 years</td>
<td>13,500</td>
<td>15,264</td>
<td>15,372</td>
<td>9,225</td>
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<tr>
<td>Expected residual value (10,000m, 3yrs)</td>
<td>9,595</td>
<td>10,795</td>
<td>9,618</td>
<td>5,775</td>
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<td>Expected residual value (15,000m, 3yrs)</td>
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<td>10,009</td>
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<td>21528.00</td>
<td>20232.00</td>
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<td><strong>Additional costs</strong></td>
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<td>Infrastructure</td>
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<td>700</td>
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<td>Pence per mile (10,000 miles)</td>
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<td>Pence per mile (15,000 miles)</td>
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<td>0.97</td>
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<td>For contract hire per month per vehicle:</td>
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<td></td>
<td></td>
<td></td>
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<td>Contract hire finance</td>
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<td>332</td>
<td>355</td>
<td>355</td>
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<tr>
<td>National insurance contributions</td>
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<td>26</td>
<td>0</td>
<td>0</td>
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<tr>
<td><strong>Total additional costs</strong></td>
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<td>358</td>
<td>355</td>
<td>355</td>
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<tr>
<td><strong>TOTAL COSTS over 3 years</strong></td>
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<td>34416.00</td>
<td>33712.00</td>
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<td><strong>TOTAL COSTS per annum</strong></td>
<td>11736.00</td>
<td>11472.00</td>
<td>11704.00</td>
<td>10495.00</td>
</tr>
<tr>
<td>Pence per mile (10,000 miles)</td>
<td>1.17</td>
<td>1.15</td>
<td>1.17</td>
<td>1.05</td>
</tr>
<tr>
<td>Pence per mile (15,000 miles)</td>
<td>1.23</td>
<td>1.41</td>
<td>1.48</td>
<td>1.04</td>
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<td>0.99</td>
<td>1.13</td>
<td>1.18</td>
<td>0.83</td>
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<td><strong>As a company car:</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benefit in kind personal tax</td>
<td>47</td>
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<td>0</td>
<td>0</td>
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<td>41</td>
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<td>71</td>
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<td>0</td>
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<tr>
<td><strong>TOTAL COSTS over 3 years</strong></td>
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<td>24084.00</td>
<td>20932.00</td>
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<tr>
<td><strong>TOTAL COSTS per annum</strong></td>
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<td>8028.00</td>
<td>7444.00</td>
<td>6235.00</td>
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<tr>
<td>Pence per mile (10,000 miles)</td>
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<td>0.96</td>
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Figure 7 highlights the opportunity of alternative business models opposed to traditional outright purchase. Traditionally consumers within the UK possess the desire to fully own assets, although it may not be the most economic form of ownership. In the case of Renault’s model of battery leasing, the competitive pricing results in a strong financial case. However the Nissan Leaf has the highest rate of depreciation highlighting the difficulty for EVs to compete within an already established and historically dominant market. It is therefore arguable that as a prerequisite of market transformation the financial models of vehicles should be re-evaluated to encourage a change in consumer approach to ownership. This is particularly relevant within the private/residential market rather than within fleets as leasing and contract hire ownership models are common approaches for commercial applications. According to Accenture, leasing the battery assists in making EVs more affordable by reducing the high initial purchase price (Accenture, 2010). This is clear in Figure 7 as the anticipated price of the Renault Zoe (due for
launch Autumn 2012) is £15,000 (after subsidy). This enables EVs to begin to compete directly with ICE vehicles as despite higher costs per month, the considerably lower purchase price makes the EV significantly cheaper compared to all vehicles in all scenarios.

Within the TCO analysis the cost of charging infrastructure has been included for the electric vehicles, however this consists of one wall mounted charger. This is the most basic charger available and would take approximately six - eight hours to charge an electric vehicle. Although this is plausible for an individual driving less than 100 miles a day, drivers extending beyond the vehicle's capabilities or instances in which there are multiple drivers such as fleets, the charging would not be sufficient. Raising the specification of the charging infrastructure and therefore the associated costs would be detrimental to the EV TCO. However it is arguable that this TCO does not include the cost of re-fuelling infrastructure for ICE vehicles and therefore should not take account of any EV charging infrastructure. However including one wall mounted charger suggests less bias to the EV business case and highlights the advantage of the existing market.

It can be seen within Figure 7 that all vehicle types (especially the Nissan Leaf) are most expensive when 15,000 miles per annum is performed. In such an instance fuel/electricity prices do not achieve maximum efficiency against the cost of servicing and maintenance of the vehicles. Whereas at 10,000 miles travelled per year costs are maintained at a minimal level which appears to vastly benefit the TCO for the electric vehicles. The only exception is within a fleet scenario when interestingly the Renault Zoe is most expensive when driven 10,000 miles per year. In contrast, at 20,000 miles, efficiency gains are achieved for the Ford Focus resulting in a strong financial incentive for consumers to remain using traditional modes of transport. Interestingly, although the Toyota Prius has the highest purchase price within the TCO analysis, in no instances is the vehicle the most expensive to operate. With unlimited range and without the need for charging infrastructure resulting in cost efficiencies, the Prius has the opportunity to ease low carbon transformation.

The concluding sections of the TCO explore the costs for a vehicle within a fleet scenario as well as for use as a company car. For a fleet the contract hire is based on a non-maintained contract for 10,000 miles per annum. Companies that procure vehicles through contract hire have the opportunity to make considerably savings through the battery leasing model. This is especially the case when the vehicles are extending their mile range to 20,000 miles per year as the payback rate is quicker. Furthermore this would not require a behavioural change or market acceptance as it fits within their existing model of vehicle finance. Alternatively the TCO highlights the cost parity between the Ford Focus and the Nissan Leaf at 10,000 miles per annum, this is exceptionally encouraging for the EV market. This however is not the case when mileage increases as the Nissan Leaf becomes the least competitive whilst the Ford Focus rises in efficiency.

Analysing the TCO for these vehicles as company cars (company tax rate 20%) highlights the advantage of the electric vehicles as the exclusion from benefit in kind taxes results in the EVs being the most competitive choice for company cars within the lowest mileage. The Renault Zoe remains most competitive across all mileages, again due to the low purchase price resulting from leasing the battery. Although the Ford Focus has the greatest TCO at 10,000 miles due to the associated taxes, interestingly as
the annual mileage increases the Ford Focus becomes more competitive than the Toyota Prius and the Nissan Leaf. Arguably this is due to the lower depreciation value of the Focus.

6.3 Reflection:

Having completed the first six months of the project the researcher has been able to reflect upon the experience thus far. The initial month at Schneider Electric was extremely revealing as the researcher spent this time visiting various entities of the business. This enabled an understanding of the organisation to be gained and aided in contextualising the business of EV charging solutions within the company. This led the researcher to focus strongly on the industry sponsor and less so on the academic demands. As a result ambiguity lay in the project and therefore resulted in a strong lack of direction. This was particularly difficult for the researcher as their role within the organisation as well as the research felt indefinable. This delayed concrete research outcomes to be produced highlighting the future need for the researcher to communicate with the project supervisors on a regular basis. Forming research questions improved the communication between the researcher and the supervisors as it became clear the researcher was struggling.

Initially the researcher attempted to incorporate a wide spectrum of factors that were too ambitious for the project brief and time frame. Consequently it became evident the project should focus upon key research topics in order to achieve an in-depth analysis, contributing significantly to knowledge. At this point the project established direction and enabled the researcher to consider the future approach necessary.

Analysing the motivations and challenges to EV fleet adoption was an ideal area to explore as it highlighted the current market understanding of electric vehicles. However the market research that accompanied this was not particularly conducive for the project. In contrast the total cost of ownership analysis was a considerable outcome that highlighted further areas for research and raised significant questions to be considered. For the remaining research it is imperative that the researcher continues to critically analyse the results found and the assumptions made either within society, the market and/or the industry.

7. Path dependency:

Having explored the total cost of ownership along with the motivations and barriers of EV adoption it led the researcher to question the constraining factors that are limiting EV market penetration. Within recent years the instability of oil prices and rising concerns upon climate change has increased governance and influenced consumer choice of vehicle. Consequently the auto manufacturers have responded to the demand, all be it low, and introduced new vehicle/fuel technologies (European Commission, 2003). Across the spectrum of alternatively fuelled vehicles it is thought HEVs have a “transitional role...in the sequence of technology adoption” as the vehicles reduce perceived risks associated with AFVs (Collantes, 2007 p.270). The introduction of the Toyota Prius in 1997 is argued to have increased versatility and flexibility within the market through unlocking the historical market of restricted designs and specifications (Ahman et al, 2007). Arguably such vehicles as the PHEV have better
long term social benefits in terms of greater efficiency and lower emissions compared to an equivalent ICE vehicle, yet these vehicles have struggled to gain market share. Cowan et al (2012 p.4) states “it is not enough that the competing technology is better...to overcome lock-in it is necessary that some extraordinary events occur”. He continues that these could be via regulation, scientific breakthrough, technological breakthrough, creation of niche markets, changes in taste and/or a crisis in the existing technology (Cowan et al, 2012). Regarding the electric vehicle market, there is not currently a crisis in existing technology and in fact ICE vehicles are technologically improving, competing heavily on efficiency and emission levels. Secondly, electric vehicles have essentially not improved technologically since the early twentieth century (Hoyer, 2007). However, regulation regarding emissions from businesses and the associated carbon credits has enhanced the business case for EVs whilst only early adopters have begun to utilise PEVs. A key aspect of electrification of transport is consumer acceptance as within many cultures vehicles are considered as status symbols. According to the Journal of Personality and Social Psychology, alternative fuelled vehicles are challenging traditional status allegiance with luxury vehicles despite the sacrifice of performance (Griskevicius, 2009). It does however raise the question whether there is a ‘generation lock-in’ in which certain age cohorts are more or less responsive to technological development. Within Cenex’s Smart Move Trail in which up to four EVs were integrated for six months within ten different fleets, it would suggest this is the case. Figure 6 highlights “83% of fleet users in their twenties felt more positive about electric vehicles after the trial, compared with a 25% opinion shift for users in their sixties” (Cenex, 2010 p.14). Unfortunately it is the ‘baby boom’ generation that are most likely to be able to afford electric vehicles at the current high prices prior to economies of scale being achieved but it would appear these individuals are impervious to the creative destruction.

Figure 6: Fleet users attitudes by age

![Users attitude towards EVs after the trial, by age group](source: Cenex, 2010)

Humankind’s perception of undesirable change intensifies preconceived notions to transport and impacts the pathway to new technology. Path dependence shapes current and future technological choices due to
preceding conditions and market developments. 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). However “if EVs are to be the agents of change that allow a significant reduction in CO2 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). This seems to be integral to the future of a low carbon world as although the premise of transport consumes fuel, creative destruction can challenge this as AFVs present an opportunity to positively alter the energy mix; this however requires the social norms to modernise (Schumpeter, 1942). At present Government incentives and regulations relating to emissions have been key catalysts in beginning to unlock ICE vehicle dominance within the market. Utilisation of electric vehicles is still minimal and it could therefore be questioned whether previous attempts to encourage electrification of transport has damaged the perception of EVs and therefore the potential market. Secondly, with such strong evidence of path dependency within the automotive industry, the characteristics which dominate the market should be analysed in order to establish the aspects of electric vehicles and electric vehicle charging that challenges the transformation. Additionally with the Plugged-in Places scheme in which businesses and public sector partners across eight locations in the UK are eligible for match-funding to encourage the installation of EV charging infrastructure, there is the possibility it could result in regional lock-in. For success the market requires open path creation across the UK but if other locations fail to enable a positive pathway the market may struggle to be nationalised (Martin, 2009). Therefore further research is required to analyse the lock-in potential electric vehicles will encounter within the automotive industry and in the wider context of society.

8. **Problem statement**

The UK is committed to decrease greenhouse gas emissions by 50% by 2025 on the 1990 baseline. The need to dramatically decarbonise and ensure a clean energy portfolio presents various challenges and opportunities. The transport sector accounts for nearly 40% of all UK energy consumption, 97% of which is the direct use of petroleum (DfT, 2010, IME, 2010). Road transport alone accounts for 22% of total UK emissions of carbon dioxide (EnvironmentalProtectionUK, 2012). Such figures suggest there are several opportunities to decarbonise the transport sector and gain oil independence, one of the greatest considered available is the electrification of transport. Although there is speculation upon the life time environmental impacts of electric vehicles, the UK Government (as well as Governments across the globe) is in full support of EVs as policy makers appreciate the need and difficulty of reducing greenhouse gas emissions. Optimisation of electric vehicles will however require a transformation of driver perceptions and expectations of vehicles, financing models and the integration of smart technologies; as well as having a large impact upon various affiliated markets. At present the EV market is facing dominating competition from ICE vehicles which is currently suppressing creative destruction (Schumpeter, 1942). There has been a wide range of plug-in vehicle forecasts as seen in Figure 5, the graph highlights an extensive difference in expected sales as time progresses. Even the higher expected rate of adoption in 2020 at 12% is relatively minimal within the automotive industry. Currently with the challenges of a new
market forming within a well established industry has resulted in the lower predictions of vehicles sold having been met. If this pattern continues Figure 5 suggests only 2% of new car sales will be plug-in vehicles in 2020. However in order for the UK to achieve the necessary carbon reduction targets the number of EVs utilised has to dramatically increase over the next decade, but how will this be achieved? The current level of EV utilisation is significantly below projected rates of adoption, the total number of EVs in the UK is 2,149 out of 28.5 million vehicles on the road (Siegle, 2012). There is a plethora of contributing factors to the slow take up of electric vehicles including costs and range, however existing research fails to significantly explore the issue of consumer readiness for EVs. Due to the robust history of ICE vehicles and the economic and marketing power of the automotive industry, social norms have been heavily installed within mankind’s expectations of the development of vehicles. Many aspects of electric vehicles challenge our mentality of transport and therefore require behavioural change; this is particularly difficult whilst ICEs remain so competitive and dominant within society. This is intensified as the UK is lacking interoperability amongst charging infrastructure, resulting in EV drivers having to register with many different schemes and providers if national mobility is required.

Figure 7: EV up-take forecasts

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

Secondly, the requirement for mass EV adoption requires access to charging infrastructure, either at residual properties, within public spaces or at work premises. Originally the Government believed charging infrastructure was a prerequisite to EV sales to reduce ‘range anxiety’ and stimulate the market. However it is questionable whether this is the case; it is suggested within the Office of Low Emission Vehicle’s (OLEV) Electric Vehicle Infrastructure Strategy (2011) to in fact be reliant upon private installations. However within the current UK economy it is recognised that this could be constrained
through lack of finance. Technological developments within charging infrastructure and battery manufacturing are integral to the sustained progression of the EV market. Enhancements in range, speed of charging and SMART integrated capabilities will vastly improve competitive positioning for EVs within the automotive industry. The challenge of this is largely economic rather than technologically difficult, especially amongst industry pressure for standardisation globally.

At present Government incentives and regulations have been highly instrumental to the progression of the EV market thus far; however it could be questioned if the right approach has been adopted to encourage vehicle transformation. The automotive industry is constrained by existing path dependant characteristics resulting in technological lock-in that may be negatively influencing the direction of the EV market. The lock-in electric vehicles encounters within the automotive industry and in the wider context of society could be heightened by the PiP scheme as it may reduce open path creation. Additionally, despite Government investment EVs remain more expensive than ICE vehicles. This is likely to restrict the fleets that will adopt the vehicles in the near term as it is currently difficult to prove a strong economic case. This is intensified for private individuals as not only are high levels of disposal income required (for outright purchase or leasing) but in most instances areas in which charging infrastructure can be installed, namely driveways are required.

9. **Research questions:**

The aim of the research is to understand how electric vehicles can break through current technological lock-in and development blocks in order to create new pathways for smart integrated technologies. The following research questions have been formed in order to analyse the challenges that the EV market are faced with, this will enable recommendations to be made addressing ease of market acceptance. This research aims to clarify whether path dependency threatens mass EV adoption and to analyse the lock-in electric vehicles are experiencing within the UK as well as potential future risks. The questions have been constructed alongside the interests of Schneider Electric as addressing such issues will enhance applicable market knowledge and therefore aid the development of the Schneider EV strategy. In order to address these questions they shall be broken down in to sub questions.

<table>
<thead>
<tr>
<th>Research questions</th>
<th>Sub questions</th>
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| What are the psychological, cultural and habitual changes necessary for consumers to fully integrate EVs? | • Within a fleet what change is required within the decision making process and the drivers application to ease EV adoption?  
• What challenges can be overcome through behavioural change rather than technological developments or regulative enforcement?  
• How effective are the various energy tariffs/commercial models in influencing charging behaviour?  
• What is the fleet perspective upon Schneider’s |
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
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| To what extent is technological, regional and generational lock-in restricting the EV market? | • How can Schneider Electric assist in preventing technological, regional and/or generational lock-in?  
• To what extent is the Plugged-in Places scheme encouraging lock-in or will it stimulate open path creation?  
• How do demographics of fleet managers/influencers affect diffusion of technology? |
| What opportunity does intelligent EV charging infrastructure have to extend the pathway of smart technologies to wider stakeholder groups? | • Within UK fleets what is the level of understanding regarding electric vehicles and smart grid capabilities? How could this be improved?  
• What are the dominant path dependent characteristics within the automotive industry that challenge the utilisation of electric vehicles and electric vehicle charging? How should the concept of mobility be developed? |

10. **Methodology:**

In order to achieve the research aims of this project three fleets that either already have EVs or fleets that are considering utilising EVs will need to be strongly incorporated into the research design. This is integral to the project as it will enable an exploration of motivations, challenges, behavioural change and expectations to be analysed. The researcher will attempt to work with a fleet that is considering EVs as this will enable a thorough analysis of the process that a fleet undergoes when integrating new vehicles. A questionnaire will be created to gain an understanding of the driver’s attitudes towards electric vehicles prior to EV integration, within the first week of utilisation, after a month and again after three months. It will also examine what vehicle characteristics drivers expect from a vehicle, the drivers will score these in importance and at the incremental stages these will be re-evaluated. Additionally if the fleet allows, ideally 50% of the drivers would be given EV training before using the EVs and 50% would receive training after initial EV integration. This would indicate how essential driver training is in terms of vehicle acceptance and behaviour change.

In contrast, analysing a fleet that contains EVs within their vehicle composition already will establish how the fleet has adapted over the period of time EVs have been used. The success of EV integration can
be assessed and compared against other fleets in attempts to understand how effective incentives are to change driver behaviour as well as recognising which habits were/are incompatible to EVs and the most difficult to change. Ideally interviews will be conducted with the fleet managers/influencers in order to distinguish the future direction of the fleet to see how effective they believe the EVs have been within the certain applications.

To explore the level of understanding within fleets regarding AFVs, smart technologies and more generally climate change, at least three fleets would be required to see if there was any correlation between knowledge of such factors and the utilisation of EVs. Therefore drivers and fleet managers of a fleet with electric vehicles, a fleet considering electric vehicles and fleet with no intention of adopting electric vehicles will be questioned on their awareness. This would hopefully provide an insight into how to weaken path dependencies of traditional forms of high emitting modes of transport. Widening the population group of participants to UK members of a car club using a simple random sampling technique would identify the expectations of the public of mobility as well as electro-mobility. The investigation would identify the level of understanding about electric vehicles and electric vehicle charging as opposed to the misconceptions held within society.

Exploring the impact the Plugged-in Places (PiP) scheme has upon the nations projected rate of EV adoption will require data regarding the total number of EVs sold under the Plug-in Car/Van Grant. Assembling such data will infer if there is any correlation between incentives, government and private investment and demographics of customers. This information can then be analysed to establish whether regional and generational lock-in is present within the market and if this is likely to be a restricting factor for opening path creation. Although the statistics for the EV sales within the PiP locations will be a central premise for this investigation, the EV sales across the rest of the UK will be extremely revealing to the regional ‘make-up’ of EV adoption, for both fleet and residential uses.
Figure 8: A pictorial adaptation of the methodology illustrates how the three aspects of the project interlink

11. **Planned activity:**

For the next six months the following steps shall be initiated in order to collect and analyse the necessary data for the first part of the research project.

Figure 9: Project management Gantt chart – stage 1
The Gantt chart above refers to the investigation in which three fleets will be provided with questionnaires (to the drivers and fleet managers) and key individuals will be interviewed. This will highlight the motivations, challenges, behavioural changes undergone and/or expected to take place. Also included within the Gantt chart are University modules, identified within brackets.

The following Gantt chart illustrates the final stages of the first project that will consume another six month period. Within this chart there is a four week interlude that remains open; this is due to the third questionnaire not being distributed until three months subsequent to the first questionnaire. In this time the following project will begin and will therefore be illustrated within Figure 11.

Figure 10 – Project management Gantt chart – stage 2

The third Gantt chart illustrates key tasks for the remainder of the project, this provides an overview of a timeframe for both research and remaining modules.

Figure 11: Project management Gantt chart – 30 months
This shall be continuously reassessed throughout the research project to ensure it is the most suitable approach to provide considerable knowledge regarding the research questions. Within the second six month report the research achievements will be discussed and analysed as well as a focus upon the subsequent stages of the project.
References:


Cenex (2010) *The Smart Move Trial.* [Online] Available at: http://www.cenex.co.uk/LinkClick.aspx?fileticket=yUKAcRDJtWg%3D&tabid=60 (Accessed on 28.01.12)


Introduction

Transportation is the fastest growing major contributor to climate change within the UK. Road transport accounts for over 90% of domestic transport emissions and demands over 50% of UK oil consumption (Reuters, 2011, OLEV, 2011, ITPOES, 2010). Reducing energy demand from road transport is a vital component to reach the UK commitment of a 50% reduction in greenhouse gases by 2025 on the 1990 baseline levels (drdni, 2010). An opportunity to drastically reduce these figures and decarbonise road transport is through vehicle electrification. It is suggested that electric vehicles (EVs) could reduce fossil fuel use by 80% by 2030 and save the UK up to £8.5 billion per year by 2030 in avoided fuel imports (AEA, 2009, WWF, 2011). It is argued that electric fleet procurement is the most logical beginning for market transformation as fleet vehicles comprise of over half of all vehicles sold in the UK (SMMT, 2011).

It is predicted that by 2015 there will be 1.3 million electric vehicles within fleets, however it is speculated whether this will materialise within the current market despite the millions invested by the Government and manufacturers (PikeResearch, 2011).

This report will analyse the motivations and barriers of EV fleet adoption and will consider the weighting, impact and mitigation options of the contributing factors to rationalise the severity of the challenge and/or stimulus. To conclude the report it will propose strategic direction for companies within the EV market, as well as recommendations for the wider context of market penetration. As a result research questions will be formed to focus the objectives of further research.

Motivations

There are numerous motivations for EV adoption within fleets, these shall be discussed below:

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 behaviour is ideal for electric vehicle use and can assist faster payback (PikeResearch, 2011). Having managed known activities is considered by the Electrification Coalition as “among the more important characteristics that could facilitate uptake of grid-enabled vehicles in fleet applications” (ElectrificationCoalition, 2010 p.59, CAR, 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. 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 (Markel, 2010).

It is suggested there is a surprising lack of knowledge across fleets upon their own operations, for instance average CO2 emissions, annual mileage and fleet budgets are not always known characteristics (Briers, 2010). Not only does this prohibit the efficiency of a ‘traditional’ fleet but the integration and
optimisation of electric vehicles. This highlights the need for education regarding both the importance of vehicle management as well as the opportunity of electric vehicles. It is suggested the operational requirements of a fleet enables an average of 20% of the vehicles to be electrified, however it is proposed that 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).

**Corporate Social Responsibility**

Researching the contribution corporate social responsibility (CSR) has had upon the existing adoption of electric vehicles suggests it is a key aspect of a fleet’s decision matrix. Firstly, 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 (LeasePlan, 2010). The Electrification Coalition (2010) document highlights engaging fleet managers with corporate sustainability initiatives can benefit brand identity, investments and employee and consumer loyalty. Additionally, Deloitte Car Consulting pledge that electric vehicles will soon become the dominant vehicle type within fleets, due to the associated positive impact EVs have on market perception (Leasedrive, 2011). It could be argued that moving in a direction that is likely to be a legal requirement in the future ahead of competitors in an area considered socially responsible is a valid reason for UK businesses to adopt EVs within their fleets. For these reason companies may be willing to purchase EVs despite a contentious financial case in which some argue EVs are less economical than ICE vehicles (IndianaUniversity, 2011). As there was approximately 1000 EVs sold in 2011, a procurement of electric vehicles for fleet use would attain considerable media attention across mainstream avenues as well as specialised industry platforms. Additionally fleet managers must be made aware it is likely to benefit CSR sustainability agendas through a reduction of carbon emissions and an image of progression and consciousness of climate change to stakeholders. Therefore extending beyond the fleet manager it broadens the justifiability of electric vehicles to management, boards etc.

**Economics of an electric vehicle**

To encourage the uptake of electric vehicles the Government introduced the Plug-In Car Grant in which electric car buyers are subsidised up to £5,000 (25% of the vehicle cost). The ceasing of funding has been extended from March 2012 to 2015 and now includes a Plug-In Van Grant, reducing the cost of eligible vans by 20% up to the value of £8,000 (FleetNews, 2012). Despite this EVs are currently up to three times more expensive than an equivalent ICE vehicle thus exaggerating the need to investigate the life time costs. However electric vehicles have comparably low fuel and maintenance costs that can counter act the high initial purchase price (IndianaUniversity, 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 compared to the petrol equivalent costing £17.16. Cost per mile for
EVs (all models) vary depending on the literature source and can fluctuate between 0.3p per mile and 3p per mile, this variant is quite significant and would impact the TCO noticeably. Even at 3p per mile it is approximately 64% cheaper than a mid range hatchback costing 14p per mile, however the high purchase price of EV makes the financial case less appealing. In an attempt to reduce the relatively high costs of an EV, Renault has initiated battery leasing by which customers buy the vehicle but lease the battery at approximately £70 a month. Although this was contentious at first it is suspected to provide lower TCO, improve the residual value and remove the expense of battery replacement. In the instance of the Nissan Leaf, Glass Guide (2011) published that the cost of the vehicle which includes the battery retains 35% of its value at a utilisation rate of 36,000 miles over three years, equating to 49p per mile. This is comparable to an EV with a leased battery over the same period of time and mileage, yet 54% of the vehicles value is retained, at a cost of 33p per mile and a saving of approximately £6,000 (GlassGuide, 2011). This equates to the overall depreciation costs over three years for the Nissan Leaf at £16,765, a range-extender at £16,570 and an EV with a leased battery at £8,275; for a similar diesel vehicle the average depreciation over three years would be £9,750 (GlassGuide, 2011). This highlights the economic advantages of purchasing an EV with a leased battery. Such figures are particularly attractive to fleet users as historically vehicles are purchased through contract hire or on finance; therefore the behaviour traits are similar and the psychology behind transforming to lower carbon vehicles is conceptually easier. This is true against that of the majority of private customers who purchase vehicles outright and will find the notion of leasing more difficult to adjust to. Furthermore, it is debateable whether charging infrastructure should be included within the TCO of electric vehicles as petrol re-fuelling stations are not considered within the financial case of an ICE vehicle. However it is possible that customers will be spending 50% more on charging infrastructure which could be increased further through required energy management solutions. Consequently the financial case may not be attractive and the alternative benefits will be of great importance.

Financial opportunities

There are various financial opportunities that should be highlighted to fleets considering EVs as they can further enhance the economic case of electric vehicles, 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 CO2 at the point of sale.
- Further opportunities lie in 5% benefit in kind for company cars that emit below 75g/km CO2, whilst EVs are exempt from company car tax entirely for five years.
- 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)
• 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 £2,278 a year for fleet vehicles.

• The Plugged-in Places (PiP) locations (London, Milton Keynes, Manchester, Newcastle, East of England, Midlands, N.Ireland, Scotland) have free/reduced priced parking for electric vehicles. This however is not standardised within the country and can require individual permits to be obtained.

• Furthermore the PiP locations have charging facilities attractively priced i.e. In London, £10 is charged for one year of unlimited charging. Although this will likely benefit the overall market, it does not necessarily bare relevance to fleets as the public infrastructure are slow chargers and are not ideally located for fleet use.

• Additionally fleets should consider the financial opportunity of allowing the 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 electricity, 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, approximately a 66% profit. Consequently the cost of infrastructure becomes more attractive and the need for energy management is more important.

Infrastructure

In the current market charging infrastructure has been developed to stimulate interest across a wide audience and to provide tangible evidence and confidence in the new market. This is not ideal for UK fleet use as potentially large vehicle numbers and limited time to charge will not benefit from the slow publicly accessible charging infrastructure currently available. 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 due to typical fleet behaviour (discussed above), the barrier is likely to be the upfront costs and behavioural change required, rather than the actual requirement to charge. However additional research suggests the advantage of fleets is that the infrastructure costs can be relatively low as the approach is targeted and the location, volume and energy requirement is known. Furthermore, fleets that utilise centralised depots could benefit from optimised battery management, economies of scale of multiple chargers in individual facilities and the independence from public charging infrastructure. Regarding fleets there may be considerable benefits from installing quick chargers to gain from efficiency but if the vehicle is parked over night or for a significant length of time, more cost effective options are available through lower cost units. This is only a relevant discussion whilst battery capacity is limited at the price at which they are currently attached to the vehicle. Furthermore over time it is questionable as fleet managers (and private consumers) gain a better understanding of the vehicles’ drive
cycles and drivers adapt their driving behaviour, whether publicly accessible infrastructure will become redundant.

Across the charging infrastructure market there is a range of products and solutions that fleets will need to gain an understanding of to discover what best suits their operations. It is likely that each fleet will have bespoke requirements in terms of products but also the level of engagement fleet managers/drivers will demand. Converting to electric transportation is expected to challenge human nature's prohibition to change and therefore in some cases customers may need to be educated at a quite basic level. Generally it is important that fleets appreciate that infrastructure can be used as a cost effective method to increase the productivity of a business in the longer term. In utilising EV fleets would be required to analyse their operations and establish the number of chargers required with the necessary power and level of energy management necessary. In instances in which vehicles within a fleet travel in excess of the battery capacity it could be suggested that the vehicle could be replaced with either plug-in hybrids or range-extended vehicles. Alternatively businesses could consider installing fast chargers along frequently travelled routes, this would bare large upfront expense unless partnerships were formed with other businesses or intangible benefits were considered.

**Sweet spots & change of utility**

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 electric vehicles 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 a sweet spot of mileage; 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 EV use 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 plan 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 market.

To enhance EV integration vehicles should not be immediately procured at the same specification as existing combustion engine vehicles (ICE) 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 it is proposed that 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 with EVs as introducing the vehicles to their drivers will be considerably easier if the transformation ‘fits’.

**Energy use**

The transport sector accounts for 50% of the oil demand in the UK however it is becoming increasingly difficult in engineering terms to extract oil which is being reflected in the price (SilverSpring, 2011). Electricity offers many competitive properties as a transport fuel compared to that of gasoline. The low cost of electricity available to businesses and the highly efficient vehicles result in extremely low fuel costs. With British utilities offering off-peak energy tariffs in which discounted rates of electricity apply for night time charging, it not only helps to balance the grid but it could be possible to save up to £1,200 per vehicle per year (Conway, 2011). However fleets may not be able to absorb this entire saving as fast charging may be required in the day at higher rates if vehicles travel in excess of 100 miles a day. A current barrier regarding electrification of transport is the carbon intensity from well-to-wheel. Although it is argued that “electric and hybrid cars create more carbon emissions during their production than standard vehicles” (Covington, 2011 p.1), 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. 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 emissions by up to 85% compared to the baseline of no action being taken (McKinsey, 2009).

Electric vehicles are a contentious issue in regards to the impact upon the national grid. Literature supporting EV adoption suggests the increase in energy demand will be minimal, suggesting by 2020 EVs will have only contributed an additional demand of 1.5% (WWF, 2011). Whereas other sources address the sensitive need to balance the grid as “even low levels of EV adoption can have significant impact on a utility and its network”, even to the extent at which peak demand would be jeopardised (SilverSpring, 2010 p.2, England, 2011). Automakers and charging infrastructure providers are encouraged to notify utilities of new charging infrastructure and estimate the predicted impact on demand to monitor necessary upgrades to the electricity grid and manage bottlenecks of stability, security and supply and demand (CPEVC, 2010). The energy demanded across a business can be managed remotely and integrated with the demands of energy suppliers. This highlights the opportunity for businesses to create a revenue stream from selling energy back to the suppliers at critical times of demand throughout the day.

**Barriers**

As Figure 1 highlights there are various barriers considered to be prevalent within the EV market preventing fleet integration, these shall discussed below:
Costs

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). The existing literature on the costs of an electric vehicle considers the high purchase price to be associated with the battery. However, the leasing model that Renault introduced in which the battery is leased assists in making EVs more affordable by reducing the high initial purchase price (Accenture, 2010, AutomotiveIndustryDigest, 2011). Optimistically, literature suggests as the volume of production rises and market knowledge of battery materials and design and manufacturing expertise increases, battery technology will advance and reduce in price (ElectrificationCoalition, 2010, BCG, 2010). However, approximately 25% of the battery cost will remain independent of economies of scale due to raw material use (BCG, 2010). High initial costs of electric vehicle mobility are also due to charging infrastructure, unlike private drivers who may use (ill-advised due to inefficiency and safety concerns) the conventional 13A plug that is provided with the car, fleets are very unlikely to operate in such a way and therefore require charging infrastructure. The cost of charging infrastructure can vary dramatically depending on the supplier, quality, power and capabilities of the equipment, ranging from £400 - £30,000. Analysing the Office of Low Emission Vehicle’s (OLEV) Electric Vehicle Infrastructure Strategy (2011), the Government suggest the growth of charging infrastructure is reliant on private investment. This is a positive outcome for fleet applications as the support provided by the Government
will be that much greater as a result. However, it is recognised that this could be constrained through lack of finance especially in such stringent economic times, 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”.

Further challenges are discussed within literature regarding the cost of the vehicle at the point of re-sale. The importance of residual values in fleet procurement is agreed upon within literature, especially within the new and unknown market of EVs. It is argued the lack of market experience, particularly relating to the long term cycle performance of a battery is hindering market developments (Electrification Coalition, 2010). There is a consensus that there is a great deal of unknowns surrounding residual values and the total cost of ownership within the emerging industry, although Ernst & Young (2011) argue that the previous five years has enabled residual values to be monitored and support comprehensive TCO analysis (Garthwaite, 2010). Assurance will come as the market develops and the second hand market is formed, this is likely to take several years to develop as a result of fleet investment, however widespread fleet integration and public adoption will subsequently increase.

**Total cost of ownership**

The viability of an electric vehicle in terms of cost parity is currently questionable as the total cost of ownership (TCO) model employed for vehicle cost analysis is widely speculated. 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 entirely conditional. This is explored via a TCO analysis conducted by Cenex which compares a Smart 4-2 coupe Diesel 40kw engine (0.8l) and a Smart ED 4-2 coupe 30kw electric motor (assumptions can be found in Appendix 1a). Following the Artemis Urban and Road drive cycle it was calculated using the Fleet Carbon Reduction Tool that in both instances the EV was more expensive (see Figure 2).
As the graph highlights costs are reduced over time, in some territories such as USA, fleet ownership can extend up to 9 years however in the UK the average is approximately 4 years. This current fleet behaviour in the UK limits the cost parity of an EV with an ICE vehicle due to the inability to gain sufficient fuel savings to offset the high purchase price of an EV.

TCO is largely dependent on the price of fuel, Figure 3 highlights possible outcomes within certain scenarios. This is based upon the same vehicles used within Cenex’s TCO analysis but solely using the Artemis Urban drive cycle, consisting of 100% town driving with max speed of 58kph and an average speed of 18kph (Cenex, pers. comms., 2011). 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 even compared to the efficient Smart Diesel.
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. However, this does not address the current challenge of TCO unless the average fleet vehicle life dramatically extends whilst maintaining a sweet spot of mileage to ensure maintenance/servicing costs are minimal. In such instances the concerns may be that technological advances considerably over the extended leasing period and efficiency gains are lost. This would suggest that within the UK EVs are not currently a strategic business decision unless early adopters of the market can find value in something other than the numbers i.e. value in a green image and kudos. It is possible that the cost can be quantified through the marketing/CSR budget in which a premium is paid for the vehicle as it based on green credentials. 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. Therefore currently the purchase price may not be a major obstacle due to the intangible benefits. However, it is questionable whether the relationship between CSR and the media could actually limit the growth of the fleet market. 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 proportion of EVs within the Tesco fleet is very small but from a marketing perspective 15 EVs were deemed sufficient to attain significant media attention and PR value. However for it to have a considerable impact upon the market a larger proportion of their fleet needs to have been electrified,
yet this will not provide additional value as despite potentially higher credibility, Tesco would be unlikely to get more media coverage. This highlights the focus on marketing value and the calculation of added value through intangible benefits.

It is argued the TCO of EVs is struggling to compete with ICE vehicles because the industry believes we should do the modelling on a total cost of ownership virtually like for like comparison which is incredibly harsh with strong hard financial barriers. Arguably the current focus needs to be on the intangible benefits and low operating costs as alternatively there would not be a market for the vehicles and consequently nor the chargers. Although a poor TCO is known amongst the industry and within fleets, EVs present the opportunity to ‘future proof’ businesses from the risks of peak oil and regulative legislation and penalty chargers. As a result businesses are likely to consider the integration of EVs within fleets as a risk averse strategy that has slightly more substance than a ‘green wash’ approach, financial and managing directors may then see the value more clearly. As there is a wide range of total costs within the automotive industry this research intends to produce a TCO comparison between an ICE vehicle, an EV and a hybrid vehicle. It will be based upon the assumptions of an EV and will perform sensitivity analysis upon 10,000, 15,000 and 20,000 miles to analyse the impact of extending mileage.

**Battery technology**

There is extensive analysis upon the current battery technology as “energy storage remains a key barrier to the viability of electric vehicles” (Kromer et al, 2007 p.30). The energy density of current lithium-ion batteries is only 1% that of gasoline and is therefore regarded within the industry as the largest barrier for rapid EV deployment (DIW, 2010, Cenex, 2010). Literature discusses the difficulties the limited battery capacity can place upon fleet applications as it restricts the range and speed of charging (SilverSpring, 2010). As a result it is a common concern that vehicle availability could be questioned, capital expenditure could rise and/or there could be a failure to operate the businesses transportation network (IntelligentEnergy, 2011). Consequently, while battery capacity and driving range are increased plug-in hybrids have the potential to serve as a transition technology (Accenture, 2011). However, the German Institute for Economic Research highlight the advantages of battery capacity restrictions (DIW, 2010). They argue the restrictions ensure EVs are light-weight and are therefore more efficient, a positive element for “specific market niches” (DIW, 2010 p.209). An alternative and holistic approach to better utilise the vehicle capacity is presented in the Sustainability and Innovation Working Paper, it suggests that “fleets exploit the strategy of extending the user base at the lower operating costs of electric cars” in order to spread the capital costs (Lerch et al, 2010 p.1). However it could be suggested that battery capacity is not necessarily a barrier for fleets as often fleets perform low daily mileage. It is suggested that the challenge of the battery capacity requires fleets to understand exactly what the operational requirements are and tailor adequately. However if the battery capacity was greater, EVs would suit a larger variety of services and would gain market share much more rapidly.

The reliability of the battery is questioned regarding the lifespan as it is proposed that the battery is limited to approximately 100,000 miles. Although this forecast would last an average fleet vehicle approximately 5 years, over time the capacity of the battery reduces and less range is achievable (ETSAP,
This requirement to replace the battery damages the TCO of the vehicle unless this necessity is removed through battery leasing. Alternatively this introduces a certain level of risk in to the purchase of an EV as the true finances are undefined, this therefore damages consumer confidence and introduces an additional challenge to the market. CAP, a vehicle residual value expert in the UK highlights battery replacement costs as one of the major issues threatening commercial EV uptake (Sunderland, 2010). However the battery at 'end of life' in a vehicle application still retains approximately 80% of its capabilities, therefore fleets could sell the battery, retain the chassis and install a new battery. This could begin to question the relationship businesses have with vehicles as fleets have a quick turnover that although has the benefit of rapid market penetration, it is not necessarily the most 'environmentally friendly' behaviour. “If EVs are to be the agents of change that allow a significant reduction in CO2 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). This highlights the necessity for businesses to alter their operational requirements for EVs to be truly efficient whilst also providing an additional revenue stream from the vehicle that would assist the TCO. This could be jeopardised however due to potential safety and performance challenges regarding lithium-ion batteries, research suggests charging in extremely hot or cold weather and/or fast charging regularly could potentially destroy the battery or create safety risks (ETSAP, 2010, DeutschBank, 2008).

As the EV market has rapidly developed within the last two years and exponential growth can be expected, the demand for advancements in battery technology is causing a bottleneck in supply. Due to the market potential EVs offer the chemical companies to supply materials and components it has become a highly anticipated commodity that the fleet market require to truly optimise the vehicle across the mass market. The current limited capacity highlights the limitation of fleet adoption and the current emphasis on sweet spots. Alternatively an emphasis on fast chargers will be required to enable customers to have access to quick energy replacement for extended mileage. Additionally with intelligent systems available in the market batteries are able to communicate data of vehicle and energy use which can be expended to change utility of the vehicle and capitalise on battery capacity. Although much larger batteries and the required chargers are available, unfortunately the market is reliant on the auto and battery manufacturers to enhance EV capabilities within the vehicle.

**Market perception**

The EV 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; arguably this is due to the limited number installed. This is the challenge of a new market that is competing within a very established industry; to truly expand it requires the mitigation of risk for businesses to accelerate the adoption curve. At present, risk is unavoidable however through the understanding of drive cycles and fleet operations, electric vehicles are beginning to be analysed conceptually. Within the 'Smart Move Trial' once non-electrified fleet drivers had driven an electric vehicle 58% of drivers felt more positive about EVs (Cenex, 2010). This highlights the need to introduce EVs into fleets so employees can experience the vehicle before forcing electrification upon the drivers which could create resentment and
consequently bad press. Government, automotive industry and manufacturers need to further educate the fleet community about the current opportunities EVs present in order to overcome the negative market perceptions. The number of trials across the country should increase and a greater number of businesses/fleet managers should educate and train their fleet drivers to use EVs.

Conclusion

The requirement for the UK to dramatically decarbonise draws attention to the opportunity of transport electrification. However, despite the Government subsidies and tax exemptions available to electric vehicle buyers, the market failed to reach predicted sales figures in 2011. Arguably this is due to the combination of challenges as discussed within this exploration of the market but it is questionable whether the lack of vehicle availability constrained the market. With nine more EVs being released in 2012 along with charging infrastructure more readily available from a number of suppliers, the challenges experienced in 2011 may naturally reduce as the vehicles are infiltrated within the mainstream. However, the barriers of high purchase price and consequently the poor TCO are not likely to be overcome in the coming year as economies of scale will not be met and nor will a second hand market be established. Therefore, EVs will be largely dependent upon fleets attempting to not only reduce their operating costs but perhaps more importantly reduce vehicle emissions and enhance green credentials.

Ultimately the barriers originate from the transformation of transport itself as through entering a new market that is competing within a very established industry it challenges human natures prohibition to change. This is intensified through the ambiguity within the market from Government policy which is establishing as the market develops and stabilises. Current TCO analysis implies electric vehicles may not be financially attractive at present, fleets are required to expand their vision beyond the bottom line to include intangible benefits and the future mitigation of regulative reform. Such considerations could have considerable financial rewards/savings that within the current economic climate could be significantly important. Alternatively the market needs to adapt to a different cost calculation in order to fully realise EV potential. It can be concluded that the business case for EV fleet integration is largely fleet specific and will rely on sweet spot operations to drive the early market developments. It is essential that investment and resources are maintained throughout 2012 despite the possibility of a struggling and slow responsive market. It can be assumed that technological advancements will continue to alter the market and will therefore require manufacturers to respond quickly to product development.
Appendix 1a:

1. Cenex’s assumptions within the TCO analysis (Cenex, pers. comms., 2011)

- The vehicles compared are Smart 4-2 coupe Diesel 40kW engine (0.8l) and Smart ED 4-2 coupe 30kW electric motor
- Assumed mileage is 11,700 miles
- Cenex ran simulations using three drive cycles including Artemis Urban, Road and NEDC
- Diesel fuel price is based on AA May 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 617.07gCO2e/kWh
- The carbon intensity of diesel is also taken from the Defra 2010 report
- Diesel vehicle purchase costs include 8625 GBP for diesel Smart with depreciation to 3875 over 3y
- Electric vehicle purchase costs include 20000 GBP (based on insurance value of new Smart ED) with 40% depreciation over 3y (Martin Ward CAP details on Leaf, Auris and Prius all have 40% depreciation)
- 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)
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Charging Infrastructure for Electric Vehicle Fleets – identify and develop
business opportunities within target sectors.

Six Month Report

Engineering Doctorate
Industrial Doctorate Centre
University of Surrey

October 2012

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Appendix 6-21
Six Month Report

The following report will reflect on the six month period between April 2012 and October 2012. It will surmise the activities taken place and will conclude with an outline for the coming six months.

1. Reflections
   i. Previous Six Month Report

The previous (first) six months provided a strong introduction to the project, consolidated the researcher’s knowledge on the topic and established the problem statement. Reflecting on the report, it took a broad approach to the research areas discussed and as a result the research questions encompassed a wide array of market indices’. This was necessary to establish the technology lock-in taking place within the automotive industry. In hindsight it is evident that the projected timeline was over ambitious and included aspects that in retrospection are not necessary. Within the original research plan the intention was to explore the impact of the Plugged-in Places (PiP) scheme upon the nations projected rate of EV adoption. On reflection this may not be the most constructive research to undertake as PiP is concluding in March 2013 and has been considered as not particularly successful. Although it would be interesting to examine the reasons for this, it may be more relevant to explore the Government scheme that replaces PiP and attempt to develop research aims alongside such deployment. Analysing the Project Management Gantt Charts the research is six months behind what was initially planned, the reasons for this are discussed in 1.ii.

   ii. Six months ending October 2012

The last six months of the project have not resulted in tangible outcomes as the time has been consumed with developing partnerships for the primary research to take place. This has somewhat dictated the pace at which the research has developed and limited the progress made. Although this has been frustrating, building the relationships with fleets and beginning to learn from their expertise and experience has been very rewarding and informative. The communication had, in most cases with fleet managers has enhanced the Research Engineer’s understanding of fleet behaviour and has triggered questions and thinking to be explored further (discussed in 3). Managing this alongside other commitments (discussed in 2) has been challenging as there has been a number of additional activities to fulfil, this has highlighted the researcher’s need to develop multi-tasking skills.

2. Summary of work to date
   i. Events

Over the past six months the Research Engineer has supported the Schneider Electric EV team at a number of electric vehicle and fleet events. In most instances Schneider Electric had a stand to promote the EVlink range of products and services. This not only enhanced the researcher’s knowledge about the possible applications of Schneider’s solutions but facilitated public engagement and network opportunities with key target audiences. Due to the infancy of the EV market, stakeholders are particularly open and keen to share information which in more mature markets may be considered sensitive. This is an ideal environment for research to take place in,
often encouraged by a seminar approach taken at EV events. Furthermore working for Schneider Electric has been a very effective tool to engage with other businesses on a more commercial level.

ii. Personal development programmes

Attending the ten day University Global Partnership Network (North Carolina State University, University of Sao Paulo and University of Surrey) involved seminars by leading experts in climate science, policy, environmental change, mitigation, adaptation and communication; as well as group discussions with leaders in government and civil-society organisations. It was a very interesting and informative multi-disciplinary workshop that helped to contextualise the research in the wider research environment. It was beneficial discussing research with fellow doctoral students with a mutual interest in climate change; equally learning from their experiences and the methodologies utilised positively enhanced the researcher’s own approach.

The University of Surrey’s Sustainability and Energy Systems Industrial Doctorate Centre orchestrated an Advanced Leadership week in Wales. This involved self reflecting on strengths and weaknesses whilst working in both teams and individually. In analysing personal behaviour and tendencies highlighted by the SDI questionnaire it indicated core areas requiring development. Consequently it suggested the Research Engineer should focus on enhancing self confidence and openness, in turn these enhanced traits are suggested to aid research progression.

Industrial supervisors suggested the Research Engineer attended the BEC Young Professionals workshop aimed at those involved in electro-technical standardisation and conformity assessment work. It focused on standardisation strategies which support national, regional and international involvement. It was a very educational workshop that gave a good insight in to the development of standards. This was particularly useful as standards have an instrumental role within the EV market especially whilst market experience is limited and standards and legislation are developing.

iii. EVlink dissemination

Over the last six months the EVlink offer has been being rolled out across the different business entities of Schneider Electric, this is likely to continue over the next twelve months. Consequently there have been multiple internal presentations as well as presentations and training given to electrical distributors and contractors. As the researcher has assisted with these it has aided personal development in confidence and communication skills; both being beneficial to Schneider Electric in the long term but also the research as it will enhance the effectiveness of conveying results.

iv. Transitions to a Low Carbon Economy

In April the Research Engineer attended the ‘Transitions to a Low Carbon Economy’ module within the Centre for Environmental Strategy at the University of Surrey. This module was of particularly relevance to this research as it focused on low carbon energy options and explored low carbon scenarios and energy system transitions. Having attended this module it widened the researcher’s perspective on the transition pathways to a low carbon economy through exploring the role of institutions, behavioural change and policy. The coursework submitted was entitled ‘The role of behaviour change in electric vehicle adoption, in the transition to a low
carbon economy’ (Appendix 2) achieving 60%. This enabled the knowledge gained within the module to be applied directly to the research and further deepen the researcher’s understanding of the problem statement.

v. **EngD conference**

The annual EngD conference required a conference paper and A0 poster (Appendix 3 & 4), providing the opportunity to share intentions of a research component and receive feedback from both industry and academia. The research project gained interest from peers in a wide range of disciplines and enabled the Research Engineer to consider making alterations both professionally and personally through learning from colleagues.

vi. **Plugged in Fleet Initiative**

The Plugged in Fleet Initiative (PiFi) led by Energy Saving Trust, Routemonkey & EDF and funded by DfT & TfL is working with 20 fleets in developing strategic plans for EV fleet adoption. It will identify where EV’s ‘fit’ within the company’s fleets in terms of duty cycle, and then develop a total cost of ownership model including infrastructure plans and costs. Schneider Electric is a member of PiFi and will receive the analysis and guidance. The Research Engineer is acting as lead coordinator of Schneider’s involvement and is in the process of increasing the company’s involvement within the Initiative. In joining the partnership further Schneider would contribute to knowledge and technical material, the Research Engineer would analyse the balance between infrastructure and vehicle utilisation to maximise vehicle miles and opportunity charge for the fleets involved. This would not sit within the current research component (discussed in 3) but would support future research exploring the charging behaviour of fleets. It would explore the opportunities intelligent EV charging infrastructure has to extend the pathway of smart technologies to wider stakeholder groups. Furthermore it would investigate the challenges that can be overcome through behavioural change rather than technological developments or regulative enforcement. Additionally this research will be valuable to Schneider Electric as it will enhance their understanding of fleet demands for charging infrastructure solutions and would position Schneider as a key player within the market. Joining the partnership would provide a good platform to demonstrate Schneider’s capabilities and entire EV solutions. It is probable that the collaboration will extend to an additional report focused on the activities a company needs to undertake once an EV is procured to successfully integrate the vehicle(s) into their business. This would be directly relevant to this research as it would examine both the technological and behavioural transition pathways necessary for EV optimisation.

3. **Current research**

   i. **Research questions**

Analysing the literature on the technology developments in the automotive industry highlights the lack of in-depth understanding regarding the economics of the UK’s road vehicles and more specifically the integration of low carbon vehicles in to fleets. The aim of this research study is to understand how electric vehicles can break through current technological lock-in and development blocks in order to strengthen the EV market and create new pathways for smart integrated technologies. Therefore the following research questions are underpinning the research in order to analyse the challenges that the fleet market are faced with.
- What are the dominant path dependent characteristics within the automotive industry and car users that challenge the utilisation of electric vehicles and electric vehicle charging?
- Are changes required within fleets’ decision making process and the drivers application to ease EV adoption? What challenges can be overcome through behavioural change rather than technological developments or regulative enforcement?
- How effective are the various energy tariffs/commercial models in influencing charging behaviour?
- Within UK fleets what is the level of understanding regarding electric vehicles and smart grid capabilities? How could this enhance the concept of mobility?

ii. Fleet collaboration

This research component is focused upon the integration of electric vehicles in to fleets, understanding the decision matrix of vehicle procurement and operations. Therefore collaborating with four fleets:

- TNT Express Services UK & Ireland - the UK’s leading business-to-business express operator delivering up to 150 million items per annum
- NHS - The UK’s National Health Service, their fleet incorporates ambulances, cars and vans.
- Schneider Electric UK - an energy management company manufacturing electrical distribution and automation control equipment
- Green Tomato Cars - a London based environmentally conscious private hire service

Prior to confirming the above fleets the Research Engineer had invested time with BT Fleet and Thames Water in the attempt to incorporate them within the study. Despite having had very interesting in depth discussions regarding electric vehicles and their fleets, they did not progress as the timing of the research was not complimentary to their own planned analysis/roll-out. This delayed the development of the project as in both instances collaboration seemed likely for some time; therefore the researcher did not pursue alternatives until the opportunity was lost. Building a new relationship with another fleet was time consuming and demonstrated the importance to not assume or rely on suggested commitment from others.

Having taken in to consideration the changes in fleets involved, the researcher reassessed the research questions to ensure they were appropriate. Consequently it was consider that there was not a need to adapt the research questions for the fleets concerned. The research questions in 3.i should satisfy the research aims (discussed further within Appendix 3) that intend to:

- Investigate the transition barriers of EVs within the industry through challenging the dominant path dependencies of internal combustion engine vehicles.
- Clarify whether path dependency threatens EV fleet adoption and analyse and address the technology lock-in electric vehicles are experiencing within the UK.
- Explore how EVs could be utilised to encourage new pathways for smart integrated technologies.

Analysing such aspects will indicate how to encourage alternative innovation within the automotive industry and develop the concepts of mobility.
iii. **Research developments**

In order to encourage participation by the fleets the Research Engineer ensured anonymity of sensitive data as well as feedback and recommendations for the individual fleets. The fleets above have begun to provide data on their vehicles in terms of quantity, size, duty, replacement cycle and mileage. This will capture the fleet’s make-up contextualising the qualitative data that will follow and it will ultimately be used in categorising fleets for recommendations of electric vehicle optimisation. In all instances there has been some exposure to electric vehicles whether it is a small pilot or a percentage of their fleet. This will provide insight into various engagement levels and experiences alongside diverse strategies due to sector or duty cycles.

The fleet’s compositions will be explored through an in-depth examination of strategic decisions in new technology adoption alongside vehicle procurement. This will analyse the individual fleet’s decision matrix and seek to understand the influence of company culture, legislative pressure, strategy and technology availability/applicability. The existing technological and possible regional and generational lock-in influencing fleet transformation will be analysed; and path analysis will examine the societal, cultural and habitual changes that are necessary for optimisation of EVs. This will form a snapshot of each fleet that can be used as a baseline at a later date to analyse further transformations undergone. This research will link in to the wider research theme of transition pathways through deepening the understanding of how EVs can overcome the transition barriers and path dependencies embedded by the ICE that dominates the automotive industry; this is further discussed in Appendix 1.

4. **Planned activity**

i. **Research study**

The first action required to explore the path dependencies challenging the utilisation of electric vehicles within the fleet market is to collect and consolidate all the fleet’s data in order to form case studies on each fleet. This will support the foundation of the interviews as although a number of questions will be structured for all four fleets, there will be a number that are more case specific in order to achieve a deeper understanding of individual fleet strategies, procurement models and operations. The Research Engineer intends to conduct interviews at the strategic level, with the fleet manager and with a driver to provide a comprehensive analysis across the fleet’s entirety. Therefore each interview will require individual objectives to attain the most relevant information. Within the interviews the correlation between climate change and low carbon vehicles/smart technologies will be addressed to compare the apparent importance of such awareness upon the adoption of EVs. The following action will be case dependant in accordance to their deployment of EVs/EV trials. However, at the fitting time questionnaires will be distributed to drivers to establish attitudes towards electric vehicles prior to EV integration, within the first week of utilisation, after a month and again after three months.

ii. **Schneider Electric**

During October the Research Engineer is attending a ‘Cutting Edge Sales Excellence’ six day training course which provides a vehicle for self learning covering the area of selling skills. This does not relate directly to the research but will give a better understanding to Schneider as a business, to the sales teams and for the researcher’s own personal development. The skills that are likely to be developed during the training will be
transferable to other activities such as presentation skills and appropriate ‘pitching’ whether it is within academia or industry. Having agreed with David Greaves, industrial supervisor, the following objectives are the focus of the training:

- Enhance self-confidence and become comfortable presenting
- Enhance communication skills
- Become more open in sharing thoughts/ideas and receiving feedback
- Improve time management, planning and organisation
- Develop team work skills

iii. Project management

For the next six months the following steps shall be carried out to complete the initial fleet research:

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<th>Nov-12</th>
<th>Nov-12</th>
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</thead>
<tbody>
<tr>
<td>Retrieve all fleet data and compile case studies</td>
<td>Cutting Edge Sales Excellence</td>
<td>Finalise interviews</td>
<td>Conduct interviews</td>
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<td>Analyse interviews and extend/compare case studies</td>
<td>Construct questionnaires</td>
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<td>Distribute and collect questionnaires (accordingly)</td>
<td>Analyse questionnaires and extend/compare case studies</td>
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This shall be re-examined regularly to ensure targets are being met and to suggest future direction for the second year of the project.
**Appendix 1: An Investigation in to the transformation of fleets towards lower carbon vehicles**

**Introduction**

Fleets are the central premise of this research as they offer the most promising opportunity for electrification in the short term (ElectrificationCoalition, 2010). This is due to (Appendix 1):

- The majority of commercial fleets having similar characteristics including high utilisation rates, centralised parking facilities and managed known activities (PikeResearch, 2010)
- Fleets are expected to have specific charging requirements derived from their drive cycle, destinations, time schedules and fleet size
- The concentration of buying power associated to fleets and the relatively small number of influential decision makers within the industry

This paper will highlight current thinking on the ‘pathway’ for electric vehicles, identifying the development blocks of alternative innovation within the market. It will discuss path dependencies and technological lock-in building upon prior knowledge, to establish the necessary approach in the primary research.

**Current philosophy**

There is an increasing demand for emission reducing technologies as emission standards become more heavily regulated and the oil price instability. This is particularly relevant to the automotive industry as carbon taxes have heightened fleet sensitivity to emissions and performance, thus altering the equilibrium conditions (Bae et al, 2011). As Figure 1 indicates expanding populations, increasing urbanisation and greater wealth will increase vehicle ownership. The technology development within the progressive automobile markets will be infiltrated in to the developing markets. This will raise transport equality across the globe but unless lower carbon modes of transport are utilised it will have detrimental impacts on climate change and air pollution.
Presently there is a lack of consensus in the market on which vehicle mode and which engine 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). Arguably the internal combustion engine (ICE) defines humankind’s perception of automobiles heightened by the vested interests within the industry that encourage resistance to new vehicles modes. This is not only in respect to consumer choice but manufacturing processes and design, thus forming “economic-technical problems that have blocked the realisation of the economic benefits of earlier innovations” i.e. the electric vehicle (Cowan et al, 1996). It would appear technical choices are being dictated by historical developments due to scale and learning economies, technical compatibility, and extensive industrial networks (Ahman et al, 2007). Beyond development blocks it is evident the automotive industry suffers from technology lock-in as the dominance from the ICE has yet to be significantly challenged by alternative fuelled vehicles. Advances in refineries have led to efficiency gains and reduced emissions increasing the barriers to open competition (Ahman et al, 2007). In the case of EVs there are multiple factors to consider in addition to technological aspects that affect the capability of entering the market and competing successfully with ICE vehicles. Such path-interdependences are stimulated through the mutually reinforcing social system of automobiles encompassing infrastructure, service stations and roads; as well as the dynamics of political, economic and technical decisions that develop within the economy (Cowan et al, 1996). Arguably the lock-in EVs experience could be contested through competitive pricing, battery developments and/or Government regulation.

Research questions
There is a lack of in-depth understanding regarding the economics of the UK’s road vehicles and more specifically the integration of low carbon vehicles into fleets. Therefore the aim of this research is to understand how electric vehicles can break through current technological lock-in and development blocks in order to strengthen the EV market and create new pathways for smart integrated technologies. The following research questions have been formed to analyse the challenges that the fleet market are faced with.

- What are the dominant path dependent characteristics within the automotive industry and car users that challenge the utilisation of electric vehicles and electric vehicle charging?
- Are changes required within fleets decision making process and the drivers application to ease EV adoption? What challenges can be overcome through behavioural change rather than technological developments or regulative enforcement?
- How effective are the various energy tariffs/commercial models in influencing charging behaviour?
- Within UK fleets what is the level of understanding regarding electric vehicles and smart grid capabilities? How could this enhance the concept of mobility?

Such research questions should aid the clarification of the transition barriers of EVs within the industry, the path dependencies that threaten EV fleet adoption and the technology lock-in electric vehicles are experiencing within the UK. It is argued that for EVs to compete successfully the vehicles would have to provide the same level of services an ICE vehicle provides. This research will question the validity of that thinking and explore the concept of transports development as opportunities exist to utilise vehicles in a more efficient transport system.

**Methodology**

For the purpose of this investigation both a qualitative and quantitative approach are required. Initially quantitative analysis will be performed on the individual fleet’s data in terms of size, vehicle type, duty cycle, activity, vehicle age/replacement cycle, CO2 average and funding method. This will capture the fleet’s make-up contextualising the qualitative data that will follow and it will ultimately be used in categorising fleets for recommendations of electric vehicle optimisation. This data will be retrieved directly from the fleet managers, thus presuming data reliability.

Subsequently a qualitative approach will be taken using both interviews and case studies, this will utilise a wide range of empirical data for a thorough investigation (Punch, 2005). This will provide a connection between the research question and the conceptualised data (Punch, 2000). This qualitative research is inductive ensuring the nature of the relationship between theory and research is analysed (Bryman, 2008). This will assist the exploration of the research questions and highlight core strategies to fleet operations. The interviews are a key element to this research in order to capture the reality amongst fleet operations and the true perceptions of the challenges of electric vehicles. Therefore a semi-structured approach will be used in order to achieve a level of comparability between the fleets as well as encouraging the embedded knowledge of the fleet managers and fleet specific behaviours to be incorporated within the research. For the purpose of this research the following interviews will be conducted:
At least one key decision maker within fleet operations to understand the theory of application and the overarching strategy of vehicle procurement; whether that be the fleet manager, the financial director or the operations manager

At least one driver who has experienced a transformation in vehicle technology

The contribution from expert elicitation aims to strengthen the analysis drawn from the results. The interviewees will be asked truly open-ended questions to “minimise the imposition of predetermined responses”, providing the opportunity for flexibility (Patton, 2002 p.353).

Activities

Therefore I intend to collaborate with:

- TNT Express Services UK & Ireland - the UK’s leading business-to-business express operator delivering up to 150 million items per annum
- NHS - The UK’s National Health Service, their fleet incorporates ambulances, cars and vans.
- Schneider Electric UK - an energy management company manufacturing electrical distribution and automation control equipment
- Green Tomato Cars - a London based environmentally conscious private hire service

The research shall explore their fleet use and management through an in depth examination of strategic decisions in new technology adaption alongside vehicle procurement. This will analyse the fleet’s decision matrix and seek to understand the influence of company culture, legislative pressure, strategy and technology availability/applicability. The existing technological and possible regional and generational lock-in influencing fleet transformation will be analysed; and path analysis will examine the societal, cultural and habitual changes that are necessary for optimisation of EVs. This will form a snapshot of each fleet that can be used as a baseline at a later date to analyse further transformations undergone.

Wider relevance and outcomes

This project aims to develop the understanding of the research questions as well as producing recommendations for fleet strategies of electric vehicle optimisation. It shall suggest possible tools for fleets to overcome barriers and recommend how ‘new technology’ is best integrated within fleets in general. This analysis will contribute to the understanding of how alternative innovation can overcome path dependencies and be encouraged within the automotive industry to develop the concept of mobility. The scope of this research extends beyond the immediate fleets involved as analysing fleet behaviour across different sectors will provide an insight in to varied fleet strategies. However current thinking is that it is not necessarily sector dependant but greater focus should be on the duty cycles, referring to “the cycle of operation of a machine or other device which operates intermittently rather than continuously” (OxfordDictionaries.com). Therefore the case studies will form a framework to categorise indices’ presenting a greater depth of understanding e.g. size, mileage, stopping time. This is then more transferable to other fleets as they can gain an appreciation for the likely challenges that due to their fleet makeup they will encounter.

Furthermore, this research will contribute to a proposed project exploring the legislation relating to electric
vehicles and the implementation of achieving the optimal level of adoption. Through analysing the regulative mechanisms taken by Government the consequent impacts on competition and green technologies can be explored and further recommendations can be presented.

Conclusion

This research component will investigate four fleet’s procurement models and their operations to gain an understanding of how EVs can overcome the transition barriers and path dependencies that dominate the automotive industry. The case studies will be completed by November 2012, allowing the analysis to be completed by January 2013. This will enable recommendations for the EV fleet market to be put forward establishing how the ‘new’ vehicle mode can be most effectively integrated within various industry sectors.
References


Executive summary

For the UK to satisfy the Climate Change Act of a 50% reduction of greenhouse gases by 2025 on the 1990 baseline levels, transportation and its modes need to be urgently addressed. This paper discusses the role and significance of behavioural change in the case of utilising electric vehicles. It explores the need for behaviour change within the market whilst taking in to consideration the limiting factors of technological lock-in as well as humankind’s perception of undesirable change. The Government’s strategy to encouraging electric vehicles is discussed resulting in public and private sector recommendations to be presented for both the short and long term. The drivers and barriers of behaviour change for electric vehicle use are explored to highlight the current market conditions.

Legislative pressure is currently driving the electric vehicle market as the Government have provided multiple grants and incentives for EV drivers, these are presently integral to the economic case. Additionally carbon policies are encouraging EVs to be used within commercial applications as businesses are forced to reduce carbon emissions, EVs are a relatively quick implementation device to do so. However these strategies cannot be successful in isolation, behaviour change and ultimately a positive attitude towards the new technology are key to the success of EVs. Trials undertaken demonstrate the impact experiencing the vehicles in daily life has upon driver perceptions of EVs. Removing negative and often ill-informed opinions of EVs vastly enhances the market as well as enabling people to question the concept of mobility more broadly.

Main body

Introduction

With tighter regulations amongst the rise of climate change awareness, electric vehicles (EVs) have become a key aspect of transport policies in order to meet carbon reduction targets across the globe. Establishing an EV market is challenging due to the need for extensive transformation across a large spectrum of societal dimensions including policy, behavioural change, fiscal models and technology dissemination.

This paper shall investigate the need for behavioural change within the UK transport sector. It shall explore the role of behaviour change in the transformation to low carbon vehicles as well as in the boarder sense of a low carbon economy. The drivers and barriers of this option are discussed alongside the policy measures taken within the UK.

The importance of behaviour change

As the fastest growing contributor to climate change methods of transportation need to be challenged in order to satisfy the UK Climate Change Act of a 50% reduction of greenhouse gases by 2025 on the 1990 baseline levels (EuropeanUnion, 2009, drdni, 2010). The UKs current fuel mix is dominated by natural gas and coal resulting
in high levels of emissions. This along with the risks of peak oil occurring before 2020 challenges affordability and accessibility of oil supply (UK Energy Research Centre, 2009). This has considerable implications upon the transport sector within Britain as transport demands over 50% of overall UK oil consumption (ITPOES, 2010). Disruption upon transport networks across the UK could have severe detrimental impacts as a wide range of businesses rely on ‘just-in-time’ business models based on highly integrated transport systems (ITPOES, 2010). This highlights the challenges of transforming to a cleaner energy portfolio and a reduction in fossil fuel use. However there are immediate opportunities for road transport to be decarbonised. Electrification of transport is argued to be a substantial opportunity for the decarbonisation of transport and the most promising in the near term (Electrification Coalition, 2010). In the case of the internal combustion engine (ICE) vehicle the majority of CO2 emissions are emitted from the vehicles use phase (Muñoz et al., 2006). Therefore it would suggest that either vehicle efficiency needs to improve (which generally it is) and/or behaviour needs to change within the decision matrix of vehicle ownership as well as driving style. If humankind’s perception of mobility advances then EV’s would likely become a more viable option for drivers and therefore gain a larger market share within the industry.

Path dependency

Across the spectrum of alternatively fuelled vehicles (AFVs) it is thought hybrid EVs have a “transitional role...in the sequence of technology adoption” as the vehicles reduce perceived risks associated with AFVs (Collantes, 2007 p.270). The introduction of the Toyota Prius in 1997 is argued to have increased versatility and flexibility within the market through unlocking the historical market of restricted designs and specifications (Ahman et al, 2007). Arguably such vehicles as the plug-in hybrid EVs have better long term social benefits in terms of greater efficiency and lower emissions compared to an equivalent ICE vehicle, yet these vehicles have struggled to gain market share. Cowan et al (2012 p.4) states “it is not enough that the competing technology is better...to overcome lock-in it is necessary that some extraordinary events occur”. He continues that these could be via regulation, scientific breakthrough, technological breakthrough, creation of niche markets, changes in taste and/or a crisis in the existing technology (Cowan et al, 2012). Regarding the electric vehicle market, there is not currently a crisis in existing technology and in fact ICE vehicles are technologically improving, competing heavily on efficiency and emission levels. Secondly, electric vehicles have essentially not improved technologically since the early twentieth century (Hoyer, 2007). However, regulation regarding emissions from businesses and the associated carbon credits has enhanced the business case for EVs whilst only early adopters have begun to utilise pure EVs. Humankind’s perception of undesirable change intensifies preconceived notions to transport and impacts the pathway to new technology. Path dependence shapes current and future technological choices due to preceding conditions and market developments. 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). However “if EVs are to be the agents of change that allow a significant reduction in CO2 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). This seems to be integral to the future of a low carbon world as although the premise of transport consumes fuel, creative destruction can challenge this as AFVs
present an opportunity to positively alter the energy mix; this however requires the social norms to modernise (Schumpeter, 1942).

**Behavioural change for electric vehicles**

It is argued that consumers must be engaged with electric vehicles for the market to develop and reduce CO2 significantly from road transport (Lane et al, 2007). The King Review (2007) estimates that savings of 10-15% could come from consumer behaviour. However many drivers are not aware of their driving patterns or average drive cycles and therefore question the suitability of a 100 mile range. The average individual journey length in the UK is 8.6 miles and the average total daily distance travelled is 25 miles (SMMT, 2010). Therefore in most instances EVs would be a suitable mode of transport, requiring drivers to be more conscious of their behaviour and adapt it if/where necessary. In the case of fleets, the opportunity is vast as the majority of commercial fleets have very similar characteristics including high utilisation rates, centralised parking facilities as well as local and predictable routes; such behaviour is ideal for electric vehicle use and can assist faster payback (PikeResearch, 2010).

In the UK the majority of vehicles are purchased outright by customers as British consumers prefer to own their possessions in their entirety. Due to the high initial price of an electric vehicle, outright purchase damages the economic case. However if an EV was leased over a period of time it vastly improves the cost parity of an EV with an ICE. Unfortunately leasing of EVs is still poorly developed due to the lack of data and uncertainty of residual values (BERR, 2008).

With the current level of charging infrastructure within the UK, driving an EV requires some planning and predictability. Not only is it required to ensure there is an opportunity to recharge the EV but also the psychology of using electricity to power a vehicle. This is likely to be the case until charging infrastructure is as common as existing refuelling stations and/or a greater number of residual and work premises install charging. This will reduce the psychological fear of running out of battery capacity with no accessibility to charging infrastructure, this apprehension is known as range anxiety (Markel, 2010).

**Smart Move trial**

Cenex’s Smart Move Trail integrated up to four EVs within ten different fleets for six months. It indicates that once non-electrified fleet drivers had driven an electric vehicle 58% of drivers felt more positive about EVs (Cenex, 2010). This highlights the need to introduce EVs to drivers in a risk free circumstance. Figure 1 highlights “83% of fleet users in their twenties felt more positive about electric vehicles after the trial, compared with a 25% opinion shift for users in their sixties” (Cenex, 2010 p.14). This raises the question whether there is a ‘generation lock-in’ in which certain age cohorts are more or less responsive to technological development. It would suggest that older generations are less likely to change their attitudes resulting in behavioural change being more difficult to achieve. Unfortunately it is the ‘baby boom’ generation that are most likely to be able to afford electric vehicles at the current high prices along with access to driveways for charging infrastructure. However it would appear these individuals are impervious to the alternative innovation.

Figure 1: Fleet users attitudes by age
Government

The UK Government is tackling transport emissions with a technology neutral approach, therefore businesses or private consumers with cars with tailpipe emissions of 75/km or less thus including electric, plug-in hybrid and hydrogen-fuelled cars are all potentially eligible for substantial grants (DfT, 2011a). However utilisation of EVs is still minimal and it could therefore be questioned whether previous attempts to encourage electrification of transport has damaged the perception of EVs. At present Government incentives and regulations relating to emissions have been key catalysts in beginning to unlock ICE vehicle dominance within the market. There are various grants and incentives available to EV drivers in the attempt to encourage new adopters. Although economic incentives are necessary for the market, they are not sufficient to change behaviour entirely (Lane et al, 2007). DEFRA suggests that alongside financial incentives charging infrastructure is required but most importantly a positive attitude by consumers (Lane et al, 2007). This however is a great deal more difficult for the government to implement. Arguably if EVs were more affordable than an ICE vehicle attitudes may change more quickly. This could be achieved if the Government were to waive 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.

Drivers and barriers of behavioural change

Research suggests that car travel is relatively inelastic to fuel price unless households have a very low income (Turrentine et al, 2007). Consequently it is important to highlight the key driver for adapting behaviour to use EVs as they offer the opportunity to assist the reduction in carbon emissions. Furthermore utilisation of electric vehicles would enhance air quality and noise pollution, desperately required within major cities. Additionally
the pathway to low carbon vehicles would extend the transition to a low carbon economy and ease market acceptance of new technologies.

An additional advantage of behaviour change is the extensive cost savings drivers could benefit from by using an EV. Fuel cost savings could amount to 90% along with no road tax, low maintenance, reduced parking and exemption from various taxes and vehicle charges.

A key motivation for fleets to change behaviour regarding vehicle mode is ‘PR value’ attached to electric vehicles. 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 (LeasePlan, 2010). Additionally, Deloitte Car Consulting pledge that EVs will soon become the dominant vehicle type within fleets, due to the associated positive impact EVs have on market perception (Leasedrive, 2011). It could be argued that moving in a direction that is likely to be a legal requirement in the future ahead of competitors in an area considered socially responsible is a valid reason for UK businesses to adopt EVs within their fleets.

In the main however 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; arguably this is due to the limited number installed. This is the challenge of a new market that is competing within a very established industry; highlighting the need for education of EVs to take place to encourage behaviour change. Education is a key component to EV utilisation as there is evidence to suggest that drivers have a “very low knowledge base regarding the impacts of low carbon and fuel-efficient vehicles” (Lane et al, 2007 p.4).

A key barrier of behaviour change is the difficulty to affect transport use as it is rooted within humanity, cultural, psychology and society (Wells, 2010). 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, 2011b, EC, 2008). A key aspect of electrification of transport is consumer acceptance as within many cultures vehicles are considered as status symbols. However according to the Journal of Personality and Social Psychology, AFVs are challenging traditional status allegiance with luxury vehicles despite the sacrifice of performance (Griskevicius, 2009). Additionally, the behaviour change may encourage a modal shift of mobility as drivers may become more strategic of when it is necessary to use a vehicle. In alternative situations public transport or walking may be considered, thus benefiting health and city congestion.

Timescale

In the short term the transport sector should encourage behavioural change through raising awareness of the benefits of change; informing people of the opportunities to change; and maintaining the level of financial incentives. In the short term driver behaviour will also be important to realise the potential for CO2 savings. Information provision and education will play a major role in enabling and encouraging efficient driving styles. Drivers must be aware of how they can change their driving behaviours to increase fuel economy and ultimately integrate EVs in to their mobility portfolio.
Additional activities that should be deployed for the foreseeable future are training, tools and support in order for the market to be self-sustaining and sufficiently competitive. The Government need to sustain the level of incentives and innovative policies to demonstrate the long term support and intentions of the government. Additionally it should be ensured that local authorities and transport operators are able to intrinsically develop new opportunities. As policy measures aimed to change behaviour are frequently unsuccessful, in the long term a ‘polluter pays’ approach could be enforced to ensure adoption, successful implementation of this strategy can be seen in Norway.

Conclusions

In the transformation to a low carbon economy, transport is an integral component of society that requires modifying. The integration of low carbon vehicles, specifically electric vehicles, relies heavily on the behaviour and attitudes of drivers. A positive attitude towards new technology is the single most important aspect that will remove technological lock-in. The automotive industry has strong path dependencies that are currently being tackled through financial incentives.

At this stage within the market education is key to inform drivers of the opportunities EVs present both environmentally and financially. Evidence suggests trials are an extremely effective method to overcome negative market perceptions and change attitudes; it is then likely to change driver’s behaviour and future decisions upon vehicle ownership. Existing regulations on carbon emissions are particularly effective within business, however it may be advisable to extend this approach to the public and implement the ‘polluter pays’ strategy. This may lead society to question the concept and sustainability of mobility modes and more broadly the transformation to a low carbon economy.
References


Appendix 3: EngD conference paper

Charging Infrastructure for Electric Vehicles – Identify and develop business opportunities within target sectors

Introduction

This project is focused on UK road transport that currently contributes 90% of domestic transport emissions (OLEV, 2011). As the fastest growing contributor to climate change, transportation and its modes need to be addressed to satisfy the UK Climate Change Act of a 50% reduction of greenhouse gases by 2025 on the 1990 baseline levels (EuropeanUnion, 2009). Electrification of transport is argued to be a substantial opportunity for the decarbonisation of transport and the most promising in the near term (ElectrificationCoalition, 2010). Although currently the high purchase price, the limited range and need for charging infrastructure is constraining the rate of electric vehicle (EV) adoption. Despite uncertainty upon the life time environmental impacts of EVs, the UK Government, as well as Governments across the globe support EVs as policy makers appreciate the need and difficulty of reducing greenhouse gas emissions. Optimisation of electric vehicles will however require a transformation of driver perceptions and expectations of vehicles, financing models and the integration of smart technologies; as well as having a large impact upon various affiliated markets. Therefore a path analysis will be undertaken to investigate how the EV market can sustain growth within the industry through challenging the dominant path dependencies of internal combustion engine (ICE) vehicles.

Fleets

Fleet applications will be the central premise of the research as the opportunity for electrification is vast. The majority of commercial fleets have very similar characteristics including high utilisation rates, centralised parking facilities as well as local and predictable routes; such behaviour is ideal for electric vehicle use and can assist faster payback (PikeResearch, 2010). Additionally fleet vehicles comprise of over half of all vehicles sold in the UK, reaching 973,233 in 2010 (SMMT, 2011). The “concentration of buying power associated with fleet operators and fleet management companies represents a significant opportunity to assist the early development of the electric vehicle industry” (ElectrificationCoalition, 2010 p13).

Although barriers to market penetration of EVs do exist in the UK, businesses have the opportunity to take advantage from a plethora of benefits EV fleets could provide. This could include up to 90% fuel cost savings, lower emissions and enhanced brand image. Additionally, through developing a strong UK electric fleet market infrastructure will be established through private investment. If the Government were to mandate i.e. through policy, this infrastructure could form the basis of a new publicly accessible fuel vector infrastructure in the medium term, reducing the burden on public spending. Furthermore by encouraging fleet uptake of EVs it could reach a significant number of private individual’s through their use and contact with fleet vehicles, these people may then see the potential for such vehicles in their domestic lives. 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 a ‘new technology’ vehicle.

Forecasts
At present the EV market is facing dominating competition from highly efficient ICE vehicles which are currently suppressing alternative innovation. There has been a wide range of plug-in vehicle forecasts as seen in Figure 1: the graph highlights an extensive difference in expected sales as time progresses.

**Figure 1: Forecasts of EV up-take**

![Graph showing EV uptake forecasts](image)

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

Due to the challenges of a new market forming within a well established industry it has resulted in low numbers of EVs having been sold. If this pattern continues Figure 1 suggests only 2% of new car sales within the range of annual growth will be plug-in vehicles in 2020. Even the higher expected rate of adoption in 2020 at 12% is minimal within the entire automotive industry; thus suggesting the dominance of the existing technology pathway. However in order for the UK to achieve the necessary carbon reduction targets the number of EVs utilised has to dramatically increase over the next decade, but how will this be achieved?

**Technological lock-in**

As discussed the current level of EV utilisation is significantly below projected rates, the total number of EVs in the UK is 2,149 (0.0075%) of the 28.5 million vehicles on the road (Siegle, 2012). There is a plethora of contributing factors to the slow take up of electric vehicles including costs and range. However existing research fails to significantly explore the challenges of fleets transforming to lower carbon vehicles. Due to the robust history of ICE vehicles and the economic and marketing power of the automotive industry, social norms have been heavily installed within humankind’s expectations of the development of vehicles. Many aspects of EVs challenge our mentality of transport and therefore will require behavioural change; this is particularly difficult whilst ICEs remain so competitive and dominant within society. This is compounded as the UK is
lacking the interoperability amongst charging infrastructure, resulting in EV drivers having to register with many different schemes and providers if national mobility is required.

The requirement for mass EV adoption requires access to charging infrastructure, either at residual properties, within public spaces or at work premises. Originally the Government believed charging infrastructure was a prerequisite to EV sales to reduce ‘range anxiety’ and stimulate the market. However it is questionable whether this is the case; it is suggested by the Electric Vehicle Infrastructure Strategy to rely on private installations (Office of Low Emission Vehicle (OLEV), 2011). However within the current UK economy this could be constrained through lack of finance. Technological developments within charging infrastructure and battery manufacturing are integral to the sustained progression of the EV market. Enhancements in range, speed of charging and SMART integrated capabilities will vastly improve competitive positioning for EVs within the automotive industry. The barriers to this are largely economic rather than technological, especially amongst industry pressure for standardisation globally.

The automotive industry is constrained by existing path dependant characteristics resulting in technological lock-in that may be negatively influencing the direction of the EV market. The lock-in electric vehicles encounter could be heightened by the Plugged-in Places scheme as it may reduce open path creation. Additionally, despite Government investment EVs remain more expensive than ICE vehicles. This is likely to restrict the fleets that will adopt the vehicles in the near term as it is currently difficult to prove a strong economic case. This is compounded for private individuals as not only are high levels of disposal income required (for outright purchase or leasing) but in most instances areas in which charging infrastructure can be installed, namely driveways or garages are required.

Project aims

The aim of the research is to understand technological lock-in and development blocks in the case of electric vehicles to eventually create new pathways for smart integrated technologies. This research aims to clarify whether path dependency threatens EV fleet adoption and to analyse the technology lock-in electric vehicles are experiencing within the UK as well as potential future risks. Analysis of the current challenges for the EV fleet market will enable recommendations to be made addressing ease of market acceptance. The research will reflect the interests of Schneider Electric as addressing such issues will enhance applicable market knowledge and therefore aid the development of Schneider Electric’s EV strategy.

In order to achieve this the researcher will work closely with multiple fleets. The fleets are either in the process of procuring EVs to integrate within their fleet or will already be utilising EVs within certain applications. As the central premise of the research design it shall extend the understanding of the decision matrix within fleets and the existing technological, regional and generational lock-in that may have been experienced. Additionally path analysis will examine the cultural and habitual changes that will be required for successful EV integration. It shall investigate the effectiveness of varying energy tariffs and commercial models as well as the opportunity intelligent EV charging infrastructure has to extend the pathway of smart technologies to wider stakeholder groups. In addressing such aspects it will indicate how to encourage creative destruction within the automotive industry and develop the concepts of mobility.

Conclusion
At present Government incentives and regulations relating to emissions have been key catalysts in beginning to unlock ICE vehicle dominance within the market. However a change in the concept of mobility is integral to the future of a low carbon world. Commercial fleet procurement offers the most logically beginning for market transformation; however many organisations will require a substantial change in culture, behaviour and vehicle application for EV optimisation to be successful. This research will collaborate with fleets in order to analyse the integration process and utilisation of EVs in order to demonstrate the implications of technological lock-in upon smart technologies.

Keywords

Electric vehicles, path analysis, fleets, technology lock-in, charging infrastructure, automotive industry, transport policy, national mobility, behavioural change, technology dissemination
References


# An investigation into the transformation of fleets to low carbon vehicles

**By Emily Gould**

## Background

UK road transport contributes 40% of domestic transport emissions (Defra, 2011). Low carbon vehicles offer a substantial opportunity for the decarbonisation of transport; electric vehicles being the most promising in the near term for the UK to meet the Climate Change Act.

An extensive transformation is required for EV optimisation within:  
- policy  
- cultural and habitual behaviour  
- technical models  
- technology dissemination

Currently, barriers to adoption do exist; these include high purchase price, restricted range and the need for charging infrastructure.

## Fleets

Fleets are a key opportunity for electrification:  
- The majority of commercial fleets have similar characteristics including high utilisation rates, centralised parking facilities and managed vehicle activities (Ford, 2010).  
- Therefore, fleets will have specific charging requirements derived from their drive cycle, destinations, time schedules and fleet size.

The concentration of buying power associated with fleets represents a significant opportunity to assist the early development of the electric vehicle industry (Electric Vehicle Coalition, 2010).

## Aim

Electric vehicles are part of an interdependent technology pathway along with roads, service stations, parking facilities and a social status system that are all mutually reinforcing. Therefore, the aim of this project is to:  
- Investigate the transition barriers of EVs within the industry through challenging the dominant path dependencies of internal combustion engine vehicles.  
- To clarify whether path dependency threatens EV fleet adoption and to analyse and address the technology lock-in electric vehicles are experiencing within the UK.

Explore how EVs could be utilised to encourage new pathways for smart integrated technologies.

## Objectives

Collaborate with fleets to analyse the integration process and utilisation of EVs to demonstrate the potential of technological lock-in on smart technologies.

- Examine existing lock-in and the cultural and habitual changes required for successful EV integration using path analysis.
- Extend the understanding of the decision-making within fleets, teasing clues to understand company culture, legislative pressure, economics, etc.
- Analyse the opportunity for intelligent EVC charging infrastructure to extend the pathway of smart technologies to wider stakeholder groups.
- Investigate the effectiveness of varying energy (EV) tariffs on consumer models.

## Case studies

This research will collaborate with the fleets below to investigate the decision matrix of the fleet composition. It shall explore the influence of company culture, legislative pressure, strategy, technology and price availability and economics. The existing technological, regional and operational lock-in influencing fleet transformation will be analysed, and path analysis will examine the societal, cultural and habitual changes that are necessary for the optimisation of EVs. This will form a snapshot of each fleet that can be used as a baseline at a later date to analyse further transformations underway.

### BT Fleet

Analysing fleet behaviour across different sectors will provide an insight into the varied fleet strategies. Using the case study framework can be constructed that will support the fleet challenges, motivations and behaviour of utilising EVs within other fleets. Recommendations will be presented on how ‘new technology’ is best integrated within fleets. In general, this analysis will contribute to the understanding of how alternative innovation can overcome path dependencies and be encouraged within the automotive industry to develop the concept of mobility.

### Summary

- The business case for electric vehicles remains case-specific. There is a narrow market in which the operational barriers are overcome and EVs work particularly well.
- Commercial fleet procurement offers the most logically beginning for market transformation.
- Change in fleet culture, behaviour and vehicle application is required for EV optimisation.

### References


### Acknowledgments

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Charging Infrastructure for Electric Vehicle Fleets – identify and develop business opportunities within target sectors

Six Month Report

Engineering Doctorate

Industrial Doctorate Centre

University of Surrey

April 2013

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Report 3: eighteen months

April 2013

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Six Month Report

The following report is based on the six month period between October 2012 and March 2013. It will reflect upon the last six months, contain analysis on transition pathways for the UK EV market and discuss future intentions.

1. Six months ending April 2013

The Research Engineer has focused on transition pathways within the automotive industry and analysed the path dependencies and technological lock-in that are impacting the electric vehicle market. This knowledge can be applied to understanding the fleet data retrieved from the interviews held with various fleets. The researcher has been recording interviews with fleet managers, fleet drivers and strategic fleet operators within four different sectors to comprehend diverse approaches to technology and vehicle use. The researcher has compiled raw fleet data and is soon to complete the interviews; on completion the information will be examined and discussed to establish themes/individualities that can be identified across sectors and roles.

Additional activities that the researcher has been involved in have provided commercial exposure and management experience, discussed further in 1.i – 1.iii

i. BMW and Ford EVlink partnerships

Schneider Electric has partnered with BMW and Ford to provide charging infrastructure solutions for domestic applications and for their respective dealerships and small fleet business. These allegiances are the first direct partnerships held between auto manufacturers and a charge point manufacturer in the UK, removing the utility company from the product hardware supply chain. As a result of the global partnerships the requirement of resource from within Schneider Electric directly working on EVlink has had to increase and as a result the Research Engineer (RE) has been involved in various elements of the projects. This has varied from back office and customer path web service translation to ensuring technical specification requirements. Although this work cannot be directly used within the researcher’s project it provides a greater insight in to Schneider Electric, the auto manufacturers’ business culture and the EV market.

ii. OLEV funding

The Government Office for Low Emission Vehicles announced in February available funds (£37 million of an existing £400 million package to support the uptake of plug-in vehicles) for homeowners in the UK with a 75% grant for a domestic charger (OLEV, 2013). Those who do not have a driveway will receive the same level of subsidy from local authorities for an on-street charger. Additional funding is available for Government and wider public estates, strategically placed fast chargers and fast chargers at railways. This announcement was extremely welcomed by the market and Schneider Electric; however the EVlink product range did not comply with specification requirements for charging manufacturers. Consequently the RE was tasked with managing the technical development of the chargers in terms of energy monitoring, smart communications and data management. Accreditation within the scheme is yet to be confirmed but is particularly important for the partnerships with Ford and BMW as they insist their customers have access to the available grants from their
charging solution providers. This has required working across entities and is still in progress to ensure the commercial offer put forward for accreditation can be achieved within the necessary time frame.

iii. Plugged in Fleet Initiative

The Plugged in Fleet Initiative (PiFi) led by Energy Saving Trust, Routemonkey & EDF and funded by DfT & TfL examined 20 fleets to develop strategic plans for EV fleet adoption. Schneider Electric was one of those fleets and the RE acted as lead coordinator for the scheme. The initiative performed a total life cost assessment on Schneider Electric’s company car fleet in London, comparing the Vauxhall Ampera with the BMW 320d, a popular choice with Schneider Electric employees. The results suggested that there is a strong business case for Schneider Electric to operate extended range EVs in place of BMW 320d’s. Although the P11D is higher for the Ampera, the lease rates are relatively similar and there are considerable tax savings that can benefit both the company and the employees. The fleet management team within Schneider Electric are aware of the initiative’s results and will be exploring viable options for EVs to be incorporated within the company’s lease policy held with Hitachi Capital.

Initially there was the intention the RE would contribute analysis on the infrastructure requirements for the 20 fleets involved; investigating methods of maximising vehicle miles through various possible infrastructure models. However this element of the initiative did not achieve funding and consequently EDF performed site surveys on the basis of 1-2 wall mounted 22KW (max) charger per case study.

2. Transition pathways for the UK electric vehicle market

The following (Sections 2i - vi) is research in to transition pathways of the automotive industry and electric vehicle market. The researcher aims to develop this research in to a journal article for publication.

i. Introduction

Transition pathways refer to the evolution of one system to another, a transition will be influenced by three key factors; government, market and societal actors. However, the dynamics are not always controllable or predictable and will often conflict with one another (Foxon, 2012). Transition pathways are used to suggest a number of scenarios that could occur; in this case in regards to the UK electric vehicle market.

The Climate Change Act requires an 80% reduction in greenhouse gas emissions by 2050 alongside the UK’s commitment to increase renewable energy. Road transport is a key market to achieve such decarbonisation as currently it contributes 90% of the UK’s domestic transport emissions (OLEV, 2011). The UK is exploring various pathways to low carbon vehicles, whether it is using efficient petrol/diesels, hydrogen or biofuels. Electric vehicles (EVs) are argued to be a substantial opportunity for the decarbonisation of transport and the most promising in the immediate to near future (ElectrificationCoalition, 2010). However, efficient internal combustion engine (ICE) vehicles are currently dominating the market with heavy investment from the automotive industry.

The automotive industry is one of the largest sectors in the UK, employing over 700,000 people and turning over £50bn annually thus representing approximately 3% of total GDP (SMMT, 2013). Whilst there are
approximately 28.7 million cars licensed in the UK, only 3,000 have been eligible for the Plug-in Car Grant\(^1\) since its inception in 2011. There are seven volume car manufactures in the UK and over one million vehicles produced annually; 75\% of which are exported equating to 10\% of total UK exports (SMMT, 2013). This highlights the importance of the motor industry for the UK economy, the imbedded characteristics and wide spread investment of technological development and manufacturing processes/designs. This is alongside increasing path dependencies that have been developed over the last century influencing Governmental policy, customer behaviour and preconceived notions of vehicle and transport solutions.

This paper will explore the transition pathway of electric vehicles within the automotive industry. Section 2.ii of the paper will discuss theoretical issues regarding path dependencies and technological lock-in; Section 2.iii will explore the traditional pathway within the automotive industry; Section 2.iv will examine the transition to date for EVs and in the wider context of alternatively fuelled vehicles (AFVs); and Section 2.v will discuss the market techniques employed to achieve heightened EV use.

### ii. Transition pathways, path dependencies and technological lock-in

A transition to a new technology is an extremely dynamic process as it extends beyond innovating and competing technologies. It requires a fundamental change in market concepts through governance, social practices and business models that have been developed upon past and present technological systems (Foxon et al, 2012b). Introducing a new technology in this vein results in a path dependent technology that is much more likely to have a long term impact on the market and successfully achieve creative destruction\(^2\) (Schumpeter, 1942). It is argued 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, 2012 p.1). Foxon’s exploration of transition pathways is based upon three core competing logics (Figure 1). This suggests that the concept within the action space is influenced by government, society and the market, and that this action space will have been comprised through past transition pathways and will influence future regimes.

Fig 1. Competing logics during transition

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\(^1\) The Plug-in Car Grant is available for vehicles that emit less than 75 grams of carbon dioxide per kilometre driven and meet minimum warranty standards. Electric vehicles must be able to travel a minimum of 70 miles between charges and PHEVs must have a minimum electric range of 10 miles. The grant awards 25\% off the cost of a car, up to a maximum of £5,000 and 20\% off the cost of a van, up to a maximum of £8,000 (OLEV, 2011).

\(^2\) The “process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one” (Schumpeter, 1942 p.82).
Placing EVs within the *action space* it is possible to examine the current transition pathway that electric vehicles are being integrated through and the roles of the each *logic*. In theory 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, 2012 p.7). The manufacturers 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. Although the auto manufacturers are in a strong position presently in the market and this will likely be the strongest *logic* in the future (as seen with ICE vehicles), it is questionable whether there is currently significant market presence to enable the manufacturers to be the principal mechanism but instead act in collaboration with the ‘competing’ *logics*.

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 electric vehicles can be witnessed in transition towns across the UK through car clubs, infrastructure investment and shared ownership, with the aim to reduce a community’s carbon and fuel use. However this is a very niche section of society, as in the majority of UK towns drivers remain relatively passive towards electric vehicles, lacking a willingness/awareness to change behaviour to adopt a new transport mode. Humankind’s perception of undesirable change acutely impacts the pathway of new technology; 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 thousand flower pathway was to be most dominant it would most likely require the greatest change in society for EVs to challenge the ICE vehicle.

However, currently the key competing logic in the EV market is *Government logic* as the Government has a vast 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 electric vehicles with real-time results. By 2025 the UK Government alone will invest over £150bn in low and ultra-low carbon vehicle technologies and over £450 million of that will be ensure the UK is at the global forefront of the development, demonstration, manufacture and use of ultra-low carbon vehicles (SMMT, 2013). The UK automotive industry is now competing against new developing markets particularly in Asia; however it appears that the majority of investment from countries such as China is on improving internal combustion engines.
is contrary to the high level of investment from TRIAD countries in to electric vehicles (KPMG, 2013). 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 electric vehicles and the necessary infrastructure. Policy action, at both the UK and European level is required to assist the dramatic shifts in lifestyle and development patterns that correspond to a transition to low carbon transport network. However, it is possible that a technology may be ‘locked-in’ due to previous market events resulting in technologies/technological systems to remain stagnant or to develop within a specific pathway. In such instances policy may not result in the desired outcomes due to high barriers to entry for competing technologies. This results in embedded technologies remaining dominant for an extended period of time, despite superior substitutes being available. This is detrimental to the market and in most cases to society as innovation is stifled and economies struggle to grow organically. It is questionable whether the automotive industry holds a level of technological lock-in as alternatively fuelled vehicles (AFVs) have difficulty gaining market share. Such path-interdependencies are stimulated through the mutually reinforcing social system of road transport encompassing infrastructure, service stations and roads; as well as the dynamics of political, economic and technical decisions that develop within the economy (Cowan et al, 1996). It is arguable that auto manufacturers have established “economic-technical problems that have blocked the realisation of the economic benefits” of electric vehicles due to existing manufacturing processes and designs (Cowan et al, 1996 p.4). In which case, Government logic is the fundamental pathway for the electric vehicle market to develop through enforcing regulative measures.

iii. Traditional pathway for the automotive industry

To understand the transition from ICES to AFVs, it requires historical influencers to be considered. The automotive industry is a key sector within the UK in terms of innovation, investment, job creation and the global economic position of the UK. The 21st century has seen the industry adapt to many challenges both economically and technologically. The key challenge for auto manufacturers is to align technology, product and business performance alongside customer value and financial constraints (DTI/BSI, 2008). The UK motor industry is a relatively sensitive market as there is a level of dependency upon the global supply chain and a necessary support from the government and European Union (Cooke, 2010). This is heightened as the UK no longer has a ‘native’ car manufacturer, although vehicles are manufactured to an extent in Britain (due to the engineering and manufacturing strengths of the nation) they are foreign owned companies; thus resulting in a lack of brand loyalty and a diverse vehicle ownership. This differs from the allegiance had in e.g. the US for Ford and in Japan for Nissan. Not having the brand association in the UK, drivers tend to purchase vehicles on the specification requirements, merit, quality, value and reliability. Due to the success and dominance of the internal combustion engine, alternative fuelled vehicles will be inhibited by the current industry structure and vehicle architecture. AFVs 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 alternative technological 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.
One of the most relevant and key drivers for change within the automotive industry is the necessity to reduce CO2 emissions. Emissions reduction is a direct result of regulation and has large implications upon the car market in terms of design, advertising, fiscal incentives and the need to raise awareness. As a result advances in ICE efficiencies have been becoming more advanced; for example turbo-compound engines which increase the output of the engine without increasing its fuel consumption through a heat energy recovery system. The direction of the technology within the industry stems from Formulae 1 for example ABS and traction control, such technologies then enter the road car market and enhance vehicle efficiency and/or safety. Recently Honda has returned as suppliers for the Formula 1 market, supplying turbo-compound engines to McLaren from 2015. This will see the efficiency of diesel engines rising from 25% to 35% (with a target of 40% within three years). Such technological developments will enhance the efficiency of the electric motor and therefore will directly benefit EV capabilities. This technological capability reflects the current strengths and structure of the sector due to the sustained investment in power train systems. This has grown in importance as the electronic and mechanical systems become more complex and the demands on reliability more stringent. Additionally, vehicle manufacturing across the supply chain and the customer path have become a great deal more streamlined and quality focused, reducing waste and costs (DTI/BSI, 2008).

Consumer behaviour within the automotive industry is very segmented between fleet and commercial and private purchases. The fleet procurement process considers not only the vehicle specification but the whole life costs incorporating price, residual value, efficiency, maintenance and servicing costs. This is contrary to the deciding factors for private individuals who tend to be more focused on the purchase price and reputation of the vehicle manufacturer. In regards to commercial vehicles efficiency has been the focus for change and has largely driven the industry due regulatory pressure and financial incentives. Trucks manufactured today are up to 35% more productive than those manufactured in 1998 in terms of payload, as well as a reduction in carbon emissions of 35% (SMMT, 2013). Additionally, the average working life for commercial vehicles is nine years thus extending the use phase of the vehicle and simplifying the recycling phase at the end of the life cycle (SMMT, 2013). Although this is positive in terms of emissions reduction, it heightens the barriers to entry for EVs as not only is the replacement cycle lengthening but the expectation of vehicle capabilities is increasing. This deepens the technological lock-in and enforces existing path dependencies within the industry; therefore it could be argued EVs are required to offer extended benefits than that of an ICE vehicle in order to compete.

iv. Electric power train vehicles

Despite the fact that electric vehicles were the first form of power train, internal combustion engines have dominated the world’s mobility system since the late 19th century (Cowan et al, 1996). With the discovery of petrol, vehicles could travel greater distances and at greater speeds, this reduced auto manufacturers’ investment of R&D in EVs and has been suggested to have led to technological lock-in of the ICE. Over the last two centuries the lock-in has become more entrenched within society and as a result there has been very limited competition for the ICE from alternative power trains. The first mass market alternative to petrol or diesel was the hybrid, in 1997 Toyota launched the Prius. This increased the versatility and flexibility within the market through unlocking the historical market of restricted designs and specifications (Ahman et al, 2007). 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 hybrid sales (5 million) in 2012. In 2013 there are twenty hybrids in the market, highlighting the
growth of acceptance with drivers both in the commercial and private sectors. The hybrid’s market developments could be paralleled to the electric vehicle market. Both challenge the dominant technology using varying degrees of electrification and therefore could be used to manage expectations of the rate of vehicle mode acceptance.

The UK have an aim of 1.7 million EVs by 2020, however it is questionable whether a new vehicle technology could be adopted so rapidly (POST, 2010). To date there have been 3,000 electric vehicles sold in the UK and 3,236 charging points installed, 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, work places 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. Understandably the range of an internal combustion engine is on average three times greater than that of an EV but it highlights the focus and importance the EV market has placed on infrastructure prior to actual requirement. This approach could be questioned as the 8,000 petrol stations were gradually added to the UK road transport network as vehicle ownership increased. The scenario faced by EVs today however, requires challenging the technological lock-in of ICEs, competing on efficiency and specification and removing the associated range-anxiety with current electric motors. Both the ‘lack’ of charging infrastructure and the restricted range of electric vehicles are argued to be key challenges for the adoption of EVs. This is in addition to the high P11D, limited range of models and the perceived social standing. More importantly though is the lack of interoperability amongst charging operators consequently forming ‘EV hubs’ around the UK that do not provide drivers with roaming abilities across or within alternative networks. This limits the functionality of an EV resulting in an additional barrier to adoption and perceived disadvantage against that of an ICE vehicle.

Apart from 21st century automotive design and communication capabilities, electric vehicles have essentially not improved technologically since the early twentieth century (Hoyer, 2007). However, regulations regarding emissions from businesses and the associated carbon credits have enhanced the business case for EVs. A key aspect of electrification of transport is consumer acceptance as within many cultures vehicles are considered as status symbols. According to the Journal of Personality and Social Psychology, alternative fuelled vehicles are challenging traditional status allegiance with luxury vehicles despite the sacrifice of performance (Griskevicius, 2009). As the adoption of EVs is challenging it is integral to understand the transition pathways and possible scenarios of EV deployment. To date the automotive industry and UK Government have already utilised market techniques to encourage sales; this will be discussed in the following section.

v. Transition pathways for vehicle electrification

The transition from ‘conventional’ vehicles types to electric vehicles 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” (EuropeanCommision, 2011 p.16). Political decisions regarding legislation, grants and taxation have to be considered against the long term trajectory and must consider key stakeholders. Game changes in the market through governance should attempt to foresee and decipher demands from the various economic and social sectors. The UK has taken a combination of consumer incentives, industry regulation and pilot projects to encourage the use of EVs. From 2012 Europe enforced regulations to limit carbon emissions from new cars and incentivised manufactures to develop EVs. Since then
there has been a threefold increase in the number of EVs in the market. This was imposed alongside consumer incentives in the UK that rewarded drivers for buying electric vehicles. Having a greater choice and availability of product as well as the combination of regulation and incentive led to a 16.6% increase in pure EV sales over the last year (see Figure 2).

Fig 2. December 2012 – EV and AFV registrations

<table>
<thead>
<tr>
<th>Vehicle Category</th>
<th>December</th>
<th>Year-to-date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2012</td>
<td>2011</td>
</tr>
<tr>
<td>Total pure electric</td>
<td>117</td>
<td>27</td>
</tr>
<tr>
<td>Plug-In Car Grant eligible</td>
<td>194</td>
<td>29</td>
</tr>
<tr>
<td>Total petrol/electric hybrid</td>
<td>1,380</td>
<td>1,773</td>
</tr>
<tr>
<td>Total diesel/electric hybrid</td>
<td>110</td>
<td>1</td>
</tr>
<tr>
<td>Alternatively fuelled vehicles</td>
<td>5</td>
<td>50</td>
</tr>
</tbody>
</table>

Source: SMMT, 2013b

It is difficult to determine the key reason for an increase in sales but this would indicate that the market is reliant on financial support from both the manufacturers’ perspective as well as that of the customer in terms of the Plug-in Car Grant, no road tax or congestion charge and lower benefit in kind etc. It is questionable whether this is a sustainable approach taken by Government, as if/when the financial endorsements are removed the market may not be in a position to survive independently. Additionally in terms of city congestion, increasing electric vehicle use will not reduce the issue. It is thought in the future when EV use has increased and Government are receiving lower revenue from fuel tax, charges will be introduced to address congestion, as a consequence this could damage the economic model for owning an EV and result in the same scenario as LPG vehicles.

Figure 2 highlights the increase in popularity of the diesel/electric hybrid thus suggesting that customers have become comfortable with the technology and are seeking economic and efficient modes of transport.

Due to heightened awareness of climate change, shifting concepts of mobility and increases in population, urbanisation and globalisation, the automotive industry has been forced to adapt to the market. As a result of wider environmentalism, both private and commercial vehicle purchase decisions include CO2 emissions and fuel efficiency; this may be through e-mobility use or smaller sized ICE vehicles. Due to the fact that 89% of the UK’s population lives within an urban area, ‘superminis’ are now designed lighter and more fuel efficient due to new high-tech materials. The introduction of stop/start technology is an example of efficiency highly suited to urban driving. Such technologies are assisting the reduction of carbon emissions and fuel consumption however, it is suggested that this is largely dependent on the vehicles drive cycle (PikeResearch, 2012).

The concept of mobility has dramatically changed over recent years; historically car ownership was a luxury status symbol whereas today with the majority of society based within cities, car ownership can be a constraint and high expenditure. Consequently in certain segments of the population ‘peak car’ has been reached in which there has been no increase or a decline in average annual mileage (LeVine et al, 2012). In terms of carbon reduction this is an ideal scenario, however for the electric vehicle market the peak car segment along with the wider population would require deep changes in behaviour when “moving towards a new post-carbon energy paradigm” (EuropeanCommission, 2011 p.17). It is those who require changes in behaviour that will likely be the last to adopt. However, evidence suggests that ‘Mobility-as-a-Service’ (MaaS) will become integral to
society providing alternatives to car ownership (KPMG, 2013). MaaS would widen the mobility solution incorporating mobile apps for payment and location-aided services, thus ensuring ease of use and functionality (KPMG, 2013). This is a considerable opportunity to decarbonise transport, especially within cities that could have multiple vehicle pick-up and drop-off locations. More importantly this is a substantial opportunity for the EV market as it removes many of the barriers to electric vehicle use, of which are mainly due to ownership models. Additionally, it presents dealerships with an option to adapt to the changing demands of customers, integrating MaaS and online services in to leasing options for example. Over the next decade it is likely that transport solutions will develop to become a more integrated system within cities, incorporating public transport, MaaS and a more diverse energy mix managed by demand response. Technologically this is conceivable however, the rate at which it can be achieved is reliant upon the acceptance of society and the mechanisms put in place by Government.

vi. Conclusion

This paper has explored the traditional pathway of the automotive industry, how it has adapted to new competing Asian markets and the implications of emission regulations. This has been examined in the broader context of transition pathways, path dependencies and technological lock-in to understand the process of a new technology entering an established market. The paper has explored the mechanisms implemented by Government and questioned the success of the transition to EVs thus far.

It has been established that the automotive industry is fundamentally built upon path dependant characteristics and has embedded preconceived notions of vehicle design and specification in to customers’ expectations. Thus technological lock-in is limiting the available market to EVs resulting in niche applications that can benefit from the available grants and incentives. It is possible that electric vehicles will follow a similar systemic process as the hybrid vehicle and be considered a mass market transport mode within fifteen years. However as the concept of mobility is developing in to a complete solution composed by various modes of transport and alternative ownership models, electric vehicles may remove technological lock-in through entering the industry as a segment of ‘smart mobility’. Future research could position smart mobility within the action space of Foxon’s competing logics theory to indicate possible scenarios that are likely to influence future regimes in regards to electric vehicle integration.

3. Planned activity

Firstly the researcher will complete the interviews with the remaining fleets to construct a cross-sector framework on fleet behaviour towards new technologies. This will indicate relevant transition pathways and dominant actors, dependant on the fleet’s scope and strategic objectives. Ideally this will be used by other fleets to establish potential opportunities and/or challenges in procuring and utilising electric vehicles. The findings will be discussed as an extension of the paper produced on transition pathways and path dependencies (Sections 2i - vi), with the intention of publication.

Having discussed transition pathways in the context of vehicle electrification it suggests the need to broaden the research scope to examine smart mobility. This is due to the influence of Mobility-as-a-Service and the developing need for societies to anticipate infrastructure requirements and adapt to integrated systems. The RE will produce a proposal for the extension of research to justify this and examine the existing research questions.
This will build upon the existing research and utilise the knowledge gained from working with fleets, using them as case study references. If the proposal is accepted by the projects stakeholders, the premise of the work will be to investigate transition pathways of a smart integrated transport system within a smart city framework.
References:


CHARGING INFRASTRUCTURE FOR ELECTRIC VEHICLE FLEETS – IDENTIFY AND DEVELOP BUSINESS OPPORTUNITIES WITHIN TARGET SECTORS.

SECOND YEAR ENG.D DISSERTATION

OCTOBER 2013

ENGINEERING DOCTORATE IN SUSTAINABILITY FOR ENGINEERING AND ENERGY SYSTEMS

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Executive Summary

Background

Electric vehicles offer a substantial opportunity to decarbonise the UK’s road transport network. Being part of an interdependent technology pathway along with roads, service stations, parking facilities and a social status system that are mutually reinforcing, it is very challenging to establish an electric vehicle (EV) market. For EVs to reach mass market an extensive transformation is required across policy, behaviour and technology dissemination. This will challenge existing path dependencies and open up new business models to alternative modes of transport.

Objectives

This project will explore possible transition pathways for electric vehicles as well as the broader concept of Mobility-as-a-Service. The Research Engineer will put forth strategies to contribute to existing policies to ease integration. The project aims to understand the path dependencies within the automotive industry and the associated technological lock-in that restricts market developments. It will explore how EVs can be utilised within society to encourage new pathways for a service based mobility model.

Justification

This research project will focus on the UK road transport market that currently contributes 90% of domestic transport emissions (OLEV, 2011). As the fastest growing contributor to climate change, methods of transportation need to be challenged in order to satisfy the UK Climate Change Act of a 50% reduction of greenhouse gases by 2025 on the 1990 baseline levels (European Union, 2009, drdni, 2010).

Outcomes

Existing outcomes are focused on the fleet market in terms of the transition pathways utilised at present and the business case for electric vehicle fleets. Over the course of the project a contribution to knowledge will be made in transition pathways for electric vehicles and Mobility-as-a-Service (MaaS). This will result in strategic recommendations upon the integration of EVs and eMaaS in the UK. These recommendations will be justified through evidence from case studies, frameworks and industry and academic expert elicitation.

Next Steps

The fleet enquiry will be tested and refined to ensure that it is a fair assessment of the market. This will be followed by a journal article on the ‘Transition Pathways for a UK electric vehicle market’. The project will then enter its next phase where it will incorporate Mobility-as-a-Service, investigating motivation crowding, existing policies and the viability of a multi modal transport system.
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1. Introduction

Within this 24 Month Dissertation, the literature on the topic will be discussed and the work to date and future research plans will be addressed.

1.1 Aims & Objectives

Electric vehicles are part of an interdependent technology pathway along with roads, service stations, parking facilities and a social status system that are all mutually reinforcing. This research aims to determine a suitable transition pathway for a sustainable and competitive electric vehicle (EV) marketplace. Consequently the following objectives of the project are:

• Investigate the transition barriers of EVs within the industry through challenging the dominant path dependencies of internal combustion engine vehicles

• Clarify whether path dependency threatens EV fleet adoption and to analyse and address the technology lock-in electric vehicles are experiencing within the UK

• Explore how EVs could be utilised to encourage new pathways for a service based mobility model

• Recommend how electric vehicles can break through current lock-in in order to create new pathways for service based models

• Explore the market techniques implemented by Government and the impact had on the EV market

1.2 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, 2011 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 hybrids generate electricity through regenerative braking, and therefore do not require a charging infrastructure solution. 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. Hybrids represent a transitional technology between internal combustion engine (ICE) vehicles and EVs, HEVs heighten awareness of AFVs without the need for behavioural change. This is an important element to consider and comparatively question the case of EV, however to explore in depth is out of the project scope. Originally the scope was defined to the fleet market for several reasons including route predictability, high vehicle utilisation rates and centralised parking facilities; this is discussed further in Section 2.3. However, the scope has
since broadened to investigate alternative business models and Mobility-as-a-Service (Mass). The Research Engineer will explore beyond fleet applications to private individuals and operators within the scope of eMaaS.

### 1.3 Overall Research Plan

A literature study has been undertaken to understand the existing research on transition pathways and electric vehicles, this is referenced throughout the document having identified gaps within the body of knowledge. In particular there is a lack of understanding on the appropriate pathway to achieve a transformation within the automotive industry. This EngD project will explore various markets to understand possible transition pathways for successful EV integration within the UK’s transportation network.

The following research questions have been formed in order to analyse the challenges that the EV market are faced with to understand the barriers preventing adoption of EVs and requirements to market acceptance. The questions have been constructed alongside the interests of Schneider Electric (sponsoring organisation) as addressing such issues will enhance applicable market knowledge and therefore aid the development of the Schneider Electric’s EV strategy.

<table>
<thead>
<tr>
<th>Research questions</th>
<th>Sub questions</th>
</tr>
</thead>
</table>
| What are the necessary changes for the market to achieve the EU set target of 1.5 million EVs in the UK by 2020? | • Within a fleet what change is required within the decision making process and the drivers application to ease EV adoption?  
• How does the total cost of ownership of an EV compare to that of ICE vehicle?  
• What challenges can be overcome through behavioural change rather than technological developments or regulative enforcement?  
• How should the concept of mobility be developed?                                                                 |
| To what extent is technological lock-in restricting the EV market?                  | • What are the dominant path dependent characteristics within the automotive industry that challenge the utilisation of electric vehicles and electric vehicle charging?  
• To what extent is public policy responsible for the adoption of EVs in ‘success’ countries?  
• To what extent has motivation crowding been a successful technique for EV adoption? |
| What opportunity do electric vehicles have to extend the pathway to a mobility as a service model? | • What are the path dependent characteristics within society that challenge MaaS?  
• How can an integrated and interoperable mobility city service be a viable proposition? |
These have developed over the last two years to best address market conditions and project aims. They however should remain constant for the remaining two years as the project concludes. The flow diagram below outlines the research plan, an overview of the objectives and outcomes at each stage.

In conjunction with the research the following modules will be completed over the four year period:

**Completed:**

- Corporate Social and Environmental responsibility
- Environmental Auditing and Management Systems
- Environmental Law
- Environmental Science and Society
- Life Cycle Assessment
- Sustainable Development
- Social Research Methods
Transitions to a Low Carbon Economy

To be completed:

- Communication management
- Ecological Economics
- Integrated assessment
- Risk & Financial Management

Along with the following workshops:

- Career management skills
- Demonstrating impact
- Leading self & your key relationships
- Project management (Prince 2)
- Public engagement

2. Background

2.1 Context

This research project will be focused on the UK road transport market that currently contributes 90% of domestic transport emissions (OLEV, 2011). As the fastest growing contributor to climate change, methods of transportation need to be challenged in order to satisfy the UK Climate Change Act of a 50% reduction of greenhouse gases by 2025 on the 1990 baseline levels (European Union, 2009, drdni, 2010). UK road transport is vulnerable to the effects of global supply constraints and price shocks, demanding over 50% of overall UK oil consumption (ITPOES, 2010). Therefore it is advisable that the UK utilises alternative fuels to separate the transport sector from the trade deficit of importing the single fuel means. It is suggested however that future transport growth will demand oil at a quicker rate and will over compensate for substituted fuel use (ITPOES, 2010). Disruption upon transport networks across the UK could have severe detrimental impacts as a wide range of businesses rely on ‘just-in-time’ business models based on highly integrated transport systems (ITPOES, 2010). This highlights the challenges of transforming to a cleaner energy portfolio and a reduction in fossil fuel use.

There are however immediate opportunities for road transport to be decarbonised. Electrification of transport is argued to be a substantial opportunity for the decarbonisation of transport and the most promising in the near term (Electrification Coalition, 2010). It is suggested that EVs are more energy efficient than an internal combustion engine vehicles within the use phase, with 75% efficiency compared to the 20% efficiency of ICEs (WWF, 2011). Additionally, EVs present the opportunity to reduce extensive fossil fuel use by 80% for the purpose of meeting vehicle motive power requirements by 2030 (AEA, 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, 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 misalignments between academia and industry regarding the life time emissions of an EV. Within industry the vehicles are marketed as ‘zero emissions’ as electric vehicles have no tail pipe emissions and therefore from tank-to-wheel are essentially environmentally ‘harmless’. However assessing the overall environmental impact of an EV from ‘well-to-wheel’ and beyond, it is evident 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). Electric vehicles are expected to cause various challenges to the UK including harmonic disturbance and peak energy demand. However it is suggested that EVs have the ability to balance the national grid positively as long as the majority of vehicles are charged over night, the consistency of energy demanded will stabilise the peaks and troughs. In order to manage this energy, 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 (with the electricity used at public charge points appearing on the owner’s domestic bill). All of these models will have different implications for the operations of back-office systems and the extent of interoperability.

2.2 EV Market

At present there are fifteen electric vehicle models available to the UK market, equating to approximately 3,000 electric vehicles and 3,236 charging points in the UK that have been sold in conjunction with Government funding. This is just 0.01% of cars licensed in the UK but it is required to rise to 6% by 2020 if UK climate change targets are to be met (WWF, 2011). Establishing an EV market is challenging due to the need for extensive transformation across policy, behaviour and technology dissemination. This is alongside the inherent challenges of EVs such as the limited range and high purchase price. As expected within an emerging market the number of companies providing charging infrastructure solutions has risen rapidly. Currently there are ten suppliers of charging infrastructure in the UK all of whom provide a range of charging points and advanced services such as billing. At present the UK EV market has reached pioneers of the technology who have thus far assisted, alongside Government investment, future longevity of the market. It is palpable that ICEs will remain in the market but over time the integration of EVs will become more prevalent. SMMT state “plug-in hybrid and electric vehicle sales are up 70.7% year on year for the first seven months of 2013” (Grant, 2013 p.1). High demand from both private and fleet sectors have led to increased forecasts of 2.2+ million units in 2013, 8.4% higher than 2012. It is argued this is due to tax breaks, increased availability of products and wider interest from consumers (Grant, 2013).

2.3 Fleet Market

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

Thus far fleets have been the central premise of this research as they offer the most promising opportunities:

- The majority of commercial fleets having similar characteristics including high utilisation rates, centralised parking facilities and managed known activities (PikeResearch, 2010)
- Fleets are expected to have specific charging requirements derived from their drive cycle, destinations, time schedules and fleet size
- The concentration of buying power associated to fleets and the relatively small number of influential decision makers within the industry (ElectrificationCoalition, 2010)

Furthermore, through developing a strong UK electric fleet market it is argued that infrastructure will be created through private investment. If the Government were to mandate i.e. through policy, this infrastructure could form the basis of a new publicly accessible fuel vector infrastructure in the medium term, reducing the burden on public spending. Additionally by encouraging fleet uptake of EVs it could reach a significant number of private individual’s through their use and contact with fleet vehicles, who may then see the potential for such vehicles in their domestic lives. 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 a ‘new technology’ vehicle.

3. Literature

3.1 Transition Pathways

A transition to a new technology is an extremely dynamic process as it extends beyond innovating and competing technologies. It requires a fundamental change in market concepts through governance, social practices and business models that have been developed upon past and present technological systems (Foxon et al, 2012b). Introducing a new technology in this vein result in a path dependent\(^1\) technology (discussed further in Section 3.2) that is much more likely to have a long term impact on the market and successfully achieve creative destruction\(^2\) (Schumpeter, 1942). Transitioning specifically within the automotive industry is extremely difficult due to the scale of the industry and “a wide range of powerful positive feedback processes that confer substantial advantage to the incumbent ICE technology” (Struben et al, 2008 p.3)

It is argued 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, 2012 p.1). Foxon’s exploration of transition pathways is based upon three core competing logics (Figure 1). This suggests that the concept within the action space is influenced by government, society and the market, and that this action space will have been comprised through past transition pathways and will influence future regimes.

\(^1\) Path dependence is a dynamic theory assuming that initial events can increasingly restrain present and future choices (Koch et al, 2009)

\(^2\) Creative destruction is the “process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one” (Schumpeter, 1942 p.82).
Figure 1. Competing logics during transition

Placing EVs within the action space it is possible to examine the current transition pathway that electric vehicles are being integrated through and the roles of the each logic. In theory 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, 2012 p.7). The manufacturers 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. Although the auto manufacturers are in a strong position presently in the market and this will likely be the strongest logic in the future, it is questionable whether there is currently significant market presence to enable the manufacturers to be the principal mechanism but instead act in collaboration with the ‘competing’ logics.

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 electric vehicles 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 this is a very niche section of society, as in the majority of UK towns drivers remain relatively passive towards electric vehicles, lacking a willingness/awareness to change behaviour to adopt a new transport mode. Humankind’s perception of undesirable change acutely impacts the pathway of new technology. However, according to the Journal of Personality and Social Psychology, alternative fuelled vehicles are challenging traditional status allegiance with luxury vehicles despite the sacrifice of performance (Griskevicius, 2009).

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 CO2 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 consumes fuel, creative destruction can challenge this as AFVs present an opportunity to positively alter the energy mix; this however requires the 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 thousand flower\(^3\) pathway was to be most dominant it would most likely require the greatest change in society in order for EVs to challenge the ICE vehicle. Struben et al (2006) explore the behavioural dynamics of consumers’ willingness to try an alternative platform to the existing practice and the impact of social exposure and additional feedbacks. 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; it is then likely to change driver’s behaviour and future decisions upon vehicle ownership. Existing regulations on carbon emissions are particularly effective within business, however it may be advisable to extend this approach to the public and implement the ‘polluter pays’ strategy. This may lead society to question the concept and sustainability of mobility modes and more broadly the transformation to a low carbon economy. Government incentives and regulations relating to emissions have been key catalysts in beginning to unlock ICE vehicle dominance within the market. Currently the key competing logic in the EV market is Government logic in which the Government has a vast 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 electric vehicles. By 2025 the UK Government alone will invest over £150bn in low and ultra-low carbon vehicle technologies and over £450 million of that will be ensure the UK is at the global forefront of the development, demonstration, manufacture and use of ultra-low carbon vehicles (SMMT, 2013). 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 electric vehicles and the necessary infrastructure. Market techniques such as these can often result in short lived system innovations, is motivation crowding\(^4\) a sustainable technique?

Policy action, at both the UK and European level is required to assist the dramatic shifts in lifestyle and development patterns that correspond to a transition to low carbon transport network. However, it is possible that a technology may be locked-in due to previous market events resulting in technologies/technological systems to remain stagnant or to develop within a specific pathway (discussed further in Section 3.2). In such instances policy may not result in the desired outcomes due to high barriers to entry for competing technologies. This results in embedded technologies remaining dominant for an extended period of time, despite superior substitutes being available. This is detrimental to the market and in most cases to society as innovation is stifled and economies struggle to grow organically. Consequently Government logic is the fundamental pathway for the electric vehicle market to develop through enforcing regulative measures.

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

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\(^3\) An approach in which citizens take a leading role in the decisions relating to how their local and national energy systems operate.

\(^4\) Motivation Crowding “suggests that external intervention via monetary incentives or punishments may undermine, and under different identifiable conditions strengthen, intrinsic motivation” (Frey et al, 2002)
• Niche-innovations that build internal momentum through learning processes, support and price and performance improvements
• Changes at the landscape level creating pressure on the regime
• Destabilisation of the regime creating opportunities for niche-innovations

The different 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). Although MLP has been heavily criticised for functionality, the three levels correspond to an extent with Foxon’s ‘competing logics during transition’. The MLP follows the same scale of interaction; society, market and governance. For example at landscape level, the transport sector is changing due to the pressure from climate change targets, resulting in behavioural and political changes (Geels, 2004). 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 (Geels, 2004). This highlights the barrier to greater utilisation of electric vehicles 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 landscape?

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. It could be argued that Foxon’s ‘competing logics during transition’ should incorporate Technology logic to address the impact of technological advances on the action space. It is questionable whether the automotive industry holds a level of technological lock-in as AFVs have difficulty gaining market share. Such path-interdependences are stimulated through the mutually reinforcing social system of road transport encompassing infrastructure, service stations and roads; as well as the dynamics of political, economic and technical decisions that develop within the economy (Cowan et al, 1996). It is arguable that auto manufacturers have established “economic-technical problems that have blocked the realisation of the economic benefits” of electric vehicles due to existing manufacturing processes and designs (Cowan et al, 1996). Consequently diverse approaches are required to stimulate the sustained transition to electric vehicles along with an understanding of the dynamic implications and reinforced feedbacks (Struben et al, 2008).

3.2 Path dependency & Lock-in

To understand the transition from internal combustion engines to alternatively fuelled vehicles, it requires historical influencers to be considered. The automotive industry is a key sector within the UK in terms of innovation, investment, job creation and the global economic positioning. Over the last two centuries internal combustion engine has dominated the market, the lock-in has become more entrenched within society and as a result there has been very limited competition for the ICE from alternative power trains. The 21st century has seen the industry adapt to many challenges both economically and technologically. The key challenge for auto manufacturers is to align technology, product and business performance alongside customer value and financial constraints (DTI, 2008). Path dependency and lock-in are often used interchangeably however there is a distinct difference. Path dependency refers to “a dynamic theory assuming that initial events can increasingly restrain present and future choices” (Koch
et al, 2009 p.67). Whereas a lock-in situation is a self-reinforcing mechanism with a dominant solution. 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 and EVs can be utilised to a greater extent along with the introduction of alternative business models.

Due to the success and dominance of the internal combustion engine, alternative fuelled vehicles will be inhibited by the current industry structure and vehicle architecture. AFVs 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 alternative technological 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.

One of the most relevant and key drivers for change within the automotive industry is the necessity to reduce CO2 emissions. Emissions reduction is a direct result of regulation and has large implications upon the car market in terms of design, advertising, fiscal incentives and the need to raise awareness. As a result advances in ICE efficiencies have been becoming more advanced, stemming from Formulae 1 technology electric motors have improved and will directly benefit EV capabilities. This technological capability reflects the current strengths and structure of the sector due to the sustained investment in power train systems.

Across the spectrum of alternatively fuelled vehicles it is thought HEVs have a “transitional role...in the sequence of technology adoption” as the vehicles reduce perceived risks associated with AFVs (Collantes, 2007 p.270). The introduction of the Toyota Prius in 1997 is argued to have increased versatility and flexibility within the market through unlocking the historical market of restricted designs and specifications (Ahman et al, 2007). 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 hybrid sales (5 million) in 2012 (Shirouzu et al, 2013). In 2013 there are twenty hybrids in the market, highlighting the growth of acceptance with drivers both in the commercial and private sectors. The hybrid’s market developments could be paralleled to the electric vehicle market. Both challenge the dominant technology using varying degrees of electrification and therefore could be used to manage expectations of the rate of vehicle mode acceptance.

Consumer behaviour within the automotive industry is very segmented between fleet and commercial and private purchases. The fleet procurement process considers not only the vehicle specification but the whole life costs incorporating price, residual value, efficiency, maintenance and servicing costs. This is contrary to the deciding factors for private individuals who tend to be more focused on the purchase price and reputation of the vehicle manufacturer. In regards to commercial vehicles efficiency has been the focus for change and has largely driven the industry due to regulatory pressure and financial incentives. Although this is positive in terms of emissions reduction, it heightens the barriers to entry for EVs as vehicle’s are in operation longer and maintain high levels of efficiency. This deepens the technological lock-in and enforces existing path dependencies within the industry;
therefore it could be argued EVs are required to offer extended benefits than that of an ICE vehicle in order to compete. Cowan et al (2012 p.4) states “it is not enough that the competing technology is better...to overcome lock-in it is necessary that some extraordinary events occur”. He continues that these could be via regulation, scientific breakthrough, technological breakthrough, creation of niche markets, changes in taste and/or a crisis in the existing technology (Cowan et al, 2012). Regarding the electric vehicle market, there is not currently a crisis in existing technology and in fact ICE vehicles are technologically improving, competing heavily on efficiency and emission levels. However, regulation regarding emissions from businesses and the associated carbon credits has enhanced the business case for EVs whilst only early adopters have begun to utilise pure EVs.

The UK have an aim of 1.5 million EVs by 2020, however it is questionable whether a new vehicle technology could be adopted so rapidly (POST, 2010). To date there have been 3,000 electric vehicles sold in the UK and 3,236 charging points installed, 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, work places 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. Understandably the range of an internal combustion engine is on average three times greater than that of an EV but it highlights the focus and importance the EV market has placed on infrastructure prior to actual requirement. This approach could be questioned as the 8,000 petrol stations were gradually added to the UK road transport network as vehicle ownership increased. The scenario faced by EVs today however, requires challenging the technological lock-in of ICEs, competing on efficiency and specification and removing the associated range-anxiety with current electric motors. Both the ‘lack’ of charging infrastructure and the restricted range of electric vehicles are argued to be key challenges for the adoption of EVs. This is in addition to the high P11D\textsuperscript{5}, limited range of models and the perceived social standing.

More importantly though is the lack of interoperability amongst charging operators consequently forming ‘EV hubs’ around the UK that do not provide drivers with roaming abilities across or within alternative networks. This limits the functionality of an EV resulting in an additional barrier to adoption and perceived disadvantage against that of an ICE vehicle.

To date the automotive industry and UK Government have already utilised market techniques and motivation crowding to encourage sales. The transition from ‘conventional’ vehicles types to electric vehicles 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” (EuropeanCommision, 2011 p.16).

Political decisions regarding legislation, grants and taxation have to be considered against the long term trajectory and must consider key stakeholders. Game changes in the market through governance should attempt to foresee and decipher demands from the various economic and social sectors. The UK has taken a combination of consumer incentives, industry regulation and pilot projects to encourage the use of EVs. From 2012 Europe enforced regulations to limit carbon emissions from new cars and incentivised manufactures to develop EVs. Since then there has been a threefold increase in the number of EVs in the market. This was imposed alongside consumer incentives

\textsuperscript{5} Tax paid by employees earning over £8500 per year for benefits provided and expense payments made to employees by employers that are not put through the payroll
in the UK that rewarded drivers for buying electric vehicles. Having a greater choice and availability of product as well as the combination of regulation and incentive led to a 116% increase in pure EV sales over the last year (see Figure 2).

Figure 2. August 2013 – EV registrations

<table>
<thead>
<tr>
<th>Vehicle category</th>
<th>Month End 2013</th>
<th>Month End 2012</th>
<th>% change</th>
<th>Year-to-Date 2013</th>
<th>Year-to-Date 2012</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plug-in pure electric</td>
<td>71</td>
<td>30</td>
<td>136.7</td>
<td>1,384</td>
<td>641</td>
<td>115.9</td>
</tr>
<tr>
<td>Plug-in other electric</td>
<td>44</td>
<td>52</td>
<td>-15.4</td>
<td>616</td>
<td>545</td>
<td>13.0</td>
</tr>
<tr>
<td>Hybrid petrol/electric</td>
<td>686</td>
<td>513</td>
<td>33.7</td>
<td>15,174</td>
<td>14,894</td>
<td>1.9</td>
</tr>
<tr>
<td>Hybrid diesel/electric</td>
<td>125</td>
<td>49</td>
<td>155.1</td>
<td>1,596</td>
<td>688</td>
<td>132.0</td>
</tr>
<tr>
<td>Cars eligible for the Plug-in Car Grant</td>
<td>115</td>
<td>80</td>
<td>43.8</td>
<td>2,000</td>
<td>1,172</td>
<td>70.6</td>
</tr>
<tr>
<td>Total new cars registered</td>
<td>65,937</td>
<td>59,433</td>
<td>10.9</td>
<td>1,391,788</td>
<td>1,260,997</td>
<td>10.4</td>
</tr>
</tbody>
</table>

Source: SMMT, 2013

It is difficult to determine the key reason for an increase in sales but this would indicate that the market is reliant on financial support from both the manufacturers’ perspective as well as that of the customer in terms of the Plug-in Car Grant, infrastructure subsidy, no road tax or congestion charge and lower benefit in kind etc. It is questionable whether this is a sustainable approach taken by Government, as if/when the financial endorsements are removed the market may not be in a position to survive independently. Additionally in terms of city congestion, increasing electric vehicle use will not reduce the issue. It is thought in the future when EV use has increased and Government are receiving lower revenue from fuel tax, charges will be introduced to address congestion, as consequence this could damage the economic model for owning an EV and result in the same scenario as LPG vehicles.

Figure 2 highlights the increase in popularity of the diesel/electric hybrid thus suggesting that customers have become comfortable with the technology and are seeking economic and efficient modes of transport.

Due to heightened awareness of climate change, shifting concepts of mobility and increases in population, urbanisation and globalisation, the automotive industry has been forced to adapt to the market. As a result of wider environmentalism, both private and commercial vehicle purchase decisions include CO2 emissions and fuel efficiency; this may be through e-mobility use or smaller sized ICE vehicles. Due to the fact that 89% of the UK’s population lives within an urban area, ‘superminis’ are now designed lighter and more fuel efficient due to new high-tech materials. The introduction of stop/start technology is an example of efficiency highly suited to urban driving. Such technologies are assisting the reduction of carbon emissions and fuel consumption however, it is suggested that this is largely dependent on the vehicles drive cycle (PikeResearch, 2012).

It has been established that the automotive industry is fundamentally built upon path dependant characteristics and has embedded preconceived notions of vehicle design and specification in to customers’ expectations. Thus technological lock-in is limiting the available market to EVs resulting in niche applications that can benefit from the available grants and incentives. It is possible that electric vehicles will follow a similar systemic process as the hybrid vehicle and be considered a mass market transport mode within fifteen years.
4. Results

4.1 Total Cost of Ownership

Fleet procurement is very much focused on the total cost of ownership (TCO) of the vehicle, therefore it is argued the high purchase price of an EV is not prohibitive due to the low running costs. TCO comparisons are currently varied in results as assumptions are inherent to the new market and unknowns of a second hand market consequently prohibit concrete residual values. This is considered a significant challenge for the fleet market due to the short ownership of vehicles, averaging three to four years. It is argued the lack of market experience, particularly relating to the long term cycle performance of a battery is hindering market developments (ElectrificationCoalition, 2010).

The Research Engineer compared a Ford Focus 1.6 TDCi 115PS Titanium X, Toyota Prius T-Spirit 1.8, a Nissan Leaf and a Renault Zoe. The comparison includes these vehicles as they provide an overview of different vehicle types whilst remaining within similar classes with equal performance. To complete the TCO certain conditions were set:

- 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 (16.01.12)
- One entry to central London per month
- Fuel/Electricity is based on manufacturers claimed vehicle consumption using AA average UK fuel prices and British Gas UK average standard rate electricity, £0.1345kwh (16.01.12)
- Depreciation figures based on CAP values (16.01.12)
- Expected residual value for 15,000 miles & 20,000 miles assumed at an additional 5% & 10% respectively of the 10,000 miles figure.
- One wall mounted charger installed

Figure 3: Total cost of ownership comparison on an EV basis

<table>
<thead>
<tr>
<th>TCO</th>
<th>Ford Focus 1.6</th>
<th>Toyota Prius</th>
<th>Nissan Leaf</th>
<th>Renault Zoe (battery leased)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catalogue price</td>
<td>21,595</td>
<td>24,870</td>
<td>29,990</td>
<td>£20,000</td>
</tr>
<tr>
<td>Discount</td>
<td>0</td>
<td>0</td>
<td>5,000</td>
<td>5,000</td>
</tr>
<tr>
<td>Additional costs of accessories</td>
<td>1500</td>
<td>1188.58</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total investment needed to purchase</td>
<td>23,095</td>
<td>26,059</td>
<td>24,990</td>
<td>15,000</td>
</tr>
<tr>
<td>£ per month</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Servicing / maintenance</td>
<td>29</td>
<td>28</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Insurance</td>
<td>81</td>
<td>76</td>
<td>69</td>
<td>69</td>
</tr>
<tr>
<td>VED</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cost Item</td>
<td>10,000m</td>
<td>15,000m</td>
<td>20,000m</td>
<td>50,000m</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>---------</td>
<td>---------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>Congestion charge</td>
<td>120.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Fuel</td>
<td>80.00</td>
<td>70.00</td>
<td>31.00</td>
<td>31.00</td>
</tr>
<tr>
<td>Subscription to Source London</td>
<td>0.00</td>
<td>0.00</td>
<td>10.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Battery leasing</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>70.00</td>
</tr>
<tr>
<td>Total mandatory costs</td>
<td>312.00</td>
<td>174.00</td>
<td>135.00</td>
<td>205.00</td>
</tr>
<tr>
<td>Depreciation cost per month</td>
<td>375.00</td>
<td>424.00</td>
<td>427.00</td>
<td>256.00</td>
</tr>
<tr>
<td>Depreciation cost per year</td>
<td>4,500.00</td>
<td>5,088.00</td>
<td>5,124.00</td>
<td>3,075.00</td>
</tr>
<tr>
<td>Depreciation cost over 3 years</td>
<td>13,500.00</td>
<td>15,264.00</td>
<td>15,372.00</td>
<td>9,225.00</td>
</tr>
<tr>
<td>Expected residual value (10,000m, 3yrs)</td>
<td>9,595.00</td>
<td>10,795.00</td>
<td>9,618.00</td>
<td>5,775.00</td>
</tr>
<tr>
<td>Expected residual value (15,000m, 3yrs)</td>
<td>9,106.00</td>
<td>10,009.00</td>
<td>8,369.00</td>
<td>5,025.00</td>
</tr>
<tr>
<td>Expected residual value (20,000m, 3 yrs)</td>
<td>7,952.00</td>
<td>8,706.00</td>
<td>7,120.00</td>
<td>4,275.00</td>
</tr>
<tr>
<td><strong>TOTAL COSTS over 3 years</strong></td>
<td>24732.00</td>
<td>21528.00</td>
<td>20232.00</td>
<td>16605.00</td>
</tr>
<tr>
<td><strong>TOTAL COSTS per annum</strong></td>
<td>8244.00</td>
<td>7176.00</td>
<td>6744.00</td>
<td>5535.00</td>
</tr>
<tr>
<td><strong>Pence per mile (10,000 miles)</strong></td>
<td>0.82</td>
<td>0.72</td>
<td>0.67</td>
<td>0.55</td>
</tr>
<tr>
<td><strong>Pence per mile (15,000 miles)</strong></td>
<td>1.00</td>
<td>1.12</td>
<td>1.15</td>
<td>0.71</td>
</tr>
<tr>
<td><strong>Pence per mile (20,000 miles)</strong></td>
<td>0.82</td>
<td>0.92</td>
<td>0.93</td>
<td>0.58</td>
</tr>
<tr>
<td><strong>Total additional costs</strong></td>
<td>291.00</td>
<td>358.00</td>
<td>355.00</td>
<td>355.00</td>
</tr>
<tr>
<td><strong>TOTAL COSTS over 3 years</strong></td>
<td>35208.00</td>
<td>34416.00</td>
<td>33712.00</td>
<td>30085.00</td>
</tr>
<tr>
<td><strong>TOTAL COSTS per annum</strong></td>
<td>11736.00</td>
<td>11472.00</td>
<td>11704.00</td>
<td>10495.00</td>
</tr>
<tr>
<td><strong>Pence per mile (10,000 miles)</strong></td>
<td>1.17</td>
<td>1.15</td>
<td>1.17</td>
<td>1.05</td>
</tr>
<tr>
<td><strong>Pence per mile (15,000 miles)</strong></td>
<td>1.23</td>
<td>1.41</td>
<td>1.48</td>
<td>1.04</td>
</tr>
<tr>
<td><strong>Pence per mile (20,000 miles)</strong></td>
<td>0.99</td>
<td>1.13</td>
<td>1.18</td>
<td>0.83</td>
</tr>
<tr>
<td><strong>As a company car:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benefit in Kind personal tax</td>
<td>47.00</td>
<td>40.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Benefit in Kind personal fuel tax</td>
<td>41.00</td>
<td>31.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Total additional costs</strong></td>
<td>88.00</td>
<td>71.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>TOTAL COSTS over 3 years</strong></td>
<td>27900.00</td>
<td>24084.00</td>
<td>20932.00</td>
<td>17305.00</td>
</tr>
<tr>
<td>TOTAL COSTS per annum</td>
<td>9300.00</td>
<td>8028.00</td>
<td>7444.00</td>
<td>6235.00</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------</td>
<td>---------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>Pence per mile (10,000 miles)</td>
<td>0.93</td>
<td>0.80</td>
<td>0.74</td>
<td>0.62</td>
</tr>
<tr>
<td>Pence per mile (15,000 miles)</td>
<td>1.07</td>
<td>1.18</td>
<td>1.20</td>
<td>0.76</td>
</tr>
<tr>
<td>Pence per mile (20,000 miles)</td>
<td>0.87</td>
<td>0.96</td>
<td>0.97</td>
<td>0.61</td>
</tr>
</tbody>
</table>

A key outcome from Figure 3 is that within the contract hire scenario the TCO highlights the cost parity between the Ford Focus and the Nissan Leaf at 10,000 miles per annum, this is exceptionally encouraging for the EV market. This however is not the case when mileage increases as the Nissan Leaf becomes the least competitive whilst the Ford Focus rises in efficiency. Interestingly, although the Toyota Prius has the highest purchase price within the TCO analysis, in no instances is the vehicle the most expensive to operate. With unlimited range and without the need for charging infrastructure resulting in cost efficiencies, the Prius has the opportunity to ease low carbon transformation. Alternatively, analysing the TCO for these vehicles as company cars (company tax rate 20%) highlights the advantage of EVs as the exclusion from benefit in kind taxes results in them being the most competitive choice within the low mileage range.

Figure 3 highlights the opportunity of alternative business models opposed to traditional outright purchase, Renault’s model of battery leasing provides a strong financial case with competitive pricing. Traditionally consumers within the UK possess the desire to fully own assets, although it may not be the most economic form of ownership. The Nissan Leaf has the highest rate of depreciation highlighting the difficulty for EVs to compete within an already established and historically dominant market. It is therefore arguable that as a prerequisite of market transformation the financial models of vehicles should be re-evaluated to encourage a change in consumer approach to ownership. This is particularly relevant within the private/residential market rather than within fleets as leasing and contract hire ownership models are common approaches for commercial applications. According to Accenture, leasing the battery assists in making EVs more affordable by reducing the high initial purchase price (Accenture, 2010). This enables EVs to begin to compete directly with ICE vehicles as despite higher costs per month, the considerably lower purchase price makes the EV significantly cheaper compared to all vehicles in all scenarios.

4.2 Fleets

This research component is focused upon the integration of electric vehicles in to fleets, understanding the decision matrix of vehicle procurement and operations. Therefore collaborating with three fleets:

- TNT Express Services UK & Ireland - the UK's leading business-to-business express operator delivering up to 150 million items per annum
- Schneider Electric UK - an energy management company manufacturing electrical distribution and automation control equipment
- Green Tomato Cars - a London based environmentally conscious private hire service
These fleets were chosen as they either already have EVs within the fleet or are considering utilising EVs. This enabled an exploration of motivations, challenges, behavioural change and expectations of electric vehicle use. To begin exploring the path dependencies challenging the utilisation of electric vehicles within the fleet market, the Research Engineer collected and consolidated fleet data in order to form case studies on each fleet. This supported the foundation of the interviews as although a number of questions were structured for the three fleets, there were a number that are more case specific in order to achieve a deeper understanding of individual fleet strategies, procurement models and operations. The Research Engineer conducted interviews at the strategic level, with the fleet manager and with a driver to provide a comprehensive analysis across the fleet’s entirety. Therefore each interview required individual objectives to attain the most relevant information. The research questions below were addressed in order to answer the following research ‘sub questions’:

- Within a fleet what change is required within the decision making process and the drivers application to ease EV adoption?
- What challenges can be overcome through behavioural change rather than technological developments or regulative enforcement?
- What are the dominant path dependent characteristics within the automotive industry that challenge the utilisation of electric vehicles and electric vehicle charging?

Analysing such aspects indicated how to encourage new innovations within the fleet market and highlighted alternative mobility concepts.

4.3 Fleet study

This fleet study aims to understand the existing transition pathway of EVs within fleets and produce recommendations for fleet strategies of electric vehicle optimisation. It shall suggest possible tools for fleets to overcome barriers and recommend how ‘new technology’ is best integrated within fleets in general. This analysis will contribute to the understanding of how alternative innovation can overcome path dependencies and be encouraged within the automotive industry to develop the concept of mobility. The scope of this research extends beyond the immediate fleets involved as analysing fleet behaviour across different sectors will provide an insight into varied fleet strategies. However current thinking is that it is not necessarily sector dependant but greater focus should be on the duty cycles.6

The fleets in the study were purposefully varied to achieve an understanding across the fleet market, although it remains very difficult to compare the ‘fleet’ approach to new technology. However, it truly highlights how individual each fleet is and that the transition pathway is determined by the motivation for the fleet’s utilisation of EVs. This too could arguably be the most important element to the success of EVs as if there is the commitment from senior management the acceptance to invest in trials etc can often be absorbed by the business. However it

6 “The cycle of operation of a machine or other device which operates intermittently rather than continuously” (OxfordDictionaries.com, 2013)
would appear that Government regulations are currently the key force to introduce fleet transformation. Therefore suggesting that as legislation tightens market competition may begin to initiate additional forces.

Green Tomato Cars' business model aims to demonstrate that an environmentally friendly business can be commercially successful and can work within a mainstream concept. Within the fleet there are; 396 hybrids, 8 of which are bio-diesel people carriers and 6 are bio-diesel executive cars (run on 30% chip fat). By the end of the year the fleet will have an additional 50 pure electric BYD E6 taxis. Introducing a range of vehicle types to the fleet challenges existing technological lock-in preconceived in the private hire car market that traditionally utilises diesel vehicles. Consequently Green Tomato Cars (GTC) are directing EVs through the logic of technology, optimising vehicle type by applicability whilst the societal logic is targeted through the direct contact with costumers (Foxon, 2012). When Green Tomato Cars utilise EVs they will continue to challenge the constraints of historical markets that are argued to restrict versatility and flexibility that could be the requirement for the necessary carbon reductions in transport. Having previously trialled EVs GTC remain realistic that despite the E6 150 mile range there may still be challenges for EV operations, the two main challenges GTC are considering are:

1) 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.

2) Winning over the stakeholders – a compelling argument can be put forward to the drivers as to why they should be driving EVs but its 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. Customers will need to be reassured of their misconceptions through good marketing.

Green Tomato Cars indicate the opportunities of Mobility-as-a-Service with their services available beyond traditional means of booking and payment, via Twitter and their own apps. What path dependencies are preventing this from being the norm?

Schneider Electric’s company car fleet consists of 1,200 vehicles, one of which is an EV used for marketing purposes. The vehicles are leased from Hitachi Capital on a four year contractual basis, the policy prescribes monthly contributions and reimbursements depending on the vehicle chosen. Currently Schneider Electric’s company car policy encourages the adoption of efficient diesels. Whilst the P11d is still high on electric vehicles it will not be a competitive option for employees, regardless of whether electric vehicles are on Hitachi Capital’s vehicle portfolio. Despite this, in this scenario the use of electric vehicles is a great deal more emotive as employees chose their own vehicle used for private and personal mileage. The key challenge to driver acceptance is likely to be use of the vehicle for private mileage due to range restrictions and the lack of flexibility it provides. Furthermore having conducted interviews it was established that within the company there is an extent of badge consciousness and psychological kudos with customers, suggesting that EVs posses negative connotations of an inferior vehicle type. To what extent are EVs challenging society’s preconceived notions of vehicle modes?

In the case of TNT, in 2006, 50 7.5 tonne electric trucks were procured from Smith Electric Vehicles. The reliability of the vehicles was continuously an issue and by 2010 they became very problematic, this was centred on the battery technology, consisting of sodium nickel chloride. As a result 10 were converted to lithium ion batteries.
which improved the reliability but the conversion costs were greater than a diesel equivalent. TNT did not intend to make these vehicles more economical to run but to be cost neutral with a diesel vehicle over the 5 year life due to the balance between higher capital costs and lower running costs. It was considered that the EVs had been a moderate success but cost prohibited. As a result all of the ‘Generation 1’ vehicles were returned to the manufacturer and TNT awaits 20 ‘Generation 2’ vehicles. This reduction in EVs is to keep the replacement costs cost neutral in terms of the depreciation on the ‘Generation 1’ vehicles and the cost of the ‘Generation 2’s’, at £65,000 each. TNT have experienced two further challenges beyond the reliability, limited range and the increased unladen weight affecting the payload due to the density of battery, both further heighten the inflexibility of vehicle use.

TNT wishes to be compliant with future Government legislation and in fact lead the way by utilising this type of technology in operation today. TNT being a dominant player within the industry with such a well established brand, and operations mainly within cities realises the pressure to be at the forefront of regulation and challenge existing path dependencies for the possible rewards.

The common challenge the fleets have with EVs is ensuring that there is a viable business model to rationalise long term investment in an operation that already functions successfully. This makes it particularly easy to fall back on path dependent characteristics of the combustion engine and consequently reinforce those development blocks. Furthermore, the auto manufacturers investments in improving efficient diesels is concerning for the EV market as the emission levels are becoming so low that apart from fuel costs and the (debateable) environmental benefits, EVs may not offer substantial benefits that justifies widespread stakeholder investment. The adoption dynamics for EVs are proven to be complex in this study due to the associated risk from powerful feedbacks of diffusion. However, Green Tomato Cars’ business model is crucial for the market as it brings witness that electric vehicles can be operational within a commercial fleet. Furthermore their use of advanced services highlights the growing importance of digital communication and offering Mobility-as-a-Service through a multitude of mediums. This broadens opportunities for customers using alternative means of transport to conventional vehicle ownership. This will require an extensive transformation in the existing system challenging the embedded path dependencies that have shaped societies desire to own transportation.

As a result the Research Engineer has formed a set of questions (Figure 4) to categorise indices’ presenting a greater depth of understanding e.g. size, mileage, stopping time. This is then more transferable to other fleets as they can gain an appreciation for the likely challenges that due to their fleet makeup they will encounter.
Figure 4: Fleet EV enquiry

<table>
<thead>
<tr>
<th>Questions</th>
<th>Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>In which industry is your fleet?</td>
<td>Company car fleet</td>
</tr>
<tr>
<td>What is the size of your fleet?</td>
<td>0 - 500</td>
</tr>
<tr>
<td>What is the motivation to utilise electric vehicles into the fleet?</td>
<td>Corporate Social Responsibility</td>
</tr>
<tr>
<td>How quickly would you like to implement electric vehicles?</td>
<td>&lt; 6 months</td>
</tr>
<tr>
<td>Where has the demand for EVs originated?</td>
<td>Senior level management</td>
</tr>
</tbody>
</table>

The likely KEY challenge that you will experience

Suggested strategy to follow to best utilise EVs within your parameters

The purpose of these questions is to identify the key challenges that a fleet is likely to experience when integrating electric vehicles into an existing petrol/diesel fleet, and the recommended strategy to achieve successful utilisation. An assumption had to be defined prior to constructing the table, that the fleet involved had already justified the finance/business case of electric vehicles. Although the recommendations will likely alter the feasibility equation for the fleet it is secondary to the ‘economics’ being a key challenge.

5. Proposed further research

5.1 Mobility-as-a-Service

The concept of mobility has dramatically changed over recent years; evidence suggests that Mobility-as-a-Service will become integral to society providing alternatives to car ownership (KPMG, 2013). MaaS would widen the mobility solution incorporating mobile apps for payment and location-aided services, thus ensuring ease of use and functionality (KPMG, 2013). This is a considerable opportunity to decarbonise transport, especially within cities that could have multiple vehicle pick-up and drop-off locations. More importantly this is a substantial opportunity for the EV market as it removes many of the barriers to electric vehicle use, of which are mainly due to ownership models. Over the next decade it is likely that transport solutions will develop to become a more integrated system within cities, incorporating public transport, MaaS and a more diverse energy mix managed by demand response. Technologically this is conceivable however, the rate at which it can be achieved is reliant upon the acceptance of society and the mechanisms put in place by Government, thus suggesting it is in fact political lock-in.

The concept of mobility is developing into a complete solution composed by various modes of transport and alternative ownership models, electric vehicles may remove technological lock-in through entering the industry as a segment of ‘smart mobility’. This is a new area of research that has been highlighted by the fleet study as having not been fully explored.
5.2 Methodology

To complete the research project a further study will be undertaken that examines city mobility and the schemes in place to integrate eMobility-as-a-Service alongside other transport modes. The Research Engineer will analyse various cities’ approach to eMaaS and the existing policy on the matter in order to recommend city level transition strategies. It will investigate the extent motivation crowding can be replicated within the MaaS market, as well as analysis on eMaaS transition pathways. This will then be compared against prior conclusions drawn within the research project, solely on transition pathways of EVs. It will explore the path dependent characteristics that currently encourage the population to own a vehicle that is expected to meet the majority of their needs rather than using the most appropriate technology for the operation.

There will be a quantitative aspect to the research as usage data will be analysed to examine utilisation. This will also be incorporated to investigate how operators can provide a viable multi-modal transport system. The Research Engineer will explore various systems to address the opportunity electric vehicles have to introduce alternative business models. In exploring business models, interviews will be performed with car club operators such as Car2Go and Zip Car to explore the level of communication and advanced services that are available and the extent to which customers interact digitally. This is an important aspect of the discussion as additional web based services are integral to any business model and therefore the rate the of adoption and integration.

5.3 Project management

The Gantt chart below outlines the key phases of the project and the dates of which these stages will be completed:
5.4 Journal strategy

The Research Engineer aims to publish two journal articles over the next two years, either within the Journal of Technological Forecasting and Social Change or Transport Policy. The first article will analyse the ‘Transition pathways for a UK electric vehicle market’ as discussed in Section 3. This shall discuss the transition pathway of electric vehicles within the automotive industry alongside the theoretical issues regarding path dependencies and technological lock-in. It will explore the traditional pathway within the automotive industry and examine the transition to date for EVs. This shall be submitted for approval by January 2014.

The second journal article will analyse ‘Transition pathways for an eMobility-as-a-Service business model at city level’. It will discuss the market techniques employed to achieve heightened EV use through a MaaS transport system. As discussed in Section 5.2 the article will include case studies of city schemes and the various strategies operators implement to integrate EVs. This shall be submitted for approval by November 2014.
References


Malsen, J (2012) Personal communication regarding Fleet 200 publication, Sewells Research & Insight. Telephone & e-mail. February 2012


Charging Infrastructure for Electric Vehicle Fleets – identify and develop business opportunities within target sectors

Six Month Report

Engineering Doctorate

Industrial Doctorate Centre

University of Surrey

April 2014

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Six Month Report

The following report is based on the six month period between October 2013 and April 2014. It will reflect upon the last six months, discuss Mobility-as-a-Service, and highlight future intentions.

1. Six months ending April 2014

Over the last six months the Research Engineer has focused on Mobility-as-a-Service, a concept providing an alternative to car ownership. This presents an opportunity for electric vehicles to be optimised within a wider network of mobility solutions, removing technological lock-in through entering the industry as a segment of ‘smart mobility’. The research remains focused on the integration of electric vehicles and the appropriate transition pathways but is centred on the city approach to a multi-modal transport network.

Additionally, the Research Engineer has written a journal article analysing the ‘Transition Pathways of Fleet Electrification’ that will be submitted to the Environmental Innovation and Societal Transitions Journal for publication. It discusses the transition pathway of electric vehicles within fleets and the theoretical issues regarding path dependencies and technological lock-in. It explores the traditional pathway within the automotive industry and examines the transition to date for EVs.

Additional activities that the Researcher has been involved in have provided commercial exposure to Schneider Electric and has direct influence on the research project, discussed further in Section 1.1.

Unfortunately for this entire six month period the Research Engineer has suffered from Glandular Fever and consequently Chronic Fatigue Syndrome persists. This has led to approximately two months being taken off work to recuperate. As a result the last six months have been rather disjointed and less progress has been made than previous reports have planned.

1.1 Northamptonshire County Council

Schneider Electric and Northamptonshire County Council (NCC) have a ‘smart partnership’ to transform the County’s connectivity, enhance the economic and environmental performance of the area and reduce carbon intensity. The Research Engineer’s initial involvement in the project was regarding electric vehicle infrastructure opportunities, NCC want to create a car club in Northampton. This could provide utilisation data that can be incorporated into the research of eMaaS and assist the understanding of plausible transition pathways.

The Research Engineer’s role within the partnership has now developed to Project Co-ordinator, managing the progress of the project. This is likely to be an ongoing involvement which will aid the RE’s knowledge on smart mobility projects across the business.

1.2 Ecological Economics

In January, the Research Engineer attended the ‘Ecological Economics’ module within the Centre for Environmental Strategy at the University of Surrey. Having attended this module it widened the Researcher’s perspective on ecological economics through exploring the role of institutions, well-being and sustainable
growth. The first coursework submitted was entitled ‘Quantitative analysis of an ecological economics problem: Personal well-being through growth’ achieving 60%. The second assignment was ‘Where are our mothers within economics’ achieving 65%. Both assignments deepened the Researcher’s understanding of the ‘green economy’ and enabled the knowledge gained within the module to be applied directly to the research project.

1.3 Presentation Skills training

The Research Engineer attended Presentation Skills training in February, this was provided by Schneider Electric but run by a management consultancy. The programme encouraged attendees to reflect on presentation styles and practice presenting. Presenters were filmed during the training and then critiqued by the group. This was a useful experience as it developed confidence and the ability to adapt to different environments.

2. Aims & Objectives

This six month period has been focused on two elements of the wider research project:

- Explore how EVs could be utilised to encourage new pathways for a service based mobility model
- Recommend how electric vehicles can break through current lock-in in order to create new pathways for service based models

This focus will continue over the next six month period to encompass empirical research on car clubs in London and case study examples in European cities. This will aid discussions on market techniques taken by various Governments to encourage EV use. The specific research questions this part of the project aims to answer are:

<table>
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<tr>
<th>Research questions</th>
<th>Sub questions</th>
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| What opportunity do electric vehicles have to extend the pathway to a Mobility-as-a-Service model? | • What are the path dependent characteristics within society that challenge eMaaS?  
• How can an integrated and interoperable mobility city service be a viable proposition? |

The Research Engineer has coined the term eMaaS to refer directly to the electrification of Mobility-as-a-Service.

3. eMobility-as-a-Service

Broadening the availability to alternatives of car ownership has the opportunity to help tackle the very high transport emissions the UK currently emits. The concept of mobility is developing into a complete solution composed of various modes of transport and alternative ownership models. Over the next decade it is likely
that transport solutions will become a more integrated system within cities, incorporating public transport, real time data on hand held devices and a more diverse energy mix managed by demand response. Evidence suggests that Mobility-as-a-Service will become integral to society providing alternatives to car ownership. MaaS will widen the mobility solution incorporating mobile apps for payment, location-aided services and multiple vehicle pick-up and drop-off locations, thus ensuring ease of use and functionality (KPMG, 2013). However the rate at which this is truly achieved is reliant upon the acceptance of society and the mechanisms put in place by Government and private enterprise.

This is a considerable opportunity to decarbonise transport within cities, reducing the need for private car ownership and utilising electric vehicles within the mobility model. More so it is a substantial opportunity for electric vehicles to enter the market as a segment of ‘smart mobility’, whilst removing many of the barriers to EVs that are mainly due to ownership models. This research will investigate city mobility services, exploring integrated eMaaS alongside other transport modes and the existing policies. This will enable transition strategies to be recommended, whilst questioning the market techniques employed to achieve heightened EV use through an eMaaS transport system. The study will explore the path dependant characteristics that prevent drivers from using the most appropriate vehicle mode for each need and how operators can provide a viable multi-modal transport system.

An expected outcome of this research is a requirement for greater collaboration between Government and private enterprise, in order to fund city schemes but also ensure they are viable in the long term. It can be expected that data must be shared to a greater extent between the public and private sector and that this is accessible to citizens. Both these factors will implicate people’s choice of transport mode through availability of vehicles and real time information of travel options. Consequentially it is likely there would be an increase in eMaaS utilisation and therefore a reduction in emissions, congestion and pollution.

3.1 e-Car clubs

London is expected to have a 14% rise in population in the next decade, which 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 and the path dependent characteristics which are reinforced by society and the automotive industry need to be fundamentally challenged. Car clubs provide an alternative to car ownership that if taken as an integrated approach with public transport has the opportunity to reduce congestion, air pollution and reinstate the equilibrium between cyclists, pedestrians and drivers. Examples need to be analysed and potentially replicated from other cities such as Paris, New York and Berlin, where car clubs have utilised electric vehicles which have become part of an urban multi-model service. How can the positive impact of e-car clubs be maximised to benefit cities such as London and its citizens?

Car sharing membership grew fivefold between 2006 and 2012 globally equating to 1.8 million drivers. However only 43,544 vehicles used in 2013 were electric, highlighting the opportunity e-car clubs have to accelerate EV deployment and increase exposure (Fairley, 2013). Additionally, with the use of real time data and smart phones, e-car clubs have the opportunity to not only be an alternative to car ownership but to best
serve certain journeys for those taking public transport. 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. It is questionable whether the Government should employ e-car clubs as a mechanism to encourage alternative transport, with the use of motivation crowding? Policy, infrastructure and incentives would be required if e-car clubs were to become a viable option in the commuters transport portfolio. This will be explored within the project in order to recommend strategies for e-car clubs to succeed in providing a sustainable transport mode.

4. Planned Activity

The Gantt chart below outlines the key phases of the project over the coming six months and the dates of which these stages will be completed:

<table>
<thead>
<tr>
<th>Activity</th>
<th>30-Apr</th>
<th>20-May</th>
<th>9-Jun</th>
<th>29-Jun</th>
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<td>Investigate motivation crowding</td>
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<td>Analyse Government car club policy</td>
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In the next six months the second phase of this project will be completed, it shall explore urban mobility and the integration of electric vehicle schemes. The Research Engineer will investigate approaches taken by other cities and suggest ways in which London (for example) can maximise the potential of e-car clubs to alter the concept of mobility. Exploring the extent policy can influence eMaaS through motivation crowding and market techniques will question the path dependent characteristics, which currently encourage the population to own a vehicle for all their needs. The Research Engineer will produce case studies through conducting interviews with car club operators such as Car2Go and Zip Car to investigate mobility service business models and the impact ICT has had on such models. Digital services such as online booking have become integral to service models, therefore it shall be questioned of operators the extent to which additional web based services are influencing the rate of adoption and the extent to which customers interact digitally. This will lead to the second journal, 'Transition pathways for an eMobility-as-a-Service business model at city level'.

4.1 EngD conference

The annual EngD conference in June requires an extended abstract and A0 poster, eMaaS will be the focus of the abstract and poster. This provides the opportunity to share intentions of the research component and receive feedback from both industry and academia.
4.2 Project title

As the project has developed it seems appropriate to change the project title. There is less focus on charging infrastructure than perhaps anticipated and a greater focus on the transition of electric vehicles within a mobility service model.

The Research Engineer proposes three titles:

- Transitions to electric vehicles - identify and develop business opportunities within target sectors
- Mobility solution of electric vehicles – identify and develop business opportunities within target sectors
- Electric vehicles as a mobility service – identify and develop business opportunities within target sectors

Over the coming months this shall be discussed between the Research Engineer and project supervisors.
References:


Fergusson, M (2014) *Car Lite London. How car clubs will help more Londoners drive less* [Online] Available at: http://www.zipcar.co.uk/car-lite-london (Accessed on 02/02/14)

Charging Infrastructure for Electric Vehicle Fleets – identify and develop business opportunities within target sectors

Six Month Report

Engineering Doctorate

Industrial Doctorate Centre

University of Surrey

October 2014

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Appendix
Six Month Report

The following report is based on the six month period between April 2014 and October 2014. It will reflect upon the last six months and discuss future intentions.

1. Six months ending April 2014

Over the last six months the Research Engineer (RE) has been continuing the second phase of the project focusing on mobility solutions. This presents an alternative to standard market entry for electric vehicles, immediately altering the path dependent characteristics that are installed by the automotive industry. Introducing new ownership models such as pay-as-you-go use further modifies societies approach to transport. These mobility service transitions have been the research focus to establish pathways of EV city utilisation.

Additional activities that the Researcher has been involved in have been both academic and commercial, both of which have influenced the research project, discussed further in Section 1.

1.1 Integrated Assessment

In May the RE attended a module at the University of Surrey entitled ‘Integrated Assessment’ that explored the relationship between environmental impact, science, policy and decision making. The RE submitted pre-work, group work and a final assignment: ‘Integrated Assessment – Bridging the gap between science and decision making to achieve Sustainable Development’. The report considered the extent to which Integrated Assessment aids decision making and how it could be improved to enhance sustainable development. The RE achieved an overall of 66% for the module.

1.2 EngD Conference

At this year’s EngD Conference the RE produced an extended abstract for conference proceedings and a poster entitled ‘Transition Pathways to e-Mobility-as-a-Service’ (Appendix 1&2). The RE was also required to carry out a thirty second pitch to the conference delegates to encourage colleagues to visit and engage with the poster. The research project gained significant interest from peers from a range of disciplines that provided the RE with alternative perspectives on the subject matter.

1.3 Viva

The Research Engineer had the midpoint Viva Voce in July, this had been somewhat delayed due to firstly, a lack of appropriate external examiner arranged and then secondly, due to the RE suffering from Glandular Fever for approximately 8 months. In the Viva the examiners focused on the project’s methodology for work carried out as well as that to be done, it was recommended that the thesis provides further explanation on the project scope and multidisciplinary approach. As a consequence of the viva the examiners requested the RE to submit a Table of Contents for the final thesis (Appendix 3). This was to act as an aid for the RE to clarify the
structure, chapters and contribution to knowledge. Feedback from examiners on the Table of Contents has yet to be received.

1.4 **Journal paper**

The Research Engineer has a journal paper entitled ‘Transition Pathways of Commercial-Urban Fleet Electrification’ (Appendix 4) under review by the Environmental Innovation and Societal Transitions Journal. As stated in the ‘Thirty Month Report’ submitted six months ago, the paper discusses the transition pathways and path dependencies of EVs within commercial-urban fleets.

1.5 **Northamptonshire County Council**

The Research Engineer continues to be the Project Co-ordinator for the ‘smart partnership’ between Schneider Electric and Northamptonshire County Council (NCC). The main focus for the RE has been the e-car club in Northampton that is now being rolled out across the county to provide fleet vehicles as well as to act as a community asset. Other projects for the county include transport solutions, energy and sustainability software and power station and smart grid provisions. This is an ongoing and developing partnership with new projects being orchestrated gradually.

1.6 **OLEV Homecharge Scheme**

Following the misuse of the Domestic Recharging Scheme launched in February 2013 by the Office of Low Emission Vehicles (OLEV), an interim and final scheme were launched in June and September respectively. The available subsidy provides 75% or up to £900 for EV charging infrastructure and installation. The RE manages Schneider Electric’s authorisation and product approval which has been an arduous process due to the documentation required and the changes in monthly reporting. The products are still under review by OLEV however approval should be attained imminently, at which point the RE will be less involved in the day to day grant activities until a new scheme is launched in March 2015.

1.7 **Cenex Low Carbon Vehicle Event**

Schneider Electric exhibited at the UK’s premier low carbon vehicle two day event, the Research Engineer attended the seminar sessions and assisted in providing expertise to stand guests. There was a particular focus from the auto manufactures on the future of sustainable transport indicating to two trends in the automotive market. Firstly, evolution for more efficient internal combustion engine (ICE) vehicles and secondly, revolution for alternatively fuelled vehicles. This technological mix is determined by the sunk costs and path dependencies of ICEs alongside EU carbon emission and air pollution targets determining AFVs.

1.8 **EV Summit**

In September the University of Surrey held the ‘Electric Vehicle Summit 2014’, providing a platform for Government, academia and the automotive sector. Following the EngD Conference, Schneider Electric was
asked to exhibit along with the RE providing a poster. Unfortunately the poster session was not fulfilled by the event but Schneider Electric displayed EVlink (charging infrastructure range) focusing on the commercial market. It was an informative event with varied speakers and an eclectic audience, however the debate did not seem to be as established or advanced as the market has become. This was primarily due to the focus on making EV mainstream which as a niche product raises questions of market infiltration and the wider implications.

1.9 Conferences

The Research Engineer has applied for three conferences for the current academic year. Depending on acceptance a poster or presentation will be required, the RE will be informed of this during the next six months. The three conferences are:

- ICSC 2014: XII International Conference on Smart Cities
- The Fifth Asian Conference on Sustainability, Energy and the Environment 2015
- Sustainable City 2015: 10th International Conference on Urban Regeneration and Sustainability

2. City mobility services

City mobility services have been the focus of the project for the last six months and will be for the remaining project. The RE has been investigating car clubs in Europe to understand the market and existing business models employed.

2.1. Context

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, 2014). This has substantial implications on energy consumption, carbon emissions and the impact on existing infrastructure, resources and services within cities. Mobility is being heavily affected by this, alongside the developing demands on service, frequency, user transparency and fluency across modes. As a result new business models are appearing and alternative service provisions. An example of such is electric vehicle car clubs that have been increasing in numbers across the world, primarily in cities due to the high population density, localised demand and the compatible user drive cycle; whilst vehicle ownership is not essential for the majority of people and it is relatively expensive.

To gain a deeper understanding of the operations and implications of e-car clubs, four European city car clubs have been examined:

2.2. 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.

This service offers a mobility solution for a broad population that requires 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). 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. 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).

Autolib’ has normalised electric vehicles 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. 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 would suggest that the importance of owning a vehicle is diminishing in younger generations, proving the shift from possession models to usage models are a viable option in cities.

2.3. **Source London, London**

The Ballore Group is replicating Autolib’ in London from March 2015, 100 cars will be introduced using existing charging infrastructure previously managed by a UK Government funded scheme. 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 carsharing 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. The scheme will aim to be high volume, 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. Gaining parking bays on a leasing agreement from 32 Boroughs will be challenging for Source London 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 for Source London as an integrated approach across the city will be required for a viable scheme, alternatively it will be a more local offer for those Boroughs involved.

It was also reported that the “UK’s strong culture and tradition of private vehicle ownership” were more significant than expected (BBC, 2014). The British attitude towards ownership is unique, societal pressures influence Brits to have material possessions owned rather than leased or rented. This has been shaped by the UK economy and tax regime but it has now become embedded within the culture. However younger generations (Generation Y and Z, from 1980 onwards) have begun to challenge this, largely due to the high
cost of living, opening up the opportunity for more service based models. Service models seem to be more prevalent in the UK’s cities hence why car clubs are becoming more popular in these areas; however it is questionable whether commercial viability has been reached.

2.4. DriveNow, Berlin

DriveNow is BMW’s carsharing service which operates in five German cities as well as San Francisco, offering eight BMW models including the Pure electric, Active E. The scheme has various DriveNow 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 Pure electric. 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, this is more important for the Active E as it becomes an education process and familiarising drivers with the technology and unlocking existing path dependencies.

DriveNow does however make it very simple for customers with the use of 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. Making the process streamlined encourages adoption and replication for other cities. 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). Thus indicating the impact car clubs can have upon a city’s congestion through reducing road vehicles alongside assisting to reinstate the balance of emissions and air quality.

2.5. Hertz BilPool, Oslo

Hertz operate a car pooling service across Norway, with Oslo being the primary area with a high concentration of vehicles including the Nissan Leaf and Volvo C30 electric. There are two different levels of membership based on hours or kilometres with optional weekend deals. It is an A-A model requiring the car to be return 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.

Hertz BilPool also offers corporate membership providing companies with access to vehicles without requiring their own fleet. 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.

For a population that is aligned with sustainability it appears e-mobility services has not gained momentum. Despite the strong Government support for EVs in Norway and the success of Tesla’s 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 the policies set have been very positive for the EV market, it has not assisted in
diminishing congestion but rather increased it, particularly in bus lanes, an incentive for EVs during rush hour. 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 (Wirgman, 2014).

3. Planned Activity

The project is under review for extension due to the RE suffering from Glandular Fever over the last year. At the Viva Voce it was agreed between Supervisors that the project deadline would be December 2015, this needs to be formalised between parties.

3.1. Transition pathways for e-Mobility Services

Following the RE’s investigation in to transition pathways for electric vehicles the second phase moves from examining a product led market to a service-led market of e-mobility. ‘Mobility service’ is the conceptual approach to study mobility with the focus on the service it provides. This perspective allows a fresh analysis of the technological and infrastructural nexus with the social needs mobility seeks to address. Therefore the following aims of the project are:

- Explore how EVs could be utilised to encourage new pathways for a service based mobility model
- Recommend how EVs can break through current lock-in in order to create new pathways for service based models

As stated, the key opportunity this research project considers for EVs to utilise a service-led model is through e-car clubs. Developing upon the city case studies, further analysis is required on market techniques to encourage e-car club use such as motivation crowding and the business models employed. This will be executed through interviews with the aforementioned car clubs to establish the plausible transition pathways.

3.2. Project Management

The Gantt chart below outlines the key phases of the project over the coming six months and the dates of which these stages will be completed:
The previous six month report stated the final stages of this phase would be completed by this quarter, however due to unexpected demands on the RE the timeframe has lapsed to the first quarter of 2015. The RE will continue to explore mobility services in urban environments and the integration of electric vehicle schemes to understand the path dependencies preventing e-car clubs becoming more mainstream. Recommendations will be compiled as to how to achieve this through policy and viable business models. As a consequence the intention is to publish a journal paper in 'Technological Forecasting and Social Change' on 'Transition pathways for an eMobility Service at city level'.

3.3. University modules

Within the next six months the RE has two modules to attend at the University of Surrey; Communications Management and Prince 2 Project Management. Both these modules will assist in developing the RE's ability to manage the delivery of the thesis as well as complimenting the skills set for future employment.

3.4. Project title

As previously discussed the project title needs to be more aligned to the subject matter. The RE has proposed the following titles which are currently being considered by the academic supervisor:

- Transitions to electric vehicles - identify and develop business opportunities within target sectors
- Mobility solution of electric vehicles – identify and develop business opportunities within target sectors
- Electric vehicles as a mobility service – identify and develop business opportunities within target sectors
References:


Wirgman, E (2014) Norwegian Govt under increasing pressure to reduce incentives for EVs [Online] Available at: https://www.zap-map.com/norwegian-govt-increasing-pressure-reduce-incentives-evs/#.VCu6UMJdW0M (accessed on 20/09/14)
Appendix:

1) EngD Extended Abstract

Transition pathways to eMobility-as-a-Service

Theme: Business application and implication for wider sector

The concept of mobility is developing into a complete solution composed of various modes of transport and alternative ownership models. Over the next decade it is likely that transport solutions will become a more integrated system within cities as the demand for intercity mobility increases. This will need to incorporate public transport, real time data and a more diverse energy mix managed by demand response. Evidence suggests that Mobility-as-a-Service (Maas) will become integral to society providing alternatives to car ownership. Maas will widen the mobility solution incorporating mobile apps for payment, location-aided services and multiple vehicle pick-up and drop-off locations, thus ensuring ease of use and functionality (KPMG, 2013). However the rate at which this is truly achieved is reliant upon the acceptance of society and the mechanisms put in place by Government and private enterprise.

This is a considerable opportunity to decarbonise transport within cities, reducing the need for private car ownership and utilising electric vehicles (EVs) within the mobility model. More so it is a substantial opportunity for electric vehicles to enter the market as a segment of ‘smart mobility’, whilst removing many of the barriers to EVs that are mainly due to ownership models. London, for example, is expected to have a 14% rise in population in the next decade, which 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 and the path dependent characteristics which are reinforced by society and the automotive industry need to be fundamentally challenged.

Car clubs provide an alternative to car ownership that if taken as an integrated approach with public transport has the opportunity to reduce congestion, air pollution and reinstate the equilibrium between cyclists, pedestrians and drivers. Examples need to be analysed and potentially replicated from other cities such as Paris, New York and Berlin, where car clubs have utilised electric vehicles to provide an urban multi-model service. How can the positive impact of e-car clubs be maximised to benefit cities such as London and its citizens?

Car sharing membership grew fivefold between 2006 and 2012 globally, equating to 1.8 million drivers. However only 43,544 vehicles used in 2013 were electric, thus highlighting the opportunity e-car clubs have to accelerate EV deployment and increase exposure (Fairley, 2013). ICT has dramatically enhanced transport systems enabling new business models, with the use of real time data and smart phones e-car clubs have the opportunity to best serve certain journeys for those using public transport. It is questionable whether the Government should employ e-car clubs as a mechanism to encourage alternative transport, with the use of motivation crowding. Policy, infrastructure and incentives will be required if e-car clubs are to become a viable option in the transportation portfolio. This will be explored within the project in order to recommend strategies for e-car clubs to succeed in providing a sustainable transport mode.
This research will investigate city mobility services, exploring integrated eMaaS alongside other transport modes and the existing policies. This will enable transition strategies to be proposed, whilst questioning the market techniques employed to achieve heightened EV use through an eMaaS transport system. The study will explore the path dependant characteristics that prevent drivers from using the most appropriate vehicle mode for each need and how operators can provide a viable multi-modal transport system. The Research Engineer will investigate approaches taken by other cities towards urban mobility and the integration of EVS, and suggest ways in which London (for example) can maximise the potential of e-car clubs to alter the concept of mobility. Exploring the extent policy can influence eMaaS through motivation crowding and market techniques will question the path dependent characteristics, which currently encourage the population to own a vehicle for all their needs. The Research Engineer will produce case studies through conducting interviews with car club operators such as Car2Go and Zip Car to investigate mobility service business models and the impact ICT has had on such models. Digital services such as online booking have become integral to service models, therefore it shall be questioned of operators the extent to which additional web based services are influencing the rate of adoption and the extent to which customers interact digitally.

An expected outcome of this research is a requirement for greater collaboration between Government and private enterprise in order to fund city schemes but also ensure they are viable in the long term. It can be expected that both static and real time data must be shared to a greater extent between the public and private sector and that this is accessible to citizens. Both these factors will implicate people’s choice of transport mode through availability of vehicles and real time information of travel options. Furthermore, it is necessary to address wider stakeholder groups via a range of business models to develop the mobility ecosystem and create competition, whilst not isolating individual communities. These elements would likely result in an increase in eMaaS utilisation and therefore a reduction in emissions, congestion and pollution.

References:


Transition Pathways to e-Mobility-as-a-Service

Emily Gould, David Greaves & Walter Wehrmeyer

INTRODUCTION
- Mobility-as-a-Service (MaaS) is the conceptual approach to study mobility vehicles. MaaS is an efficient system that integrates transport systems, utilising technology and infrastructure. This project focuses on the use of real-time data and smart phones to maximise intercity mobility.

METHOD
- The smart mobility system can be segmented, with each layer adding value to the system as a whole. This research focuses on the physical, administrative and the user layers.

EXPECTED OUTCOMES
- Changes across the market will be required to achieve a fundamental shift towards MaaS.

CONCLUSIONS
- Mobility-as-a-Service (MaaS) is the conceptual approach to study mobility vehicles. MaaS is a new service, utilising technology and infrastructure. This project focuses on the use of real-time data and smart phones to maximise intercity mobility.

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- Diklor & P. Walter: Handbook of Public Sector Administration (2013)
- KPMG: Global Automotive Executive Survey 2013. London, KPMG
- LSE (2013) "Urban Mobility in the Smart City Age"
- Schneider Electric and to academic supervisor, Dr. Walter Wehrmeyer. Thank you to the industrial supervisor, Mr. David Greaves from Schneider Electric. This research is being undertaken as part of the University of Surrey Energy Systems (SEES). It is supported by EPSRC and Schneider Electric.

ACKNOWLEDGMENTS
- This research is being undertaken as part of the University of Surrey Energy Systems (SEES). It is supported by EPSRC and Schneider Electric. Thank you to the industrial supervisor, Mr. David Greaves from Schneider Electric.
1. Introduction

1.1. Schneider Electric

Contextualise the project, company strategy/intent and the environment the project is being carried out in – fast changing market and dynamic business strategy. Original focus for the project was commercial fleets due to the opportunity fleets have to alter the market. However due to Schneider Electric’s position in the market focus altered towards the auto manufacturers and smart mobility solutions. This alongside results from fleet research directed the project to mobility services and specifically e-car clubs.

1.2. Project Aim

Electric vehicles are part of an interdependent technology pathway along with roads, service stations, parking facilities and a social status system that are mutually reinforcing. The challenges within the EV market will be explored to identify the barriers preventing EV adoption and the requirements for market acceptance. This research aims to identify transition pathways towards a sustainable electric vehicle mobility system.

1.3. Project Objectives

- Investigate transition barriers of EVs within the industry through challenging the dominant path dependencies of internal combustion engine vehicles
- Clarify whether path dependency threatens EV fleet adoption; analyse and address the technology lock-in electric vehicles are experiencing within the UK
- Explore how EVs could be utilised to encourage new pathways for a service based mobility model
- Recommend how electric vehicles can break through current lock-in in order to create new pathways for service based models

There are sub questions within each objective that are more specific, for example; how does the total cost of ownership of an EV compare to that of an ICE vehicle?

1.4. Scope
Define scope across entire project: Literature – up to June 2015, Technologies – Plug-in vehicles, Regions – UK focus with EU case studies, Mobility-as-a-Service – e-car clubs, Sector – commercial urban fleets. State the timeframe of the project, what is the desirable transition pathway and from what standpoint

1.5. Thesis structure & methodologies

Multi-disciplinary approach – social sciences and economic analysis. Interviews conducted with semi-structured questions.

2. Background

Contextualise the project, why are EVs the focus:

- Decarbonisation of transport, carbon emissions targets – opportunities EVs provide
- Size of EV and fleet market – consider the slow uptake
- Government incentives
- Range of projections – high, medium & low forecasts (use medium forecast throughout report as a reference point)
- ‘Concept of mobility’ – MaaS – as a subset of services as a totality, e-car clubs are then a subset of MaaS. Alternatives to car ownership is beyond the technology and can provide a range of innovative transport solutions
- Technological, societal and economic dynamics – interaction within the EV market, existing behaviours, ICE lock-in, EV transition pathways

2.1. Introduction

2.2. Electric vehicle market
   2.2.1. Forecasts

2.3. Fleet market

2.4. Mobility-as-a-Service
   2.4.1. E-car clubs

2.5. Conclusions

I do not intend to explore the electricity supply system or the automotive industry in depth as it would widen the project scope significantly and could not be given the exploration required.

3. Literature Review

Examine existing literature on the characteristics of the market as background to Transition Pathways. Critique literature on the policy and market techniques employed to alter and manipulate market conditions. Develop my own ideas on literature – contribution to knowledge, and focus on research questions. Introduce the 4th logic acting upon the ‘action space’: technology within
transition pathways.

3.1. Path dependency
3.2. Lock-in
3.3. Transition Pathways
   3.3.1. Multi-Level Perspective
   3.3.2. Competing Logics
3.4. Motivation Crowding
3.5. Conclusions

4. Methodology

Discuss each aspect of the project and research objectives in line with social science/economic research methods and discuss the limitations of those methods

4.1. Total Cost of Ownership
    Address how it was constructed, where the data was sourced and how it answers the research objective.
   4.1.1. Framework
   4.1.2. Vehicle comparison
      4.1.2.1. Sensitivity analysis
4.2. Fleets
   4.2.1. Case studies
   4.2.2. Interviews
      What was the purpose of the interviews, how was the information used and digested and how it address research objectives.
   4.2.3. Analysis
4.3. E-car clubs
   4.3.1. Interviews
   4.3.2. Case studies
   4.3.3. Analysis
4.4. Methodological Considerations
   4.4.1. Limitations
4.5. Conclusions

5. Results
5.1. Total Cost of Ownership
Including sensitivity analysis as well as a comparison between TCO performed previously in 2011 and TBD in 2015

5.2. Fleets

Present sections as case studies.

5.2.1. Schneider Electric
5.2.2. TNT
5.2.3. Green Tomato Cars

5.3. E-car clubs

5.3.1. E-car, London
5.3.2. DriveNow, Berlin
5.3.3. AutoLib, Paris
5.3.4. TBC, Oslo

5.4. Conclusions

6. Discussions

Link results with literature, draw similarities and raise questions. Are there elements that can be transferable across concepts/countries or are there commonalities in policies? Make clear objectives have been met and the contribution to knowledge – transitions to EVs.

6.1. Research outcomes

Structured alongside the research objectives. Are these outcomes desirable? Who will it affect – how and why – is the EV market currently a false market or is it sufficiently stimulated?

6.1.1. Fleets
6.1.2. E-car clubs

6.2. Research contributions
6.3. Conclusions

7. Conclusions

Make final conclusions - what has been discovered.

8. Recommendations and further work

What needs further investigation / needs to be done in this area.

References

Appendix
TRANSITION PATHWAYS OF COMMERCIAL-URBAN FLEET ELECTRIFICATION

ABSTRACT

This paper considers current thinking on the pathway for electric vehicles, identifying the development blocks of alternative innovation within the market and analyse technological lock-in. The relationship between transition pathways and technological lock-in is largely under-researched particularly in the field of e-mobility. This paper is based on a study with three commercial-urban fleets that examines strategic decisions in new technology adaption alongside vehicle procurement and driver perspective. The paper will analyse the fleet’s decision matrix upon electric vehicles and seek to understand the influence of company culture, strategy and technology applicability, within the context of transition pathways.

RESEARCH HIGHLIGHTS

- The automotive industry is fundamentally built upon path dependant characteristics and has persistent embedded preconceived notions of vehicle design and specification in to customers’ expectations
- Diverse approaches are required to stimulate synergistically the transition to EVs along with an understanding of the dynamic implications and reinforced feedbacks
- The concept of mobility is developing into a complete solution composed by various modes of transport and alternative ownership models

KEYWORDS

Electric vehicles, fleets, transition pathways, path dependencies, commercial-urban

ABBREVIATIONS

Electric vehicles – EV
Internal combustion engine – ICE
Alternatively fuelled vehicles – AFV

TRANSITION PATHWAYS OF COMMERCIAL-URBAN FLEET ELECTRIFICATION

1. INTRODUCTION:

The UK fleet market comprises of approximately 14 million vehicles and is valued at £17 billion a year, with new fleet registrations equating to £106,491,424 (Maslen, 2012). The larger fleets will spend up to £3 billion a year on vehicles and fleet services (Maslen, 2012). Fleet vehicles comprise of over 50% of all vehicles sold in the UK and has steadily increased over recent years (SMMT, 2012). Therefore, any effort to decarbonise transport must address fleets. In addition fleets offer promising opportunities for alternative vehicle technology, particularly electric vehicles as:
The majority of commercial fleets having similar characteristics including high utilisation rates, centralised parking facilities and managed known activities (PikeResearch, 2010)

Most fleets have space to accommodate charging infrastructure

Fleets are expected to have specific charging requirements derived from their drive cycle, destinations, time schedules and fleet size

Decision-making on vehicle choice and specification is expected to be less emotive

The concentration of buying power associated to fleets and the relatively small number of influential decision makers within the industry (ElectrificationCoalition, 2010)

SMMT (2014) published sales for cars eligible for the plug-in car grant1 are up 172% year on year (SMMT, 2014). It is argued this is due to tax breaks, increased availability of products and wider interest from consumers (Grant, 2013).

Despite the potential there is a lack of in-depth understanding regarding the integration of low carbon vehicles into fleets. This research aims to understand the impact of current technological lock-in and development blocks on electric fleets in fleets to strengthen the EV market. It explores the existing transition pathway of EVs within fleets to produce recommendations for fleet strategies of electric vehicle optimisation. This analysis will contribute to the understanding of how radical innovation can overcome path dependencies and be encouraged within the automotive industry to develop the concept of mobility.

2. METHODOLOGY:

This study explores fleet use and management through an in-depth examination of strategic decisions in new technology adaption alongside vehicle procurement and driver perspective. This will analyse the fleet’s decision matrix and seek to understand the influence of company culture, legislative pressure, strategy and technology applicability. The existing technological lock-in influencing fleet transformation will be analysed; and path analysis will examine the societal, cultural and habitual changes that are necessary for optimisation of EVs. This will form a snapshot of each fleet that could be used as a baseline at a later date to analyse further transformation undergone.

The three fleets examined are:

- TNT Express Services UK & Ireland - the UK’s leading business-to-business express operator delivering up to 150 million items per annum
- Schneider Electric UK - an energy management company manufacturing electrical distribution and automation control equipment
- Green Tomato Cars - a London based environmentally conscious private hire service

To carry out this research, analysis was performed on each fleet’s data in terms of size, vehicle type, activity, vehicle replacement cycle and funding method. This captured the fleet’s make-up contextualising the

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1 Grant funding to support private and business buyers looking to purchase a qualifying ultra-low emission car
data in order to better categorise fleet recommendations of electric vehicle optimisation. The data was retrieved directly from the fleet managers and/or senior level management, thus presuming data reliability. Subsequently interviews were conducted with key decision makers within fleet operations to understand the theory of application and the overarching strategy of vehicle procurement; and where possible drivers who experienced a transformation in vehicle technology.

The interviews were conducted to capture the reality amongst fleet operations and the perceptions of the challenges of EVs. Therefore a semi-structured approach was used to achieve a level of comparability between the fleets as well as encouraging the embedded knowledge of fleet managers and fleet specific behaviours to be incorporated within the research. The contribution from practitioners aims to strengthen the analysis drawn from the results. This qualitative research is inductive, ensuring the nature of the relationship between theory and research is analysed and highlight core strategies to fleet operations (Bryman, 2008). The scope of this research extends beyond the immediate fleets involved as analysing fleet behaviour across different sectors will provide an insight in to varied fleet strategies.

3. THEORY:

The 21st century has seen the automotive industry adapt to many challenges both economically and technologically. The key challenge for auto manufacturers is to align technology, product and business performance alongside customer value and financial constraints (DTI, 2008). Due to the success and dominance of the ICE, AFVs will be inhibited by the current industry structure and vehicle architecture. 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 (Perkins, 2003 p.1). 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). Such path-interdependences are stimulated through the mutually reinforcing social system of road transport encompassing infrastructure, service stations and roads; as well as the dynamics of political, economic and technical decisions that develop within the economy (Cowan et al, 1996). It is arguable that auto manufacturers have established “economic-technical problems that have blocked the realization of the economic benefits” of EVs due to existing manufacturing processes and designs (Cowan et al, 1996 p.3). Consequently diverse approaches are required to stimulate the sustained transition to EVs in conjunction with an understanding of the dynamic implications and reinforced feedbacks (Struben et al, 2008). It is reasoned that in order to ensure transformative change, as a basic premise new vehicle technology must be economically attractive for market acceptance (Kley et al, 2010). AFVs 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 alternative technological industries. Industries such as telecommunications are more likely to have a high rate of creative destruction.

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2 Path dependence is a dynamic theory assuming that initial events can increasingly restrain present and future choices (Koch et al, 2009)

3 Creative destruction is the “process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one” (Schumpeter, 1942 p.82)
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.

A transition to a new technology is an extremely dynamic process that extends beyond innovating and competing technologies. The multi-level perspective (MLP) of transition pathways argues transitions are a result of interactions between processes at three levels (Geels et al, 2007):

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

The different 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 gradual political and economic changes (Geels, 2004). The greater the instability of a sector the more likely an innovation can enter the mass market and compete with the existing system, influencing the wider landscape (Geels, 2004). 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 discontinuous shift across an established landscape?

It is argued that a transition requires a fundamental change in market concepts through governance, social practices and business models that have been developed upon past and present technological systems (Foxon et al, 2012). Introducing a new technology in this vein result in a path dependent technology that is much more likely to have a long term impact on the market and successfully achieve creative destruction (Schumpeter, 1942). Transitioning within the automotive industry is extremely difficult due to the scale of the industry and “a wide range of powerful positive feedback processes that confer substantial advantage to the incumbent ICE technology” (Struben et al, 2008 p.3).

It is argued 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, 2012 p.1). Foxon et al (2012) introduces this concept based on three competing logics; society, market and government however this article considers a fourth logic; technology. These logics can create market conditions that can be beneficial to product development or alternatively the existing combined relationship can limit success. The relatively low number of EVs available today has led to manufacturers adopting a more influential and public role in legislation than usual so that they are holding a dominant position. Governance will ultimately specify systemic goals and structures but manufactures of both vehicles and charging infrastructure have been able to influence Government funding and policy. Ensuring that stakeholders are invested within the market on various levels will allow Government to retract when the market is self-sustaining, and the manufactures, to maximise market opportunity ensure they are the “principal coordination mechanism” within the transition pathway (Foxon, 2012 p.7).
Technologically, electric vehicles are a great deal easier and cheaper to service mechanically but they require a greater level of driver interaction than an ICE vehicle. This is a consequence of the range of the vehicles and the requirement to charge, taking some degree of management due to the relative scarcity of charges and the time required. This immediately alters the way drivers approach vehicle use, particularly in fleet applications considering drive cycles and vehicle optimisation. 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 motors. Both the ‘lack’ of charging infrastructure and the restricted range of electric vehicles are argued to be key challenges for the adoption of EVs. To date there are 3,236 publically accessible charging points installed to 3,000 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, work places 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 1: Refueling analysis

<table>
<thead>
<tr>
<th></th>
<th>ICE</th>
<th>EV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refueling stations</td>
<td>8,000</td>
<td>3,236</td>
</tr>
<tr>
<td>No of vehicles</td>
<td>28,700,000</td>
<td>3,000</td>
</tr>
<tr>
<td>Refueling time/hours</td>
<td>0.116</td>
<td>0.333</td>
</tr>
<tr>
<td>Opening hours</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>No of refueling points/station</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Charging capacity per station</td>
<td>22.4</td>
<td>8</td>
</tr>
<tr>
<td>Capacity of all stations to refill</td>
<td>179,200</td>
<td>25,888</td>
</tr>
<tr>
<td>In % of available cars</td>
<td>0.60%</td>
<td>863%</td>
</tr>
</tbody>
</table>

Table 1 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 but it highlights the focus and importance the EV market has placed on infrastructure prior to actual requirement. 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. Consequently ‘EV hubs’ have been formed around the UK that do not provide drivers with roaming abilities across alternative networks. This scenario has been stimulated through the Plugged-in Places scheme and has unfortunately limited to an extent the functionality of an EV resulting in an additional barrier to adoption.

A reinforcing path dependant characteristic that is limiting the Pure EV market is the reduced range to that of an ICE and the anxiety it causes. This is despite the average trip length in the UK being 7 miles and

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4 The government provides match-funding to consortia of businesses and public sector partners to install electric vehicle charging points
6,981 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 et al, 2013 p.1). Alternative fuelled vehicles however do appear to challenge traditional status allegiance with luxury vehicles despite the sacrifice of performance (Griskevicius et al, 2009). Although EVs challenge attitudes towards vehicles, humankind’s perception of undesirable change acutely impacts the pathway of new technology. 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 synthesis of technological lock-in as seen with the ICE results in a pathway to be determined that is regardless of the positive feedbacks.

Across the spectrum of AFVs it is thought hybrid vehicles have a “transitional role...in the sequence of technology adoption” as the vehicles reduce perceived risks associated with AFVs (Collantes, 2007 p.270). The introduction of the Toyota Prius in 1997 is argued to have increased versatility and flexibility within the market through unlocking the historical market of restricted designs and specifications (Ahman et al, 2007). 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 hybrid sales (5 million) in 2012 (Shirouzu et al, 2013). In 2013 there were 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’s market developments could be paralleled to the electric vehicle market. Both challenge the dominant technology using varying degrees of electrification and therefore could be used to manage expectations of the rate of vehicle mode acceptance.

Presently society has not played a major role transiting the automotive market as electric vehicle technology is still at ‘early adopters’ stage and in the main under-utilised commercially. The RAENG (2010, p.12) states “if EVs are to be the agents of change that allow a significant reduction in CO2 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 the existing path dependant characteristics need to be unlocked to allow the general concept of transport modes and travel patterns to be adapted to meet actual demands, whilst also being more sustainable. 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. Struben et al (2008) explore the behavioural dynamics of consumers’ willingness to try an alternative platform to the existing practice and the impact of social exposure and additional feedbacks. 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 effective method to overcome negative market perceptions and change attitudes; it is then likely to change driver’s behaviour and future decisions upon vehicle ownership.

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5 A hybrid vehicle uses two or more distinct power sources, (most commonly and) in this article referring to hybrid electric vehicles (HEVs). HEV use an internal combustion engine and an electric motor.
Existing regulations on carbon emissions are particularly effective within business, however it may be advisable to extend this approach to the public and implement the ‘polluter pays’ strategy. This may lead society to question the concept and sustainability of mobility modes and more broadly the transformation to a low carbon economy.

Policy action, at both the UK and European level is required to assist the dramatic shifts in lifestyle and development patterns that correspond to a transition to low carbon transport network. The policy field of sustainable innovation and technology is somewhat different from other types of policy due to the focus on social benefits and a reduction of environmental risks, rather than focusing on economics (Norberg-Bohn, 1999, Kemp, 2010). However, it is possible that a technology may be locked-in due to previous market events resulting in technological systems to remain stagnant or to develop within a specific pathway. In such instances policy may not result in the desired outcomes due to high entry barriers for competing technologies. This results in embedded technologies remaining dominant for an extended period of time, despite superior substitutes being available. This is detrimental to the market and in most cases to society as innovation is stifled and economies struggle to grow organically. Consequently the fundamental pathway requires Government intervention for the EV market to develop through enforcing regulative measures. One of the most relevant and key drivers for change within the automotive industry is the necessity to reduce CO2 emissions. Emissions reduction is a direct result of regulation and has large implications upon the car market in terms of design, advertising, fiscal incentives and the need to raise awareness. As a result advances in ICE efficiencies have been becoming more advanced; stemming from Formula 1 technology, electric motors have improved and will directly benefit EV capabilities. This technological capability reflects the current strengths and structure of the sector due to the sustained investment in power train systems.

In regards to commercial vehicles, fuel efficiency has been the focus for change and has largely driven the industry due to regulatory pressure and financial incentives. Although this is positive in terms of emissions reduction, it heightens the barriers to entry for EVs as vehicles are in operation longer and maintain high levels of efficiency. This deepens the technological lock-in and enforces existing path dependencies within the industry; therefore it could be argued EVs are required to offer extended benefits than that of an ICE vehicle in order to compete. Cowan et al (1996 p.4) states “it is not enough that the competing technology is better...to overcome lock-in it is necessary that some extraordinary events occur”. He continues that these could be via regulation, scientific breakthrough, technological breakthrough, creation of niche markets, changes in taste and/or a crisis in the existing technology (Cowan et al, 1996). Regarding the EV market, there is not currently a crisis in existing technology and in fact ICE vehicles are technologically improving, competing heavily on efficiency and emission levels. However, regulation regarding emissions from businesses and the associated carbon credits has enhanced the business case for EVs whilst only early adopters have begun to utilise Pure EVs.

Government incentives and regulations relating to emissions have been key catalysts in beginning to unlock ICE vehicle dominance within the market. Although the UK Government state they are technology neutral in terms of emission reduction in vehicles, the government is currently involved substantially in the system integration of EVs and are investing heavily in to EVs: by 2025 the UK Government alone will invest
over £150bn in low and ultra-low carbon vehicle technologies and over £450 million of that will be to ensure the UK is at the global forefront of the development, demonstration, manufacture and use of ultra-low carbon vehicles (SMMT, 2013). 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 electric vehicles and the necessary infrastructure. Market techniques such as these can often result in short lived system innovations, is motivation crowding a sustainable technique?

To date the automotive industry and UK Government have already utilised market techniques and motivation crowding to encourage sales. 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 Commision, 2011 p.16). Political decisions regarding legislation, grants and taxation have to be considered against the long term trajectory and must consider key stakeholders. Game changes in the market through governance should attempt to foresee and decipher demand patterns from various economic and social sectors. The UK has taken a combination of consumer incentives, industry regulation and pilot projects to encourage the use of EVs. European Union legislation have enforced mandatory emission reduction targets on new cars, all cars sold within the EU must emit a maximum of 130g/km CO2 by 2015 (18% less), this was introduced in stages from 2012 (Europa, 2014). The regulation gives manufacturers further incentives to produce vehicles with emissions below 50g/km, with each low emitting vehicle in their portfolio being equivalent to up to 2.5 vehicles it reduces the total average emissions of the car fleet (Europa, 2014). Since 2012 there has been a threefold increase in the number of EVs in the market. This was imposed alongside consumer incentives in the UK that rewarded drivers for buying EVs. Having a greater choice and availability of product as well as the combination of regulation and incentive led to a 116% increase in Pure EV sales over the last year (SMMT, 2013).

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 in to customers’ expectations. Thus technological lock-in is limiting the available market to EVs resulting in niche applications that can benefit from the available grants and incentives. Is it possible that electric vehicles will follow a similar systemic process as the hybrid vehicle and be considered a mass market transport mode within fifteen years? It could be argued that hybrid technology is the bridging technology between ICEs and EVs, introducing drivers to the alternative power train but with the security of extended range and a network of petrol stations. Consequently, humankind can experience a gradual transition to a ‘new’ transport mode with greater exposure and knowledge of the technology.

4. RESULTS:

Green Tomato Cars offer “an environmentally friendly private hire mini cab service in London for corporate accounts and one off bookings” (GTC, 2013 p.1). The business model aims to demonstrate that an

Motivation Crowding “suggests that external intervention via monetary incentives or punishments may undermine, and under different identifiable conditions strengthen, intrinsic motivation” (Frey et al, 2001)
environmentally friendly business can be commercially successful and can work within a mainstream concept. The two fundamental elements being to provide a good quality service at a competitive price and within a branding context that was mainstream and accessible rather than niche. Within the fleet there are 410 vehicles; 8 of which are bio-diesel people carriers, 6 are bio-diesel executive cars (run on 30% vegetable oil) and 396 hybrid cars. By 2014 the fleet will have an additional 50 Pure electric taxis. Introducing a range of vehicle types to the fleet challenges existing technological lock-in preconceived in the private hire car market that traditionally utilises diesel vehicles. Consequently GTC are directing EVs through the logic of bridging technology, optimising vehicle type by applicability whilst society is targeted through the direct contact with costumers (Foxon, 2012).

Operationally, Green Tomato Cars’ drivers do on average 120-150 miles per day mainly within central London. Contracted clients include Coca Cola and B Sky B, who use GTC to contribute to their own carbon reduction targets. The vehicles are leased and maintained by GTC and drivers rent and fuel the vehicles, taking a percentage of each job. A number of vehicles are kept at the depot in Isleworth whilst the majority of drivers will take their vehicle home. Green Tomato Cars trialled two Renault Fluence’s on the fleet last year for six months. These vehicles had an effective, actual range of 60 miles (Renault’s states 99 miles) and were charged nightly without the ability to fast-charge. As a result the vehicles could only be used for half a day and were limited to certain journeys, with greater emphasis on the destination rather than the pick-up point. However it was logistically difficult to manage and was not commercially viable. Ultimately the Fluence did not have the range to be a viable component part of a fleet of an established private hire company.

GTC’s experience of EVs highlights a key issue for both commercial and residential applications, namely vehicle range. When routes are not predictable and there needs to be an element of flexibility, the electric vehicles trialled have not been adequate. This 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. However due to the start-up and innovative nature of the business GTC continued to explore the EV market, procuring the BYD E6, a utility vehicle with a range of 150 miles with air con/heating on at approximately 20%. At such a specification it offers drivers an EV without the need to ‘compromise’ and alter behaviour. Therefore Green Tomato Cars can operate confidently through profiling efficient day drivers as there are a greater number of short journeys that go back to back than at night when typically there are longer journeys.

GTC remain realistic that despite the sufficient range there may still be challenges for EV operations, the two main challenges GTC are continuing to consider are:

1) 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). GTC have been in discussions with existing customers regarding their willingness to have chargers installed on their premises as part of GTC’s infrastructure network planning. GTC think it is a compelling business proposition as the companies can show their green credentials whilst also having cars available on site.
2) Winning over the stakeholders – a compelling argument can be put forward to the drivers as to why they should be driving EVs but its 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. Customers will need to be reassured of their misconceptions through good marketing and an evolving message as customer expectations and awareness develops.

The two challenges GTC discuss truly highlight not only the infeasibility of existing EVs on the market within a private hire fleet but are also very relevant to the general market of EVs. Range, infrastructure and perception are three very influential elements that need to be addressed for the electric vehicle to compete with the internal combustion engine. The direct contact GTC has with the public will assist in overcoming those development blocks in society as it familiarises people with the technology and dispels myths. Furthermore, the client base of GTC could be argued to be technology assertive as GTC offer bookings through Twitter, an iPhone app and an online account. Offering their services through a multitude of mediums introduces the concept of Mobility-as-a-Service, broadening opportunities for customers using alternative means of transport to ‘conventional’ vehicle ownership.

TNT provides an express parcel delivery services to the UK, Europe and International destinations offering same day, next day and express parcel services. Within the UK, they own 4,743 vehicles, including tractor units, rigid trucks, semi trailers and cars across 134 operating locations. This research focused on the rigid trucks which are used for local delivery/collection. There are 1,398 7.5 tonne trucks that on average travel 56,000km per annum, although there is a variance in the annual mileage.

In 2006 the board of directors instructed the fleet to procure electric vehicles to contribute to the zero emission targets of the company. An EV truck had been previously trialled and had been fairly successful in terms of operations, therefore TNT procured a further 50 7.5 electric trucks. The ‘Generation 1’ trucks were bought from Smith Electric Vehicles and were in operation for 3.5 years until 2010. The reliability was continuously an issue but by 2010 they became very problematic, this was centred on the battery technology which at the time was sodium nickel chloride. As a result, 10 were converted to lithium ion batteries which improved reliability, however the conversion costs were greater than a diesel equivalent due to the charging infrastructure on the vehicle having to be changed.

TNT did not intend to make these vehicles more economical to run but to be cost neutral with a diesel vehicle over the 5 year life balancing higher capital costs and lower running costs. However, that did not prove to be the case by the third year due to the unreliability and the subsequent conversion costs. It was considered that the EVs had been a moderate success but cost prohibitive. As a result all of the ‘Generation 1’ vehicles were returned to the manufacturer and TNT awaits 20 ‘Generation 2’ vehicles. This reduction in EVs is to keep the replacement cost neutral in terms of the depreciation on the ‘Generation 1’ vehicles and the cost of the ‘Generation 2’s’, at £65,000 each.

TNT states that if the reliability of ‘Generation 2’ is proven then it is likely TNT will procure more from Smith’s as there are limited manufacturers of electric trucks. TNT’s National Fleet Engineer predicts that TNT will focus on electric vehicles in the foreseeable future with the use of telematics. TNT being mainly based in
city centres believes electric vehicles will be the future of mobility and can see that ICES will be prohibited from entering cities. TNT wishes to be compliant with future Government legislation and in fact lead the way by utilising this type of technology in operation today. This clearly demonstrates a transition pathway for TNT being Government forces, being a dominant player within the industry with such a well-established brand, it heightens the pressure to be first movers at the forefront of regulation. However being such a large company with stringent CO2 targets, they have the budget to absorb the challenges as the potential rewards including fuel savings, PR value and market advantage are high.

TNT has previously trialled prototype hybrids for various auto manufacturers, due to the available petrol tank they were a lot easier for TNT to manage operationally. However, TNT found they were not suitable vehicles for densely populated urban roads due the greater efficiency of demand than breaking regeneration. The fuel saving was between 16-18% but due to the nature of hybrids they have relatively low mileage so not as influential as if they were high mileage vehicles. TNT performed 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. As the replacement cycle for TNT is 5 years, these vehicles are not feasible within this model.

In terms of the electric vehicles the challenges that TNT have experienced beyond the reliability issues were, like GTC the limited range of the vehicles. Consequently the vehicles had to be in locations were the depot operations met the requirements of the daily range, introducing a certain amount of inflexibility in the fleet at that depot, unlike a diesel vehicle. The second challenge is the increased unladen weight affects the payload due to the weight of the battery. As a result less weight could be carried which could be extremely limiting for a courier business, however fortunately TNT are not as payload sensitive as other operators. However it did require more planning on which loads can go in which vehicle. Furthermore, the EU has been considering increasing the gross vehicle weight for EVs because of the necessity to meet the duty requirements of the operator and the effect this has on companies adopting electric vehicles. It is questionable whether this would be safe as the EU is not suggesting additional mechanisms such as breaks to cope with the increased weight.

Schneider Electric has approximately 1,200 vehicles in the company car fleet. Employees are graded dependant on their role, this along with the number of miles driven (at least 10,000 miles p.a or out the office more than 3 days/week) decides if and what car the employee is entitled to and at what contribution rate. Drivers can choose vehicles up to 25% above their allowance with the majority of drivers trading up rather than down, suggesting somewhat the desire to own a vehicle perceived as attractive. However, anyone performing less than 2000 miles p.a receives a cash allowance as it is not cost effective to provide them with a car. Within this scheme the Benefit in Kind (BIK) tax is now based on the P11D and the CO2 emissions of the specific vehicle. Schneider Electric funds the vehicles through Hitachi Capital and the driver pays the BIK to the HM Revenue & Customs. This step change is quite dramatic as the drivers choice of vehicle can now be based around the efficiency of the vehicle rather than based on maximising the fixed BIK, regardless of the CO2 level.

\[ ^7 \text{Tax paid by employees earning over £8,500 per year for the benefits provided and expense payments made to employees by employers that are not put through payroll} \]
As a result the fleet may start to see more hybrids in the fleet due to incentive of low emissions and associated BIK.

There are two lease schemes that co-run providing four year cycles. Until 2013 the company was partnered with ALD Automotive which had 100% employee car ownership scheme, introduced to maximise tax efficiency for the company. Schneider Electric pay monthly rental for the vehicle, insurance, maintenance but do not pay BIK tax, employees pay a contribution based on a benchmark vehicle (Vauxhall Isignia). Under this scheme drivers were reimbursed for the number of miles driven, 45p per mile for the first 10,000 miles and then 25p per mile thereafter, with no consideration given to the efficiency of the vehicle or the driver behaviour. 70% of drivers remain on this scheme until their contracts are terminated, 30% of drivers have leased a car during 2013 from Hitachi Capital. On the new scheme the company reimburses the driver one pence per mile based on +15% of the mpg. This is to encourage drivers to drive more efficiently and potentially contribute to their private mileage which is not paid by the company. The new scheme is influenced by Government regulation and is clearly the motivations for Schneider Electric’s policy, however the cap of 160g/km\(^8\) on vehicles is still relatively high. Schneider Electric are aware that Government are to enforce more stringent limits but Schneider Electric are clearly comfortable reacting when necessary in order to maintain satisfied employees.

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 on 49 company cars based in London due the opportunity city driving provides EVs with shorter distances and regular (regenerative) breaking. This alongside the Mayor of London’s pledge to make London the EV capital of Europe led funding partners to stipulate vehicles were London based (Johnson, 2009). Of these vehicles the average business mileage is 14,042 and total mileage including private mileage is 18,755, whilst 44% were below 10,000 miles per annum.

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Number</th>
<th>%</th>
</tr>
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<tbody>
<tr>
<td>Diesel</td>
<td>36</td>
<td>73%</td>
</tr>
<tr>
<td>Petrol</td>
<td>12</td>
<td>24%</td>
</tr>
<tr>
<td>Hybrid</td>
<td>1</td>
<td>2%</td>
</tr>
<tr>
<td>EVs</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Total</td>
<td>49</td>
<td>100%</td>
</tr>
</tbody>
</table>

Source: EST, 2013

Mileage between 10,000 and 20,000 is usually positive when considering a Pure EV as range is a lesser concern and efficiency gains are reaped. Furthermore the analysis considered the monthly and whole life costs for both the company and the employee. It is apparent in comparing a BMW 320d Modern Auto (popular car on the fleet) with a Vauxhall Ampera Electron, the Ampera is cost effective for both the employee and the employer. 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

\(^8\) Cars with CO2 emissions of 160g/km or less are eligible for 100% of their lease payments to be offset against corporation tax (BVRLA, 2012)
are considerable financial savings to both Schneider and their drivers of selecting an EV alternative” (EST, 2013 p.3).

Although the analysis put forward a business case for the Ampera in place of the BMW 3 Series, it is very unlikely Schneider Electric employees will begin adopting these vehicles as the contribution rate required by employees will be high and in most instances would therefore not be shown on the vehicle list. BMW for instance provide attractive discounts (up to 30%) to Hitachi Capital, making them feasible for employees to effectively own. Furthermore due to the disputed residual values of electric vehicles the higher depreciation may mean again they would be too expensive compared to efficient alternatives. This emphasises the unattractiveness for Schneider Electric employees to sign a four year contract for an electric vehicle. However if Schneider Electric were to adapt the policy in order to encourage EV use, the necessary marketing materials would need to be communicated across the business to educate employees of the vehicle type, choice and the policy implications.

5. DISCUSSION:

The three fleets involved in the study were purposefully chosen to be in different industries and to have different use regimes to understand the path dependencies and the associated transition pathways for EVs in different fleet scenarios. In regards to Schneider Electric’s company car policy there seems to be little motivation to adapt the policy to incorporate electric vehicles at present. While the P11D is still high on EVs it will not be a competitive option for employees, regardless of whether EVs are on Hitachi Capital’s vehicle portfolio. The low cost of electricity is not a particular draw to the employee as the company reimburses company mileage, removing a key incentive of electric vehicles. Although this is not the norm, economics is still 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. In this respect there are little economic barriers to the adoption of EVs as financially they can provide a more robust business case over time than an ICE. This has been strengthened in recent months with greater knowledge on the residual values of AFVs.

The key challenge to Schneider Electric driver acceptance is likely to be use of the vehicle for private mileage 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, employees would not substitute flexibility and the practicality of the vehicle, suggesting technological lock-in. This accompanied by the fact that the reliability of the cars is not a consideration factor as the scheme prescribes that the vehicle has to be less than a year old/10,000 miles and will be regularly serviced throughout the contract. Additionally, it is clear that within Schneider Electric there is an extent of badge consciousness and the psychological kudos with customers. This emotive dimension of vehicle choice is much harder to address than technological or ecological factors and is arguably a development block that will be overcome with market exposure.

The evidence suggests that the transition pathway to fleet electrification is much more focused on the technology, both in terms of availability to fast charging infrastructure as well as the vehicle aesthetic appeal
and specification. The low cost benefit of the vehicles may be enticing to small company car fleets based within cities but this is unlikely to have the necessary impact the EV market needs to become mainstream, influence the provision of charging infrastructure or influence the second hand car market. Due to individual path dependent characteristics companies are challenged to alter social practices in order to change behaviour at work. This along with the company car culture in the UK, sales companies are unlikely to tighten policies beyond the set legislation whilst encouraging low emitting vehicles. In order to instigate a considerable shift in behaviour and company strategies, a new socio-economic approach is required through introducing a tax for carbon emitting cars, rather than the currently incentivising low emitting vehicles. There are examples of this practice in Scandinavia where EVs are the highest selling vehicles. For example the Norwegian Government has encouraged EV sales through offering tax breaks, free parking and driver access to bus lanes, consequently there are 21,000 EVs in the country of 5 million people (compared to 5,000 in the UK with 63 million people) (Revell, 2014).

TNT provides a very different scenario to discuss, in that they operate 7.5 tonne electric trucks. This enters a new market with little competition between manufacturers. A key reason for this is due to Euro 6 Regulation (EC) No 715/2007 (Europa, 2013), taken into effect in January 2014: “all vehicles equipped with a diesel engine will be required to substantially reduce their emissions of nitrogen oxides... emissions from cars and other vehicles intended to be used for transport will be capped at 80g/km (an additional reduction of more than 50 % compared to the Euro 5 standard)” (Europa, 2013 p.1). Therefore manufactures have been investing into more efficient diesel engines rather than in electric motors. Consequently for TNT’s operations the Smith’s Newton model was the only acceptable vehicle in 2010, and interestingly that remains the case so far.

Unfortunately for TNT it does not seem the electric truck market is as advanced technologically as is required for full integration within the fleet. It does, however, highlight that economic attractiveness is not the only driver to transformative change but a number of factors that are unlikely to result in a positive cost-benefit analyses (Nilson et al, 2012). In this instance there were a number of uncertainties within the trial that were coherent to the needs of the drivers. Although procuring the electric trucks creates positive PR, the expense cannot justify the activity and therefore it could be suggested that TNT either explores alternative business models i.e. leasing or alternative vehicle types that can utilised to a greater extent or wait for the market to develop gradually.

This highlights the market’s position at present, despite attempts to alter the vehicle portfolio the ICE remains locked in. The requirement for a transition is technology availability but this is not a competitive market for EV manufacturers due to the size of the vehicles. Consequently it is unlikely that there will be viable and reliable electric vehicles for some time, constricting freight companies vehicle choice. This relationship is creating mutually enforcing path dependencies as EVs cannot break through the ICE technological and societal lock-in. This however does not apply to the smaller freight vehicles in which companies such as TNT could successful integrate and benefit from today.

Green Tomato Cars offers another example of EV use which is the most successful application explored. The premise of the company is to use AFVs within the private hire market, not only offering a
unique selling point during an age where companies have to prove their social and environmental conscience. This led to an extremely successful business model that is now trying to bridge the gap between hybrid and electric technologies within a commercial operation. Having launched in 2006, the hybrid (Toyota Prius) had previously challenged the technological-lock-in that had resulted in the same conceptual designs being retained for centuries. Green Tomato Cars joined the movement of AFVs, through utilising EVs GTC will continue to challenge the constraints of historical markets that are argued to restrict versatility and flexibility that could be the requirement for the necessary carbon reductions in transport.

A driver at Green Tomato Cars who has trialled various electric vehicles, bio-diesel vehicles and hybrid vehicles was interviewed. When asked specifically of experience with the Renault Fluence, trialled for 6 months, the Driver proclaimed that the range was very limiting, although it was suitable for city driving, motorways proved challenging. The Driver did not think that EVs were suitable for a taxi provider if it were a driver’s sole vehicle due to the battery capacity as they would not be able to earn money while the vehicle is charging and often the operating hours can be long. Whereas he argued that hybrids are much more suitable for this type of business, whilst at the specification of the Fluence.

Green Tomato Cars believe they have a responsibility to be test beds of new technology as an element of the brand is to be pioneering with new technology where competitors who are either green wash or ‘copy cat’ do not have that same commitment. This indicates why Green Tomato Cars did not wait till the market develops with further advances in EVs, but instead focused on utilising technology that is less polluting than existing vehicles. When the management are forward thinking in this way it begins to eliminates 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.

Considering motivation crowding across the three fleets, the current Government position of financial incentives appears to have had little influence on the fleets. Due to the fact that both Green Tomato Cars and Schneider Electric lease their vehicles they will be unable to take direct advantage from the incentives, similarly TNT will not be compliant with the funding due to the size of the vehicles. However all three fleets would be able to utilise funding for electric vehicle charging yet this was not a key motivator for TNT or Schneider Electric due to the stage at which they are at but for Green Tomato Cars it contributed significantly to the business case.

6. **CONCLUSIONS:**

This paper has explored the impact path dependencies have had on the electric vehicle market and the consequent transition pathways that are being led by industry. The preconceived notions of vehicle specification are being challenged through Government incentives that encourage societal, organisational and cultural change. The fleets investigated demonstrate different levels of engagement with electric vehicles yet the development blocks experienced are of similar vein, this indicates the market is still embryonic and would arguably not be self-sustaining without Government support. It is questionable how long the Government will be prepared to continue incentivising EVs if the technology fails to meet EU targets.

The transition to electric vehicles requires not only behaviour change but an emotive acceptance of
an alternative fuelled vehicle, which has yet to be broadly achieved. Companies such as Green Tomato Car positively encourage this change within society and allow customers to ‘touch’ the technology without any level of immediate commitment. Technological lock-in to an extent is limiting the market but it is far from the full explanation for the very low number of EV sales. Path dependencies arguably have a greater impact on the market as the current regime and relationships that the international market is built upon reinforces people’s reliance on the internal combustion engine.

This research highlighted the area of Mobility-as-a-Service (MaaS) that is suggested to be integral to society in the future, providing alternatives to car ownership (KPMG, 2013). MaaS would widen the mobility solution incorporating mobile apps for payment and location-aided services, thus ensuring ease of use and functionality (KPMG, 2013). This is a substantial opportunity for the EV market as it removes many of the barriers to electric vehicle use, many of which are due to ownership models. Over the next decade it is likely that transport solutions will develop into a more integrated system within cities, technologically this is conceivable however, the rate at which it can be achieved is reliant upon the acceptance of society and the mechanisms put in place by Government. The concept of mobility is developing into a complete solution composed by various modes of transport and alternative ownership models, electric vehicles may remove technological lock-in through entering the industry as a segment of ‘smart mobility’. This is a new area of research that has been highlighted by the fleet study as having not been fully explored.

ACKNOWLEDGMENTS

I would like to thank the fleets involved in this research and their cooperation in sharing information. Similarly thank you to EPSRC (EP/G037612/1) for their contribution to the research and the support given.

REFERENCES


Charging Infrastructure for Electric Vehicle Fleets – identify and develop business opportunities within target sectors

Six Month Report

Engineering Doctorate

Industrial Doctorate Centre

University of Surrey

April 2015

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Six Month Report

The following report is based on the six month period between October 2014 and April 2015. It will reflect upon the last six months and discuss future intentions.

1. Six months ending April 2015

Over the last six months the Research Engineer has been continuing Phase Two of the project focusing on e-mobility services. The research has been investigating e-mobility in the context of product-service systems in order to recommend transition strategies to achieve more sustainable city car solutions. An expected outcome of this research is a requirement for greater collaboration between Government and private enterprise, in order to fund city schemes but also to ensure they are viable in the long term. It can be expected that data must be shared to a greater extent between the public and private sector and that this is accessible to citizens. Both these factors will implicate people’s choice of transport mode through availability of vehicles and real time information of travel options. Additional activities that the Researcher has been involved in have been both academic and commercial, both of which have influenced the research project, discussed further in Section 1.

1.1 Journal papers

The Research Engineer had a journal paper entitled ‘Transition Pathways of Commercial-Urban Fleet Electrification’ rejected by the Environmental Innovation and Societal Transitions Journal. This paper is in the process of being reviewed and restructured to submit to Technological Forecasting and Social Change (under discussion).

The Research Engineer is writing a second paper on ‘Transition Pathways of e-Mobility Services’. This is currently being constructed for the Sustainability City 2015 conference but will be published following the conference through the Wessex Institute.

1.2 University Modules

Within the last six months the Research Engineer attended two modules at the University of Surrey: (i) Communications Management and (ii) Prince 2 Practioner Project Management. The Research Engineer successfully completed the assignments/exams and has therefore finished the taught element of the Engineering Doctorate.

1.3 OLEV Homecharge Scheme

The Office of Low Emission Vehicles (OLEV) has launched a revised edition to the Electric Vehicle Homecharge Scheme. From mid-April 2015 the subsidy will provide 75% or up to £700 for EV charging infrastructure and installation. The Research Engineer continues to manage Schneider Electric’s authorisation and product approval process, with currently two products pending submission.
2. **E-Mobility services**

City e-mobility services continue to be the focus of the project and will be for the next three months. The RE has been investigating product-service systems to understand the transition from a product led industry with a high proportion of ownership, to a pay-as-you-go service approach to car travel.

2.1. **Context**

Cars currently contribute 12% of total EU emissions of carbon dioxide; the European Union target requires a 40% reduction by 2021 (European Commision, 2015). As the fastest growing contributor to climate change methods of transportation need to be challenged (OLEV, 2011). Broadening the availability to alternatives of car ownership has the opportunity to help tackle the challenge of transport emissions. A study conducted by LSE (LSE Cities, 2013) indicated that shifting to greener modes of transport e.g. electric vehicles, is the most important strategy to achieve sustainable transport.

The concept of mobility has dramatically changed over recent years; evidence suggests that Mobility-as-a-Service (MaaS) will become integral to society. Incorporating mobile apps for payment and location-aided services ensures ease of use and functionality (KPMG, 2013). MaaS is a considerable opportunity to decarbonise transport through introducing alternatively fuelled vehicles in to the city transport portfolio. This research will specifically consider electric vehicles (EVs) in an urban context. Electric vehicles being used across a city at multiple vehicle pick-up and drop-off locations, removes many of the barriers to EVs such as high purchase price and range anxiety. The move from a product-led business model of traditional car ownership and leasing, to a product-service system introduces car sharing, renting and pooling. This introduces new ownership and revenue structures that use subscription or pay-as-you-go based models, transferring vehicle responsibility and risk on to the service provider (Weiller, 2012). This transition in vehicle use requires a shift in behaviour and asset culture to dematerialise the transport sector. In seeking to deepen understanding on how to achieve this within a city, the research will explore examples of e-mobility models. Product-service systems will be analysed with particular focus on use-orientated services, as the business models are most explicitly linked to car sharing, renting and pooling. The aim of the project is to then address how cities can appropriately transition to such use-oriented services.

2.2. **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). Mont (2002) 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”. 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. These are particularly important in mobility solutions and add value through customer experience, building unique relationships and customer loyalty.
PSSs can be classified into three main categories (i) product-orientated services (ii) use-orientated services and (iii) result-orientated services. 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).

There are 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 (Mont, 2002). These approaches require a greater level of responsibility from the producer or service provider for the product’s life cycle, and require greater customer involvement to use and operate the service. However there are three uncertainties of PSS, (i) the readiness of companies to adopt, (ii) the readiness of consumers to adopt, and (iii) the environmental implications (Mont, 2002). This research will consider (i) and (ii) as fundamental requirements for a transition to e-mobility services, but does not consider the environmental implications.

Ehrenfeld (Ehrenfeld, 2001) introduced five key evaluative criteria: (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 electric vehicles in cities, e-mobility services relates directly to (iv) and (v) categories. Ehrenfield (2001) indicates that changing the product concept eases the system transition; therefore it could be argued that using electric vehicles in services such as car clubs will encourage drivers to adopt the service rather than if it were internal combustion engine vehicles (Williams, 2007).

2.3. 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). As seen in Figure 1, 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.

Types of use-orientated services within the automotive industry
2.3.1. **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, disassembled and re-used as raw materials. 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.

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.

2.3.2. **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 examples (explored in the thirty-six month report) 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). This is the biggest opportunity for e-mobility services to leverage within cities.

2.3.3. **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 and therefore will not be explored to any great detail.

2.4. Discussion

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 in to (i) the adaptation of a dominant system or (ii) the attempt to take over the dominant position (Marletto, 2014). When an innovation is widely 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 a combination of forces including, societal and cultural norms (lock-in) along with no direct policy incentive. Despite this, mobility services are acting in ‘coalition’ to the dominant system of internal combustion owned vehicles. 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” (Marletto, 2014). 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 electric vehicles can play a secondary role. The difficulty is to approximate the necessary level of motivation crowding to influence users within reasonable margins. It is also necessary to consider regulations and other measures such as tax incentives to ensure e-mobility schemes are viable (Roy, 2000).

Transitioning to a functional ‘experience’ economy by which profitability is based on the provision of services to meet essential human needs rather than on material production and consumption (Jackson, 1996). Shifting the role of the manufacturer to the provision of services diversifies the market and is argued to be complimentary to the penetration of new products (Mont, 2002) (Fioruzzi, 1997). Furthermore customers are “willing to pay more than would be justified on the basis of ‘rational’ calculation” due to intangible added value (Tukker, 2004). However, as there is only a limited network that supports e-mobility, further investment in infrastructure is required by city operators. PSS requires a fundamental shift in culture, resources and behaviour in order to overcome the psychological barriers, whether it is in companies or the general populous.

Mont (Mont, 2001) suggests companies follow a five step process to do 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. 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” (Williams, 2006). This requires “close integration of all actors within the life-cycle of a product-service” (Mont, 2002). Furthermore, there are 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 (Mont, 2002). Car sharing and leasing are based on that “the artefactual system remains more or less the same, but where innovative institutional arrangements produce beneficial changes” (Ehrenfeld, 2001).

Schemes such as car sharing can considerably reduce car ownership and car mileage whilst studies suggest that use of public transport is increased (Roy, 2000). Although this is positive in terms of congestion, air pollution and emissions within cities, it intensifies the peak demand of public transport which needs consideration. The project will not consider this aspect of transitioning to e-mobility services, but will use PSS theory along with transitions theory, and case study examples such as BMW DriveNow, to identify transition pathways for e-mobility solutions.

3. Project Management

Following illness, the project extension request was successfully approved by the Board. The new completion date is 18th December 2015. Over the next three months Phase Two of the project will be completed, leaving six months to complete ‘loose ends’ and compile the thesis.

3.1. Conferences

The Research Engineer is attending two conferences in the six months:

2. Sustainable City 2015: 10th International Conference on Urban Regeneration and Sustainability

At the first conference the Research Engineer will present Phase One of the research project – transitions pathways of fleets; and at the second conference Phase Two will be presented – e-mobility services. Consequently the Research Engineer will have both project phases challenged and critiqued by peers prior to writing the thesis.

3.2. Project Activity

In seeking to address the project aims: (i) explore how EVs could be utilised to encourage new pathways for a service based mobility model and (ii) recommend how EVs can break through current lock-in in order to create new pathways for service based models; there will be further investigation of existing models of e-mobility services such as BMW DriveNow. This will then be applied to the theory of product-service systems to produce transition strategies; this will result in the Research Engineer’s second journal paper. This will then conclude the two phases of the project and result in the project write-up and submission.

The Gantt chart below outlines the key phases of the project over the coming six months and the dates of which these stages will be completed:
### Case studies
- April 2015

### Complete journal paper #2 (and submit)
- April 2015

### Re-structure journal paper #1 (and submit)
- April 2015

### Transition pathways for Maas & EV
- April 2015

### "Loose ends" of project phases
- April 2015

### Compile thesis
- April 2015
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Transition Pathways of e-Mobility Services

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Abstract

The concept of mobility is developing into a complete solution composed of various modes of transport and alternative ownership models. Evidence suggests that Mobility-as-a-Service will become integral to society, incorporating mobile apps for payment and location-aided services, thus ensuring ease of use and functionality [1]. This is a considerable opportunity to decarbonise transport within cities, reducing the need for private car ownership and utilising electric vehicles within the mobility model. There is however uncertainty of what and how this should be implemented and therefore requires further research within the transitions field.

This research will investigate city mobility services, specifically e-mobility. This will be considered in the context of product-service systems to explore the existing market and identify transition pathways. Use-oriented services are the primary focus as the business models are most explicitly linked to car sharing, renting and pooling.

The level of uptake of e-mobility services is reliant upon the interest and acceptance of society and the mechanisms put in place by Government and private enterprise. An expected outcome of this research is a requirement for greater collaboration between Government and private enterprise, in order to initially fund city schemes but also ensure they are viable in the long term. It can be expected that data must be shared to a greater extent between the public and private sector and that this is accessible to citizens. Both of these factors will affect people’s choice of transport mode through availability of vehicles and real time information on travel options.

Keywords: Electric vehicles, urban, e-mobility, mobility-as-a-service, product service systems, use-oriented

1 Introduction

Cars currently contribute 12% of total EU emissions of carbon dioxide; the European Union target requires a 40% reduction by 2021 [2]. As the fastest growing contributor to climate change methods of transportation need to be challenged [3]. Broadening the availability of alternatives to car ownership has the opportunity to reduce transport emissions. The concept of mobility has dramatically changed over recent years; evidence suggests that Mobility-as-a-Service (MaaS) will become integral to society. MaaS incorporates mobile apps for payment and location-aided services to ensure ease of use and functionality [1]. A transition to MaaS will require a fundamental change in market concepts in order to “shift from one socio-technical system to another i.e. a system innovation” [4].
A study conducted by LSE [5] indicated that shifting to greener modes of transport is the most important strategy to achieve sustainable transport. MaaS can introduce alternatively fuelled vehicles (AFVs) in to the city transport portfolio. This paper will specifically consider electric vehicles (EVs) in an urban context. EVs being used across a city at multiple vehicle pick-up and drop-off locations, removes many of the barriers to EVs such as high purchase price and range anxiety. More so, the niche application of EVs within this context can assist the transition to an established and broader EV network.

The move from a product-led business model of traditional car ownership and leasing, to a product-service system introduces car sharing, renting and pooling. This introduces new ownership and revenue structures that use subscription or pay-as-you-go based models, transferring vehicle responsibility and risk on to the service provider [6]. This transition in vehicle use requires a shift in behaviour and asset culture to dematerialise the transport sector. In seeking to deepen understanding on how to achieve this within a city, the paper will explore examples of e-mobility models. Product-service systems will be analysed with particular focus on use-orientated services, as the business models are most explicitly linked to car sharing, renting and pooling. It will then be discussed how cities can appropriately transition to such use-oriented services.

2 Product-service systems

Sustainability of the automobile industry requires behavioural and system-level changes [7]. In order to achieve this there is an emphasis to adopt a product-service system (PSS). This has been defined as “a marketable set of products and services capable of jointly fulfilling a user’s need” [8]. Mont [9] 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”.

Product-service systems have the opportunity to continuously innovate and develop new offers [9]. 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. These are particularly important in mobility solutions and add value through customer experience, building unique relationships and customer loyalty [10].

Broadly PSSs can be classified in to three main categories (i) product-orientated services (ii) use-oriented services and (iii) result-orientated services. This paper will focus 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 e.g. mobile phone contract [9] [11]. In doing so alternative profitable revenue streams can be identified and considerable changes in behaviour and culture can be achieved [11].

Applying PSS to e-mobility services, there are three approaches that can be introduced (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 [9]. These three PSS elements will be considered in regards to the examples given in Section 3 and then discussed in Section 4.

In order to evaluate PSS initiatives, Ehrenfeld [12] introduced five key evaluative criteria: (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 necessary to
introducing and managing PSSs, e-mobility services relates directly to (iv) and (v) categories. Furthermore, Ehrenfield indicates that changing the product concept eases the system transition; therefore it could be argued that using EVs in car clubs instead of internal combustion vehicles will encourage drivers to adopt the service [11]. This will be discussed further in Sector 4.

3 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” [6]. As seen in Figure 1, 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.

Figure 1: Types of use-orientated services within the automotive industry

3.1 Product lease

Vehicle leasing is growing in popularity both by companies and private users as a means to finance vehicle purchase. 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 two forms of leasing (i) traditional use and return, and (ii) eco-leasing whereby the product is returned, dissembled and re-used as raw materials. Eco-leasing introduces a more sustainable approach to car ownership than outright purchase.

Product 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.

A mobility offer from BMWi 360° offers a range of services including ‘mobility solutions’ for those who purchase a BMWi EV. Customers wishing to carry out extended journeys beyond the range of an EV can hire an appropriate vehicle [13]. 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.

3.2 Product renting or sharing

There are a growing number of vehicle rental or sharing schemes that offer access to a variety of vehicles to suit customer 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. There are a number of examples of vehicle renting or sharing across the globe that account for
1,788,000 car sharing members that have access to 43,500 cars [14]. This is the biggest opportunity for e-mobility services to leverage, below are three examples of EV schemes in progressive European cities:

3.2.1 AutoLib’, Paris

Following trials Autolib’ launched in June 2012 with 250 of their own ‘Bluecars’ and 250 stations and centres. Today there are approximately 2,000 ‘Bluecars’ and 4,300 stations within the forty square mile city [15] [16]. 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 internal combustion engine (ICE) [15].

There are a range of payment models that offer flexibility and freedom to travel across the city using a point-to-point business model unlocking the full potential of electric car sharing [16]. 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 [8]. The city is 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. Furthermore, “cars in Paris are driven only about 5% of the time and stay parked the remaining 95% of the time” thus enforcing the business case of e-mobility [6].

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 that challenge the embedded technological lock-in of ICE vehicles. 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 [17]. This would suggest that the importance of owning a vehicle is diminishing in younger generations and the shift from product models to service models may increase in popularity and viability.

3.2.2 Source London, London

In 2014 the Ballore Group took ownership of 1,300+ charging points across London from the previous Government led ‘Plugged in Places’ scheme. Charging infrastructure will increase to 4,500 by 2018, this will be a considerable shift for London, especially if a pay-as-you-go model is used. The scheme will aim to be high volume, 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. With 37% of all trips in London per day (26 million trips a day) made by private transport, the opportunity for EVs to populate the city is vast [18].

Gaining parking bays on a leasing agreement from 32 Boroughs will be challenging for Source London 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 of working with the Boroughs. This will require careful consideration for Source London as an integrated approach across the city will be required for a viable scheme, alternatively it will be a more local offer for those Boroughs involved.
3.2.3 DriveNow, Berlin

DriveNow is BMW’s carsharing service which operates in five German cities as well as San Francisco and most recently London. In Berlin there are eight BMW models available for hire including the pure electric, Active E. The scheme has various DriveNow 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 pure electric. 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, that being more important for the Active E to educate and familiarise drivers with the technology, thus unlocking path dependencies.

DriveNow has streamlined the process of activating vehicles, charging and parking encouraging adoption and replication for other cities. 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 [19]. This indicates the impact car clubs can have upon a city’s congestion through reducing road vehicles alongside assisting to reinstate the balance of emissions and air quality.

3.3 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 [10]. There are two distinct client bases, the public and members often in a workplace environment.

3.3.1 Hertz BilPool, Oslo

Hertz operate a car pooling service across Norway, with Oslo being the primary area with a high concentration of vehicles including the Nissan Leaf and Volvo C30 electric. There are two different levels of membership based on hours or kilometres with optional weekend deals. It is an A-A model requiring the car to be return to the same location after use [20]. This does not provide the same level of flexibility for drivers but guarantees parking availability and charging infrastructure.

Hertz BilPool also offers corporate membership providing companies with access to vehicles without requiring their own fleet. This removes the need for company cars and/or a leasing agreement removing asset management, maintenance and high overhead costs. Companies using this model can gradually introduce AFVs to employees, bearing little risk.

For a population that is aligned with sustainability it appears e-mobility services has not gained particular momentum. Despite the strong Government support for EVs in Norway and the success of Tesla’s amongst other models in Oslo, surprisingly there is not an overwhelming number of e-car clubs in the city [21]. It could be argued this is due to the numerous incentives and subsidies that make it attractive to own an EV. Although the policies set have been very positive for the EV market, it has not assisted in diminishing congestion but rather increased it. Consequently there is rising pressure on Norwegian ministers to reduce incentives for EVs. Alternatively, funding could be redirected to support schemes to reduce vehicle ownership such as e-mobility services [22].
4 Discussion

It is inevitable that urban mobility will adapt to regulatory pressures of climate change, resulting in gradual political and economic changes [23]. However, due to the stability of the transport sector the rate of which innovation can compete with the existing system is gradual [23]. Currently mobility services are acting in ‘coalition’ (albeit with small market share) to the dominant system of internal combustion owned vehicles. PSS requires a fundamental shift in culture, resources and behaviour in order to overcome the psychological barriers, whether it is in companies or the general populous.

Current cultural norms around car ownership and driving practices affect the uptake of e-mobility services. For instance it is reported that the “UK’s strong culture and tradition of private vehicle ownership” were more significant than expected, one of the reasons for Car2Go exiting the market [24]. This has been shaped by the UK economy and tax regime but it has now become embedded within British culture. However younger generations (Generation Y and Z, from 1980 onwards) have begun to challenge this, largely due to the high cost of living, opening up the opportunity for more service based models.

PSSs diversify the market for customers, introducing new services, business models and vehicle technology. These will “simultaneously weaken the dominant position of the ‘individual car’ system, and support alternative transition pathways” [14]. The examples examined in Section 3 highlight four different business models with varying degrees of user flexibility, whilst offering alternatives to car ownership and fuel type. Having a wider portfolio of e-mobility services across car sharing, leasing and pooling will likely increase suitability to a wider populous and therefore adoption rate. Over time it will become evident which service has greatest demand, at which point market forces will respond and it will become a more competitive PSS.

As Mont [9] suggests there are three approaches of PSS that can be introduced (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. As it has been identified, e-mobility services require approaches (i) and (iii) in any given scenario and approach (ii) more specifically in product leasing applications. The extent to which these approaches are achieved indicates the rate and degree of which e-mobility will be adopted; a way of which to measure this is not currently considered but deserves further attention.

It is suggested by Brown et al [25] 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 aligns with the transition pathways strategy of socio-technical systems which can be categorised in to (i) the adaptation of a dominant system, when an innovation is widely adopted and becomes the dominant system through gradual changes supported by a coalition of actors; or (ii) the attempt to take over the dominant position which can create unstructured transition strategies and unaligned forces [14]. Currently e-mobility services are gradually entering the market along an established transition pathway due to societal forces and cultural norms that prevent quick diffusion, along with no direct policy incentive. Therefore the niche application of EVs requires greater support from policy in order to gain sufficient momentum for a socio-technical transition.

Transitioning to a functional ‘experience’ economy shifting the role of the manufacturer to the provision of services is argued to be complimentary to the penetration of new products [9] [26]. Furthermore customers are “willing to pay more than would be justified on the basis of ‘rational’ calculation” due to intangible added value [10]. However as there is only a limited network that supports e-mobility, further investment in infrastructure
(hardware and software) is required by city operators to make it a viable proposition. This is intensified as transitioning to e-mobility moves the point of profit from a product sale to the point of service that could be long term contracts or memberships. This requires “close integration of all actors within the life-cycle of a product-service” [9].

Marletto [14] argues there needs to be a multilevel and multidimensional policy for integrated urban transport by which EVs can play a secondary role. The difficulty is to approximate the necessary level of motivation crowding to influence users within reasonable margins. It is also necessary to consider regulations and other measures such as tax incentives to ensure e-mobility schemes are viable [27]. Car sharing and leasing are based on “the artefactual system remains more less the same, but where innovative institutional arrangements produce beneficial changes” [12]. Supporting policies incentivising car sharing for those in the life-cycle of the product/service will further encourage the transition. Additionally, policy makers could use e-mobility services as a strategy to target key groups i.e. those who suffer from transport poverty.

Mont [28] 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. This should be applicable when transitioning to e-mobility services from a city perspective (working in partnership with infrastructure and service providers); examining the city platform to see where and what services can be used. 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” [29]. This requires regular stakeholder consultation to monitor efficiencies and user satisfaction from the perspective of a service user and city inhabitant.

Finally, as previously identified two (of the five) of Ehrenfeld’s [12] evaluative criteria: (i) changes in vehicle ownership structure and (ii) changes in modes of producer-user interactions, are key in considering transitioning to e-mobility services. The examples considered in this paper have demonstrated a market for alternative ownership structures and producer-user relationships that have proven to be successful in the urban context. In order to fully optimise e-mobility services, alongside public transport, real-time data of vehicle/charging availability should be accessible to users.

5 Conclusions

E-mobility services can substantially decrease a city’s transport emissions and congestion through reduced car ownership and car mileage. This requires transitioning to a PSS approach with new market concepts and business models. This paper has explored various use-oriented models to understand how cities can introduce MaaS.

Adopting PSSs can introduce new revenue streams for companies in new market segments and can facilitate innovation and competitiveness [9]. This is particularly so in a mature industry such as the automotive industry. BMW for example, have introduced a service to their standard portfolio (DriveNow) at a high level of quality that will be difficult to replicate. Although this remains a niche market and market offer it introduces a new approach to travel. Use-orientated services challenge the embedded path dependent characteristics and social norms of car ownership, fuel type and revenue structure.
The e-mobility services explored highlight the need for society to have a new relationship with the car, adapting to a PSS requires a significant change in behaviour. The premise of PSSs to continuously innovate means the market will be led by a combination of market and societal forces. As the market develops and more players compete, society will determine the dominant use-oriented service. Until then, e-mobility services are being diffused through adoption of the dominant ICE asset system.

Taking a combined approach to city transport can reduce congestion, air pollution and emissions but requires an open data platform to be accessible to monitor availability. In order not to put excess pressure on existing city services, especially during peak demand, governments should work closely with service providers. Furthermore target audiences or geographical areas could be focused upon with the use of tax incentives and grants.

Further research will conduct interviews with service providers, such as DriveNow. These will be semi-structured interviews across the three use-oriented services to elaborate on the existing knowledge of PSSs and applicable transition pathways within the transport sector. Additional research should be conducted on the environmental implications of e-mobility services, considering the vehicle life-cycle and the substituted use of owned vehicles.
References


Transition pathways of commercial-urban fleet electrification in the UK

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Abstract: Road transport accounts for 90% of UK transport emissions; by 2027 this is targeted to be reduced by 50% (OLEV, 2011). Electric vehicles offer a substantial opportunity to reduce road emissions, particularly to decarbonise the fleet market due to the sheer number of new registrations for business applications. However the diffusion of electric vehicles requires a transition across a large spectrum of societal and economic dimensions. The relationship between transition pathways and technological lock-in in the transport sector is under-researched, particularly in the field of e-mobility.

This paper explores the pathway for electric vehicles, identifying the development blocks and technological lock-in of existing vehicle types, in order to understand the opportunities for technology diffusion within commercial fleet applications. This study takes a small sample of cases to achieve an in depth exploration of the motivations and barriers to this technological change. Three UK commercial-urban fleets in differing sectors are examined to understand their individual contexts and the level of correlation with the challenges experienced by the fleet market as whole, and how these have or have not been overcome.

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 and market logics. It is evident from the cases that an ‘innovator logic’ is competing to unlock EVs through technology innovation that extends beyond the transitional role of hybrids.

Keywords: Competing logics, electric vehicles, innovation, multi-level perspective, lock-in, path dependency, road transport

JEL Classification: L2, MO, O3

Abbreviations: Electric vehicles – EV, Internal combustion engine – ICE, Alternatively fuelled vehicles – AFV
1. Introduction

Road transport accounts for 90% of UK transport emissions; by 2027 this is targeted to be reduced by 50% (OLEV, 2011). Within the Government’s Carbon Plan (2011 p,5) “ultra-low emission vehicles including fully electric, plug-in hybrid, and fuel cell powered cars are being developed” to decarbonise transport. An opportunity to reduce UK emissions is through the electrification of the fleet market; fleet vehicles comprise over 50% of all vehicles sold in the UK; this proportion has steadily increased over recent years and now accounts for approximately 14 million vehicles (SMMT, 2012) (Maslen, 2012).

This suggests that a decarbonisation of the UK is impossible without substantive changes to transport and that a decarbonisation of UK transport is impossible without serious attention to the fleet market. For many companies, fleet logistics impose the greatest financial and environmental burden due to the procurement, operations and maintenance of vehicles. Therefore this paper will focus on fleets adopting alternative vehicle types, specifically electric vehicles.

Fleets have used EVs for numerous reasons, including:

- Commercial fleets often have high utilisation rates, centralised parking facilities as well as managed and known use patterns (PikeResearch, 2010)
- Most fleets have space to accommodate charging infrastructure and are expected to have specific and known charging requirements derived from their drive cycle, destinations, time schedules and fleet size
- The concentration of buying power associated to fleets and the relatively small number of influential decision makers within the industry (ElectrificationCoalition, 2010)

However, a step change is required for EVs to gain further momentum in the fleet market. This may be best understood using the concept of path dependency and technological lock-in.

Therefore this paper will explore this field, asking:
(i) What are the current drivers and barriers of the fleet market towards EV?
(ii) What is path dependency and technological lock-in and how can this explain the evident lack of take-up?
(iii) What are the policy options to support a greater take-up?

In addressing these questions the paper will consider the broader extent to which UK fleets contribute to the transition to EVs and recommend how to enhance the rate at which this happens.

The paper is organised as follows: Section 2 explains the existing research in this field, including transition pathways, path dependencies and technology lock-in; set within the wider approaches of the multi-level perspective and competing decision logics; Section 3 explains the methodology of the three UK commercial-urban fleet case studies; Section 4 applies the ideas from technology lock-in and path dependency to the cases; Section 5 evaluates drivers and barriers that may explain the lack of take-up; and Section 6 concludes with a discussion of how technology lock-in can be addressed in this context.
2. Theory

This section will question (i) what are the current drivers and barriers of the fleet market towards EV? And (ii) what is the nature of path dependency and technological lock-in in the fleet transport context as well as (how) can this explain the evident lack of take-up? In order to explore these questions, this section will make use of the multi-level perspective and competing logic theories to organise the analysis; along with lock-in and path dependency theories that assist in defining a successful transition pathway.

2.1 Transition Pathways

Transition pathways can be defined as “a shift from one socio-technical system to another i.e. a system innovation” (Geels, 2005 p.682). It is further explained as the analytical framework utilised to examine a transition process and considers the key dynamics (Geels, 2010). Such a shift requires fundamental changes in market concepts through governance, social practices and business models that have been developed upon past and present technological systems (Foxon et al., 2012).

Transitioning within the automotive sector is extremely difficult due to “a wide range of powerful positive feedback processes that confer substantial advantage to the incumbent ICE technology” (Struben et al., 2008 p.3). The conversion from ICEs to EVs relies heavily on the bidirectional relationship between users and technology with influence from factors such as price, availability and convenience (Epprecht et al., 2014). In order to encourage technology diffusion within the automotive sector there are a number of mechanisms that could be implemented; remove market entry barriers, remove technology lock-in factors, focus on non-technical factors that prevent transitioning or focus on path-dependent technologies that may actually support the transition.

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. The policies in place today are appropriate for the early stages of the market, attempting to encourage EV uptake through monetary incentives, these however are not directed to commercial fleets.

2.2 Lock-in

Since the 20th century the car has been the dominant form of transportation, this has led to “a society, economy and culture tightly bound to [the] ICE” (Epprecht et al., 2014) (Koch et al., 2009 p5). 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 (Perkins, 2003 p.1). Technology lock-in is further described as the impact on the market and standard for future designs from a dominant technology (Vooren et al., 2012). The key aspect this paper considers is the restriction lock-in places on new innovations entering a market i.e. electric vehicles in the automotive sector. More specifically, it considers the extent to which the car and the ICE rely on, and reinforce, systems, practices or habits that prevent the diffusion of EVs.

Lock-in is defined most frequently in pure technology terms such as battery capacity and vehicle design. However it is useful to consider social and cultural constraints such as range
anxiety, status, driver expectations and brand allegiance. Such barriers are not overcome by technological innovation and regulation independently but require a combined approach within market specific conditions (Epprecht et al., 2014). This is particularly relevant with infrastructure-dependent vehicles which rely on investment in advance of use and non-exclusive to the funder, thus introducing economic lock-in intensified by sunk costs (Vooren et al., 2012). Unlocking vehicle technology requires humankind’s perspective of undesirable change to be adequately challenged using a collective methodology of economic, societal and technological change management models.

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. The role of 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).

Jänicke (2000) emphasises the relationship between technology and policy is extensive and varied, and that technology diffusion can result from any sequence of policy innovation, policy diffusion or technology innovation. 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.

Applying the concept of technological lock-in to EVs, three questions arise:

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

Answering these will establish the extent to which EVs are locked-out of the automotive based mobility system in the UK and the implications of a mutually reinforcing structure dominating vehicle manufacturing, procurement and use, 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.

2.3 Path dependencies

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. (2008) 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., 2008 p.7). Therefore to understand the EV market and the diffusion of technology in fleets it is essential to explore 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 et al., 1996). These
have been 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 behavior as a result.

Path dependencies of cars range from design, specification, price and (sunk) technological costs. These path dependencies relate to the cost of manufacturing a car but also to the substantial infrastructure costs that allow the ICE to operate effectively. Path dependencies play an important role on innovation and entrepreneurship and are often fueled by low cost of entry, low unit costs and flexible and broad channels of supply.

Existing literature explains the significance of path dependency on new innovations; however it at times fails to consider the extent to which new (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 begin to explore the extent path dependencies are restricting the transition to EV fleets; there is a need for further research specifically on this subject matter.

2.4 Multi-level perspective

The multi-level perspective (MLP) as a framework has been used to understand past transitions and consider current and future transitions (Mazur et al., 2014). The MLP argues transitions are a result of interactions between processes at three levels (Geels et al., 2007):

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

Niche-innovations are alternative technologies, organising systems and/or adapting behavior that can destabilise the existing market and achieve a transition. 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. Alternatively, landscape pressures referring to, for example, climate change awareness results in action taken by governments leading to national and international targets towards a low carbon economy. Despite this, the automotive industry remains relatively stable; the lack of sector instability makes it more difficult for EVs to enter mass market and influence the wider landscape (Geels, 2004).

The processes internal dynamics and interactions can lead to a breakthrough in mainstream markets and existing regimes allowing competition to gain market share (Geels, 2004). EVs are being introduced within a path dependent innovation system, considered as niche-innovations that have begun to challenge and potentially destabilise the existing regime.

2.5 Competing logics

Foxon argues “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, 2012 p.1). Foxon et al. (2012) introduces this action-space concept based on a conceptualisation of there being three principle sets of competing actors in the governance
of a low carbon system, each with their own governance logic; (i) market actors, (ii) government actors, (iii) civil society actors.

Foxon’s three logics represent the influence on the transition of new innovations as well as the fate of incumbent technologies but it is unclear whether this approach include all the dimensions associated to, and all possible pathways available to, a niche technological market. Innovation requires support from all of the existing three set of actors but it is important also to consider actors directly associated with technological change and technology availability, as they underpin the market. This argument is particularly relevant when applying the theory of competing logics to the automotive sector which suffers from extensive lock-in, both in terms of the technology itself and its conventional infrastructure (Foxon et al., 2013). This could be considered primarily as an element of the ‘market logic’ but 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.

The EV market is currently relying heavily on the investment and promotion of niche players that are commercial entities but that sit outside of the set of current market actors, and have a distinct logic in their approach to the low carbon transition. 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’, a technology innovation led approach to a low carbon transition in which niche players respond rapidly to market needs. Although the innovator logic may have relatively small market shares, the actors have significant influence on the action space. 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. As in Foxon’s use of the original three logics, the ‘innovator logic’ is not assumed to operate exclusively, but is intertwined with the logics of the other set of actors, with innovators being reactive to the dynamic processes of path dependencies and structural changes.

3. Methodology

The research took a considered approach to gathering data on the niche technologies, choosing to create three in-depth fleet case studies. Case study research was appropriate to employ in order to help reveal how actors - in this case fleet owners and operators - influence the transition to a new dynamic and the impact of an ‘innovator logic’.

The fleets were chosen 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.

To examine the extent to which UK fleets contribute to the transition to EVs, the concept of path dependency and technological lock-in has been applied to three UK commercial-urban fleets:
- TNT Express Services UK & Ireland - the UK’s leading business-to-business express delivery operator
- Schneider Electric UK & Ireland - an energy management technology company
- Green Tomato Cars - a London based environmentally conscious private hire service

Interviews were conducted across a range of employees, including key decision makers, managers and, where possible, drivers experienced in using EVs. 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. 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 with climate change, as alongside the transformative change of vehicle type it has broader social implications. Questions were focused on the strategic intent and extent of EVs use and the associated targets, along with the challenges and barriers experienced and integration strategies.

A semi-structured approach 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 behaviors to be incorporated within the research. The contribution from practitioners strengthens the data and its analysis. All interviews were conducted by telephone for convenience of the interviewee whilst also gaining a level of rapport and flexibility. 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.

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). The scope of this research extends beyond the immediate fleets involved as analysing fleet behavior across different sectors will provide an insight into varied fleet strategies. Regarding 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). More specifically, summative content analysis was applied to compare the content and interpretation of the underlying context of each fleet (Hsieh et al. 2005).

The transition to EVs is based on the interaction between competing logics upon the action space; therefore the MLP 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.

### 4. Results

This section will analyse each fleet’s current positioning on EV procurement, which will then be discussed in the context of transition pathway theory in Section 5.
4.1 GTC

Green Tomato Cars offer “an environmentally friendly private hire minicab service in London for corporate accounts and one off bookings” (GTC, 2013 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. Within the fleet there are 410 vehicles; 8 bio-diesel people carriiers, 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 trialed 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. As a result, the vehicles could only be used for half a day and were limited to certain journeys, with greater emphasis on the destination rather than the pick-up point. However it was “logistically difficult to manage and was not commercially viable” (GTC, 2013). Ultimately “the Fluence did not have the range to be a viable component part of a fleet of an established private hire company” (GTC, 2013).

GTC’s experience demonstrates the embedded path dependent characteristics of ICE vehicles within the market that instigate the need to have 300+ miles and refueling within 5 minutes. This is particularly challenging if routes are unpredictable and requires flexibility. A driver at GTC who has trialed 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, 2013). 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, 2013).

Strategically, GTC see themselves as a pioneering brand and consequently feel “they have a responsibility to be test beds of new technology” (GTC, 2013). 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 offer 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 behaviors in society, thus giving the market the opportunity to gain momentum and learn from operational problems.

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

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

This supports the case for the technological unsuitability of existing EVs for a private hire fleet, but these are also very relevant to the general market of EVs. Range, infrastructure and perception are three very influential elements that need to be addressed for EVs to compete with the ICE. This highlights the strength of GTC’s business model, to use hybrids as a flexible bridging technology and EVs as a USP aligned to innovative progress (GTC, 2013).

4.2 TNT
TNT is a parcel delivery company to the UK, Europe and beyond. This research focuses on the 1,398 rigid 7.5 tonne trucks that on average travel 56,000km per annum, used for UK local deliver and collection. In 2006 the Board of Directors instructed the fleet managers to procure EVs to contribute to the zero emission targets of the company. 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 experienced two key barriers:

(i) The limited range of the vehicles introduced inflexibility and further requirement for logistical planning
(ii) 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, 2013)

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 equivalent with a diesel vehicle over a 5 year life span. 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. TNT considered the procurement as a moderate logistical success but cost prohibitive.

Regarding hybrids, TNT has previously trialed prototypes for various auto manufacturers. TNT found these vehicles much easier to run due to the available petrol tank; but a total cost of ownership analysis revealed the hybrids would need to be in operation for 13 years to be cost neutral with a diesel. As the replacement cycle for TNT is 5 years, these vehicles are not economically feasible within this business 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, 2013), 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. This relationship is creating mutually enforcing path dependencies as EVs cannot break through the ICE technological and societal lock-in.

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.

4.3 Schneider Electric
Schneider Electric is an energy management company providing automation, electrical distribution and installation systems. Schneider Electric has approximately 5,000 employees based in the UK & Ireland and 1200 vehicles in the country’s company car fleet. The vehicles vary broadly in specification, but there are only 2 AFVs.

In the company car scheme, employees are graded depending on their role and the number of miles driven (at least 10,000 miles p.a or out the office more than 3 days/week) which decides if and what car the employee is entitled to and at what contribution rate. Drivers can choose vehicles up to 25% above their allowance with the majority of drivers trading up rather than down.

The company reimburses the driver one pence per mile based on +15% of the mpg. This is to encourage drivers to drive more efficiently and potentially contribute to their private mileage which is not paid by the company. The new scheme is influenced by Government regulation and is clearly the motivations for Schneider Electric’s policy, however the cap of 160g/km on vehicles is still relatively high. Schneider Electric are aware that Government are to enforce more stringent limits but Schneider Electric are clearly comfortable reacting when necessary in order to maintain satisfied employees.

Within the scheme the Benefit in Kind tax is now based on the P11D and the CO₂ emissions of the specific vehicle. This “encourages drivers to base vehicle choice on efficiency rather than maximising the fixed BIK” regardless of the CO₂ level (SchneiderElectric, 2013). As a result the fleet may start to see more hybrids in the fleet due to incentive of low emissions and associated BIK.

In regards to the company car policy there seems to be little motivation to adapt the 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. Although this is not the norm, economics is still 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. 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. In this respect there are few economic barriers to the adoption of EVs as financially they can provide a more robust business case over time than an ICE. This has been strengthened in recent months with greater knowledge on the residual values of EVs.

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 on 49 company cars based in London due to the opportunity city driving provides EVs with shorter distances and regular regenerative braking. 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, 2013 p.3).

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 will be high. Furthermore due to the disputed residual values of electric vehicles the higher depreciation may mean again they would be too expensive compared to efficient alternatives. This emphasises the unattractiveness for Schneider Electric employees to sign a four year contract for an electric vehicle. However if Schneider Electric were to encourage EV use, the necessary marketing materials would need to communicate across the business the new policy, vehicle type, choice and the implications.

The key challenge to Schneider Electric is likely to be “driver acceptance for the use of vehicles for private mileage” (SchneiderElectric, 2013). 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 (SchneiderElectric, 2013).

Additionally, it is clear that within Schneider Electric “badge consciousness and psychological kudos with its customers” (SchneiderElectric, 2013). This emotive dimension of the ‘civil society logic’ is much harder to address than technological or ecological factors and is arguably a development block that is pointing at the existence of a separate ‘innovator’ logic of which EVs are currently excluded due to social drivers. Arguably the lack of commitment demonstrated by Schneider Electric is a reflection on weak government policy regarding the environmental impact of company car fleets.

5. Discussion

This section evaluates drivers and barriers of EV take-up in the context of transition pathways. Using the case study evidence, it will question the extent to which UK fleets contribute to the transition to electric vehicles.

Diverse approaches are required to stimulate the sustained transition to EVs in conjunction with an understanding of the dynamic implications and reinforced feedbacks (Struben et al., 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., 2010). The interviews conducted with the three commercial-fleets highlighted common challenges: the economics, range, vehicle suitability and driver behavior. 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 senior management support to begin challenging the traditional fleet dynamics and overcome technology lock-in. In the case of Schneider Electric where high level sponsorship from management is lacking, 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, which 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.

Within individual path dependent characteristics companies utilising EVs are challenging business and social practices and changing behavior at work. Considering these dynamics at the multi-level perspective, a company appears to build momentum through ‘niche-innovations’, whilst employee behavior destabilises the regime to make the ‘niche-innovation’ possible, and social practices create pressure on the existing regime at the landscape level.

However, 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., 2009 p.). 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., 2009). However, as Mazur et al. (2014) highlights there is greater complexity than a systems perspective, innovation theory requires a socio-technical system approach to investigate the impact of transitioning.

The case study evidence suggests that in order to instigate a considerable shift in behavior and company strategies, the policy field of sustainable innovation and technology should focus on social and environmental benefits (Norberg-Bohn, 1999, Kemp, 2010). Here, a new socio-economic approach is required within the existing regime, for example through introducing a tax for carbon emitting cars, rather than the currently incentivising low emitting vehicles.

The current UK Government position of financial incentives 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 from the incentives, similarly TNT will not be compliant with the funding due to the size of the vehicles. However 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.

EVs challenge the technological lock-in of ICEs, competing on efficiency and specification and removing the associated range-anxiety with current electric drive trains. Both the ‘lack’ of charging infrastructure and the restricted range of EVs is argued to be key challenges for the adoption of EVs by all three fleets, in particular GTC and TNT.

It is desirable 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 change would need to be supported through the ‘civil society logic’ as adapting behavior 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 Toyota Prius in 1997 increased
versatility and flexibility within the market through unlocking the historical market of restricted designs and specifications (Ahman et al., 2008). This exemplifies the ‘innovator logic’ challenging traditional status allegiance with luxury vehicles despite the preconceived sacrifice of performance (Griskevicius et al., 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 hybrid 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 the transitional, interim technology to ease acceptance of the EV market and used to manage expectations of the rate of vehicle mode acceptance.

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 et al., 2007). This further highlights the case for an ‘innovator logic’ as EVs act as a niche innovation with interdependent dynamics upon the ‘action space’.

Adapting the ‘competing logic’ theory from the energy sector to the EV market, highlights that the transition of EVs is more closely focused on innovation and technology. Examining the case studies it is evident the three existing actor-logics are insufficient in 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, this indicates the need for further innovation which cannot be directly stimulated by government, market or civil society logics. 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 ton trucks is an ambitious feat that will require technological advances in regards to both the vehicles and the charging, as well as support from Government regulation.

Considering these factors, it is concluded 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 Commision, 2011 p.16). This reflects Foxon’s theory of ‘competing logics’ but again infers the benefit of incorporating a fourth ‘innovator logic’, by which more explicit representation is accredited to niche innovations. Close attention to the roles of innovators will assist in unlocking EVs within the fleet market and further destabilising the existing regime and introducing it allows further study of this technology and innovation-driven pathway.

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 regulatory 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 currently suitable hence the importance of the innovator logic.

6. Conclusions

This paper has explored the transition of fleets to electric vehicles, exploring existing literature on approaches taken to analysing transition pathways, with particular attention to path dependencies and technology lock-in. This provided a basis to question the drivers and barriers of EVs for the fleet market and suggest policy options to increase the uptake. The three case studies demonstrate different levels of engagement with EVs yet the development blocks experienced are similar, namely range and driver acceptance.

This paper suggest that the slow uptake of EVs is 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. This research explores the extent to which this has caused technology lock-in within the industry or within individual sectors, preventing the uptake of EVs. The fleet case studies demonstrate the integration of EVs requires an extensive transformation across a large spectrum of societal dimensions including policy, behavioral 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 paper demonstrates that the automotive industry is fundamentally built upon path dependant characteristics and has embedded and strong preconceived notions of vehicle design and specification suited in to customers’ expectations. Thus technological lock-in is limiting the available market to EVs resulting in niche applications that can benefit from the available grants and incentives. The paper argues that greater attention to the role of ‘innovators’ and an innovation-led logic in the low carbon transition for fleets is useful for representing the technological change of a niche innovation with interdependent dynamics. An ‘innovator logic’ can provide a technological focus on examining lock-in and market development, stimulate traction across the other three sets of actors as well as providing a heuristic perspective, thus expanding upon Foxon’s theory.

It is arguable that currently the market would not be self-sustaining without government support, but if there were to be more support for businesses, uptake would be considerably higher. Government incentives and regulations relating to emissions have been key catalysts in beginning to unlock ICE vehicle dominance within the market. 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). Existing regulations on carbon emissions are particularly effective within business but it is questionable how long the UK Government will be prepared to continue incentivising EVs. It could be recommended to introduce the ‘polluter pays’ strategy as part of the whole-system, to encourage fleets to question the concept and sustainability of mobility modes and more broadly the transformation to a low carbon economy.

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