An examination of the factors influencing the decision to adopt alternative fuel vehicles

By

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A Doctoral Thesis

Submitted in partial fulfilment of the requirements for the award of

Doctor of Philosophy of Loughborough University

October 2014

Acknowledgements

This doctoral thesis would not have been possible to write without the kind help and support of the people around me and I would like to express heartfelt thanks to all of them.

I would firstly like to thank my supervisors, Dr Tim Ryley and Prof. Rob Thring, whose help, advice, feedback and encouragement have been invaluable throughout.

I would like to thank Loughborough University and the Hydrogen, Fuel Cells and their Applications Centre for Doctoral Training (CDT) for providing the opportunity for me to undertake this research.

The research would not have been possible without the financial support I have received from Birmingham City Council. Special thanks must go to George Bailes, David Harris and Nick Tringham for their interest and input into this research.

Without the assistance of the market research company, Research by Design, I would probably still be knocking on doors in Birmingham, so thanks must go to the staff at Research by Design for providing an extremely professional, experienced and efficient service.

Thank you to Dr Alun Owen and Richard Buxton of the Statistics Advisory Service at Loughborough University for their help.

I would also like to express my sincere thanks to my examiners, Prof. Stephen Potter and Prof. Stephen Ison.

Finally, and most importantly, a huge thank you goes to my wonderful family and friends for the support and encouragement they have given me, especially my mum who also took on the arduous task of proof reading! I would particularly like to thank my fiancé, Chris Fry, for his love and patience, and for keeping me motivated right through to the end.

Abstract

Concerns over the environmental impacts of the transport sector have led to the United Kingdom (UK) Government establishing a legally binding commitment of an 80% reduction in greenhouse gas emissions by 2050 (relative to the 1990 baseline) through the Climate Change Act 2008. The decarbonisation of the transport sector by 2050 will substantially contribute towards achieving this target.

Technological innovations, therefore, have an important role in supporting policy objectives. One innovation that is being developed for this purpose in the transport sector is an alternative fuel vehicle. While there are several alternative fuel vehicle technologies, the only two with zero tailpipe (exhaust) emissions are battery electric vehicles and hydrogen fuel cell vehicles. Both of these technologies are not yet at a stage in their development where they can successfully compete with conventional fuel vehicles (internal combustion engine vehicles). They face a variety of technological hurdles that include range, performance, cost, and infrastructure. Hydrogen fuel cell vehicles are not commercially available, although battery electric vehicles have been on the commercial market for several years. Uptake of alternative fuel vehicles is occurring at a slower pace than hoped by policy makers and manufacturers.

The aim of this thesis is to examine the factors influencing the decision to adopt an alternative fuel vehicle, and is underpinned by Rogers' (2003) Diffusion of Innovations theory. The Innovation-Decision Process from this theory posits that an individual must first know about an innovation before forming an attitude about it. Innovativeness is instrumental in determining the knowledge an individual has of an innovation and how early in the diffusion process they are likely to become an adopter. Perceptions of the innovation are influential in forming an attitude towards it.

The focus of the research is on Birmingham, the UK's second largest city. The first stage of the research involves establishing the locations of individuals across the city that possess socio-demographic characteristics associated with early adopters of alternative fuel vehicles. This is achieved by applying cluster analysis to Birmingham census data, which enabled the identification of a strong spatial cluster of potential early adopters in the suburb of Sutton Coldfield.

In the second stage of the research, a household questionnaire was undertaken with 413 respondents in Sutton Coldfield. The analysis of the questionnaire data firstly involves the verification of the early adopter characteristics from stage one by examining the relationship of these characteristics with innovativeness. Analysis is then undertaken of the level of knowledge and the perceptions that the respondents have of alternative fuel vehicles. The final step in the analysis is an evaluation of the characteristics of current models of electric vehicles and how well aligned they are with the driving needs and vehicle expectations of respondents.

The results confirm that the knowledge of alternative fuel vehicles is limited and individual perceptions have led to the development of negative attitudes towards them. Socio-demographic characteristics were significant in influencing these factors. There were 5% (21) of respondents who have previously considered the adoption of an electric vehicle but have not yet done so. There is evidence from the survey of active rejection among a small number of respondents. The reasons largely relate to three problems: purchase price, limited range, and poor infrastructure availability. However, the majority of respondents have passively rejected alternative fuel vehicles, such that they have never given consideration to the adoption of one. This confirms that a concerted effort is required to inform the general public about alternative fuel vehicles. Opportunities for increasing adoption have been identified for policy and marketing, including education and awareness-raising campaigns.

Contents

Chapter 1: Introduction

1.1 Background and context to the research problem

In this first chapter, the research background will be discussed (Section 1.2). Section 1.3 introduces the study area for the research and the local policies in place affecting alternative fuel vehicle uptake. The research aim and objectives are outlined in Section 1.4 before presenting an overview of the structure of this thesis in Section 1.5.

Since the 1970s, the United Kingdom (UK) has experienced a sharp rise in vehicle dependency; in 1971 there were 19 million cars on the road in the UK (Leibling, 2008), and by 2003 this figure had increased by 56% to 29.7 million cars (SMMT, 2013). In the nine years between 2003 and 2012, the figure rose a further 6%, taking the total number of cars on the road to 31.5 million cars (SMMT, 2013). Projections suggest that this figure may increase to 44 million cars by 2020 (Leibling, 2008). A similar pattern has been seen worldwide, with overall vehicle stock having increased at an average annual rate of 4.6% from 122 million in 1960 to 812 million in 2002, and this figure is expected to have reached 2.08 billion by 2030 (Dargay et al., 2007).

The fastest levels of growth in vehicle ownership are predicted to take place in economically developing countries that are experiencing high rates of income growth. The highest rates of growth can currently be seen in China, India and Indonesia. In comparison to the UK, where in 2010 there were 519 cars per 1,000 people, in China the figure was 58 cars per 1,000 people (The World Bank, n.d.). However, vehicle ownership in China is growing by 10.6% per year, outpacing per-capita income growth. India is experiencing 7% growth and in Indonesia, the number of vehicles per capita is growing at 6.5% (Dargay et al., 2007). Adding to a growth in demand for transport is also a growth in the global population, which is anticipated to rise by a third by 2025 (Potter, 2007a). Described by Stradling et al. (2000) as 'inexorably increasing' demand, the rise in transport dependency has naturally been accompanied by an increasing demand for fossil fuels and negative environmental impacts from the combustion of these vehicle fuels.

Oil is considered to be the fuel that drives the economy (Gupta, 2008). One major problem is the finite nature of crude oil's availability (Aleklett and Campbell, 2003), a finding which was brought to the fore in the 1950s when pioneering work by M.K. Hubbert enabled him to predict that the United States' (US) oil supplies would reach a peak in the early 1970s (Deffeyes, 2009). There continues to be conflicting opinions as to exactly when oil has peaked or, in some cases, will peak. An oil crisis would create turmoil for economies worldwide, also bringing with it serious social implications (Deffeyes, 2009). Geopolitical conflict further impacts energy security and is commonplace in many of the countries that form the Organisation of Petroleum Exporting Countries (OPEC). These countries hold 75% of the world's oil reserves and control 42% of oil production (Gupta, 2008). As oil production in non-OPEC countries is reaching the point of decline, countries such as the US and the UK will become increasingly reliant on OPEC countries for its oil supply, leaving them exposed to volatile markets that are vulnerable to disruption (Gupta, 2008). A reduction in oil availability also poses a threat to agricultural production processes, which could affect global food security (Aleklett and Campbell, 2003) as the population grows and demand for food increases.

Of particular concern is the contribution of carbon dioxide (CO_2) emissions on climate change (Potter, 2007b). The amount of carbon dioxide (CO_2), the main greenhouse gas, produced in the UK in 2012 was 479 million tonnes (DECC, 2013), an increase of 4.5% on the previous year, and the transport sector was responsible for 24% of the emissions making it the second largest contributor behind energy supply (DECC. 2013).

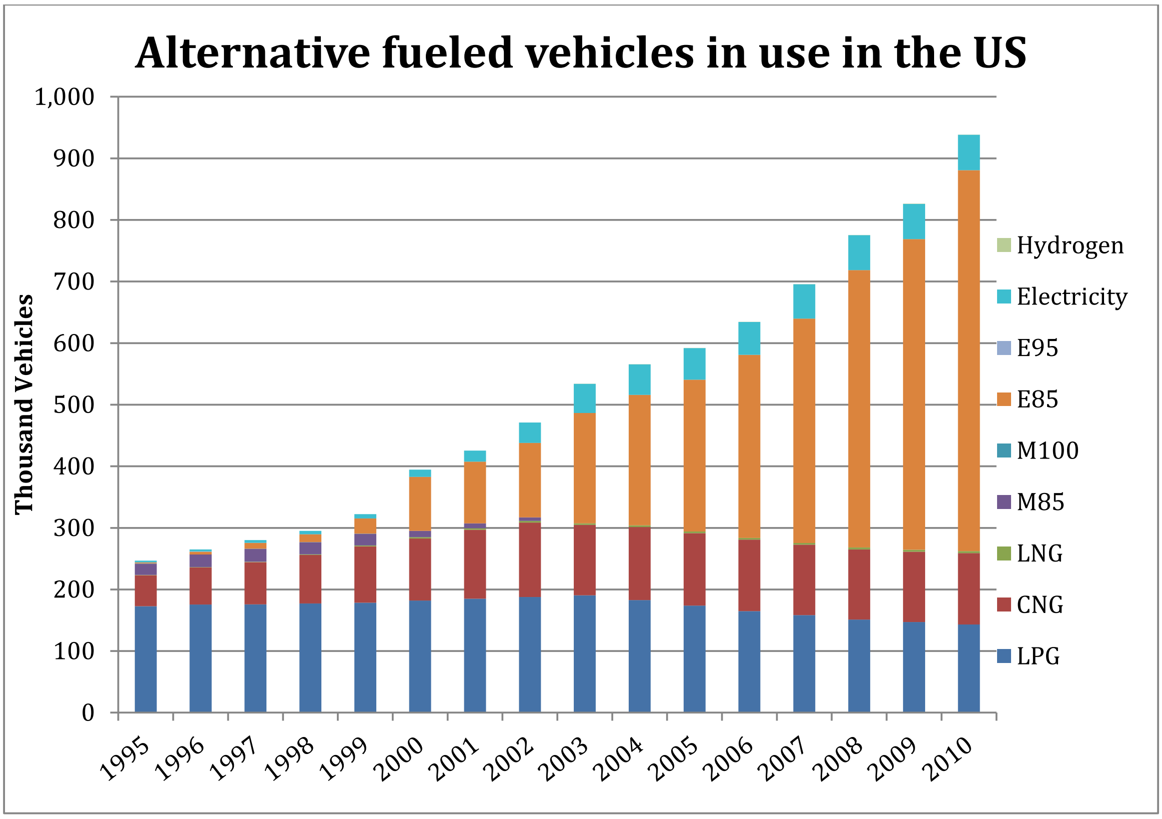
Addressing the anthropogenic impacts on climate change from transport use are a major challenge for central and local government. The UK central Government has taken steps to reduce UK greenhouse gas emissions through the establishment of the Climate Change Act of 2008 (DECC, 2008), which has set out legally binding targets of an 80% reduction in greenhouse gas emissions by 2050 (from a 1990 baseline). More recently the Government outlined a Carbon Plan (DECC, 2011) in order to set out how the UK would meet the Climate Change Act targets, making £400 million in funding available for research and development of alternative fuel vehicles until 2015 and a further £500 million between 2015 and 2020.

Alternative fuel vehicles (AFVs) involve relatively new and emerging vehicle technologies, also referred to as low-emissions vehicles (LEVs), in the case of hybrids (HEVs) and plug-in hybrids (PHEVs), and zero-emissions vehicles (ZEVs) in the case of battery electric vehicles (BEVs or EVs) and hydrogen fuel cell vehicles (FCVs). The adoption of cleaner and more efficient vehicles are considered to offer many positive externalities, particularly to the public, including cleaner air, a reduction in the risk of adverse health effects, reduced carbon emissions and a potential to reduce oil dependency (Kurani and Turrentine, 2002).

1.2 The problem of consumer acceptance of alternative fuel vehicles

Electric vehicles have been commercially available for around ten years although hydrogen fuel cell vehicles are not yet available for the public to purchase. Uptake of electric vehicles has been lower than expected in the UK. In the UK, 1,051 plug-in vehicle registrations were made in 2011, followed by 2,198 in 2012 and 3,445 in 2013 (DfT, 2014a), increasing substantially each year. Plug-in vehicles include hybrid vehicles and electric vehicles. Despite the rapid growth, 3,445 plug-in vehicles equates to 0.001% of the total number of vehicle registrations in the UK in 2013. Targets for vehicle numbers have not been set by the UK, although the Committee on Climate Change made a recommendation of aiming for 1.7 million electric vehicles to be sold in the UK by 2020 (Parliamentary Office of Science and Technology, 2010).

Low uptake of electric vehicles has also been experienced in other countries (Shepherd et al., 2012). In the US, President Obama set a target for the US to have one million electric vehicles on the road by 2015 (US Department of Energy, 2011), with this target including plug-in hybrids. In September 2013 the cumulative total of electric vehicles (plug-in hybrids and battery electric vehicles) was just over 130,000 vehicles (Electric Drive Transportation Association, 2013); a figure that indicates the US is a long way from reaching the target. Figure 1.1 shows the overall growth in the number of alternative fuel vehicles in use in the US, including the growth of electric vehicles.



Note: E95 and E85 are ethanol fuels; M100 and M85 are methanol fuels; LNG is liquefied natural gas; CNG is compressed natural gas; LPG is liquefied petroleum gas.

Figure 1.1 *Sales of electric vehicles in the US. Source: Alternative Vehicles and Advanced Vehicles Data Center (US Department of Energy, 2012).*

In China the target has been set for five million electric vehicles and plug-in hybrid vehicles to be on the road by 2020. The interim target for 2015 is 500,000 electric vehicles and plug-in hybrid vehicles, however the sales in 2011 and 2012 made up only 4% of this target (Yue, 2013). Germany is experiencing a similar problem having set a target of reaching one million electric cars by 2020 but currently the figure stands at 4,500 (Gifford, 2013).

The technological constraints faced by alternative fuel vehicles, such as limited range, refuelling duration and lack of infrastructure, in addition to being more expensive than conventional vehicles to purchase, presents policy makers and vehicle manufacturers with a challenge for gaining acceptance of these vehicles among consumers. While much research is being undertaken to improve understanding of consumer acceptance of alternative fuel vehicles (e.g. Roche et al., 2010; Ricci et al., 2008; Lane, 2005; Schulte et al., 2004) and consumer behaviour regarding transport choices (e.g. Jansson et al, 2010; Anable et al., 2006; Anable, 2005), a broader understanding is required as to who constitutes the target market for these vehicles and what can be done to enhance their likelihood of adoption.

In order to identify possible opportunities for increasing the adoption these vehicles, there is an obvious need for understanding more about consumer acceptance of alternative fuel vehicles and the factors that influence acceptance.

1.3 Aim and objectives

Aim

The aim of this research is to examine the factors that influence the decision to adopt alternative fuel vehicles.

Objectives

In order to ascertain the factors and their influence, the objectives for this research project are outlined below:

1. To understand the key consumer acceptance issues of alternative fuel vehicles.
2. To identify the socio-demographic characteristics of early adopters of alternative fuel vehicles and the locations of such individuals.
3. To investigate the relationship between potential early adopters' socio-demographic characteristics and innovativeness.
4. To examine potential early adopters' knowledge of alternative fuel vehicles and the factors that influence it.
5. To examine potential early adopters' perceptions of alternative fuel vehicles.
6. To evaluate the alignment of private transport expectations and alternative fuel vehicle characteristics.
7. To make recommendations for policy that will support the adoption of alternative fuel vehicles.

1.4 Thesis structure

This thesis contains nine distinct chapters, the interrelationship of which is now outlined.

Chapter 2: Policy Environment

The policy environment for alternative fuel vehicles is outlined, noting the policies in situ for establishing a reduction in the reliance on fossil fuels and for reducing greenhouse gas emissions in the transport sector.

Chapter 3: Literature Review of Consumer Acceptance of Alternative Fuel Vehicles

A review of the literature is used to consider the social, technical and political factors affecting the acceptance of alternative fuel vehicles. This chapter begins by exploring consumer expectations for mobility and the complex relationship that consumers have with their cars, highlighting some of the challenges faced in introducing new technologies that require a change to the current practice. The effect on behaviour of attitudes towards climate change is also considered in order to understand how the two are inter-linked. The review then investigates consumer acceptance studies that have been undertaken for alternative fuel vehicles so as to establish the key drivers and barriers to their acceptance.

Chapter 4: Theoretical Underpinning: Diffusion Theory

Given the understanding of the topic area, this chapter seeks to frame the research using a theoretical approach. Chapter 4 introduces the theoretical underpinning of this research, which is the well-established theory of the Diffusion of Innovations (Rogers, 2003). More specifically the Innovation-Decision Process, a sub-theory of the Diffusion of Innovations theory is outlined.

Chapter 5: Research Design and Methods

The research design defines the ontological position of the researcher and the research strategy used in this thesis. The methods employed to achieve the objectives outlined in Section 1.3 are outlined and justified in this chapter.

Chapter 6: Identifying the socio-demographic characteristics of early adopters of alternative fuel vehicles and determining their geographic locations

This chapter represents the first stage in the analysis and begins by identifying the socio-demographic characteristics of potential early adopters. The analysis relies on a cluster analysis method applied to census data in order to determine the geographic locations of potential early adopters within the city of Birmingham.

Chapter 7: Knowledge phase – investigating the factors influencing knowledge of alternative fuel vehicles

This chapter is the first of three that constitute the second stage of the analysis and relies on data collected in the questionnaire survey. It begins by introducing the survey sample. It then examines the innovativeness of the individuals, which is considered to influence an individual's knowledge of an innovation. The characteristics that influence innovativeness are socio-economic characteristics, personality variables and communication behaviour of the individual. The analysis in this chapter is, therefore, focused on the individual, or the 'decision-making unit'.

Chapter 8: Persuasion phase – examining perceptions of alternative fuel vehicles

The analysis in this chapter examines the perceptions that are held about alternative fuel vehicles. Perceptions are considered to be important in shaping attitudes and ultimately affect whether the individual forms a positive attitude towards the innovation that leads to its adoption.

Chapter 9: Decision phase - the vehicle purchase decisions of the most innovative

This chapter relies on the findings of the previous three chapters, to define a target market segment constituting those who are most innovative. It then explores the preferences of these individuals when purchasing a new vehicle, while also considering the characteristics of existing household vehicles. These preferences are then studied in the context of electric vehicles in order to establish how well aligned preferences are with the characteristics of currently available electric vehicles.

Chapter 10: Conclusions and recommendations

This thesis is brought to a close in by discussing the findings with regard to the research aim and objectives. Recommendations are made for both policy and marketing approaches that will be necessary in order to increase the diffusion speed of alternative fuel vehicles. It also addresses the contribution of this work to both the field of innovation diffusion and consumer acceptance of alternative fuel vehicles. The chapter closes by discussing the limitations faced in the research and analysis process before making recommendations for future diffusion theory and consumer acceptance of alternative fuel vehicles.

Chapter 2: Policy context

2.1 Introduction

This Chapter presents the policy background to the research problem. In Section 2.2, an overview of international climate change mitigation policy, followed by European policy, is presented. Section 2.3 then introduces examples of alternative fuel vehicle policy from Europe and the US. A review of UK transport policy on alternative fuel vehicles is presented in Section 2.4, including an outline of the incentives in place to encourage consumer adoption. Section 2.5 provides a summary of the chapter.

2.2 Energy demand for transport and mitigating the associated environmental impacts

Evidence on climate change, deemed as unequivocal (European Commission, 2011), has fuelled concern worldwide relating to the associated future economic and social implications that may arise. It was in the early 1990s that nations from around the world came together to officially address the anthropogenic impact on climate change. At the United Nations Conference on the Environment and Development in Rio de Janeiro in 1992, the very first international agreement came into force through the Framework Convention on Climate Change (UNFCCC, 2013), ratified by the European Union and 193 countries. This was followed by the establishment of the Kyoto Protocol in 1997 which outlined specific emissions reduction targets, committing participating parties to abide by legally binding targets.

The UK was one of the 37 countries that committed to the Kyoto Protocol and, following its ratification in 2002, the treaty was finally adopted in 2005. In 2009, three years prior to the end of the Kyoto Protocol's first commitment period, a Climate Change Conference was held in Copenhagen where it was hoped that a global climate framework would be finalised that would have a new round of emission reduction targets for developed countries already party to the protocol. There was also anticipation that a new agreement might be drawn up that would address the emissions of developed and developing countries (Bodansky, 2010). Tensions between negotiators meant that Copenhagen failed to bring about international consensus, however agreement was reached the following year in Cancun (2010) with agreement of a long-term goal that global warming would be held below 2^{o}C. Negotiations to draw up a new global climate agreement that concerns all countries are underway. The new United Nations Framework Convention on Climate Change is to be finalised by 2015 and put into action from 2020.

The Intergovernmental Panel on Climate Change (IPCC) is the body responsible for assessing climate change, with contributions to its work coming from scientists all over the world, and its reports are used to inform policy. The Fifth Assessment Report (AR5) is currently in progress, while the most recent report, the Fourth Assessment Report (AR4), was published in 2007. The report confirmed that carbon dioxide is the most important anthropogenic greenhouse gas, with annual concentrations growing at a far faster rate than would occur naturally. The combustion of fossil fuels is considered to be the main cause of the increased concentration of carbon dioxide and the consequences of climate change have been increases in global average air and ocean temperatures, extensive melting of snow and ice and a rise in global average sea level (Metz et al., 2007). More frequent observations of weather phenomenon such as droughts, tropical cyclones and heavy precipitation have also been attributed to climate change (Metz et al., 2007).

The European Union (EU) plays an important role in international negotiations on climate change and was influential in the development of the UN Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol (European Commission, 2011). It also helps to fund developing countries to tackle climate change (European Commission, 2011). The member states of the European Union (EU) ratified the Lisbon Treaty in December 2007, and it entered into force in December 2009. This Treaty built on the previous Treaties of Amsterdam (1997) and Nice (2001), empowering EU member states to act in a variety of policy areas that include energy, climate change and scientific research. As far as these policy areas are concerned, a set of clear objectives were outlined in the Treaty (TFEU, 2007): a functioning internal energy market, security of energy supply, the promotion of energy efficiency and the development of new and renewable sources of energy, and the promotion of energy networks. Article 194 (TFEU, 2007) provides the EU members with a legal framework and legal basis on which to work on achieving these objectives.

Following on from this, the European Commission launched a new strategy in 2010 entitled 'Europe 2020', the priority of which is sustainable growth through the promotion of a more resource-efficient, more sustainable and more competitive economy (European Commission, 2010). Member states are committed to reducing greenhouse gas emissions by 20%, increasing the share of renewables in the EU's energy mix to 20%, and achieving 20% energy efficiency by 2020. To assist with measures for reducing greenhouse gas emissions, 20% of the €960 billion EU budget for 2014-2020 will be spent on climate change related action. This will compliment climate finance from individual EU members (European Commission, 2010).

The Europe 2020 strategy forms a part of the long-term roadmap towards achieving a reduction of 80-95% greenhouse gas emissions by 2050, in order to keep climate change below 2°C. The Roadmap sets out targets for low carbon innovation recognising that electricity will play a central role in a low-carbon economy but that a fully decarbonised power sector is vital to achieving the emissions reduction target by 2050. The transition will be aided by technological innovation in the transport sector that focuses on three factors: vehicle efficiency (through new engines, materials and design); cleaner energy use through new fuels and propulsion systems; better use of networks and safer and more secure operation through information and communication systems (European Commission, 2011). Improved efficiency for vehicles is envisaged through the development of hybrid engine technologies, which will lead to a transition towards market penetration of cleaner vehicle technologies, such as plug-in hybrids and electric vehicles (battery and fuel cells) over time.

2.3 Policy examples from other countries

The country with the largest overall electric vehicle market share out of 19 European countries (and Russia) in 2013, is Norway with 5.75%, followed by the Netherlands with 1%. The UK sits in 16th place with a 0.12% market share (Shahan, 2014).

A Grøn Bill ("Green Car") project was set up in Norway to facilitate the introduction of 200,000 electric vehicles and hybrid electric vehicles by 2020 (Clean Vehicle Europe, 2014). The Norwegian Ministry of Traffic and Transport has established a target market share for electric vehicles of 10% by 2020, which would constitute approximately 300,000 vehicles (Clean Vehicle Europe, 2014). In 2014, 20,000 electric cars were registered in Norway. The incentives for adopting electric vehicles include (Norway Toll Customs, 2014):

- Exemption from import duty and value added tax (VAT);
- Reduced annual road tax (equivalent of £40 as opposed to £300);
- Exemption from toll-road charging;
- A 50% discount on company car tax;
- Free municipal parking;
- Free access to bus lanes.

Import duty taxes are calculated according to the weight, engine rating, retail price, CO_2 and NO_x (nitrous oxide) emissions, and are very high for conventional vehicles (Norsk Elbilforening, 2014). VAT is 25%, which means a substantial reduction in the cost of a vehicle, particularly once import duty has also been taken into account. Norway also boasts the highest number of electric vehicle charging stations per capita (Clean Vehicle Europe, 2014).

In the Netherlands, a government programme entitled GAVE was announced in 2011 to support the development and introduction of alternative fuel vehicles (Netherlands Enterprise Agency, 2014). GAVE translates to "Action Plan for Electric Driving" and it estimates that by 2020, one million electric vehicles will be registered in the Netherlands, constituting a 20% market share (Clean Vehicle Europe, 2014). Until 2018, electric vehicles are excluded from purchase tax, equating to a discount of €5,000 (£4,000), and annual registration tax (Clean Vehicle Europe, 2014). The Netherlands also introduced a fuel economy labelling system to allow consumers to easily recognise each vehicle's environmental impact.

In the US, the incentives vary from state to state. There are a total of 95 grants available, 19 of which are Federal. An example of a Federal grant is American Taxpayer Relief, which is available for alternative fuel vehicles until 2014 (US Department of Energy, 2014). California is the state that offers the most grants, including alternative fuel vehicle incentives, electric vehicle supply equipment grants, alternative fuel vehicle and fuelling and infrastructure grants, and low emissions school bus grants. Parts of the San Francisco Bay Area (California) have introduced a policy plan to develop and expand infrastructure to promote the use of electric vehicles, including providing incentives for employers to install charging infrastructure and developing standard regulations for electric vehicle charging infrastructure across the Bay Area.

In Ilinois, the Chicago Department of Transportation has a Drive Clean Chicago programme, which provides vouchers and rebates for purchasing alternative fuel vehicles. The vouchers are available for $30,000 (£17,000) for electric vehicles (US Department of Energy, 2014). In Houston, Texas, the Clean Vehicles Program provides a grant of up to 75% of equipment costs to install electric vehicle charging infrastructure.

The state of Washington is among those that offer the most incentives for electric vehicles, providing tax credits on commercial alternative fuel vehicles, domestic alternative fuel vehicles, emissions reduction and electric vehicle supply equipment.

2.4 UK policy environment for alternative fuel vehicles

In the 1980s, vehicle congestion became increasingly problematic following a period of reduced fuel costs. This made driving more affordable, together with an increase in company cars and deregulation of public transport. In the 1990s, the problem of increased vehicle use began to be investigated from an environmental impact perspective, and in 1994, following a commitment by countries around the world to sustainable development at the UN Earth Summit at Rio (UN, 1992). The UK then produced a national Sustainable Development Strategy (Department of the Environment, 1994). When the Labour Government was elected in 1997, they pledged that environmental concerns would be a focus of policy-making. The new government merged the Department of Transport and the Department of the Environment to form the new Department of the Environment, Transport and the Regions and was responsible for revising the Sustainable Development Strategy in 1999. The key aims of the new strategy, 'A better quality of life' (DETR, 1999) covered economic and social progress, and the protection of the environment and natural resources.

In 2002, the Government set out a strategy 'Powering future vehicles strategy' (DfT, 2002) with a target for 10% of all new car sales to be cars emitting 100g/km of CO_2 or less at the tailpipe (DfT, 2002), while also indicating the intention of establishing a target for sales of cars with zero tailpipe emission in the region of 10% by 2020. The commitment to a more sustainable transport future was further supported through the publication of the White Paper 'The Future of Transport – a network for 2030' (DfT, 2004). In addition to improving travel choices, the policy recognised the role of cleaner cars in supporting policy objectives. In this respect the Government stated in this policy that it wanted to encourage the "development, introduction and take-up of new vehicle technologies and fuels" and for the UK to become a world leader in this field (DfT, 2004).

A further White Paper, 'Towards a Sustainable Transport System – Supporting economic growth in a low carbon world' (DfT, 2007) recognised the role that transport must play in supporting sustainable economic growth, but also its role in reducing carbon emissions. Complete decarbonisation of road transport was considered to be possible if sufficient progress is made in overcoming the technology challenges associated with electric vehicles, although only if decarbonisation of the power sector occurs alongside it (DfT, 2007).

A substantial step towards reducing the nation's carbon emissions was demonstrated by the UK Government through the establishment of the Climate Change Act in 2008 (DECC, 2008), with a target of reducing the UK's greenhouse gas emissions by 80% by 2050 (from a 1990 baseline). The actions involve setting national policy and strategy that contribute to the reductions, reducing energy demand, improving energy use efficiency and investing in low-carbon technologies. The Climate Change Act recognised that transport is responsible for 25% of the UK's greenhouse gas emissions as well as affecting air quality (DECC, 2008).

Despite the establishment of tough EU CO_2 targets for 2015 and 2020 (European Commission, 2010), in addition to rising fuel prices, already exemplified by significant improvements made to the fuel economy of vehicles (Wells et al., 2013), environmental regulation has proven to be contentious in the automotive market. It is considered by some to raise costs that may reduce profit margins or even reduce demand. However, Wells et al. (2013) suggest that regulation may present considerable benefits to the industry when set against global competition. Similarly, Rennings (2000) maintains that regulatory support will be necessary to overcome the weak market demand for products created in support of environmental objectives. Innovations that contribute to satisfying environmental objectives also demonstrate the potential to satisfy economic objectives. Porter and van der Linde (1995) assert that regulation may encourage innovation and competitiveness, but to appeal to the market regulations must also incorporate incentives such as taxes and tradable permits.

Demonstrating its commitment to reducing transport emissions and setting the vision for every car and van to have zero tailpipe emissions by 2050 (OLEV, 2013a) the UK Government's Department for Transport (DfT) established the Office for Low Emission Vehicles (OLEV). The programme oversees research initiatives into low-emission vehicles and their supporting infrastructure, and making grants available to consumers wishing to purchase an 'ultra-low emission vehicles'. Funding programmes worth £400 million, to bring about the advancement of ultra low emissions vehicles and to encourage consumers to purchase and use them, have been made available through the following grants (OLEV, 2013a):

- Plug-in Car Grant
- Plug-in Van Grant
- Domestic charge-points
- Residential on-street charge-points
- Residential on-street and rapid charge-points for local authorities
- Train station and car park charge-points
- Charge-points on the public sector estate

Providing investment in new technologies involves OLEV supporting automotive manufacturing and the UK supply chain, as well as funding projects targeted at low and ultra-low vehicle technologies, such as low carbon vehicle technology research and development. An example of this is the UKH_2 Mobility project (UKH_2 Mobility, 2013), which aims to evaluate hydrogen fuel cell vehicles' potential in the UK as well as develop a roadmap for their deployment from 2015.

A framework for the development of recharging infrastructure to support electric vehicles has been set out by OLEV (OLEV, 2011) in addition to the provision of funding for the development of a UK recharging network through the Plugged-in Places programme (OLEV, 2013b). The Programme is currently operational in eight locations: east of England, Greater Manchester, London, Midlands, Milton Keynes, north east

England, Northern Ireland and Scotland. This has allowed the installation of 4,000 charge points, of which 65% are accessible to the public (OLEV, 2013b).

The Plug-in Car Grant has been available since 2011 for vehicles that emit less than 75g of CO_2 per kilometre driven (OLEV, 2014). There are currently 18 vehicle models that are eligible for the Grant, which are a mixture of hybrid electric vehicles and battery electric vehicles. The Grant is available for 25% of the cost of the vehicle up to a maximum of £5,000 to both individuals and businesses (OLEV, 2014). As of March 2014, 8,724 claims have been made through the Plug-in Car Grant scheme (OLEV, 2014). Purchase subsidies are also available for photovoltaic systems, which may play a part in the future of hydrogen production (Hollmuller et al., 2000; Bilgen, 2001). In addition to purchase subsidies, owners of battery electric vehicles in the UK are currently exempt from excise duty (a tax on ownership) and the minimum level of company car tax (OLEV, 2011).

Projections suggest that the widespread use of fuel-efficient vehicle technologies would enable the UK to reach almost 50% of its CO_2 emissions reduction target (Potter, 2007b), but so far the subsidy policy has failed to have a significant impact on battery electric vehicle sales in the UK, a situation also experienced in other European countries (Shepherd et al., 2012).

2.5 Summary

As the problems of climate change have become increasingly apparent (Section 2.2), there has been involvement from countries internationally to bring about a reduction in the anthropogenic impacts. At an international level, the United Nations Framework Convention on Climate Change is in the process of establishing the next Framework for greater participation from countries around the world with more substantial targets for a reduction in greenhouse gas emissions.

In Europe, the 2020 strategy (Section 2.2) forms a part of the long-term roadmap towards achieving a reduction of 80-95% greenhouse gas emissions by 2050, and requires the full decarbonisation of the power sector. This will be aided by technological innovation in the transport sector. So far, Norway and the Netherlands (Section 2.3) are the two leading countries in Europe with regard to electric vehicle market share. Tax incentives play an important role in both countries. In the US, incentives vary in the different states, and those relating to tax deductions are most commonly used.

In the UK, there is a strong policy focus on reducing the environmental impact of transport, and as such a target has been set to decarbonise the transport sector (Section 2.4). The Office for Low Emission Vehicles (OLEV) is responsible for research development and funding of alternative fuel vehicles and infrastructure. Grants are available to consumers wishing to purchase alternative fuel vehicles. Through the OLEV funding a network of 4,000 charging points has also been implemented across the UK. Despite the incentives, subsidy policy is failing to have a substantial impact on vehicle sales.

The policy evidence demonstrated in this chapter creates a strong argument of the need for research to identify how a transition to a low carbon economy can be undertaken. Alternative fuel vehicles are viewed as having a key role in reducing the environmental impact of transport. Therefore, it is particularly importance to develop an understanding of how a transition to alternative fuel vehicles can be achieved.

The subsequent chapter reviews the literature on consumer acceptance of alternative fuel vehicles.

Chapter 3: Literature review of consumer acceptance of alternative fuel vehicles

3.1 Introduction

This chapter presents a review of the literature on consumer acceptance of alternative fuel vehicles (AFVs). The literature review begins with Section 3.2 considering demand for private motorised transport before introducing the problems that have stemmed from this demand. In Section 3.3 the two alternative fuel vehicle technologies that are considered to have zero tailpipe emissions are discussed and the technological barriers that they face in competition against conventional vehicle technologies are explored. Section 3.4 examines the social, ethical and environmental impacts of alternative fuel vehicles, followed by section 3.5 that considers the role of stakeholders in the uptake of alternative fuel vehicles.

In Section 3.6 and 3.7 the challenges involved in changing and managing consumer behaviour are reviewed. Section 3.8 considers attitudes towards climate change and the effect that such attitudes have on adopting sustainable behaviour. Section 3.9 investigates the attitudes of consumers to alternative fuel vehicles. This section reviews the acceptance studies that have been undertaken for electric vehicles and hydrogen vehicles and the barriers to their adoption. Section 3.10 then investigates the literature on alternative fuel vehicle adopter characteristics, in order to establish an early adopter profile. Finally, Section 3.11 provides a summary of the studies and introduces the gaps that have been identified for further exploration in this thesis.

3.2 Demand for personal vehicle use and the impacts

This section begins by examining the demand for motor vehicle use in Section 3.2.1, before considering the motives behind the demand in Section 3.2.2 and finally, Section 3.2.3 notes the need for technological innovation in the transport sector.

3.2.1 The demand for personal vehicle use

Transport demand is important for economic growth, emissions and safety (DfT, 2013), however there are negative externalities associated with transport demand that include climate change emissions and air quality problems (DfT, 2013).

The majority of transport energy in the UK (80%) is used in motor vehicles, and approximately 75% is consumed by cars (Potter, 2007b). Private car use has, therefore, been deemed a major contributor to global and local environmental problems (Haustein and Hunecke, 2007). Since the 1970s, transport demand in the UK has seen a sharp increase with the number of car miles per person increasing from approximately 1,700 miles to approximately 4,200 miles (DfT, 2012). More recently, however, a period of economic recession saw a reduction in road traffic in the UK, although this is an exception to the growth trend that was evident prior to the recession. By 2035, road traffic levels are expected to increase by 44% from 2010 levels (DfT, 2012). In the Department for Transport's road transport forecasts 2011 (DfT, 2012), the average number of trips for a person in the UK in 2010 was 960, totalling 6, 726 miles; the average trip lasting approximately 22 minutes. The trend of increasing transport demand has been observed worldwide; the transport sector is one of the largest growing sectors, and is responsible for over half of world oil consumption (Dargay and Gately, 1999).

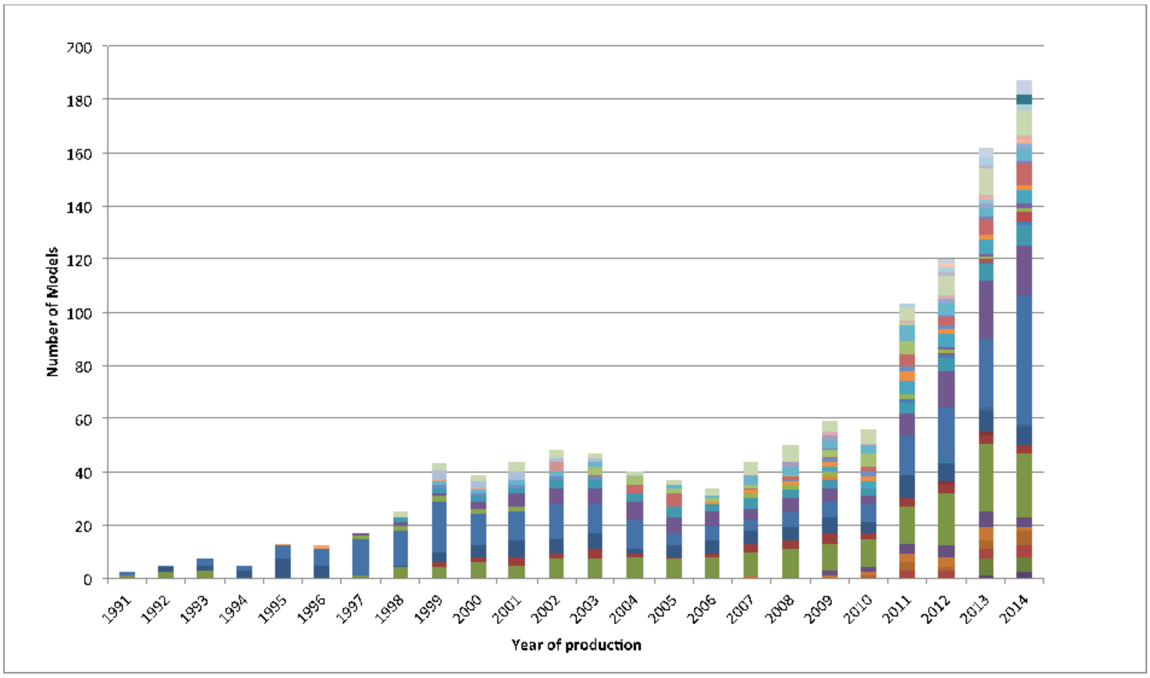
3.2.2 Motivations for personal vehicle use

Consumption of personal motorised transport fulfils a variety of roles in society. Its primary function is utilitarian (Steg, 2005; Hickman et al., 2010) and satisfies concerns for journey time, effort minimisation, and monetary cost (Gardner and Abraham, 2007).

Beyond its utilitarian purpose, the car plays a role in satisfying the need for creating social distinction and identification (Jackson, 2005). The car has been described as a cultural phenomenon, symbolising freedom and independence (e.g. in Jensen, 1999; Hickman et al., 2010) while simultaneously satisfying social and psychological needs (Hickman et al., 2010) such as the need to convey social status. Sheller (2004) maintains that individuals can build deep and meaningful relationships with cars and driving, which are embodied through 'automotive emotions', a finding also supported by Steg (2005).

3.2.3 Approaches for decarbonising the transport sector

Over 90% of energy that is consumed by transport is petroleum-based (Romm, 2006), which is considered to be a 'scarce commodity' that may run out in 2050 (Marbán, and Valdés-Solís, 2007). Owing to a need to reduce the carbon emissions from transport, in addition to reducing the demand that transport places on fossil fuels, there is now a requirement to ultimately replace petrol/diesel with a zero-emissions fuel (Romm, 2006). Vehicle manufacturers are working on technological changes to improve the efficiency of internal combustion engines (Steg and Gifford, 2005), which will contribute towards mitigating climate change. However, since the early 1990s car manufacturers have been facing an increasing pressure to produce alternative fuel vehicles (Gärling, 2000). Figure 3.1 shows how there has been rapid growth in the number of alternative fuel vehicle models since 2006 (US Department for Energy, 2014). In 2012, the number of models available grew by 17%, followed by 33% in 2013 and by a further 15% in 2014.



Note: Each colour refers to a different manufacturer.

Figure 3.1 *Alternative fuel vehicles (including hybrid vehicles) offered by vehicle manufacturers between 1991 and 2014. Source: US Department of Energy, Alternative Fuels Data Center, 2014.*

Alternative fuel vehicles are considered to be 'disruptive innovations' (Hardman et al., 2013), such that their establishment in the marketplace upsets the pre-existing system. Others have referred to alternative fuel vehicles as 'eco-innovations' (e.g. Machiba et al., 2012; Jansson, 2011, Albino et al., 2009; Hellström, 2007). Eco-innovations are considered by Machiba et al. (2012) to be necessary in enabling a long-term transition towards a 'greener' economy, and need to be more radical and systemic than simply incremental. In their report for the Organisation for Economic Co-Operation and Development (OECD) project on Green Growth and Eco-Innovation, Machiba et al. (2012) note that a variety of factors surround an eco-innovation, including technology, infrastructure, regulations, and changing consumer behaviour. Each of these factors will be considered in the subsequent sections of this literature review, beginning with an overview of alternative fuel vehicle technology and infrastructure.

3.3 The technological status of alternative fuel vehicles and infrastructure

Section 3.3 provides an overview of the alternative fuel vehicle technologies that are considered as having zero-emissions, and examines the status of the technologies and supporting infrastructure.

3.3.1 Alternative fuel vehicles

There are a several options being pursued to reduce the level of carbon emissions from vehicles, which include bio-fuels, compressed natural gas, hybrid-electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV), battery electric vehicles (BEV or EV), and hydrogen fuel cell vehicles (FCV) (Shears, 2007). From this point forward hybrid vehicle technologies are referred to as hybrid vehicles and battery electric vehicles are referred to as electric vehicles.

There is debate as to which power train offers the most appropriate long-term solution. With respect to hydrogen and electric vehicle technology, Van Bree et al. (2010) argue that neither technology is superior over the other, nor is either superior over conventional vehicles. On-going improvements to the efficiency of internal combustion engines will make it exceedingly difficult for new vehicle technologies to become competitive (Potter, 2007b). On the other hand, hydrogen fuel cell vehicles have been described as being "a comprehensive solution in the fight against global warming'' (Shears, 2007, pg 1). Similarly, battery electric and hydrogen vehicles have been claimed by the car manufacturing industry as offering the two most promising solutions for the future (Bakker et al., 2011), principally because they have the potential to meet environmental, energy and economic challenges (van Bree et al., 2010).

So far, the only two types of alternative fuel technology that have zero tailpipe emissions are battery electric vehicles and hydrogen fuel cell vehicles. Both of these vehicles use electrical rather than mechanical drive trains (Lane and Warren, 2007). Battery electric vehicles were first produced in a relatively high volume in the early 1900s, although the first battery electric vehicle was produced in Scotland in 1842 (Gärling and Thøgerson, 2001). However, internal combustion engines soon rose to the fore as oil was found in abundance and was inexpensive (Gärling and Thøgerson, 2001). More recently, concerns over energy security and carbon emissions have heightened, and the interest in electric vehicles has gathered momentum once more (Lane and Warren, 2007); Karplus et al., 2010; and Musti and Kockelman, 2011).

The purchase cost of an electric vehicle is high but the fuel costs are extremely low, costing approximately 1.6p/mile (Lane, 2006). The vehicles are also extremely energy efficient (Gerssen-Gondelach and Faaij, 2012) with the battery system having an efficiency of approximately 90%; 10% is lost due to the internal battery resistance and thermal management of the battery stack (Thomas, 2009). By 1999 several of the major car manufacturers, including GM, Ford, Nissan, Honda, Volkswagen and Peugeot, were in the process of developing at least one electric vehicle (Gärling, 2000). In the US, the pioneers of all-electric vehicles have been Nissan with the Leaf in 2011 and Ford with the Focus in 2012 (Carley et al., 2013). It is expected that all major vehicle manufacturers will have an all-electric or hybrid electric vehicle on the market by 2014 (Carley et al., 2013; FCH-JU, 2010).

Hydrogen is an energy carrier rather than a fuel (Marbán, and Valdés-Solís, 2007), which can be used in modified internal combustion engines as well as in fuel cells. The fuel cell works by converting the chemical energy found in hydrogen directly into electric energy, through an electrolytic process, that supplies a continuous electric current to drive an electric motor in a vehicle. There are no emissions at source other than the by-products of water and heat. A hydrogen fuel cell vehicle has lower energy efficiency compared to a battery electric vehicle, having a net efficiency of approximately 54% in the conversion of hydrogen to electricity (Thomas, 2009). The vehicles have not yet been commercially deployed and there have not been any precise predictions as to when they might be available to consumers. The status of the technology makes predicting the commercialisation date of hydrogen fuel cells challenging – the technological barriers faced by alternative fuel vehicles will now be explored in the subsequent parts of Section 3.3.

3.3.2 Technological barriers for alternative fuel vehicles

Meeting the needs and expectations of consumers in terms of vehicle technology and the supporting refuelling infrastructure is causing concern for vehicle manufacturers. There is a chicken and egg problem, which is well cited in sustainable transport literature (e.g. Romm, 2006; van Bree et al., 2010) and highlights the issue of the construction of fuelling infrastructure for alternative fuel vehicles before the actual vehicles are built and vice versa. Battery electric vehicles do not experience quite the same chicken-and-egg problem because electricity is widely accessible (van Bree et al., 2010). However, demand for a high-density refuelling network from vehicle manufacturers and profitable demand levels from energy companies prior to investment is creating a barrier to the development of hydrogen fuel cell vehicles (Bersani et al., 2009).

There are technological limitations for both battery electric vehicle and hydrogen fuel cell vehicle technologies. For battery electric vehicles the constraints include range, battery size, weight, performance, cost, availability of electricity produced through zero-emissions processes, and grid expansion, while for hydrogen fuel cell vehicles, these include range, cost, performance, infrastructure and the availability of hydrogen produced through zero-emissions processes (Shears, 2007).

3.3.3 Battery electric vehicles

The battery technology used in electric vehicles is one of the major barriers to their success. The type of battery most commonly used in electric vehicles is a lithium-ion (Li-ion) battery. This is due to the low energy density (Helmers and Marx, 2012; Offer et al., 2010) and because it is one of lightest commercially available batteries. The current battery range of battery electric vehicles is around 150 km (93 miles) (Gerssen-Gondelach and Faaij, 2012), and does not currently match the range of an internal combustion engine vehicle. The range of the batteries is restricted by their heavy weight and bulkiness (Pearre et al., 2011), which has a direct effect on the cost and efficiency of the vehicle. As capacity is increased and weight is reduced, the cost of the battery significantly increases (Ulrich, 2005). This creates a dilemma for manufacturers who are trying to keep the costs of electric vehicles to a minimum. For this reason, many of the electric vehicles that are currently available are small and suited only to shorter trips (FCH-JU, 2010), as they require smaller batteries (Hazeldine et al., 2009).

A further problem associated with the batteries is the lifespan, which is approximately seven years (Gerssen-Gondelach and Faaij, 2012), at which point the battery needs replacing. This cost raises a concern that the battery lifetime is too short for the running costs of an electric vehicle to offset the initial purchase price (Graham-Rowe et al., 2012). With further research and development, the lifetime of Li-ion batteries is expected to increase to around 10-12 years by the year 2025 (Gerssen-Gondelach and Faaij, 2012), which indicates that it may take some time before electric vehicles are able to successfully compete with conventional vehicle technology, unless a solution is found to offset financial risk. The option of battery leasing, whereby the manufacturer retains liability for the battery, is offered by some vehicle manufacturers to make electric vehicle ownership more affordable by removing the associated financial risk for consumers (Hazeldine et al., 2009).

3.3.4 Hydrogen fuel cell vehicles

One of the main hurdles for hydrogen vehicles is the on-board vehicle storage of hydrogen (Balat, 2008). Hydrogen can be stored on board as compressed gas, liquid or contained in metal hydrides. Due to its low density, a much higher volume of hydrogen than petroleum oil is required to achieve the same range (Balat, 2008). To combat the limited range, hydrogen storage becomes bulkier and weightier than petroleum oil. Due to the weight and size of the on-board storage tank, hydrogen fuel cell vehicles are considered to be more suitable for larger vehicles and longer trips, beyond the range of battery electric vehicles.

The high cost and lack of reliability of fuel cells is obstructing the route to commercialisation for hydrogen fuel cell vehicles (Zegers, 2006). There is a clear cost differential between fuel cells and internal combustion engines when comparing the cost per kilo Watt of energy; the price of fuel cells currently cost between $3,000 to $5,000/kW (mostly due to them being handmade) in comparison to $50/kW for an internal combustion engine (Florida Solar Energy Center, 2012). Meeting the same costs as that of a conventional vehicle will be very challenging for private vehicles (Zegers, 2006), and Romm (2006) asserts that of all the alternative vehicle technologies, hydrogen fuel cells offer the least cost-effective solution to climate change. The durability of fuel-cell stacks is a concern for hydrogen fuel cell vehicle manufacturers because their lifespan currently falls short of the 5,000 hour lifespan required to meet the standards for light-duty vehicles (Wipke et al., 2007), while lorries and buses require a 40,000 – 100,000 hour lifespan (Zegers, 2006).

There are also health and safety risks surrounding its use in private vehicles. Hydrogen is a highly flammable gas and could be very dangerous in a confined space, although less so in open spaces where it diffuses rapidly (Marbán, and Valdés-Solís, 2007). One of the advantages of using hydrogen in place of oil is that it is possible to produce hydrogen from a variety of sources, including geothermal, solar and wind power (Shears, 2007). This makes it a more accessible fuel than oil (Balat, 2008). Producing it from grid electrolysis is a carbon-intensive process and could have the adverse effect of increasing carbon emissions rather than reducing them (Romm, 2006).

3.3.5 Infrastructure

In order for a new vehicle fuel to be successful, Flynn (2002) argues that several criteria must be fulfilled - infrastructure profitability, public and commercial access to fuel, profitable fuel retail in order to develop a network of refuelling stations, and education programmes that promote the technology should be introduced, with careful consideration given to avoiding exaggerated claims that will damage the market. The failure of natural gas vehicles to become commercially sustainable as a result of a lack of refuelling infrastructure, and consequently a poor sales growth rate, has meant reluctance among vehicle manufacturers to commit too soon to other alternative fuel technologies (Flynn, 2002).

Limited infrastructure presents a risk to the market development of electric vehicles (FCH-JU, 2010). The current costs for electric vehicle charging infrastructure have been calculated to range from €1,500 - €2,500 (£1,200 - £2,000) per vehicle over its lifetime (FCH-JU, 2010). However, the vehicles can be plugged in almost anywhere, using standard domestic electrical outlets, and can take between six and eight hours for a full charge. Public charging points are becoming increasingly available, but it is expected that consumers will mostly charge their vehicles at home (FCH-JU, 2010; van Bree et al., 2010). The length of time to recharge clearly poses a problem given the restricted range, which means that regular access to charging is required. Fast charging (rapid charging) infrastructure is being considered, which can reduce charging time to 10 minutes for a 50% charge, but it is an expensive technology, costing between £10,000-£30,000 per charging point (Lane, 2006). Charge points with the standard 13-Amp socket cost between £500 and £2,000 (Lane, 2006), which is considerably less than the rapid charge points. To encourage uptake of the vehicles, a comprehensive network of charging infrastructure is required, particularly so that vehicles can be charged during trips (Egbue and Long, 2012). It would also represent the convenience of the extensive refuelling network that vehicle users are currently familiar with (Williams and Kurani, 2006).

Similar to battery electric vehicles, the lack of supporting infrastructure also poses a barrier to the commercialisation of hydrogen fuel cell vehicles. It has been calculated that the cost of hydrogen infrastructure will be €1,000 - €2,000 (£800 - £1,600) per hydrogen fuel cell vehicle (over the vehicle's lifetime) (FCH-JU, 2010). Other than single filling stations in a small number of cities, hydrogen infrastructure for refuelling is not yet available (Helmers and Marx, 2012). Unlike electric vehicles, which are able to tap into an existing network of electricity, hydrogen vehicles face the problem of relying on access to hydrogen from a distribution network that is not yet established.

To create a centralised production system, as exists with oil, the costs are vast and much of this cost is associated with the required distribution system. There are approximately 16,000km of hydrogen pipelines that exist for carrying hydrogen to chemical plants (Marbán and Valdés-Solís, 2007), although the possibility of using existing natural gas pipelines is unfeasible due to their porosity. The requirement of a non-porous material such as steel makes the cost of the pipelines double that of natural gas pipelines (Marbán and Valdés-Solís, 2007). One of the advantages of hydrogen is that it can be generated from a variety of sources, one of which is electricity. There is on-going research into electricity production from renewable energy sources (e.g. Greiner et al., 2007). However, based on the existing renewable energy capacity, Potter (2007b) suggests that it would not be possible to support the existing electricity market as well as a new market for hydrogen for transport energy. Opportunities exist for the decentralised production of hydrogen from renewable sources, such as an isolated wind-hydrogen energy system, although Greiner et al. (2007) found that the costs of producing hydrogen from an isolated system, €6.2/kg (£4.9/kg), amount to far more than a grid-connected system, €2.8/kg (£2.2/kg). Consequently, centralised production is considered to be the safest and most efficient method (USDOT, 2010).

A criticism of research into the costs of the hydrogen economy is that they are often assessed on the assumption of it being in its 'end state' (Romm, 2006). However, Shears (2007) suggests that an immediate transition to hydrogen would not be necessary, but rather an incremental approach as the number of consumers of hydrogen fuel cell vehicles grows steadily from around the year 2027. Similarly, it has been calculated that if a 25% market share is assumed, hydrogen fuel cell vehicle infrastructure would cost approximately €3 billion in the first decade and €2-3 billion per year thereafter (FCH-JU, 2010). However, this does not seem much when considering the regular annual infrastructure investments that are required in all industries, including oil and gas and telecommunications, amounting to approximately €50-€60 billion each year (FCH-JU, 2010).

3.4 The social, ethical and environmental impacts of alternative fuel vehicles

In Section 3.2.3, the term 'eco-innovation' was introduced, and despite eco-innovations offering environmentally sustainable practices in the long term, Hellström (2007) notes that to achieve this, a degree of environmental destruction is necessary in the short term. Hellström remarks that a degree of destruction of natural capital in addition to the energy and material demand is required to reset old processes and establish services to support new processes.

The shift from conventional fuel vehicles to alternative fuel vehicles in order to achieve societal gains raises the question of "who decides what is good for us" (e.g. Kurani and Turrentine, 2002). One of the key difficulties for gaining support for alternative fuel vehicles is that the positive externalities associated with their adoption fall largely within a global rather than local context (Kurani and Turrentine, 2002).

Further, there are issues with constituent vehicle parts not being sustainably produced and there is not the ability for sustainable disposal. Similarly, the dominant methods for the production of electricity and hydrogen, which would be used to fuel alternative fuel vehicles with zero tailpipe emissions, are reliant on fossil fuels that generate carbon emissions. The carbon intensity of electricity and hydrogen is highly dependent on the production method used (McCarthy and Yang, 2009). Both can be produced from renewable energy sources, but coal and natural gas, both non-renewable, are the dominant energy sources currently used in the United Kingdom (Alderson et al., 2012). Currently 80-85% of hydrogen is produced by steam methane reforming of natural gas (Simpson and Lutz, 2007). The problem is that steam methane reforming is the most economical method of producing hydrogen (Crabtree et al., 2004).

Carbon capture and storage (CCS) may, however, provide a future solution to this problem, although this would increase the hydrogen production costs by 3-5% for natural gas reforming and 10-15% for coal gasification (Ball and Wietschel, 2009). Until electricity can be produced from renewables on a large-scale, Høyer (2008) questions whether electric vehicles can become anything more than a niche motoring option for limited urban driving. A similar concern exists for hydrogen vehicles. When the hydrogen for a hydrogen fuel cell vehicle has been produced from electrolysis, the vehicle has been found to consume four times as much electricity per mile as an equivalent sized battery electric vehicle (Brooks, 2004).

In order to compare the energy and emissions impact of different vehicle technologies, a well-to-wheel analysis can be undertaken (McCarthy and Yang, 2009). Battery electric vehicles have been found to have the lowest well-to-wheel energy consumption and emissions (Gerssen-Gondelach and Faaij, 2012), being four times more energy efficient than an internal combustion engine vehicle (Helmers and Marx, 2012). Fuel cell vehicles are slightly lower in energy efficiency than a battery electric vehicle. However, efficiencies are lost during the production of the compressed hydrogen (Helmers and Marx, 2012). Fuel cell vehicles are expected to incur high costs to society in their early years, predominantly due to the infrastructure overhaul that will be required, although if hydrogen is not taxed in the same way as petroleum oil they could be cost-competitive with conventional vehicles by 2020 (FCH-JU, 2010).

Lithium-ion batteries are commonly used in battery-electric vehicles, although the environmental impacts of their production, use and disposal are not well known (Notter et al., 2010). Notter et al. (2010) found that lithium-ion batteries to generally have a low environmental burden, but metal supply and process energy are the main contributors to the environmental burden of the batteries. There are also concerns that national electricity grids will be unable to support a mass deployment of electric vehicles, and that charging times may need to be regulated in order to avoid impacting heavily on daily electricity demand (Perujo and Ciuffo, 2009).

Increased energy efficiency at the microeconomic level can lead to a reduction of energy use at this level, but also leads to an increase in use at a national or macroeconomic level (Herring, 2006). This is because, as efficiency of a product is improved, it allows the price of that product to fall and as a result stimulates consumption. The push for economic growth is likely to lead to increasing demands for materials and energy. Similarly, efficiency gains in conventional fuel vehicles may lead to an increase in consumption, which will, in turn, generate other problems. Rudin (2000) maintains that in order to protect the environment, the emphasis should be on conservation and restraint and not improved energy efficiency; "efficiency tells us what to buy, not how to behave" (Rudin, 2000, pg 5).

The Center for Entrepreneurship and Technology outline several macro-economic impacts linked to the deployment of electric vehicles in California. These are (Becker et al., 2009): a reduction in greenhouse gas emissions, a reduction in oil imports which leads to an improved trade deficit, new business opportunities for investment, creation of new jobs and an improvement in health due to lower pollutant levels which will mean reduced healthcare costs. Cocron et al. (2011) also note that the lower noise level of electric vehicles, and how they are deployed, would lead to cities becoming much quieter, thus increasing the quality of life. At the same time they question whether quiet vehicles might actually be a curse - participants in the study responded positively to the quietness of the vehicle, although they did express concern about other road users being less aware of their presence.

A challenge faced by policy makers is which technology to back (van Bree et al., 2010; Raven et al., 2009). If electricity is to become the main source of energy for both transport and stationary applications, then it is likely that there will be a transition away from oil companies playing the most important role in personal mobility and towards utility companies (van Bree et al., 2010). Any of the societal benefits associated with the use of alternative fuel vehicles may struggle to outweigh the high costs of ownership, the vehicle range, lengthy refuelling times, battery lifespan, speed and acceleration of the vehicles, and a lack of refuelling infrastructure.

3.5 Stakeholder involvement in the uptake of alternative fuel vehicles

It is recognised that the market for alternative fuel vehicles cannot rely on technological developments alone, and is highly reliant on the cultural and political will of those in research, government, industry and the marketplace (Turrentine and Sperling, 1992). Van der Meulen et al. (2003) maintain that "intensive stakeholder interaction" is essential in managing uncertainty, while Thøgerson (2005) makes the point that governments and businesses are responsible in ensuring their activities are aligned so as to ensure sustainable consumption.

The steering of new technology development and implementation has often been undertaken using a top-down approach, which is denied by Raven et al. (2009) to be the most appropriate method for achieving societal acceptance of new technologies. In support of this view, Rennings (2000), van Bree et al. (2010) and Dijk et al. (2013) recognise a requirement for a co-evolutionary process, which involves aligning supply and demand to combine top-down and bottom-up approaches. As such, the process considers the supply and demand actors involved at all stages of the diffusion of a new technology (Dijk et al., 2013).

Looking at future scenarios for the success of cleaner vehicles, Dijk et al. (2013) maintain that the success of hybrid electric vehicles is dependent on suppliers committing to the development and production of hybrid electric vehicles, and also on consumers not valuing hybrid vehicles simply as environmentally friendly diesel vehicles. Van Bree et al. (2010) consider two possible scenarios for a transition to alternative fuel vehicles. One scenario sees the diffusion of alternative fuel vehicles following the tightening of emissions regulations that compel manufacturers to focus the commercialisation of alternative fuel vehicles. The other scenario sees a gradual transition from conventional vehicles, through hybrid vehicles, then battery electric and finally fuel cell vehicles, in response to rising fuel prices.

3.5.1 The role of the research community

The research community performs a vital role in setting the basis for expectations, which are important for technological change because they play an important role in guiding activities, providing structure, generating interest and also in mobilising resources at both a micro- and macro-level (Borup et al., 2006). Managing expectations is necessary to avoid the disappointment and subsequent investments withdrawal from sponsors that can arise when high expectations lead to opportune innovation (Bakker et al., 2011). This was the case with electric vehicles in the 1990s. Electric vehicles were predicted to be widely available in the mid 1990s, but Cowan and Hulten (1996) maintain that their lack of success in diffusing the market was as a result of the battery technology not living up to expectations.

The majority of research in the area of alternative fuel vehicles focuses on electric vehicles. Research and development for new technologies is reliant on investment, which generally comes from the government, without which new technologies would struggle to succeed (Romm, 2006).

Zegers (2006) suggests that if hydrogen vehicles do not successfully make it to market within five years, then there is a danger of loss of interest and investment in hydrogen technology. This may currently be the case as interest in hydrogen technology has taken a backseat to electric vehicle technology. If recent activity focused on hydrogen technology is to be considered a 'mistake', then Bakker et al. (2011) maintain that mistakes are an important step in allowing technological change is to proceed, as it can only do so through trial and error (Bakker et al., 2011). Eisler (2009) argues that the aspirations of producing a marketable fuel cell have not come to fruition because expectations have tended to outpace the knowledge base.

The rigour of hydrogen research is often challenged. Sovacool and Brossmann (2010) accuse academics of getting caught up in the "rhetoric and fantasy" of the hydrogen economy and dismissing attacks on the hydrogen economy. They argue that themes of "independence, patriotism, progress, democracy, and inevitability have powerfully penetrated intellectual and public discourse about the hydrogen economy" (Sovacool and Brossmann, 2010). Scientists and academics involved in work on hydrogen vehicles and other pro-environmental innovations must try to remain aware of the bigger picture to ensure that their work remains in line with the best interests of the public (Sovacool and Brossmann, 2010). Similarly, Bakker (2010) blames vehicle manufacturers for creating hype for hydrogen vehicles over the last few decades, which has led to disillusionment and disappointment, particularly so now that it has been replaced with hype for electric vehicles. In earlier research, Romm (2006) argues that hydrogen was overestimated and has failed to live up to the expectations that were created.

3.5.2 The role of government

Without government support, it may not be possible to bring about major changes to the transport system (FCH-JU, 2010; Romm, 2006). Government has a role to play in reducing the structural and institutional barriers that discourage behavioural change in the context of pro-environmental choices (Ockwell et al., 2009). Governments must also work to reduce investment risk in the roll-out of battery electric vehicles and hydrogen fuel cell vehicles (FCH-JU, 2010); the risk will be further reduced if governments co-ordinate the roll-out and support it with specific regulation and funding (FCH-JU, 2010).

Legally binding targets for an 80% reduction (relative to 1990 levels) in greenhouse gas emissions by 2050 were established by the UK Government in the Climate Change Act 2008 (DECC, 2008). In order to achieve this ambitious target, the Government stated its commitment to decarbonising the transport sector by 2050. The urgency to reduce carbon emissions has led to the pursuance of electric vehicle technologies, while hydrogen vehicles have become less of an interest (Bakker et al., 2011). Three other factors have been identified as being responsible for the imbalance of interest in electric vehicle and hydrogen vehicle technologies, as Hickman (2011) notes. The first factor is that the Government is influenced by popular opinion, in addition to pressure from lobbying groups. This leads to the development of specific policies. An example is given: Daimler-Benz is at the centre of Europe's hydrogen strategy, but has not shown much interest in the UK. The UK government, however, has persuaded Nissan to build its electric vehicle, the Nissan Leaf, in the UK. This, along with other carbon reduction reasons (e.g. Climate Change Act 2008), has led to the UK becoming electric vehicle oriented. The second factor is to do with vehicle manufacturers; many are equipped with the resources to be able to produce electric vehicles but are still some time away from being able to produce hydrogen vehicles. The third factor relates to efficiencies; a hydrogen fuel cell vehicle requires different vehicle architecture, but many manufacturers are attempting to produce hydrogen fuel cell vehicles that behave like conventional vehicles, which leads to poor improvement in energy consumption.

In order to bring about the commercialisation of hydrogen vehicles, governments must also play a role in creating the right conditions for such vehicles to be able penetrate the market. Education will also help to reassure the public; Reijalt (2010) maintains that a European-wide coordinated curriculum programme is necessary to enable the acceleration of market uptake by gaining acceptance from families, local businesses and the school communities themselves. However, funding for education programmes has received low priority, and Reijalt (2010) suggests the reason for this is that the hydrogen fuel cell application suppliers and decision makers expect the uptake of hydrogen fuel cells to occur in the same way as with mobile telephones (Reijalt, 2010), the market for which experienced explosive growth (Sheller and Urry, 2006).

Unruh (2000) uses the term Techno-Institutional Complex to describe how industrial economies have become locked into a fossil fuel based energy system that has occurred due to the co-evolution of technological systems and governing institutions. In Figure 3.2, Unruh provides an illustration of the techno-institutional complex of an automobile-based transport network, which shows how a government, as an institution, is largely responsible for the continuous cycle of development of the current transport system that has led to carbon lock-in (Unruh, 2000).

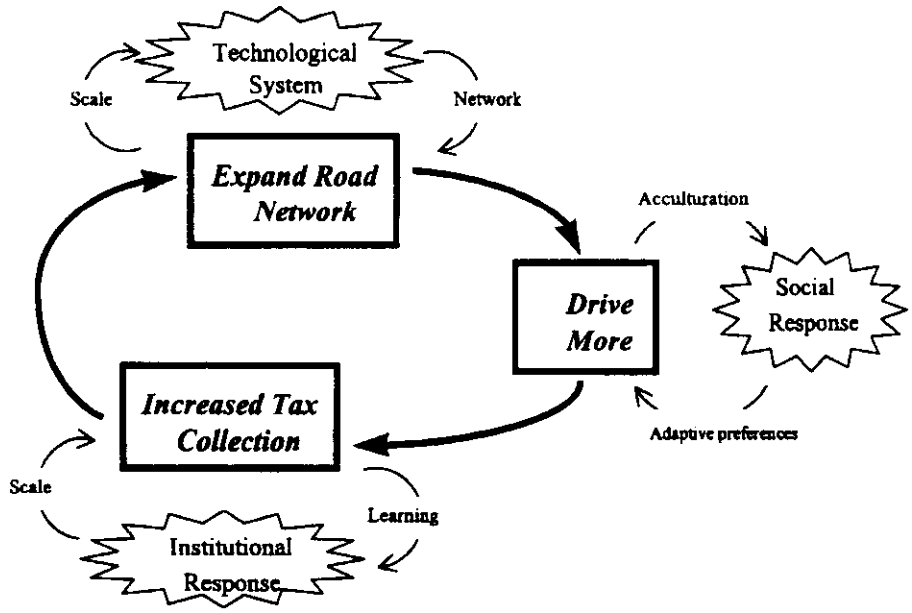


Figure 3.2 *Techno-institutional complex in automobile-based transportation networks. Source: Unruh (2000)*

Seyfang and Smith (2007) refer to the same interrelationship as reported by Unruh (2000), noting how a 'socio-technical regime' is a barrier to sustainable alternatives. The authors propose community action as a means to introduce sustainable innovation and that research and policy should give greater consideration to grassroots initiatives.

Policy enables the Government to achieve objectives that are considered to be in the best interests of all members of society (Torjman, 2005). This is important considering that, aside from technology lock-in, there is also behavioural lock-in where behavioural norms lead to a resistance to change (Jackson, 2005). Policy can therefore be used as an approach to implement change, such as through policies to raise public awareness of climate change in order to stimulate public support (Anable et al., 2006). Rennings (2000) argues that policy is a vital tool to enabling new technologies to succeed, and so long as policy fails to punish environmentally harmful impacts, there will remain a distortion between environmental and non-environmental technological advancement.

Schwanen et al. (2011) remark that a key difficulty surrounding transport policy is the issue of too much or not enough governance. Policy may be a useful tool for increasing the demand for electric vehicles and, in the future, hydrogen vehicles. An increase in fuel duty and zero-emissions vehicle purchase subsidies could improve the chances of these vehicles diffusing (Shepherd et al., 2012). These suggestions also support an earlier assertion by Porter and Van der Linde (1995) that carefully constructed regulation achieves a number of important goals. These goals are to make companies aware of any potential resource inefficiencies and potential technological improvements, to reduce uncertainty of investment in addressing environmental objectives, to encourage innovation and progress, to force the raising of corporate awareness, and to create a level playing field during the transitional period. The latter is considered necessary in situations when the cost of compliance is unlikely to be offset by the innovation in the short term and requires a long-term investment. Technological innovation is also a mechanism that enables governments to synthesise economic and environmental goals (Schwanen et al, 2011).

One of the initial steps that need to be taken on the path to commercialisation of hydrogen technology is the setting of national and international codes and standards, which will help to reassure consumers' concerns about risk (Andrews and Weiner, 2004). By doing so, governments will be pursuing social objectives (Andrews and Weiner, 2004). Credible legislation is also considered to have a role in reducing infrastructure investment risk (FCH-JU, 2010).

3.5.3 The role of social media

There is little research on the effect of social media on influencing attitudes towards alternative fuel vehicles, although Egbue and Long (2012) recognise the potential it has influence public opinion, offering a channel to communicate the non-financial benefits of adopting electric vehicles. There is evidence of the success of using social media in communicating with consumers in the car industry. Ford, the vehicle manufacturer, used social media to reintroduce the Ford Fiesta to the U.S. in 2009 (Wilson et al., 2011); it held a competition to find 100 volunteers who had large social followings. The winners were then lent a Fiesta for six months, during which period they agreed to use social media to talk about their on-going experiences with the car. Ford found that the $5 million campaign generated 50,000 sales to new customers, a demand for 35,000 test-drives and almost 40% pre-release brand awareness (Wilson et al., 2011).

Experts employed by car manufacturers are also becoming increasingly involved in blogging. Suzuki, a vehicle manufacturer, has recognised the benefits of blogs and has created a more interactive website, allowing consumers to leave comments and feedback (Fitzgerald, 2007). Such activities may be useful in engaging with earlier adopters of alternative fuel vehicles.

3.6 Changing consumer behaviour

Changing behaviour can be a difficult process, particularly if perceived by individuals as an inconvenience and an infringement of their freedom (Steg and Gifford, 2005). An equal willingness among individuals to change their behaviour to become more sustainable is unlikely (Thøgerson, 2005). Individual and social barriers, such as distrust of information, scepticism, poor awareness or knowledge, personal values, and physical barriers, may prevent behaviour change (Lorenzoni et al., 2007).

Technological change is influenced by preferences, values, needs and aspirations of individuals, but there is a tendency to separate technological change from behavioural change (Schwanen et al. 2011). Changes in behaviour are aimed at reducing car dependence through the introduction of 'soft measures', which attempt to reconfigure the psyche of those using the transport system (e.g. Anable, 2005; Cairns et al., 2008). By reducing car use, it is hoped that both local and global environmental quality, and accessibility will be improved (Steg and Gifford, 2005). In order to understand behaviour, there has been a growing trend in transport studies to incorporate approaches from sociology and psychology. The most influential approaches to understand and predict behaviour in the context of climate change mitigation (Schwanen et al., 2011) are the Theory of Planned Behaviour (TPB) (Ajzen, 1991) and Norm Activation Model (Schwartz, 1977). Ozaki and Sevastyanova (2011) argue that these approaches present a rational and linear relationship between consumer beliefs and environmental behaviours but limit perspectives for understanding consumer motivations in the case of alternative fuel vehicles.

With respect to transport innovations, it is a difficult task to test major change other than on a large scale, which in reality occur as part of a process rather than a single event in isolation (Ward, 1984), therefore giving an inaccurate indication of how change might take place. In trying to encourage behavioural change it is important for a range of choices to be available to the consumer (Kaplan, 2000) and for the consumer not to feel as though they have to make sacrifices for the common good. If too few make the sacrifice then everyone suffers (Dawes, 1980), or those who have made the sacrifice feel foolish (Kaplan, 2000). However, it is more likely that individuals will make a pro-environmental choice if they do not have to make a sacrifice (Kaplan, 2000). How alternative fuel vehicles can add value to consumers' lives, so that their adoption does not feel like a sacrifice is being made, is therefore a question that needs answering. Steg et al. (2001) suggest that affective-symbolic factors play a role in how people evaluate the attractiveness of car use (e.g. the need for self expression and social position). Consequently, in order to adopt pro-environmental behaviour, there needs to be an incentive or personal benefits for the consumer (Flynn et al., 2009; Lorenzoni et al., 2007). Concern for the health and wellbeing of future generations is also a reason for behavioural change (Flynn et al., 2009).

The findings of this section emphasise how an integrated approach combining technological change with behaviour change will be necessary to reduce transport's contribution to climate change (Anable et al, 2012). Kenworthy (2007) also argues that technological change alone is inadequate to allow cities to adapt to an age where oil is no longer available, which is confirmed by the complexities of consumer acceptance and attitudes informed by the studies above.

3.7 Managing consumer behaviour to promote the uptake of pro-environmental behaviour (including alternative fuel vehicle use)

A process for managing behaviour change is termed 'social marketing' (e.g. Kurani and Turrentine, 2002). Social marketing provides a framework for selecting the appropriate messages, media and methods, such as education, marketing and law.

Although technological advances will have an important role to play in meeting climate change and energy security objectives, behavioural change with respect to individual car use is also necessary (Haustein and Hunecke, 2007). Consumer behaviour, as a field of study, is relatively new (Solomon et al., 2002). However, it is influenced by multiple perspectives from a variety of academic disciplines, including psychology, human ecology, sociology, economics, history, business and anthropology (Solomon et al., 2002). Consumer behaviour has predominantly been studied from a marketing perspective, but more recently the understanding of consumer behaviour has been recognised as a pre-requisite for environmental protection (Ölander and Thøgersen, 1995). The complexity of the decision-making process involved in the consideration of environmentally friendly products (Englis and Philips, 2013) and pro-environmental lifestyles (Young et al., 2010) has resulted in confusion among consumers as to which practices they should be adopting. This presents behavioural scientists with a major challenge as to how to encourage environmentally responsible behaviour (Kaplan, 2000).

From a marketing perspective, the consumer decision-making process begins with need recognition or problem awareness, which includes functional as well as emotional and psychological needs (Jobber, 2001). For example, before a consumer purchases a new car, they would need to identify that they have a need or a desire to make the purchase (e.g. Solomon et al., 2002). The difference between the current and desired situation needs to be perceived as significant enough to bring about the motivation to move to the next stage in the consumer decision-making process – the information search (Jobber, 2001).

There is also the possibility that 'need inhibitors' exist which mean that the consumer is not aware of having a need for a specific product or service, which opens up an opportunity for marketing to stimulate a need by increasing the relative importance of purchasing a specific product relative to others (Jobber, 2001). Need identification and stimulation can also be made challenging when the purchase decision is made by a household, whereby each individual within the household plays a role in the decision-making process (Jobber, 2001). The individual who is responsible for making the purchase decision may not necessarily be the actual user (Solomon et al., 2002), for example, the case when a parent purchases a car for a son or daughter after passing their driving test, and the son or daughter could have a strong influence in the decision-making process.

It has been recognised that some decisions are made with a higher or lower involvement that requires the individual to use different cognitive processes that involve a different level of effort (Solomon et al., 2002). Solomon (2002) describes effort level as a scale, with routine response behaviour at one end through limited problem solving to extensive problem solving at the other end. The level of consumer involvement increases as the cost of the product or service increases (Solomon et al., 2002). It can, therefore, be assumed from Solomon's explanation that a new vehicle is high-involvement product. With high-involvement products, the consumer tends to gather as much information as possible to assist them in the decision (Solomon et al., 2002).

3.8 Attitudes towards climate change

Climate change is recognised as a problem by Government, and is considered an important driver of reducing car use (Hickman et al., 2010). Approximately half of the population in the UK recognise that there is a link between car use and climate change (Anable et al., 2006). In Europe, this figure stands at 80%, although this awareness is failing to translate into changing car use behaviour (van Rijnsoever et al., 2009).

Studies on the public awareness of climate change have largely shown that knowledge of environmental issues has a minimal impact on travel behaviour (Nilsson and Küller, 2000). The public have expressed a need for more information, particularly in relation to the choices available to them in order for them to be able to act in a way that will contribute towards mitigating climate change (e.g. Flynn et al., 2009; Whitmarsh, 2009). Many believe that climate change does not pose a significant personal threat for many years to come (Ockwell et al., 2009). Mistrust of the source of information has been recognised as an important element in the general public's poor level of commitment to pro-environmental behaviour (Ockwell et al., 2009; Flynn et al., 2009). This is reflected in the public's lack of trust of politicians who exploit environmental rhetoric at election time in order to win votes (Flynn et al., 2009).

Despite awareness of climate change issues increasing among members of the public, there is a tendency not to act in accordance with what they know is necessary to reduce the anthropogenic impact on climate change (Whitmarsh, 2009; Whitmarsh et al., 2011). In a study on car preferences, van Rijnsoever et al. (2009) found that despite nearly 70% of respondents having a positive attitude towards the environment, just over 10% of these individuals translated their attitudes into pro-environmental behaviours. The discord between stated beliefs and intentions and actual behaviour is referred to as the value-action gap (Flynn et al., 2009; and Schwanen et al., 2011), attitude-action gap (Lane, 2005; Lane and Potter, 2007) or the attitude-behaviour gap (Anable et al., 2006). This has been recognised in transport, whereby individuals have expressed dissatisfaction about the volume of traffic on the road and suggesting that they would drive less frequently, yet at the same time inferring that they could not go about their daily activities without a car (Jensen, 1999). Much of the research in the field of alternative fuel vehicle adoption has focused on attitudes or behaviour rather than on examining the relationship between the two (Lane and Potter, 2007).

The core values of individuals are determined to be at the root of climate change scepticism (Poortinga et al., 2011). The same observation was also made by Stern and Dietz (1994), who maintain that environmental attitudes are the product of an individual's value set. Consequently, Stern and Dietz (1994) propose there to be three value bases: egoistic values, altruistic values and biospheric values. Egoistic values are concerned with individuals trying to protect the environment from change if they believe it will have personal costs. Altruistic values are concerned with individuals trying to protect the environment from change if they believe it will adversely affect others. Biospheric values are concerned with individuals trying to protect the environment from change if they believe it will adversely affect non-human objects. Stern and Dietz (1994) argue that an appreciation of these values is important in order to focus political debate and especially for the role of social movements in shaping public support and concern.

Denial mechanisms have been reported in instances where people put up psychological barriers to justify reasons for not taking actions that may contribute to mitigating climate change because of the sacrifices they may have to make through doing so (Stoll-Kleemann et al., 2001). Some people feel as though climate change has already progressed too far and the damage is irreversible (Lorenzoni et al., 2007). Stoll-Kleemann et al. (2001) suggest nine types of denial that occur amongst the public to assuage guilt and justify resentment or anger. These are: displaced commitment, condemning the accuser, denial of responsibility, rejection of blame, ignorance, powerlessness, fabricated constraints, comfort and, "after the flood", which is where the individual asks "what is the future doing for me?". However, on the other hand, there may be a desire to behave responsibly that is impacted by a feeling of helplessness, and, as a consequence, such individuals may distance themselves from environmental issues (Kaplan, 2000). Kollmuss and Agyeman (2010) note that the need to establish distance from a problem stems from the individual's locus of control, such that those with a strong internal locus of control believe that their actions can influence change, while those with an external locus of control believe that their actions are unlikely to make a difference.

Communication campaigns have been used in the UK in an attempt to cultivate pro-environmental attitudes and promote behaviour change (e.g. the Energy Savings Trust's "Act on CO_2" campaign) and, although they have increased awareness of climate change issues, engagement with the public has been limited (Ockwell et al., 2009). More recent examples of campaigns are Connect4Climate (Connect4Climate, 2013) and Earth Hour (WWF, n.d.).

3.9 Attitudes towards alternative fuel vehicles

Although research on consumer response to alternative fuel vehicles is in its relatively early stages, the understanding of consumer attitudes and acceptance of such vehicles will be critical to their success (van Bree, 2010) and thus research in this area continues to grow.

3.9.1 Consumer uncertainty and risk

The variety of proposed new technologies for vehicles can create confusion for consumers. The vehicle-manufacturer, Mercedes-Benz, recently undertook a survey in the US, which found that nearly half of participants are delaying the purchase of an alternative fuel vehicle and are confused about the differences between the various technologies (Montvale, 2010). The confusion experienced by consumers is influenced by a lack of policy consistency in the market place for energy technologies (Brown & Chandler, 2008) and a shift in technology choices over time, which has also caused confusion among vehicle manufacturers as to which technology to invest in (Michigan Department of Transportation, 2011). Schwanen et al. (2011) note that there is a great deal of uncertainty surrounding alternative fuel vehicle technologies, which makes it challenging to predict which facets of behaviour and routine will have to change. Bakker (2010) blames the car industry for generating hype for hydrogen vehicles over the past four decades, which created high expectations for the technology. Bakker raises the question as to whether the technology is pushing its limits and maintains that hydrogen technologies have not lived up to expectations. Romm (2006) also argues that hydrogen is overestimated and will be unable to live up to expectations.

When investing in a new and unfamiliar technology the consumer must take a risk, and the level of risk associated with the investment will therefore have an impact on the technology's ability to be successful and to fulfil consumer expectations (Schulte et al., 2004). In one of the risks identified by Flynn et al. (2006), and applicable in the case of alternative fuel vehicles, is the uncertainty of future consequences when making a decision. A more elaborate explanation of risk associated with investment specific to transport innovations is made by Ward (1984), who identified three types of risk: the first is that the technology will not meet the performance and cost expectations, the second that the market response to the innovation is poorer than anticipated leading to poor revenues, and the third risk is the impacts of the innovation that cannot be predicted, such as spatial development patterns. The more specialised an innovation is, the more limited an individual's risk assessment will be (Purcell et al., 2000), which may lead to misperceptions of risk. Poortinga et al. (2011) maintain that a transition to a low carbon economy rests heavily upon addressing the perceptions and attitudes of the public. For electric vehicles, one of the risks linked to uncertainty stems from the vehicles not yet having undergone a full lifetime in real-life conditions (FCH-JU, 2010). In the literature there are functional and psychological risks associated with adopting alternative fuel vehicles, which are shown in Table 3.1.

Table 3.1 *The functional and psychological risks for consumers of alternative fuel vehicle adoption*

Functional risk	Financial risk	Ziegler, 2012; Graham-Rowe et al., 2011; Karplus et al., 2010; Yasumoto-Nicolson, 2008; Lane and Potter, 2007; Shears, 2007; Zegers, 2006
	Performance risk	Ziegler, 2012; Shepherd et al., 2012; Yasumoto-Nicolson, 2008; Lane and Potter; Shears, 2007; Zegers, 2006
	Infrastructure risk e.g. refuelling	Ziegler, 2012; Shears, 2007
Psychological risk	Uncertainty of future consequences	Schwanen et al., 2011; Flynn et al. 2006
	Image/ visual identity	Graham-Rowe et al., 2012; Yasumoto-Nicolson, 2008; Lane and Potter, 2007
	Change to lifestyle/routine/behaviour	Ricci et al., 2008; Jackson, 2005; Stoll-Kleemann et al., 2001
	Safety	Shaheen, 2008 Ricci, 2006 Mourato et al., 2004

When buying a new car and being faced with the choice of a conventional vehicle or an alternative fuel vehicle, socio-cultural forces that favour socially desirable behaviours may influence the willingness of consumers to invest in new transport technologies (e.g. Collins et al., 2010). The challenge lies in the scepticism that individuals feel about having to make sacrifices and change their behaviour for the benefit of the environment (Ricci et al., 2008). Therefore, an electric vehicle or a hydrogen vehicle needs to be seen as having an advantage over a conventional petroleum engine vehicle. Rogers (2003) refers to this concept as 'relative advantage', which is 'the degree to which an innovation is perceived as being better than the idea it supersedes' and is determined by 'economic profitability, social prestige, or other benefits'.

In order to understand the more specific responses associated with acceptance of alternative fuel vehicles, the two that are considered zero emissions vehicle technologies will now be investigated. These two vehicle technologies have been found to invoke different responses due to their varying characteristics.

3.9.2 Acceptance of hydrogen fuel cell vehicles

The majority of vehicle manufacturers have a fuel cell car development programme in place (Lane, 2006). However, there are concerns as to the degree of acceptance of hydrogen among the public (Schulte et al., 2004). A significant hurdle in understanding consumer response to hydrogen vehicles is that they are not yet commercially available, and the point at which this will happen remains uncertain (e.g. Lane, 2006).

Until more recently, the research into hydrogen acceptance has been relatively limited. Many of the earlier studies have been undertaken in Germany (e.g. Altmann and Graesel, 1998; Dinse, 1999; Dinse, 2000; Lossen et al., 2003). The summaries of these earlier studies are summarised in Table 3.2. A common finding in the studies is the poor awareness of hydrogen, particularly in transport applications. In most cases the level of acceptance was positive, but often, respondents (other than the BMW employees in Dinse, 2000) felt they were not well enough informed about the technology.

Since these earlier studies, several other hydrogen studies have emerged. The first UK study on hydrogen acceptance by Mourato et al. (2004) involved a survey to investigate the preferences of taxi drivers for driving a hydrogen vehicle. Over half of the taxi drivers had heard of fuel cells although their knowledge of fuel cells was poor. Generally the taxi drivers showed a positive attitude towards fuel cell taxis and showed a willingness to participate in a pilot survey. They did not object to the limited range, and showed little concern about the safety of fuel cell vehicles. Shaheen (2008) also found safety not to be a major concern. Ricci (2006) suggests that public safety concerns for hydrogen vehicles is more of a preoccupation of researchers than the public themselves.

Table 3.2 *Summary of early hydrogen acceptance studies*

Hydrogen Acceptance Project	Researcher(s)	Details of study	Findings
HyWeb (Munich, Germany)	Altmann and Graesel (1998)	Three-part study with hydrogen bus passengers and secondary school children to ascertain: - Level of acceptance for hydrogen technologies. - Knowledge and understanding of hydrogen technologies and associations with these technologies. - Demand for information about hydrogen technologies.	High level of acceptance among hydrogen bus passengers and among secondary school students. Hydrogen is not spontaneously associated with danger or with past incidents. First study found students had a low level of knowledge about hydrogen and demanded more information.
Acceptance of hydrogen fuel cell vehicles (Institut für Mobilitätsforschung, Germany)	Dinse, G (1999)	Street interviews in Berlin to random sample with general questions relating to hydrogen awareness and associations.	High levels of acceptance of hydrogen-based transport despite low levels of knowledge. Positive relationship between knowledge and acceptance of hydrogen vehicles.
Hydrogen fuel cell vehicles and their application (Institut für Mobilitätsforschung, Germany)	Dinse, G (2000)	Employee survey at BMW to explore how to increase the acceptance of hydrogen vehicles and hydrogen fuel	Hydrogen vehicle technology is highly accepted. Higher qualified employees, particularly male, showed a more positive, open-minded view of the technology.
Factors influencing the market success of vehicles powered by hydrogen	Lossen et al. (2003) Bayerische Eliteakademie, Munich, Germany	Qualitative interviews with high-level executives from science, industry and the public sector. Internet survey to representatives of popular media websites.	The personal and societal advantages of hydrogen cars were assessed as medium to low. Some reservations were noted with respect to safety but these were limited. Respondents felt they were not well informed about hydrogen. The level of education was found to have a high influence on acceptance.

O'Garra et al. (2005) undertook a study in London that explored the awareness and attitudes of local residents to hydrogen vehicles. This study found that awareness of hydrogen vehicles was very low as well as the awareness and understanding of wider environmental issues. Associations with hydrogen were largely neutral, although marginally more positive than negative, with older respondents having more negative associations with hydrogen. A need for more information has been commonly cited across both hydrogen and electric vehicle acceptance studies, although precisely what information is needed by the general public has rarely been asked (Ricci et al., 2008).

Low awareness, or understanding, has been a common factor in hydrogen acceptance studies (Dinse, 1999; Dinse 2000; O'Garra et al., 2005; Ricci et al., 2008; Yetano Roche et al., 2010). Only one study appears to have found a weak connection between knowledge and acceptance, and that was an early hydrogen acceptance study undertaken by Altmann and Graesel (1998). A correlation between awareness of hydrogen vehicles and gender, age, education and environmental knowledge, has been observed by O'Garra et al. (2005), However, they note that their sample was biased towards educated and high-income respondents. Less than 45% of their study population were aware of hydrogen vehicles, but those who were aware tended to be older males who had received a university education. In a stated preference survey in Germany, individuals with a good environmental awareness had a higher stated preference for hydrogen and electric vehicles, which was particularly the case for males (Ziegler, 2012).

Direct contact with the technology has a positive influence on acceptance (Shaheen, 2008; Mourato et al., 2004; Altmann and Graesel, 1998). This is supported by Rogers' (2003) Diffusion of Innovations theory, that recognises the ability to observe the innovation being used and also to trial it as important factors in determining technology adoption. This was, however, not the case for the Clean Urban Transport for Europe (CUTE) project (O'Garra, 2005), which ran a series of bus pilot projects across London, Luxembourg and Berlin. Experience and exposure to hydrogen transport did not appear to influence an individual's acceptance any more so than an individual who had not had direct experience or who had previously never heard of a hydrogen bus.

A study that reports a poor acceptance of alternative fuel vehicles is Ziegler (2012), who found that potential car buyers in Germany had a low stated preference for hydrogen and electric vehicles. It is noted that the lack of charging infrastructure, the high cost of batteries, limited driving range and a short battery lifetime are affecting acceptance of electric vehicles.

The acceptance of hydrogen technology depends on a personal perception of risk, which may be very different from scientific risk (Schulte et al., 2004). Risk in the context of danger is likely to be the focus of people's attention when faced with a new technology (Purcell et al., 2000). The safety issues of hydrogen therefore need to be clearly communicated to the public, although it is the responsibility of the research community and policy makers to minimise and mitigate risk wherever possible. One major disaster may blight the future of hydrogen, for example, associating hydrogen with events such as the Hindenburg disaster (e.g. Shaheen et al., 2008). Consideration also needs to be given to the production of hydrogen using nuclear energy. Nuclear disasters, such as Fukushima in 2011, have led to opposition to nuclear energy (Kim et al., 2013). Regardless of how safe it may become in the future, the success of the hydrogen economy will be affected if the production method is not accepted by the public.

Despite poor levels of awareness of hydrogen applications, many of the studies have found acceptance among the public to be good. This may be taken as a positive sign, in that once made aware of hydrogen, individuals and groups have developed high levels of acceptance. Caution should, however, be taken in the interpretation of the results of hydrogen acceptance in the literature due to high frequency of 'no opinion' responses that have presented themselves in many of the attitudinal studies (Ricci et al., 2008). Low awareness demonstrates the need for education and marketing programmes to increase public awareness of hydrogen vehicles if they are, one day, to be successful in the market.

3.9.3 Electric vehicles

The commercial availability of electric vehicles in the marketplace enables opinions and acceptance to be studied more reliably (than hydrogen vehicles). Following a week-long trial of battery electric vehicles and plug-in hybrid electric vehicles, in a study by Graham-Rowe et al. (2012), participants were mainly concerned about cost minimisation and the uncertainty of the durability of the vehicles. The environmental benefits of using these vehicles were not highly valued. More influential, was whether the vehicles would meet the participants' needs in terms of battery range and driveability. However, Egbue and Long (2012) identify that there is a gap between consumer expectations of driving range of an electric vehicle and the driving range actually covered on a daily basis. It was also shown that if the speed of recharging the battery significantly improves, the expectations of range will be lowered. A term used for concerns relating to range is 'range anxiety' (e.g. Pearre et al., 2011; Carley et al., 2013). The visibility of recharging stations within a community was discovered by

Carley et al. (2013) to have a significant effect on the awareness of plug-in vehicles, who suggest that increasing the number and visibility of charging points will be an important factor in reducing range anxiety.

Although cost of the vehicle is a key concern when it comes to electric vehicles (Lane and Potter, 2007), the concern for cost and range varies depending on vehicle use and type (Lieven et al. 2011). Price, for example, was an important consideration for micro cars but less so for executive cars. Range was not an important consideration for micro cars, leisure cars such as sports vehicles or off-road vehicles, but considered very important for luxury cars. It is not only costs, however, that have been found to be a barrier to consumer acceptance of electric vehicles; limited vehicle range, poor choice of vehicles, vehicle charging concerns and vehicle safety have also been found to be key barriers to plug-in hybrid electric vehicle purchase in the US (EPRI, 2010).

Battery leasing can help to minimise vehicle cost and reduce investment risk, and is estimated to cost approximately £60-70 per month but this cost is likely to cancel out the savings on fuel (Lane, 2006). Research by EPRI (2010) notes that leasing has a mixed response from consumers. Some consider it to be a more cost-effective approach than buying a battery, while others are concerned about possible enforced limits on mileage and the risk of the leasing company going out of business.

The key benefits of electric vehicles perceived by consumers are the savings in petroleum oil they would bring, lower vehicle emissions, and the environmental impacts (EPRI, 2010). In line with these recognised benefits, focusing on fuel expenditure in the advertising of electric vehicles rather than fuel economy, is argued by Musti and Kockelman (2011) to be more likely to realise a shift towards more sustainable choices. In a study by Egbue and Long (2012) the sustainability and environmental performance of electric vehicles was questioned by those who were considered technologically-minded, a question, that the authors conclude, may also be asked by those with high environmental awareness.

One of the difficulties in trying to bring about behavioural change towards the adoption of alternative fuel vehicles, is that many of the existing consumption patterns are unsustainable, and people are finding themselves locked in to them (Jackson, 2005), such as with internal combustion engine vehicles (van Bree et al., 2010; Cowan and

Hulten, 1996). The problem stems not only from the economic, political and technical barriers that are hindering the diffusion of more sustainable technologies with reduced carbon emissions (Unruh, 2000) but also from social factors such as values, norms, habits, routines and expectations (Jackson, 2005). Symbolism and social status, identified by Lane and Potter (2007) as a key factor in reinforcing anti-environmental travel behaviour, was determined not to be delivered by the aesthetics and visual identity of electric vehicles by Graham-Rowe et al. (2012). However, some participants in the study by Graham-Rowe et al. felt it symbolised their commitment to the environment. Similarly, Lane and Potter (2007) found that some drivers wish to advertise their 'green' credentials, such as through the purchase of a G-WIZ electric quadracycle, while a Prius driver indicated a preference for a less conspicuous vehicle.

3.9.4 Barriers to alternative fuel vehicle adoption

Consumers are becoming increasingly aware of the impact of their purchase decisions on the environment (Laroche et al., 2001) and pollution reduction has been identified as a reason for purchasing environmentally beneficial goods (Hidrue et al., 2011). However, environmental benefits were not readily mentioned as a reason for purchasing a Toyota Prius (hybrid vehicle), but rather financial gain was the main reason (Ozaki and Sevastyanova, 2011). Similarly, expected fuel savings was the main motivation for considering an electric vehicle (Hidrue et al., 2011) and Lane and Potter (2007) also found environmental issues have a low priority when purchasing a new car. Despite the potential environmental gains in the uptake of alternative fuel vehicles, the transition away from conventional vehicles requires the user to make sacrifices in terms of price and range (Gärling and Thøgerson, 2001), creating tough market conditions for alternative fuel vehicles.

Eco-innovations (refer to section 3.2.3) will not achieve the objective of reducing anthropogenic impacts on the environment if they fail to be adopted or lifestyles do not change to support such objectives (Jansson, 2011). It is, therefore, essential for marketers to recognise who the potential early adopters of the product are (Goldsmith and Flynn, 1992). Hellström (2007) describes eco-innovations as being largely niche innovations that are market-demand driven, although Rennings (2000) implies that market demand for eco-innovations is weak and requires regulatory support to overcome this.

Consumer culture has become a dominant culture in modern societies perpetuated by a need for individuals to create status and distinction (Thøgerson, 2005), which offers a potential opportunity for alternative fuel vehicles. Gärling and Thøgerson (2001) suggest that for an alternative fuel vehicle, the target market at this early stage in their development should be eco-conscious consumers. To appeal to eco-conscious consumers, Jansson's (2011) findings indicate that, not only does an eco-innovation need to satisfy pro-environmental objectives but it must also satisfy the traditional expectations of a vehicle, such as safety and reliability. A further finding is that nearly all adopters of an alternative fuel vehicle described their vehicle as being environmentally friendly (Jansson, 2011).

Poor public awareness is an obstacle to the acceptance of alternative fuel vehicles (see Section 3.9.2 and 3.9.3) but one which will be reliant on effective marketing to educate the public in order to enhance awareness and familiarity (Schulte et al., 2005). Presently there are no, or very few, public awareness raising activities relating to fuel cells, which means that levels of awareness of both the public and decision makers are limited (Synnogy, 2005). In the UK there has never been a hydrogen public awareness building campaign (Cherryman et al., 2008). Due to the varying levels of awareness across different demographics it is argued that information campaigns and education initiatives need to be targeted and differentiated (O'Garra et al., 2005). Following an untargeted ten-year education campaign to promote electric vehicles in California, there was an increase in the number of those who considered electric vehicles not to be 'clean' (Kurani and Turrentine, 2002), which emphasises a need for more targeted campaigns. It is argued that campaigns should focus specifically on the vehicle rather than on 'generalist environmental goals' (O'Garra et al., 2005) and a 'skilful' marketing approach will be required to bring about consumer acceptance and diffusion of these vehicles (Gärling and Thøgerson, 2001).

In encouraging the adoption of environmentally friendly products, Englis and Phillips (2013) suggest that there is a need for marketing messages to emphasise the 'new and unique' characteristics of the product, indicating that consumers may show more interest and acceptance if the products represent new ideas. Lane and Potter (2007) advise that purchase price, long payback times, ease and convenience of use should serve as 'hotspot' factors for leveraging low carbon products.

3.9.5 Reducing the barriers to adoption

Already noted as reducing the financial risk is battery leasing (Section 3.9.3), while another alternative is exposure to alternative fuel vehicles through a car club business model. Car clubs enable consumers to familiarise themselves with electric vehicles over a long period of time without having to financially commit to buying the vehicle, as well as having the potential to raise their profile through the high utilisation rates of car club vehicles (Hazeldine et al., 2009).

Hackbarth and Madlener (2013) assert that a combination of measures will be necessary to encourage the adoption of zero-emissions vehicles. These include incentives, such as tax exemption and free parking, a purchase premium of €5,000, an increase in fuel availability to 100% and a decrease in battery charging time to 7.5 minutes. Tax and parking incentives are already in place in the UK, but have struggled to make a considerable impact on uptake so far, as section 1.2 demonstrated.

3.10 Early adopters of alternative fuel vehicles and their socio-demographic characteristics

Early adopters are defined as those who adopt early (McDonald and Alpert, 2007) and are innovative in their behaviour (Rogers, 2003). Rogers describes innovativeness as "the degree to which an individual is relatively earlier in adopting new ideas than other members of a (social) system'' (Rogers, 2003, pg 22). However, McDonald and Alpert (2007) criticise the definition for failing to offer any real insight into understanding the reasoning prior to the adoption of an innovation and therefore offering no indication as to who might adopt a new innovation prior to its launch. They argue that categorisation of adopters cannot occur until after the diffusion process has taken place.

A distinction that has been made regarding early adopters is to do with the information source that influences the adoption decision (McDonald and Alpert, 2007). For example, the adoption decision of some early adopters is influenced by mass media communications, whereas adoption by others is influenced by interpersonal communications, such as word-of-mouth (McDonald and Alpert, 2007). Bass (1969) refers to early adopters as imitators of the innovators. After the innovators, early adopters are the second wave of adopters, and constitute approximately 13.5% of final total of innovation adopters (Rogers, 2003).

Research into profiling the early adopters of alternative fuel vehicles is rather limited, with a strong leaning towards electric vehicles. Lane and Potter (2007) stress the need for further research to confirm the role of UK early adopter segments and how these individuals can be encouraged to adopt alternative fuel vehicles, suggesting there is a need for targeted incentives.

Following a study of consumer awareness and purchase barriers of vehicle owners in the US, along with interviews with executives from vehicle manufacturers, car dealers and energy companies, Deloitte (2010) pinpointed the characteristics of those most likely to purchase electric vehicles between 2011 and 2020. They identified the profile of early adopters as being young, having a very high household income (in excess of $200,000, equivalent to £117,000), and already owning more than one vehicle. The early majority, which is those who constitute the early phase of mass adoption, also have a very high household income of around $114,000 (£67,000), are more likely to be male, drive an average of 100 miles per week, and have a garage with power. These people live in urban and suburban locations, perceive electric vehicles to be ''green and clean'' and they are influenced predominantly by the reliability of the vehicle. According to Deloitte, there is a population of 1.3 million people in the US that fit this profile, with a concentration in California where there is already electric vehicle charging infrastructure to support vehicle use. The Deloitte (2010) study also revealed a predicted profile of 'non adopters', constituting those who have low household incomes and are price sensitive. The majority of 'non adopters' do not have a garage, creating a challenge for secure home charging. Nemry and Brons (2010) suggest that a lack of charging infrastructure will inhibit market penetration until 2020 at the earliest.

Price is likely to be a major factor in determining who the early adopters of alternative fuel vehicles will be. A survey of 1,000 car owners conducted by Low CVP (2010) found that the median car price paid by those who had recently bought a new or nearly-new car was between £11,000 and £15,000, which falls significantly below the price of an electric vehicle. The high cost of alternative fuel vehicles was found to be a prohibitive factor for individuals considering plug-in hybrid electric vehicles in research by Karplus et al. (2010). They suggest that price premiums need to be significantly reduced to make them commercially viable. Price was also noted as top of purchase criteria in an opinion survey undertaken by Musti and Kockelman (2011) in Austin, Texas. However, Carley et al. (2013) identify income as not being significantly associated with stated intent to purchase a plug-in vehicle.

Hidrue et al. (2011) undertook a nationwide (US) survey, part of which looked at the demographics of electric vehicle drivers. Variables which increased a respondent's electric vehicle orientation include: being of a younger or middle-aged age category; having a Bachelor's or higher degree; expecting higher fuel prices in the next five years; having made a shopping or lifestyle change to help the environment in the last five years; having a place they could install an electric vehicle electrical outlet at home; being likely to buy a small or medium-sized passenger car on next purchase; and having a tendency to buy new products that come on to the market. They note that the number of vehicles per household and the type of residence are important variables in electric vehicle choice. With respect to education, O'Garra et al. (2005) also identified that being highly educated is strongly linked to an individual's likelihood of having prior knowledge of new vehicle technologies. Being young and well-educated was pin-pointed as an important characteristic by Hackbarth and Madlener (2013) who suggest that such individuals should comprise the target market. Similarly, as education level reduced, the interest in in plug-in vehicles also reduced in a study by Carley et al. (2013).

In the early phase of electric vehicles, Gärling and Thøgerson (2001) suggest targeting three market segments; public sector organisations, eco-conscious companies and multi-car households, constituting an early adopter market of over 2.5%. They argue that multi-car households may offer significant opportunities for electric vehicle sales because the household possesses one or more conventional vehicles that can be used for journeys currently beyond the range of electric vehicles. This research supports the work of Kurani et al. (1995) who, in their Neighbourhood Electric Vehicle Drive Trials study, found that many households would consider an electric vehicle if they incorporated it into their existing 'household vehicle fleet', so that there was always an option of an internal combustion engine vehicle for long-range journeys. In a more recent study, Graham-Rowe et al. (2012) found the same attitudes still remain; consumers find the range of current battery electric vehicles too restrictive to have the electric vehicle as the only household vehicle, but rather as a second vehicle that can be used to make short, local journeys. For this reason Hackbarth and Madlener (2013) suggest that marketing strategies should focus on urban consumers.

The age characteristics of a hybrid-electric vehicle driver in research undertaken by Ozaki and Sevastyanova (2011) in collaboration with Toyota, involving a survey of buyers of the Toyota Prius, contrasts with both Deloitte's (2010) predicted 'early adopter' age profile and the age characteristics identified in a study of electric vehicle drivers by Hidrue et al. (2011). The majority of Toyota Prius vehicle owners in their survey were men aged 50 and over, which was found to be a true representation of Toyota GB's hybrid customers. The survey results also showed household composition of hybrid vehicle owners tends to be retired (couple or single), with a net monthly household income of over £4,000, and owning more than one vehicle. The contrast in findings between Ozaki and Sevastyanova (2011), Deloitte (2010) and Hidrue et al. (2011) may have been influenced by other factors, such as branding of the Toyota Prius, perhaps leading to it appealing to a slightly older market. Again, there is a contrast in the results of Hidrue et al.'s (2011) research and that of Ozaki and Sevastyanova (2011) when it comes to income and car ownership, whereby Hidrue et al. (2011) identify income and owning more than one car as not being significant in increasing electric vehicle orientation. Ozaki and Sevastyanova (2011) suggest that their survey results may have been affected by the uncertainties associated with the economic climate at the time of the survey (2009), when the respondents' financial prospects may not have been as good as when they purchased a Toyota Prius in 2007 or 2008.

With the exception of Williams and Kurani (2006), there has been little research into profiling who the early adopters of hydrogen vehicles are likely to be. Williams and Kurani (2006) conducted a study looking at Californian residents to estimate the early market potential for hydrogen fuel cell vehicles. They identified the consumers most likely to benefit from 'mobile energy' innovations, such as vehicle-to-grid technology to create 'mobile electricity'. The authors suggest that consumers will be more likely to make supporting modifications and investments in the required infrastructure if they own their homes and have parking facilities close by. They also recognise the initial price premiums associated with new vehicle and mobile energy technologies, and therefore choose not to consider unemployed households, or households with no income, as target consumers.

Table 3.3 provides a summary of the early adopter characteristics associated with alternative fuel vehicles.

Table 3.3 *Summary of alternative fuel vehicle early adopter characteristics*

Characteristics	Author
1. Younger and middle-aged individuals	Deloitte (2010); Hidrue et al. (2011).
2. High household income	Musti and Kockelman (2011); Karplus et al. (2010); Deloitte (2010)
2. High level of education	Hidrue et al. (2011); O'Garra et al. (2005).
3. Home owner	Williams and Kurani (2006).
4. Multiple vehicle owner	Graham-Rowe et al. (2012); Ozaki and Sevastyanova (2011); Deloitte (2010); Gärling and Thøgerson (2001); Kurani et al. (1995).

3.11 Summary of the literature

As relatively new technologies, this is an emerging area of research offering substantial scope to make contributions to knowledge. There are two key alternative fuel vehicle technologies that will enable the transport sector to become decarbonised and contribute to the Climate Change Act target of an 80% reduction in greenhouse gas emissions in the UK (section 3.5.2) - electric vehicles and hydrogen fuel cell vehicles. The transition to vehicle technologies with zero tailpipe emissions also addresses the objective of reduced fossil fuel dependency (Romm, 2006). As stated in section 3.3, both technologies face a number of obstacles in terms of their ability to compete with conventional fuel vehicles, principally relating to high cost, limited vehicle range, and lack of supporting refuelling infrastructure. Access to electricity via the grid has enabled the commercialisation of battery electric vehicles much sooner than hydrogen fuel cell vehicles, for which the obstacles of hydrogen production and distribution (section 3.3.4) have so far inhibited the availability of these vehicles for public consumption.

Alternative fuel vehicles have been termed eco-innovations (section 3.11) due to their ability to contribute to satisfying environmental objectives. The low levels of uptake of electric vehicles (section 1.2) are challenged by the difficulties in changing consumer behaviour to adopt more sustainable practices (e.g. Schwanen et al., 2011; Steg and Gifford, 2005; Thøgerson, 2005). The decision-making process involved in the consideration of pro-environmental innovations is complex (Englis and Philips, 2013), making it problematic to identify how consumers can be influenced to adopt alternative fuel vehicles. The decision is likely to be affected by the risk and uncertainty associated with adopting new technology (section 3.9.1), which concerns financial risk, performance risk, uncertainty of future consequences, image, and the changes to lifestyle that may be required.

The adoption of an alternative fuel vehicle must not be perceived as requiring sacrifices to be made (e.g. Ricci et al., 2008) and must, therefore, have characteristics that will be more highly valued than conventional fuel vehicles, particularly cost-minimisation (Graham-Rowe et al., 2012). As section 3.9.3 illustrated, the environmental benefits offered by alternative fuel vehicles are not highly valued. Section 3.9 emphasised the barriers to consumer acceptance as being low awareness, high purchase price, limited vehicle range, poor choice of vehicles, concern about infrastructure, and vehicle safety.

In section 3.10 an early adopter profile for alternative fuel vehicles was identified, with the most important characteristics defined as younger or middle-aged individuals, high household income, high level of education, home owner and a multiple vehicle household. Lane and Potter (2007) stress the need for further research to confirm the role of UK early adopter segments and how these individuals can be encouraged to adopt alternative fuel vehicles.

The key findings of this literature review have determined the following gaps:

1. Consumer knowledge and awareness of alternative fuel vehicles is recognised as being limited. However, it is likely to evolve as consumers become increasingly aware of climate change and more alternative fuel vehicles become

commercially available. On-going research on consumer knowledge and awareness of alternative fuel vehicles is, therefore, necessary.

2. There are limited studies that establish a profile of an early adopter for the purpose of market segmentation.
3. Consumer perceptions and attitudes towards alternative fuel vehicles must be addressed on an on-going basis in the same way as knowledge and awareness. It is possible that perceptions and attitudes will also evolve in time.
4. Alternative fuel vehicles have largely been framed in acceptance studies as eco-innovations, focusing on their environmental attributes. There is scope to examine alternative fuel vehicles simply as innovations for which the technological attributes should also be a key element.
5. Approaches to improving consumer acceptance of alternative fuel vehicles in order to quicken their uptake remain to be established.

The gaps identified will be overcome by focusing on individuals who have the early adopter characteristics shown in Table 3.3. The knowledge and perceptions of these individuals towards alternative fuel vehicles will be examined to identify what factors are influencing consumers' adoption of these vehicles. Alternative fuel vehicles will be addressed in the research as innovations, such that they are new technologies. The gaps in the literature review will therefore form the basis for the research of this thesis and the methodology and methods that will be used to contribute to filling these gaps in knowledge will be addressed in the two subsequent chapters.

Chapter 4: Theoretical principles of diffusion theory

4.1 Introduction

In Chapter 1, the problems associated with transport use in the environmental context were highlighted. Chapter 2 presented how UK and international policy states that a transition to new low-carbon technologies, such as electric vehicles and fuel cell vehicles will be necessary to achieve an overall reduction in carbon emissions. However, the uptake of low-emissions vehicles has been slow. In Chapter 3, it was identified in the literature that there are gaps in understanding when it comes to consumer knowledge of, and attitudes towards, alternative fuel vehicles. As such, an approach that addresses factors influencing adoption of a new idea or 'innovation' is diffusion theory. The purpose of this chapter is to give an overview of the key components of diffusion theory. Rogers' (2003) Diffusion of Innovations theory forms the theoretical background to the research within this thesis. In Section 4.2 an overview of applications that use this theory will be presented, followed in Section 4.3 with an overview of its use with alternative fuel vehicles. Section 4.4 presents a justification for its use. An introduction to the theory itself is provided in Section 4.5 and the Innovation-Decision Process of this Theory is presented in Section 4.6. A brief summary is provided in Section 4.7.

4.2 Applications of diffusion theory

Innovation diffusion theory seeks to understand the social processes that occur during learning and communication as an innovation becomes widely used, or alternatively fails to diffuse (Turrentine and Sperling, 1992). The adoption of a new idea, behaviour or innovation has been of interest in academic research for quite some time, with diffusion theories having been applied using a variety of perspectives and interdisciplinary approaches, such as in rural sociology (e.g. Ryan and Gross, 1943) public health (Coleman et al., 1957) marketing and communication (e.g. Bass, 1969), and in information technology (e.g. Moore and Benbasat, 1991). The broad range of disciplines has required the theory to be adjusted and tailored in each application in order to account for contextual differences (Fichman, 1992). More recently it has been applied to ecological innovations, with contributions from economics (e.g. Rennings, 2000), psycho-socio disciplines (e.g. Jansson, 2011; Kaplan, 1999), marketing (e.g. Ottman et al., 2006) and economics (agent-based modelling) (e.g. Dijk et al., 2013).

Until 2000, Karakaya et al. (2014) found little evidence of publications relating to eco-innovations but in 2011, 22% of the publications that referenced Rogers were on eco-innovations. The majority of these publications have come from Ecological Economics, journal of Cleaner Production, and Technological Forecasting & Change, with no significant number of publications coming from transport journals. In spite of this, a study by Graham-Rowe et al. (2012) on consumer response to alternative fuel vehicles in the Transportation Research journal is found to be the 17th most frequently cited publications on eco-innovations.

There are predominantly four strands of criticism of diffusion theory research, which Rogers (2003) outlines as follows:

1. The pro-innovation bias – an implication of researchers that an innovation is positive and should be adopted by all members of a social system.
2. The individual-blame bias – whereby the research has focused on individuals as being responsible for their problems rather than the social system of which they are a part.
3. The recall problem - the difficulty of respondents of the research to remember the moment at which they adopted the innovation.
4. The issue of equality – access to an innovation may vary according to socio-economic gaps in a particular social system, and these gaps may be widened as a consequence of the innovation.

The pro-innovation bias has largely been the result of research undertaken on a post hoc basis and has therefore tended to focus on innovations that have been successful (Rogers, 2003; Turrentine and Sperling, 1992; Ram and Sheth, 1989). However, Sheth (1981) raises the point that in reality many innovations will fail, indicating that there is a need for research to consider innovations regardless of how successful or unsuccessful they might be if diffusion is to be better understood.

4.3 Alternative fuel vehicle applications of diffusion theory

One of the earliest references to diffusion theory in conjunction with alternative fuel vehicles is the review of theories for new technology purchase decisions undertaken by Turrentine and Sperling (1992). They recognise that the strength of the Diffusion of Innovations theory is the relationship between information and influence between consumers in new product markets. Identifying innovators is considered to be a central task of Diffusion of Innovation research (Turrentine and Sperling, 1992). The authors suggest that the diffusion of alternative fuel vehicles will follow a bell-shaped curve (see Figure 4.1), with the earliest adopters being experimenters, followed by imitators, then choice simplifiers and finally compensatory choosers.

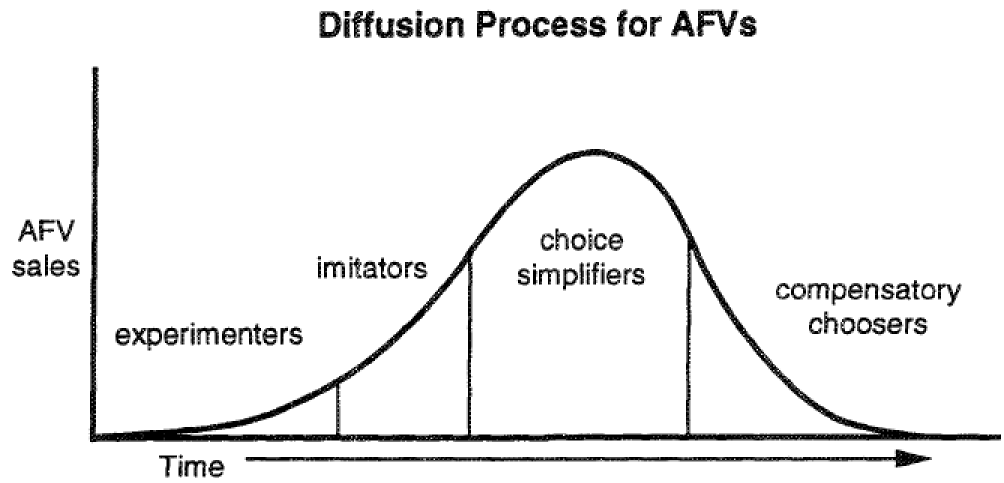


Figure 4.1 *Diffusion Process for AFVs. Taken from Turrentine and Sperling (1992)*

Alternative fuel vehicles have been referred to as 'eco-innovations' in recent diffusion literature in this topic area (e.g. Jansson, 2011; Albino et al., 2009; Hellström, 2007). Jansson (2011) indicates concern about its applicability for eco-innovations, suggesting that Rogers' diffusion framework does not account for high-involvement products that involve green-purchase decisions. However, Englis and Philips (2013) determine that the 'affinity for new ideas' or, innovativeness, which is one of the key attributes in the diffusion process, is a strong predictor of pro-environmental behaviour. Similarly, Morton (2013) notes that innovativeness is a key feature in determining preferences for alternative fuel vehicles. The number of studies applying the Diffusion of Innovations theory to eco-innovations remains relatively limited, a finding also supported by Karakaya et al. (2014) who maintains that there is a gap in understanding diffusion in the context of eco-innovations. They note the need to focus on the understanding of consumers' behaviour and the decision process.

Some authors choose to apply elements of Rogers' Diffusion of Innovations theory due to it offering several 'sub theories', which Yates (2001) defines as:

1. The Innovation-Decision Process Theory
2. The Individual Innovativeness Theory
3. The Theory of Rate of Adoption
4. The Theory of Perceived Attributes.

In this respect, Englis and Philips (2013) analyse innovativeness and pro-environmental behaviour, and Morton (2013) assesses the influence of innovativeness on preferences for the different alternative fuel vehicle technologies.

Lane and Potter (2007) investigate the attitude-action gap when it comes to the adoption or rejection of alternative fuel vehicles, focusing specifically on the perceived characteristics element of the Diffusions of Innovation theory. To support their examination, additional factors relating to utility, interconnectedness and symbolism were incorporated. A further alternative fuel vehicle study that relies on the use of Rogers' theory is Ozaki and Sevastyanova (2011), who apply it in the context of consumption and focus on 'motivational constructs' to discover the meanings attached to the Toyota Prius. They argue that Rogers' theory allows the rational and affective aspects that contribute to consumers' decisions to adopt a sustainable innovation to be investigated.

Rogers (2003) criticises existing diffusion literature for failing to investigate the interdependence that may exist between certain innovations, remarking that most diffusion studies have investigated innovations in isolation without considering how closely interrelated elements of technology, or 'technology clusters', diffuse through the individual's system. This suggests that there may be a need to consider new vehicle technologies as a group rather than necessarily as individual innovations. It has also been noted that there is a need for more diffusion studies relating to the perceived attributes of innovations and the innovation-decision process (Ostlund, 1974; and Tornatzky and Klein, 1982). In this respect, it may be necessary to evaluate alternative fuel vehicles as a group rather than an electric vehicle or a hydrogen fuel cell vehicle in isolation.

4.4 Justification for Rogers' Innovation-Decision Process framework in the context of the research problem

Rogers' Diffusion of Innovations theory is the most cited of diffusion theories, with first publications appearing in 1963. The theory has continued to be applied to studies for over 50 years, which is likely due to its simplistic and pragmatic applicability across the academic disciplines. In a review of emerging literature between 1990 and 2012, Karakaya et al. (2014) found that there have been 1024 publications that include a reference to Rogers' theory and since 2008 the number of annual publications has seen substantial growth from fewer than 10 per year to just under 40 in 2012.

It is evident from the previous applications of the Diffusion of Innovations theory that it offers a versatile framework, lending itself well to use across a variety of research disciplines. The reasons for which this theory is considered appropriate for underpinning the present research problem will now be outlined.

Firstly, the broad range of applications across a multitude of research disciplines, including eco-innovation diffusion, demonstrates the versatility of the theory. The theory postulates that the characteristics of the technology, the adopter, and the social system are all influential in the adoption decision (Rogers, 2003), which makes it a particularly appealing theory in understanding what is impacting alternative fuel vehicle adoption. Other than Englis and Phillips (2013) and Morton (2013) there appear to be relatively few studies that have tested the relationship between pro-environmental attitudes and consumer innovativeness and this is something that can be explored in the context of alternative fuel vehicles.

Secondly, this theory presents a framework with which to consider the reasons for non-adoption of alternative fuel vehicles, which is especially important for marketing purposes in order to reduce the chances of the innovation failing in the market place (Roehrich, 2004). Diffusion of electric vehicles is occurring at a relatively slow rate, and it is of interest, both academically and for the purpose of stakeholders involved in new and existing vehicle technologies, to understand consumer acceptance and attitudes, and the reasons for their resistance. The innovation-decision process, therefore, provides a useful framework to identify what is influencing perceptions and attitudes towards zero-emissions vehicles that is stalling their adoption. Non-adoption or rejection is an important part of the diffusion of innovation theory, and a part that often is overlooked in the literature, simply because of the bias towards successful innovations (Rogers, 2003).

Thirdly, most applications of Rogers' Theory have been undertaken post hoc (having tended to focus only on successful innovations) and Rogers' suggests there is a need for theoretical contributions that apply the theory at different points in the innovation's lifetime as a means to understanding more about when an innovation fails or becomes successful in its diffusion. Ideally it would be undertaken as a longitudinal study and followed up over the entire diffusion period of alternative fuel vehicles, however resource constraints prevent that in the case of this research. Few have tested the theory's versatility of application at a single point in time during the innovation's diffusion, rather than at the end of the diffusion period. Rogers (2003) notes that there may be a problem in studying diffusion at a single point in time, rather than as a process, suggesting it will be 'yesterday's innovativeness, however with most studies having been undertaken post hoc and therefore reflecting on past innovativeness, it seems there is scope for trying a relatively novel approach to its application, with the potential for it to provide insight into adoption likelihood. As has already been noted, contributions to diffusion literature are already beginning to develop in the field of alternative fuel vehicles and it is the intention of this research to contribute to the understanding of the 'process' of alternative fuel vehicle diffusion.

4.5 The Diffusion of Innovations theory

Rogers identifies the innovation, its communication, time and the social system as the four main constructs of diffusion, defining the innovation diffusion as, ''the process in which an innovation is communicated through certain channels over time among the members of a social system'' (Rogers, 2003, pg 5). The over-arching theory will now be looked at in greater detail, and the sub theories, as outlined above, will become clearer.

The **innovation** refers to an idea, concept, practice or information that is perceived as new by an individual (or other unit of adoption) (Rogers, 2003). The newness of an innovation is subjectively perceived by individuals and might be expressed through knowledge, persuasion or the decision to adopt. Although technological innovations are generally designed to bring benefit to the user, the benefits are not always immediately clear to the intended early adopter. The potential adopter of an innovation passes through an innovation-decision process, whereby they undertake information gathering in order to learn more about the possible advantages and disadvantages of the innovation (Rogers, 2003). Knowledge of the innovation is important in reducing uncertainty in the adoption/rejection decision process.

Perceptions relate to the innovation itself rather than to the use of the innovation. Agarwal and Prasad (1997) maintain perceptions are especially important in explaining acceptance behaviour. Rogers describes five conceptually distinct characteristics of innovations that have been found to have the greatest influence on the rate of adoption. These are relative advantage, compatibility, complexity, trialability and observability, and are detailed in Table 4.1.

Table 4.1 *The characteristics affecting perceptions of an innovation according to Rogers (2003)*

Characteristic	Definition	Influencing factors
Relative advantage	The degree to which an innovation is perceived as better than the idea it supersedes.	Economic advantages; Social prestige factors; Convenience; Satisfaction.
Compatibility	The degree to which an innovation is perceived as being consistent with the existing values, past experiences and needs of potential adopters.	Value system; Previous experiences; Needs.
Complexity	The degree to which an innovation is perceived as difficult to understand and use.	Understanding of functionality; Ease of use.
Trialability	The degree to which an innovation may be experimented with on a limited basis.	Access to test innovation.
Observability	The degree to which the results of an innovation are visible to others.	Visibility of innovation being used by peers; Results experienced by peers.

According to Moore and Benbasat (1991), the perception of these characteristics is highly subjective between individuals, and as a consequence may result in different resulting behaviour. However, the likelihood of an innovation to successfully diffuse through a social system i.e. cumulative adoption, will be greater if: the innovation demonstrates an advantage over the incumbent or competing technologies, it fits with the values and culture of the society, its functionality is relatively easy to understand, it can be tested before fully committing to it, and lastly that it is possible to observe its use by others in society (Moore and Benbasat, 1991).

Communication channels refer to the process by which information is transferred from one individual to another in order to facilitate mutual understanding of an innovation.

A barrier to diffusion can arise from individuals within a social system being quite heterophilous (different), whereby there is little communication between individuals who are different. This could arise from differing levels of technical competence or simply from differences in demographic characteristics. Individuals who are quite homophilous (similar) are preferable for innovation diffusion because communication is likely to be more effective among individuals who possess similar attributes. Homophilous individuals are likely to have similar interests and perhaps live or work close to one another. However, being too similar will lead to limited exchange of new information, therefore a degree of heterophily is desirable for innovation diffusion.

The **time** dimension of the diffusion process is involved in three different ways. Firstly it can refer to the period in which an individual passes from the moment of first knowledge of the innovation through to the point at which they adopt or reject the innovation (the innovation-decision process). Secondly it can refer to the innovativeness of an adopter as to whether they are an early adopter or a late adopter in comparison to other adopters, and thirdly it can refer to the innovation's rate of adoption within a social system i.e. how many individuals adopt the innovation within a given time period.

A **social system** is the setting in which the innovation is adopted or not adopted and is defined as "a set of interrelated units that are engaged in joint problem solving to accomplish a common goal" (Rogers, 2003, pg 23). As such, the 'units' constitutes individuals or formal/informal groups. The social structure of a social system affects diffusion to the extent that the behaviour of individuals and the structure of a system are not all the same. Human behaviour can, to an extent, be predicted based on a particular social structure due to the regularity and stability that it provides. The structure is created either formally through social rank or informally though interpersonal networks and governs how information is passed from one person to the next. Communication flows occur within a communication network that sees regular patterns of communication among a group of homophilous individuals and can predict behaviour of individual members within a social system, such as when they are likely to adopt an innovation.

Within a social system there are also established behaviour patterns called social norms that will affect diffusion. Norms shape the behaviour of a social system by defining standards for behaviour and can therefore act as a barrier to change.

There are also varying levels of influence of individuals within a social system, such that some individuals will be opinion leaders. Opinion leaders conform to the social norms within a social system but they have a higher degree of influence over the attitudes or behaviour of other individuals in a system through an informal leadership. The opinion leader serves as a social role model within his or her informal interpersonal communication network, and whose innovative behaviour is often imitated by other individuals in a social system.

4.6 The Innovation-Decision Process

Within Rogers' diffusion theory, it is Innovation-Decision Process that provides the underpinning of the research in this thesis.

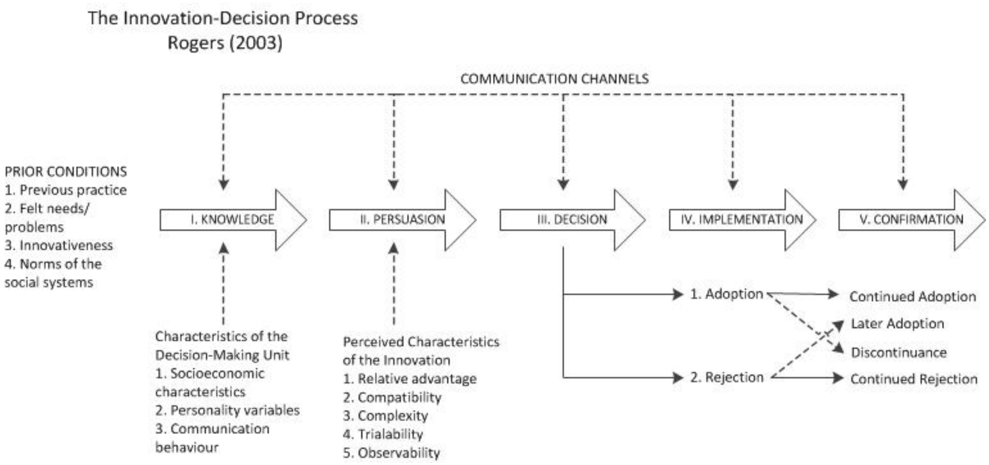


Figure 4.2 *The innovation-decision process (Rogers, 2003)*

The innovation-decision process involves information seeking and information processing (Rogers, 2003), whereby it is suggested that an individual passes through several stages before adopting or rejecting an innovation. Five steps in this process have been identified (Rogers, 2003): (1) knowledge, (2) persuasion, (3) decision, (4) implementation, and (5) confirmation, as shown in Figure 4.1.

A series of 'prior conditions' are relevant to the acquisition of knowledge (Kaplan, 1998) including previous practice, felt needs/problems, innovativeness, and norms of the social system. Not all the potential adopters within a social system will adopt the innovation simultaneously, and the point in time at which an individual adopts an innovation in relation to the other adopters in a social system, is referred to by Rogers (2003) as innovativeness.

4.6.1 Innovativeness of the individual (decision-making unit)

Innovativeness is the most commonly used dependent variable of diffusion studies (Rogers, 2003) and is defined as, "the degree to which an individual is relatively earlier in adopting new ideas than other members of a system" (2003, pg 267). Rogers describes innovativeness as the "bottom-line behaviour in the diffusion process" (Rogers, 2003, pg 267). As such, those who are most innovative will actively seek information about new ideas and innovations, they will be highly exposed to mass media, have wide-reaching interpersonal networks, cope well with uncertainty and are less reliant on the subjective information about innovations from others within the social system. Innovativeness is influenced by the characteristics of the decision-making unit, as depicted in the Innovation-Decision Process in Figure 4.2, which include socio-economic characteristics, personality values and communication behaviour. These characteristics are ultimately considered to have an influence on the knowledge that the individual has of the innovation.

Adopters are defined by their degree of innovativeness and, as such, are categorised into groups of individuals who adopt an innovation around a similar time: (1) innovators, (2) early adopters, (3) early majority, (4) late majority, and (5) laggards. Within each category, individuals are expected to have similar characteristics.

Rogers (2003) makes a series of generalisations about the typical socio-economic status, personality values and communication behaviour of earlier adopters (Table 4.2).

The characteristics indicate what might be expected for the earlier adopters of alternative fuel vehicles.

Table 4.2 *Characteristics of earlier adopters*

Socioeconomic characteristics
• No different from later adopters in age. • More years of formal education than later adopters. • More likely to be literate than later adopters. • Higher social status than later adopters. • Greater degree of upward social mobility than later adopters.
Personality variables
• Greater empathy than later adopters. • Less dogmatic than later adopters. • More able to deal with abstractions than later adopters. • More rationality than later adopters. • More intelligence than later adopters. • More favourable attitude towards change than later adopters. • Better able to cope with uncertainty and risk than later adopters. • More favourable attitude towards science than later adopters. • Less fatalistic than later adopters. • Higher aspirations (e.g. education, occupation, status) than later adopters.
Communication behaviour
• More social participation than later adopters. • More highly interconnected through interpersonal networks in their social system than later adopters. • More cosmopolite than later adopters. • More contact with change agents than later adopters. • Greater exposure to mass media than later adopters. • More actively seek information about innovations than later adopters. • Greater knowledge of innovations than later adopters. • Higher degree of opinion leadership than later adopters.

4.6.2 Knowledge phase

Looking at each of the five phases in turn, *knowledge* is the point at which the individual first learns of the innovation's existence and begins to develop an understanding of its function. It is a predominantly cognitive stage, and is the point at which an individual first becomes aware of an innovation, either selectively (the individual consciously tunes in to communication messages that are consistent with values and beliefs, and tunes out of messages that conflict) or passively (becoming aware of the innovation unintentionally) (Rogers, 2003). The individual's perception of the innovation in terms of whether they identify a need for it is referred to as 'selective perception' and affects how communication messages are interpreted.

Three types of knowledge are relevant in this step (Rogers, 2003):

1. Awareness knowledge – knowledge of the innovation's existence and its purpose.
2. How-to knowledge – knowledge about how to use the innovation.
3. Principles knowledge – knowledge about the underlying functionality of the innovation.

4.6.3 Persuasion phase

Persuasion the second phase in the innovation-decision process, is the affective stage and is the point at which the individual develops a favourable or unfavourable attitude towards the innovation (Rogers, 2003). In contrast to being persuaded simply by marketing communication messages, the persuasion step here is specifically concerned with how the individual is persuaded or dissuaded by the attitude that they have formed towards the innovation. Attitude formation is shaped by the individual's perceptions of the innovation's attributes, particularly its relative advantage, compatibility, and complexity. At this stage, the individual is dependent on the opinions of peers in influencing their attitude formation; all information gathering at this point is to justify or modify the individual's attitude (Seligman, 2006), which may help to allay any uncertainty the individual may have about the innovation.

4.6.4 Decision phase

The next phase is the decision about whether to adopt or reject the innovation. The decision stage follows the persuasion stage and is the point at which the individual undertakes activities that ultimately lead to the adoption or rejection of the innovation (Rogers, 2003). Adoption does not necessarily need to be complete – it may be only partial adoption, such as trialling the innovation before committing to it completely. Being able to trial an innovation prior to its adoption is considered to speed up the adoption rate.

The alternative to adoption is *rejection*, which can occur at any of the five stages of the innovation-decision process. Two types of rejection are identified by Rogers (2003): *active rejection*, whereby the individual considers adopting the innovation but then decides not to, and *passive rejection*, which is where an individual has never considered using the innovation. Passive rejection is also referred to by Rogers as non-adoption.

4.6.5 Implementation phase

Implementation occurs when the individual turns the decision to adopt into actively putting the innovation into use. During this stage, the adopter will continue to observe other users of the innovation, possibly also seeking feedback from peers; all of the informational cues that the adopter will use at this stage are important to the individual in constructing their identity (Seligman, 2006).

4.6.6 Confirmation phase

The final stage in the innovation-decision process is *confirmation*, which occurs once the individual has used the innovation and then seeks reinforcement of their innovation-decision, and may at this stage choose to discontinue using the innovation if they are exposed to information that conflicts with what they currently know.

4.6.7 Adoption conditions

Although Rogers has outlined five stages in the innovation-decision process, it is intended as a means to simplify the complexities of such a process, rather than a rigid framework that implies a clear distinction between each of the stages (Rogers, 2003).

The adoption of an innovation may not always be an optional decision made by an individual. It could be a collective decision among members of a social system to adopt or reject and innovation, or it could be an authority decision where the adopting individual has no choice over the innovation adoption decision. The different influences in the diffusion of an innovation lead to different diffusion rates. Authority innovation-decisions generally have the greatest rate of adoption. When the decision is optional the decision process is generally quicker if it concerns an individual rather than a collective.

According to Rogers (2003), the adoption decision is dependent on how closely the technological innovation is compatible with the underlying values, needs and experiences of the individual or other unit of adoption. However, the individual must also have a degree of knowledge about the innovation, such as its purpose, in order for the individual to begin to form an attitude towards it. Once the individual becomes aware of the innovation, they may then be exposed to external factors such as trialability and observability. Trialability allows the individual to give meaning to the innovation, while being able to observe the innovation being used by other members of society may help to emphasise the individual's perception of the innovation's status.

The rate of adoption is the speed with which an innovation is adopted within a social system. To begin with the rate of adoption is rather slow, but it begins to gather pace as more individuals adopt the innovation. When the process is plotted on a cumulative frequency graph, it is common with most innovations for there to be an s-shaped curve of adoption. If the process is not plotted cumulatively, it is represented as a bell-shaped, normal adoption distribution curve (as shown in Figure 4.3). Tarde (1903) was the first to discover that that adoption of an innovation generally followed the s-shaped curve and the increase in adoption was principally due to individuals 'imitating' earlier adopters. Rogers (2003) notes how the curve is shaped by innovativeness, which is expected to be normally distributed due to the normal distribution associated with most human traits. Depending on the rate of adoption the curve will be steeper for a faster rate of adoption or gentler for a slower rate of adoption. Such frequency curves, however, only occur in the case of successful innovations (Rogers, 2003).

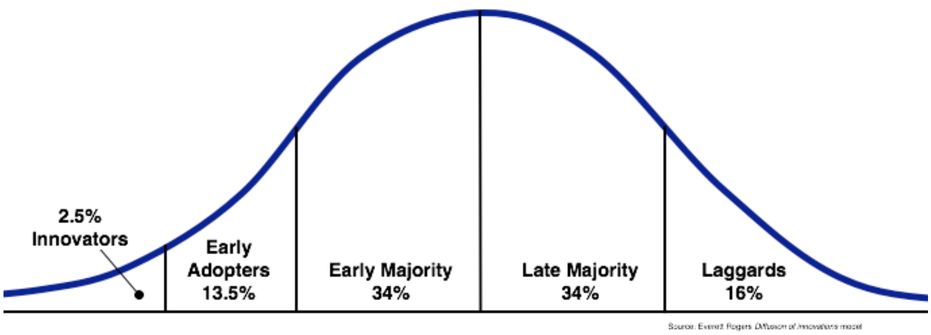


Figure 4.3 *Normal adoption distribution curve. Source: Rogers (2003)*

4.7 Summary

The Innovation-Decision Process represents the time element of the Diffusion of Innovations theory, positing that an individual must pass through several stages before a decision is made about whether to adopt or reject an innovation. Five steps are conceptualised in the innovation-decision process: knowledge, persuasion, decision, implementation and confirmation. The innovation-decision process presents an opportunity for research into understanding what is affecting the uptake of alternative fuel vehicles, taking into consideration consumers' knowledge and attitudes towards such innovations. Using this theory can therefore aid with the examination of specific decision-influencing factors, while also enabling contributions to be made to knowledge with respect to using an innovation that has not yet successfully achieved market diffusion. The method for the application of the Innovation-Decision Process will be outlined in Chapter 5.

Chapter 5: Research design and methods

5.1 Introduction

In the previous chapters, the key areas of interest for this research were introduced and the empirical and theoretical context that the research occurs within was identified. In Chapters 2 and 3, the literature on the topic of alternative fuel vehicle acceptance and policy environment that alternative vehicles sit within were explored. In Chapter 4, alternative fuel vehicle acceptance was considered at a broader level within the context of the diffusion of eco-innovations, and is placed within the existing theoretical framework that is Rogers' Innovation-Decision Process. These initial stages allow this chapter to state how the research will be designed and the methods that will be used to enable the research aim, as stated in Chapter 1, to be addressed:

"To examine the factors influencing the decision to adopt alternative fuel vehicles"

In the present chapter, Section 5.2 outlines the design of the research, which acts as a framework for the research in this thesis. In Section 5.3, the study area of Birmingham (UK) and the characteristics of this city are introduced. This research is constituted of two stages, the first of which relies upon census data to define the specific study area within Birmingham while the second stage involves the main data collection. Section 5.4 introduces stage one of the research and outlines the methods used in the analysis of census data. Section 5.5 presents stage two of the research, beginning by introducing the development of the questionnaire survey followed by the methods of analysis used. A comparison of electric vehicle models available in the UK and conventional vehicles is undertaken in Section 5.6. Section 5.7 presents a summary of the contents of this chapter.

5.2 Research Design

The research concerns alternative fuel vehicles and, given the UK Government's Low Carbon Transport strategy (DfT, 2009) to completely decarbonise the transport sector by 2050, the focus is largely on battery electric vehicles, which are considered to be a zero emissions technology (at the point of use).

Epistemologically, this research follows a positivist approach. A positivist approach relies largely on quantitative methods of analysis and, as such, entails the collection and use of objective data that is amenable to statistical modelling (Walliman, 2006). The logic of enquiry is deductive and is an approach that frequently involves the testing of hypotheses and theories (Potter, 2006). In this case the data has been gathered as a means of testing the Innovation-Decision Process from Rogers' Diffusion of Innovations theory, as shown in Figure 5.1.

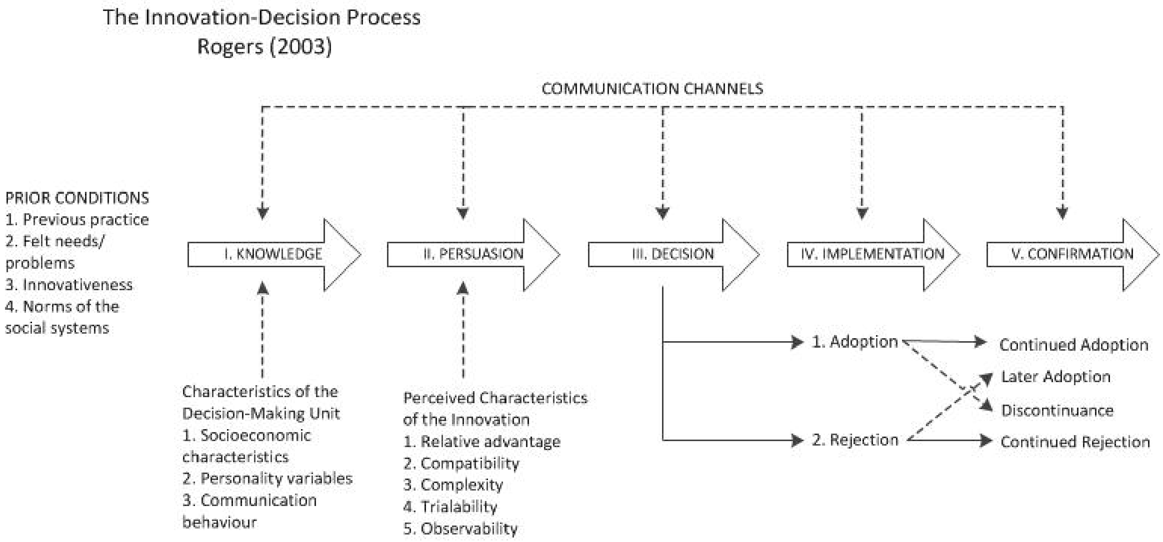


Figure 5.1 *The Innovation-Decision Process (Rogers, 2003).*

The knowledge, persuasion and decision phases in Figure 5.1 are the three phases that will be concentrated on in this research. This is because the research is concerned with the factors that are affecting the decision to adopt, or 'implement' the innovation.

The study design constitutes two stages. The first stage utilises empirical data from the UK Census in order to identify geographic locations of potential early adopters of alternative fuel vehicles. The second stage builds on the first stage and involves a survey questionnaire to obtain information from potential early adopters about their knowledge and perceptions of alternative fuel vehicles. The research is undertaken in the city of Birmingham, United Kingdom, the characteristics of which are presented in Section 5.3. The city was chosen for its size, demographics and also its demonstration of commitment to reducing the impact of carbon emissions from transport. Table 5.1 details the six objectives and indicates how the objectives are linked to the Innovation-Decision Process from Rogers' Diffusion of Innovations theory.

The consumers considered in this research are those who make personal decisions when it comes to vehicle purchases i.e. not commercial purchasers such as fleet operators. Despite consumers constituting a relatively smaller market (just under 50% in the UK) than the fleet sector (OLEV, 2013a), this group represents a substantial market and are therefore an important consideration in alternative fuel vehicle adoption. In the case of this research, the consumer is intended to be an individual who is most likely to be among the earlier adopters of alternative fuel vehicles. They may not necessarily be an innovator (see Section 4.6.1), as it is possible that innovators in the alternative fuel vehicle diffusion process may have already purchased such a vehicle. However, in such a case, the research methods allow for the identification of innovators among the survey population.

Table 5.1 *Research design*

Objective	Innovation-Decision Process element	Data	Chapter	Research stage
1. To understand the key consumer acceptance issues of alternative fuel vehicles.		(Literature)	2	
2. To identify the socio-demographic characteristics of early adopters of alternative fuel vehicles and the locations of such individuals.	*Knowledge phase* (decision-making unit characteristics): Socio-demographic characteristics of the decision-making unit	Census	6	1
3. To investigate the relationship between potential early adopters' socio-demographic characteristics and innovativeness.	*Knowledge phase* (decision-making unit characteristics): socio-demographic characteristics, personality characteristics, communication behavior.	Questionnaire survey	7	2
4. To examine potential early adopters' knowledge of alternative fuel vehicles and the factors that influence it.	*Knowledge phase* (knowledge of the innovation)	Questionnaire survey	7 & 8	2
5. To examine potential early adopters' perceptions of alternative fuel vehicles.	*Persuasion phase* (attitude towards the innovation)	Questionnaire survey	8	2
6. To evaluate the alignment of private transport expectations and alternative fuel vehicle characteristics.	*Decision phase*: decision to adopt or reject (actively or passively) the innovation.	Questionnaire survey	9	2
7. To make recommendations for policy that will support the adoption of alternative fuel vehicles.			10	

Objective 1: To understand the key consumer acceptance issues of alternative fuel vehicles.

In Chapter 2 an overview of the political context from which the alternative fuel vehicle problem emerged was presented. Chapter 3 then reviewed the literature on consumer acceptance, which began by describing key issues relating to alternative fuel vehicle technologies, attitudes towards the political context from which alternative fuel vehicles have emerged (i.e. climate change), the behavioural changes required for their uptake, and the level of acceptance of different vehicle technologies.

Objective 2: To identify the socio-demographic characteristics of early adopters of alternative fuel vehicles and the locations of such individuals.

The socio-demographic characteristics of early adopters of alternative fuel vehicles were identified in the literature review, as shown in the profile in Table 5.2.

Table 5.2 *Socio-demographic characteristics of early adopters of AFVs.*

Socio-demographic characteristic	**Criteria**	**Author**
Age	Younger (18-35) or middle-aged (36-55)	Hidrue et al. (2011).
	Young	Deloitte (2010).
Income	High household income of $114,000 - $200,000	Deloitte (2010).
Education	High level of education	Hidrue et al. (2011).
	Having a bachelor’s degree or higher	O’Garra et al. (2005).
Car ownership	Owning more than one vehicle	Kurani et al. (1995); Gärling and Thøgerson (2001); Graham-Rowe et al. (2012).
Home ownership	Home owner	Williams and Kurani (2006).

In Chapter 6 the characteristics are adapted to apply to Census data for Birmingham Metropolitan District. This is to enable the identification of spatial concentrations of individuals who have the characteristics of early adopters of alternative fuel vehicles in addition to spatial concentrations of those who have few of the characteristics and therefore, perhaps, least likely to adopt an alternative fuel vehicle.

Objective 3: To investigate the relationship between potential early adopters' socio-demographic characteristics and innovativeness.

In Chapter 7 questionnaire data is used to investigate whether the socio-demographic characteristics of a potential early adopter can be validated by the individual's degree of innovativeness (see Section 4.6.1). As such the relationship between socio-demographic characteristics, personality values and communication behaviour is analysed.

Objective 4: To examine potential early adopters' knowledge of alternative fuel vehicles and the factors that influence it.

In order for an individual to consider adopting an innovation, they first have to know about it. In Chapter 7, knowledge of contextual factors that indicate knowledge of the reason for the existence of an alternative fuel vehicle are first examined, before knowledge of the innovation itself is examined in both Chapter 7 and Chapter 8.

Objective 5: To examine potential early adopters' perceptions of alternative fuel vehicles.

Chapter 8 examines the perceptions held about alternative fuel vehicles. Perceptions ultimately influence the attitude towards the innovation, which can be considered as the degree of persuasion an individual feels towards adopting the innovation.

Objective 6: To evaluate the alignment of private transport expectations and alternative fuel vehicle characteristics.

In Chapter 9, the decisions that have been made in relation to current vehicle purchases and the likely decisions that will be made regarding the next vehicle purchase to evaluate how well aligned vehicle expectations are with the characteristics of alternative fuel vehicles.

Objective 7: To make recommendations for policy that will support the adoption of alternative fuel vehicles.

The findings from the analysis then form the basis for a number of policy recommendations to transport sustainability decision makers, which forms the sixth objective and is detailed in Chapter 10.

5.3 An introduction to the study area: Birmingham, UK

This section provides an overview of Birmingham, which is the study location that has been used to undertake the research contained in this thesis. Birmingham was considered as a case study for this research due to its large population size and its socio-economic characteristics.

The city and metropolitan district of Birmingham has a population of 1 million making it the most populous British city outside of London (ONS, 2013). It also has the second largest number of households outside of London, containing a total share of 4.1% of the England and Wales population (Centre for Cities, 2012). It is a major commercial centre and its economy is also the second largest in the UK. This research considers Birmingham Metropolitan District, which is a form of single-tier local authority found in some of the larger areas of England (ONS, 2010). In Birmingham the Metropolitan District is formed of 40 wards, with a ward being defined by the Office for National Statistics (ONS, 2010) as "the base unit of UK administrative geography, being the areas from which local authority councillors are elected". Population is the primary determinant of a ward and boundaries are often easily identifiable at ground level, demarcated by rivers, major roads and railways for example (ONS, 2010).

The employment level of those who are 'economically active' in Birmingham is 61% which is 7% lower than that for the West Midlands region and almost 10% lower than that for the United Kingdom. 'Economically active' refers to those between the ages of 16 and 74 and therefore this figure does not take into account those who are retired, in education or those who choose not to work e.g. homemakers.

Road transport accounts for almost 25% of Birmingham's carbon emissions (Birmingham City Council, 2012). In 2010 Birmingham City Council published a 'Climate Change Action Plan' (Birmingham City Council, 2010a) in recognition of the changes the city needs to make in order to reduce its impact on the environment and to create a more sustainable economy. The Action Plan follows closely on the Council's 2015 Birmingham Declaration (Birmingham City Council, 2009) and outlines the steps the city will need to take in order to meet a 60 per cent reduction in carbon emissions by 2026. One of the 'Early Actions' it sets down as a key priority is "reducing the environmental impact of the city's mobility needs through low carbon transport".

Projected carbon emissions per capita from transport are expected to reduce as a result of the mitigation measures Birmingham is introducing. Between 1990 and 2026, the projections are as follows (Birmingham City council, 2010a):

1990: 1.25 tonnes
2005: 1.57 tonnes
2007: 1.54 tonnes
2011: 0.89 tonnes
2026: 0.66 tonnes

One of the targets in the Council's 2015 Birmingham Declaration is to have at least 500 electric vehicles on the streets of Birmingham as the city develops the electric vehicle infrastructure. Plugged-in-Places funding will therefore contribute to reaching this target by ensuring electric vehicle charging points are installed before 2015. Organisations based in Birmingham have also started showing commitment to electric vehicles. In 2012 Price Waterhouse Coopers (PwC) participated in a six-month trial of a Mitsubishi i-MiEV, attempting to demonstrate their commitment to work with new technologies and in reducing the organisation's environmental impact (PwC, 2012a).

Sixty-five per cent of the population of Birmingham are of working age, however the employment level of those who are of working age (16-74) is 61%, which is 7% lower than that for the West Midlands region and almost 10% lower than that for the United Kingdom. This figure does not take into account those who do unpaid work, are retired, in education, unable to work or those who choose not to work. Manufacturing has previously played a major role in job provision in Birmingham, although employment in this sector has reduced by almost 40%, as a result leaving a large population of low skilled individuals with few qualifications and opportunities for employment. High levels of 'worklessness' (those of working age who are not employed) and unemployment prove costly to its economy (Birmingham City Council, 2010b).

Figure 5.2 shows the spread of worklessness rates across the Metropolitan District of Birmingham. The city centre of Birmingham borders the Ladywood and Nechells wards. This map shows clearly that the lowest rates of worklessness are in the furthest north-eastern wards of Sutton Four Oaks, Sutton Trinity, Sutton Vesey and Sutton New Hall, while Edgbaston and Selly Oak to the south of the city centre also display fairly low levels of worklessness.

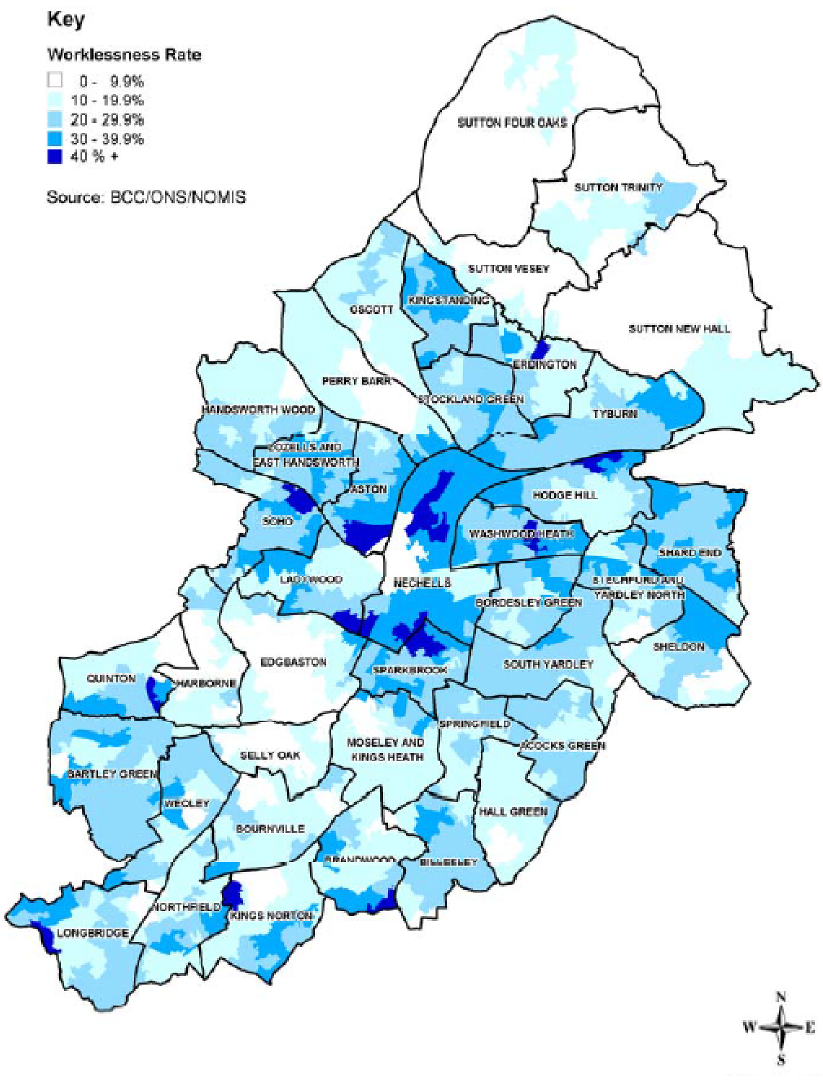


Figure 5.2 *'Worklessness' rates in Birmingham by ward in 2009. Obtained from Birmingham City Council (2010b) reproduced from Ordnance Survey Material, Crown Copyright.*

Almost 21% of Birmingham's working age population have no qualifications, a figure which is 8% greater than the national average. Within the Birmingham city area, the inner city and several outer city estates have the highest levels of residents with no qualifications (Birmingham City Council, 2010b). The economic output per person in 2007 was £19,000, while the economic output per worker was £37,000, not dissimilar from that of Greater Manchester South and Leeds, but £14,000 and £17,000 respectively below that of London. Birmingham is currently making a multi-billion pound investment into the regeneration of the Eastside, which is hoped to create thousands of jobs (Birmingham City Council, 2010b).

There are high levels of deprivation in Birmingham – 41% of residents live in wards that are amongst the 10% most deprived wards in the country (Birmingham City Council, 2010b). The most deprived wards in Birmingham include Washwood Heath, Nechells, Lozells & East Handsworth, Aston and Sparkbrook. No official figures for neighbourhood data on household income exist, however Figure 5.3 shows a map of household income based on average annual household income for 2009 of £19,400 (ONS, 2012), produced by Birmingham City Council. There is a concentration of households with incomes over £35,000 in the wards of Sutton Four Oaks, Sutton New Hall and Sutton Trinity, which form the suburb of Sutton Coldfield. ACORN (A Classification of Residential Neighbourhoods) has been used by Birmingham City Council (2010b) to define parts of the city, and a concentration of 'wealthy achievers' ('wealthy executives & families and affluent older people') was identified in the wards of Sutton Coldfield. Between these outer wards and the city centre wards of Ladywood/Nechells, there is a large concentration of wards containing households that fall into the categories of 'hard-pressed' ('struggling families, singles and older people') and 'moderate means' ('skilled workers, young low income families').

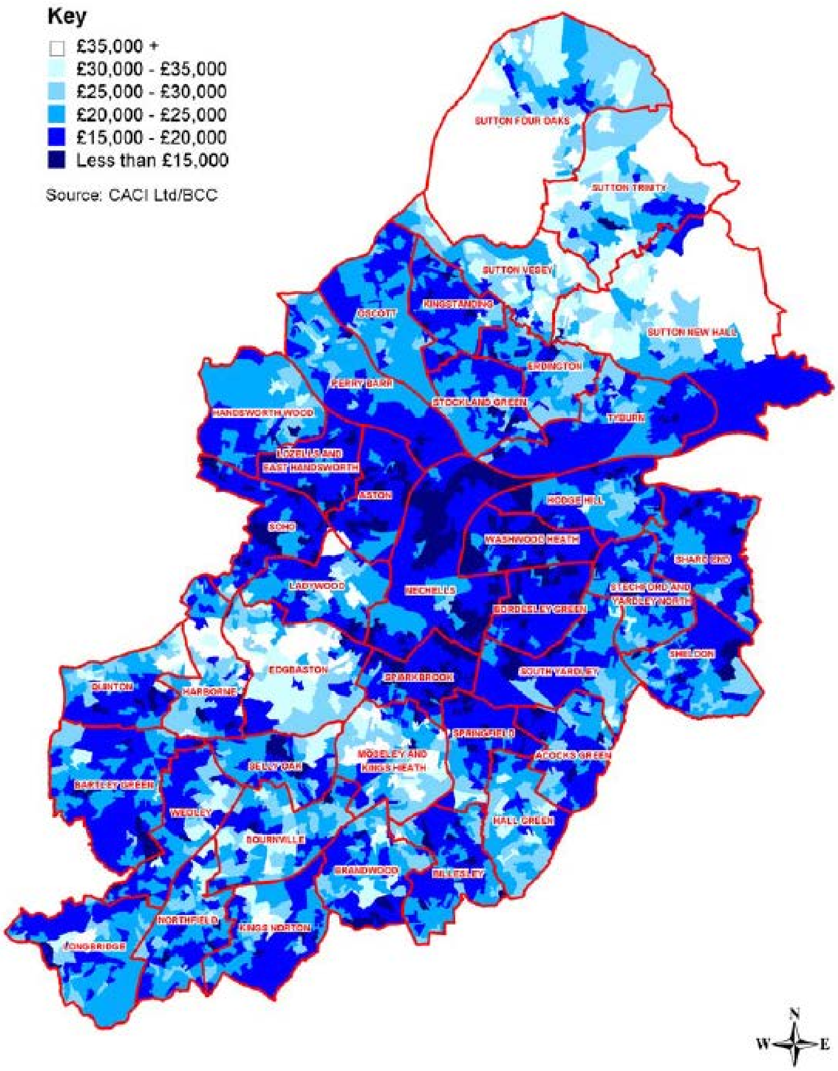


Figure 5.3 *Birmingham Modal Household Income by ward. Obtained from Birmingham City Council (2010b) reproduced from Ordnance Survey Material, Crown Copyright.*

Home ownership in Birmingham is 60%, which is a much lower percentage than in many other authority areas in England and Wales. Car dependency is lower than many other authorities in England and Wales with 38% of households in Birmingham not owning a car or a van and 20% of households owning two or more cars/vans. In a Car Dependency Scorecard (Campaign for Better Transport, 2012), Birmingham was ranked as the 15th most car dependent city in England out of 26 cities. Cycling and walking as alternatives to the car faired very poorly, ranking it 25th. Birmingham is however making plans to reduce car dependence and congestion in the city as part of the Council's core strategy.

A lower level of car dependency in Birmingham may lead to the assumption that a larger than average proportion of the population travel to work by public transport in Birmingham, however, unlike London, Birmingham does not have a high capacity public transport system. A report by Pricewaterhouse Coopers (2012b) identifies that Birmingham's transport system is below average relative to the Index for Core Cities. The city is currently investing £600 million in redeveloping New Street Station, Birmingham's main railway station, to help stimulate economic growth and ease traffic congestion (Birmingham City Council, 2010b). In order to make other necessary improvements to public transport, further investment is required, although it is feared that the scarcity of public funds will hinder such activity (Birmingham City Council, 2010b).

5.4 Research stage one

In the first stage of the research, a geo-demographic segment of potential early adopters is identified. The procedure that was followed to identify the characteristics and then locate individuals who possess the characteristics will now be explained.

5.4.1 Early adopter characteristics

An early adopter is defined by Rogers (2003) as an innovative individual who has a high degree of opinion leadership and who is well integrated in the local social system. They are usually one of the first to adopt an innovation, an action that reduces the perceived uncertainty held by others in the social system, and they can therefore trigger critical mass. Early adopters are considered an appropriate target segment for this research due to the current low adoption rate of electric vehicles. A low rate of adoption suggests that market penetration will take some time, and therefore identifying the early adopters who might be able to trigger this critical mass is of great interest.

The characteristics that constitute an early adopter of an alternative fuel vehicle were determined by the literature review, as presented in Table 5.2. In addition to the socio-demographic characteristics outlined in Table 5.2, having the suitable infrastructure at home, such as a garage with an electric plug-in point, was also considered by Hidrue et al. (2011) to be an influential factor for electric vehicle adoption. Having determined the common socio-demographic characteristics of adopters of electric vehicles, the next step involved identifying the locations of individuals who fulfilled these criteria within the Birmingham Metropolitan District.

5.4.2 Selecting Census data characteristics

In order to determine the locations in Birmingham of those who fit the profile of a potential alternative fuel vehicle adopter, the UK Census was considered to be the most appropriate resource for obtaining the relevant data. The volume of data collected by the Census would not fall within the scope of this project, and nor would it make sense to duplicate data that is already in existence.

The national Census in the UK takes place every ten years and collects information concerning the numbers of people, demographic and social information about everybody (including age, birthplace, ethnic group, marital status, religion), employment and qualifications of people aged 16-74 (including academic qualifications, professional qualifications, employment status, hours worked and means of travel to work), the number of households, and housing (including accommodation type, availability and use of cars and vans, and tenure). The Census does not collect data on income as it is considered that it would prejudice the completion rates and, for small areas, income can be estimated using other variables (House of Commons Public Administration Select Committee, 2011). In this research, socio-economic status and home ownership will be used as a guide to the wealth of inhabitants of the different wards and their sub areas.

The Census data used in this research is taken from the 2001 Census. As the Census is taken every ten years, a subsequent Census took place in March 2011. However, the release date for the data containing local characteristics was scheduled to take place between July and October 2013, a period that fell outside the timescale for this project. The data used is therefore over ten years old, so any demographic changes that have taken place in Birmingham over the course of the past ten years will not be reflected in this research. In 2004 the ward boundaries in Birmingham changed, however the census data collected in 2001 has been manipulated by the Office for National Statistics to take this change into account. The dataset used constitutes 3,126 census output areas (COAs), which are within the 40 census wards of Birmingham Metropolitan District. COAs are the small geographical units built from postcode units that provided the foundation for the 2001 Census, and they are the most local figures available. Each COA contains an average of 125 households; at the time of this research there were 3,126 COAs in Birmingham, however a restructure has now meant there are 3,777 COAs in Birmingham.

In accordance with the socio-demographic characteristics identified for a potential adopter of an alternative fuel vehicle, the variables in Table 5.3 were selected from the Census data.

Table 5.3 *Census data variables utilised in the analysis (refer to Table 3.3)*

Criteria	**Reason for inclusion**
1. Age group 16-59	Literature review (Section 3.10)
2. Higher education	Literature review (Section 3.10)
3. Home owner	Literature review (Section 3.10)
4. Own at least two cars or vans	Literature review (Section 3.10)
5. Home is detached or semi-detached	Homes in the UK are more likely to have off-road parking (for electric charging and vehicle-to-grid infrastructure) if they are detached or semi-detached.
6. Socio-economic status ('higher professional occupations' or 'lower managerial and professional occupations')	Used in the absence of income data being available in the Census.
7. Drive a car to work	This group demonstrate a higher dependence on their motor vehicle.

In using secondary data, the choice of variables is constrained by the specificities of the data collected in the Census. The choice of variables selected will now be further elaborated.

The age groupings in the Census that are included in the analysis are: 16-25, 25-44 and 45-59. These age groups have been assumed to constitute a younger and middle-aged population. Despite age 16 being below the legal driving age (in the UK the legal driving age is 17), it was considered unnecessary to exclude the age category 16-24 due to the majority within this age group being eligible to drive.

The literature suggested that an individual was more likely to adopt an alternative fuel vehicle, particularly an electric vehicle, if they have a garage or parking facility with access to an electric plug point. Information on whether a property has a garage facility or not is not collected in the Census, therefore a further assumption was made that a property that is detached or semi-detached is more likely to have a garage or an off-road parking facility that may provide suitable access to an electric plug point. It is also considered more likely for individuals to install the necessary infrastructure if they own their home. In lieu of income data in the Census, homeownership is also a useful indicator of higher income.

Using a car to drive to work indicates the level of vehicle dependency, and thus an assumption has been made that an individual who is dependent on a vehicle is more likely to adopt an alternative fuel vehicle than somebody who is not dependent on a vehicle.

In the census, socio-economic status is determined by occupation. As a high income is found necessary to be able to afford an alternative fuel vehicle, the two highest occupation categories were selected: higher professional occupations and lower managerial and professional occupations. As the names indicate, these occupations refer to those that are managerial or professional e.g. finance manager, solicitor, scientist, teacher.

As far as education is concerned, the variable higher education comprises all those who have reached a level of education that constitutes one of the following: First degree; Higher degree; NVQ levels 4 and 5; HNC; HND; Qualified Teacher Status; Qualified Medical Doctor; Qualified Dentist; Qualified Nurse; Midwife; Health Visitor.

From this point forward, these characteristics will be referred to as socio-demographic characteristics and will be used to complement 'socio-economic characteristics' of the decision-making unit in the analysis. Incorporating the additional social and demographic characteristic will ensure that the innovativeness of the individual can be analysed in the context of characteristics specific to alternative fuel vehicle adoption.

5.4.3 Cluster analysis of the census data

In order to identify locations of potential alternative fuel vehicle drivers, it is necessary to establish homogeneous groupings in the data. Working with such a large volume of information, as the dataset presents, it was necessary to classify the information into manageable subgroups. Cluster analysis is selected as the most suitable approach due to its three key objectives, according to Hair et al. (2010), being: to identify natural groups within the data, to simplify the data into groups of similar observations and to reveal relationships within the simplified structure. As such, cluster analysis performs objective data reduction and recognises the inter-relationships between the variables.

Using an appropriate algorithm, a sample of entities is sub-divided into a small number of mutually exclusive groups based on the similarities (or differences) among the entities but unlike discriminant analysis the groups are not pre-defined. Due to the nature of cluster analysis, as a non-parametric test, there are not strict assumptions, although the variables must be independent. Analysis should be undertaken without any pre-conceptions of the user, but the results do depend on their judgement (Hair et al., 2010). It is acknowledged that the cluster analysis technique generates suggested groups for review rather than definite solutions.

The agglomeration procedure, or algorithm, used in this instance is Ward's method, which is a hierarchical procedure. It is selected as an appropriate algorithm due to its ability to produce clusters with minimum within-cluster variance and of approximately equal size. Ward's method calculates the sum of squares (distance) between an object in the first cluster and an object in the second cluster, which is then summed across all variables (Hair et al., 2010).

In determining the distance between clusters, a variety of measures exist. The distance measures are a measure of similarity as the proximity of observations to each other across the variables in the cluster variate (Hair et al., 2010). The Euclidean distance is the most commonly used distance measure due to its ability to determine a straight-line distance, although the squared Euclidean distance offers the advantage of undertaking fast computations because, unlike the Euclidean distance measure, it does not take the square root. This distance measure is recommended for use with Ward's agglomeration method.

There are two key criteria that should be addressed in cluster analysis, that of representativeness of the sample and multicollinearity (Hair et al., 2010). The first criterion, representativeness of the sample, is not a concern when using census data, as is the case in this research.

Multicollinearity can cause a problem in cluster analysis as it can impact the weighting of variables in the analysis and, in turn, affect the similarity measure. It is therefore recommended that highly correlated variables are not included (Hair et al., 2010). To measure the association between two variables, Pearson's correlation coefficient (r) is a technique that is used, whereby the closer the value of the coefficient to '1', the greater the degree of multicollinearity. As a rule of thumb correlation values that exceed 0.8 and 0.9 are considered to be very highly correlated (Field, 2009).

In determining how many clusters should be formed, there is no standard objective procedure, such that the user is guided by the 'stopping rule, which involves selecting the number of clusters that most appropriately represents the data set (Hair et al., 2010). To validate the clusters, the cluster centroids (mean values) can be examined through a process of internal validation, which should demonstrate heterogeneity between one another. Profiling is also considered as a form of cluster group validation (Hair et al., 2010) such that if it is straightforward to assign a profile to each cluster group then it demonstrates heterogeneity between groups.

In this research cluster analysis is applied to Census data, specifically the variables in Table 5.3, for the area of Birmingham Metropolitan District. This area consists of 3,126 census output areas, which vary in size, constituting between 53 and 259 households with an average of 125 households. This translates into an average census output population size of 312 individuals. Previous examples applying Ward's method of cluster analysis to transport applications in order to determine market segments include Morton (2013) who used it to determine preferences for different alternative fuel vehicle technologies. Ryley (2006) used this method to identify households in Edinburgh with the greatest propensity to use non-motorised travel modes, while Anable (2005), uses cluster analysis to identify six distinct travel behaviour segments.

5.5 Research stage two

In the first stage of this research project, a geo-demographic segment of those with the highest potential of being an adopter of an alternative fuel vehicle was identified. This subsequent stage required the development of a survey that would enable contact with the potential early adopter segment. The aim is to investigate and understand acceptance of these vehicles among those considered most likely to adopt with the intention of understanding reasons for non-adoption.

5.5.1 Questionnaire design: data collection method and pilot survey

There are two categories of data collection media, interviewer-administered questionnaires and self-completion questionnaires. Interviewer-administered questionnaires can be undertaken face-to-face or by telephone. Although time and cost is greater with a face-to-face method it is advantageous in accessing respondents, maintaining control of the survey and speed of completing questionnaires. A self-completion approach is often cheaper and allows respondents time to consider their answers.

The nature of the questionnaire in this research requires specific characteristics of the respondent household, such that the household must have a driveway or a garage. This is guided by the recognised need for a secure location to store and recharge an electric vehicle close to the home (Kurani, 2006). In order to be able to identify addresses that fit this description, telephone-administered questionnaires would not be appropriate. An interviewer-administered questionnaire and a 'call-and-collect' method were the two approaches considered to be most appropriate in addressing this issue. A call-and-collect method involves the questionnaire being dropped off at a household by an interviewer who explains the study to the respondent and then returns at an agreed time to collect the questionnaire. This approach, along with an interviewer-administered face-to-face method, was tested in pilot work.

As part of the research design, pilot work was undertaken on Sunday 9th December (daytime) and Monday 10th December (evening) prior to the main data collection. The pilot involved testing the questions and the methods. A geographic location, containing roughly 100 residences, within one of the wards identified in stage one as having a population of potential early adopters of alternative fuel vehicles. A face-to-face method and call-and-collect method were both tested. Respondents were invited to participate in the survey and were given the option of self-completion if they expressed disinterest when attempting to undertake the questionnaire using a face-to-face method. A total of 37 questionnaires were completed. Despite face-to-face methods generally being a preferred method in survey work, in the pilot survey the self-completion method was found to have the highest response rate, with only six undertaken using a face-to-face method. This may have been due to the inexperience of the researcher in undertaking doorstep surveys, such that a degree of skill and persuasiveness is required to encourage participation. Two respondents who agreed to self-complete indicated at the agreed collection time that they decided they did not wish to participate. There were five respondents who requested to self-complete the questionnaire but were not at home at the agreed collection time. A stamped-addressed envelope was posted through the door for the return of the questionnaire, however this approach proved unsuccessful, with none of the five questionnaires being returned. The pilot work emphasised the need for skill in survey work in order to achieve a high response rate. The testing of questions also highlighted a need for some to be re-worded to enable better understanding as well as indicating that a change in the order of questions might improve the flow of the questionnaire. The questionnaire length was found to be acceptable at approximately 20 minutes in length when conducted face-to-face.

On the basis of the questionnaire taking 20 minutes to complete, it was recognised that to undertake approximately 400 questionnaires, it would take in excess of 130 hours before considering the time to move between households. In the interests of undertaking the questionnaire as efficiently as possible under the natural time constraints of the research, a decision was taken to recruit a team of interviewers to assist in undertaking the data collection. Two options were considered, the first being to recruit colleagues to undertake the survey and the second to commission a fieldwork agency. In comparing the costs and benefits of each approach, a decision was taken to commission a fieldwork agency to undertake the interviewing process. Using a fieldwork agency makes it possible to utilise the skills and experience of professionals and ensure the survey is completed in the shortest possible amount of time.

The main questionnaire survey was undertaken between 21st February 2013 and 16th March 2013. Both the face-to-face and call-and-collect methods were utilised by the agency, although the call-and-collect method was used only if an individual was unable to complete the questionnaire with the interviewer, but willing to complete alone for later collection. Four interviewers undertook the data collection collecting a total of 413 completed questionnaire surveys, with 62% (256) having been completed face-to-face and the remaining 38% (157) were completed using a call-and-collect method. In order to reduce the potential of any demographic bias among respondents, the questionnaires were conducted over this period in the daytime and evenings during weekdays and weekends. The interviewer was required to request to undertake the questionnaire with an individual from the household who is involved in the decision-making process when purchasing a new vehicle. The sampling approach for selecting the households with which to undertake the questionnaire will now be discussed in section 5.5.2.

5.5.2 Questionnaire design: sampling approach

The sampling approach used involves a largely purposive sampling technique but also incorporates an element of random sampling and will now be explained.

Stage one of this research identifies a strong spatial cluster in the Sutton Coldfield area of Birmingham of individuals who most closely fit the profile of a potential early adopter of an alternative fuel vehicle. The suburb of Sutton Coldfield constitutes four wards, which are shown on the map in Figure 5.4.

Figure 5.4. *Map of Birmingham Metropolitan District showing the four Sutton Coldfield wards*

As census data was used for this research, it was possible to identify individuals from the 'early adopter cluster' from stage one at a postcode level of detail. Due to data protection, it was not possible to pinpoint specific addresses to the census data. Birmingham City Council was able to provide a list of postcodes for all output areas that fell within the 'early adopter' cluster and the addresses in each postcode. This part of the sampling forms the purposive part in that the sample is intended to be those who fit the early adopter profile. An example of matching the output area codes from the Census data to postcodes is shown in Table 5.4.

Table 5.4. *An example of matching output area codes to postcodes*

Ward	OA Code	Postcode
SUTTON NEW HALL	00CNGN0049	B72 1JB
SUTTON TRINITY	00CNGM0041	B72 1JD
SUTTON VESEY	00CNGN0015	B72 1JG

In terms of the random sampling, a target sample population size of 400 respondents was chosen, partly limited by budget, but which was considered sufficient to reduce any sampling error and also narrow the confidence interval. To achieve a balance across the four wards, the target was to achieve 100 questionnaires per ward. To take into account non-responses, a 10% response rate was assumed, which required a potential sample of approximately 1,000 addresses per ward. Using a random number generator, 15 output areas were revealed in each ward generating approximately 2,000 addresses. In order to reduce this to 1,000 addresses per ward, every other address was selected (i.e. every other row). Addresses that were identified as being flats or apartments were filtered out from each ward along with addresses that were used in the pilot survey. The latter constituted 12 addresses from the Sutton Trinity Ward. Due to the change in ward boundaries since the 2001 Census, some of the output areas were identified as being across the boundary of two wards. This constituted a total of 47 addresses, which were removed.

From the final list of addresses in each ward, a target was established of five to fifteen addresses per output area to ensure there was a spread of respondents from across the output areas, ensuring that no fewer than five questionnaires were undertaken in a single output area. From the selected households, the survey was undertaken with an individual who considered him/herself as a key-decision maker in a car-purchase decision.

5.5.3 Questionnaire design: types of question

The questionnaire was designed in accordance with the research aim and guided by the Innovation-Decision Process framework (Figure 4.2, Section 4.6). As such, the knowledge, persuasion and decision phases of the framework were influential in the choice of statements and questions.

Two types of question exist for questionnaires (Walliman, 2006), closed-format, where the respondent selects an answer from a choice of options, and open-format, where respondents answer freely in their own words and style.

In order to satisfy the research objectives it was necessary to collect a large amount of data, which necessitated the use of predominantly closed-format questions. This format enables questions to be answered quickly while also allowing easier coding in the analysis process. A variety of question techniques are used and are listed below (adapted from Walliman, 2006). An example of a statement/question from the questionnaire survey is provided in parentheses.

- Single answer (e.g. Q11. Do you know the current price of fuel y/n?)
- Multiple answer (e.g. Q10. When considering a new vehicle purchase, which three of the following characteristics are the most important and which three are the least important)
- Numerical (e.g. Q9a. What was the year of [vehicle] purchase)
- Likert scale (e.g. a scale of 1-5 indicating level of agreement: Q7a: Having a motor car is a necessity?)
- Semantic differential (e.g. choose from a range of possibilities: much stronger, somewhat stronger, neither stronger nor weaker, somewhat weaker, much weaker as in Q21. How do you believe a fully electric vehicle compares to a petrol or diesel vehicle?)

Disadvantages of closed-format questions are that the range of possible answers is limited and the respondent is prevented from qualifying responses. In order to gain better insight into responses, the questionnaire also included some open-format questions, which include:

> Q17. Please list any advantages you think you (or your household) might experience by owning or leasing a fully electric vehicle.
>
> Q18. Please list any obstacles you (or your household) might experience by owning or leasing a fully electric vehicle.

A disadvantage of including open-format questions is that they are difficult to code and the responses are open to the interpretation of the researcher (Walliman, 2006).

In order to identify and measure the variation in a set of variables, measurement scales are required (Hair et al. 2010). An ordinal scale was selected as the most appropriate measurement scale for the majority of the data collected in the questionnaire; this was largely due to the non-metric nature of the majority of the questions. Capturing the attitudes of respondents requires care in developing a measurement scale, which functions to divide people into homogeneous groups according to attitude (Oppenheim, 2005). According to Oppenheim (2005) attitude scaling methods must have the following five characteristics: uni-dimensionality, linearity and equal intervals, reliability, validity, and reproducibility.

There are several scales which can be used to measure attitude. The four most popular are: Bogardus, Thurstone, Likert and Guttman scales (Oppenheim, 2005), although each concentrates on a different characteristic of those listed above, while paying less regard to the others (Oppenheim, 2005). Oppenheim (2005) notes that the appropriateness of each scale is based on its strength to solve a specific problem. Bogardus proposes a social-distance scale that orders individuals or groups regarding their ethnic attitudes. Thurstone scales enable the study of group differences. Likert developed an attitude scale that focuses on uni-dimensionality that enables the study of attitude patterning. Guttman developed scalogram analysis which focuses on uni-dimensionality and reproducibility, supporting the study of attitude change.

Goldsmith and Hofacker (1991) undertook extensive research into scale analysis in diffusion studies and found that Likert scales were highly reliable and a useful indicator of an individual's level of innovativeness. Innovativeness is defined by Rogers (2003) as the "degree to which an individual is relatively earlier in adopting an innovation than other members of the social system".

In this research the Likert scale has been selected for attitude measurement; it is an ordinal scale that is commonly used by social scientists and psychologists due to its suitability for making comparisons across respondents (Walliman, 2006). The Likert scale constitutes an analogue scale with a simple weighting system of five scores/positions, 1-5, ranging from a favourable attitude at one end and an unfavourable attitude at the other end (Oppenheim, 2005). The scores can then be recorded across each of the respondents and then added up across all the attitude statements to give a total score for each respondent. This enables scores to be compared across all respondents, making it possible to group respondents according to attitudes. One of the key criticisms of this measurement scale is its lack of reproducibility, in that the scores can be obtained in different ways (Oppenheim, 2005). Likert scales have also been criticised for failing to have a neutral point or clear intervals between values (Oppenheim, 2005; Norman, 2010), which can lead to the wrong conclusions if an inappropriate statistical technique is used (Norman, 2010). On the other hand, Norman (2010) addresses the issue of 'robustness' of using parametric statistics for ordinal data from Likert scales, maintaining that they are ''versatile, powerful and comprehensive'' (Norman, 2010, pg 627) and should be used with no concern that the wrong conclusion will be arrived at (Norman, 2010). Similarly, Goldsmith and Hofacker (1991) maintain that using a standardised scale (Likert) is preferred in the field of measuring consumer innovativeness due to its reliability and validity being well established and therefore enables cross-comparisons in diffusion literature.

Likert scales have been used successfully to identify attitudes in alternative vehicle acceptance studies (e.g. Ozaki and Sevastyanova, 2011 and Shaheen, 2008). They are used in this research as a means to capture attitudinal characteristics that indicate an individual's innovativeness. The statements that have been developed in accordance with Rogers' generalisations relating to personality values and communication behaviour are presented in Table 5.5.

In establishing the personality values, it is not possible to relate these values specifically to alternative fuel vehicles, however the attitudinal responses will provide an indication of the respondents' degree of innovativeness. A similar problem is found in composing communication behaviour statements, however a generalisation of communication behaviour is considered to be greater knowledge of innovations, which made it possible link communication behaviour and alternative fuel vehicles for this construct. The pre-determined characteristics outlined in the profile in stage one (Table 5.3) will also enable the determination of the relevance of personality values and communication behaviour specific to the innovation. The full questionnaire can be found in Appendix 2.

Table 5.5 *Questionnaire attitude statements according to generalisations*

Decision-Making Unit Characteristic	Early adopter generalisation	Attitude statement	
Personality values	Less dogmatic	8b	You want to be among the first people to try a new technology
	Favourable attitude towards change	8c	You invest in new technologies soon after they become available for puchase
	Less fatalistic	8e	You often take your time before making a decision to invest
	Able to deal with abstractions	8h	You rarely invest in new technologies
	Favourable attitude towards science	8a	You have a keen interest in new technologies
	Empathy	6f	You are often good at understanding other people's feelings
	Greater rationality	6h	You are often contemplative when you are making a decision
	Favourable attitude towards change	6i	You are often reluctant to change your routine
	Less fatalistic	6j	The future is determined by fate
	Able to deal with abstractions	6g	You often find abstract ideas confusing
	Favourable attitude towards change	8f	You are often sceptical about new technologies
	Able to cope with uncertainty and risk	8g	You tend to invest in new technology once you have been convinced about the benefits of using it
	Less dogmatic	8i	You prefer to stick to existing technologies that you are familiar with
	Able to cope with uncertainty and risk	8j	You would consider yourself willing to take a risk when it comes to investing in new technologies
	Able to cope with uncertainty and risk	8k	The uncertainty of not knowing how successful a technology will be in the long-term would make you feel uncomfortable about investing in it
Communication behaviour	Greater social participation	6a	You regularly participate in social activities
	Highly interconnected in their social system	6b	You regularly interact with people in your local community
	Cosmopolitan - networks broader than local system	6c	You are often involved in matters that require you to interact with people outside of your local network
	Cosmopolitan - networks broader than local system	6d	You have a small network of people you know
	Greater contact with change agents	6e	People you know are often influential (through their advice or opinions) when you are considering buying a new technology
	Greater exposure to mass media communication channels	23	You try to keep up to date with what is happening in the media
	Seek information about innovations	8a	You have a keen interest in new technologies
	Greater knowledge of innovations	12	Level of knowledge of Hybrid
	Greater knowledge of innovations	12a	Level of knowledge of FCV
	Greater knowledge of innovations	12b	Level of knowledge of EV
	Greater degree of opinion leadership	8d	Friends will often use you as a point of reference for new technologies
	Greater contact with change agents	23a	you often follow the views of experts on matters that are important to you

Note: Statement numbers correspond with the statement number in the questionnaire. A copy of the full questionnaire can be found in Appendix 2.

5.5.4 Analysis of the questionnaire data

The methods used for the analysis of the questionnaire data will now be introduced.

Knowledge, Persuasion and Decision are the three phases of the Innovation-Decision Process that are of interest in this research. Examining these phases will provide insight into non-adoption decisions. Implementation and Confirmation are therefore not relevant at this stage, which was also confirmed by the fact that none of the respondents were found to own a vehicle with zero tailpipe emissions.

The analysis in stage two serves three purposes. It seeks first to identify current understanding and attitudes towards alternative fuel vehicles through the use of descriptive techniques. Secondly it tests for a relationship between the socio-demographic profile identified in stage one and knowledge and persuasion attributes as a means of verifying the socio-demographic characteristics in recognising the potential earlier adopters of alternative fuel vehicles. Thirdly it will establish the suitability of the Innovation-Decision Process for use with an 'eco-innovation'. An overview of the statistical methods used in stage two are given in Figure 5.5.

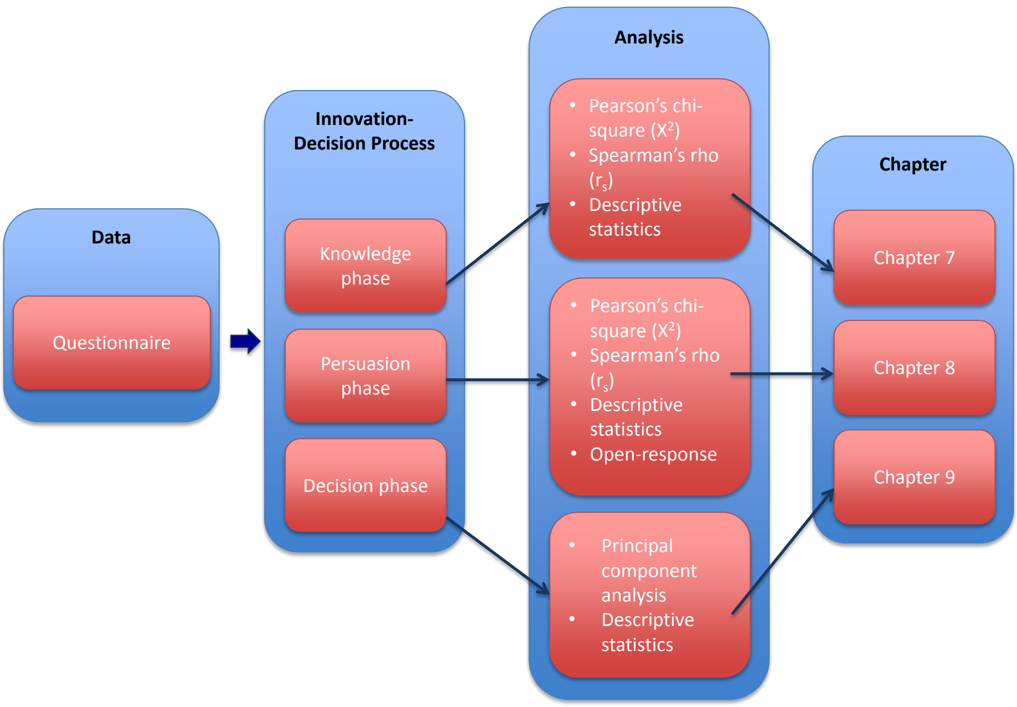
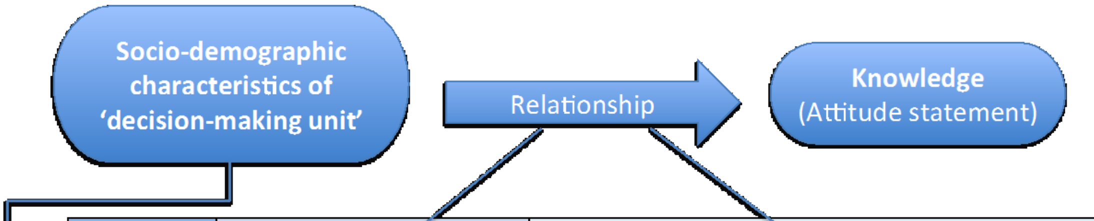


Figure 5.5 *Outline of stage two of the research*

Pearson's Chi-Square and Spearman's rho

Pearson's Chi-Square (X^2) test and Spearman's rho (r_s) are the two statistical techniques used for testing the effect of socio-demographic characteristics on attitudes. They are used predominantly in Chapter 7 due to this chapter focusing on the innovativeness characteristics of the individual, but also feature in Chapter 8. Pearson's Chi-Square (X^2) tests for a linear relationship between two categorical variables while Spearman's rho (r_s) tests the correlations between continuous or scale data. Figure 5.6 provides an example used in Chapter 7 of the categorical nature of the socio-demographic characteristics used in Pearson's Chi-Square test and how the same socio-demographic characteristics were input in their scale form for use with Spearman's rho.



Socio-demographic characteristic	Pearson's chi-square (X^2)		Spearman's rho (r_s)	
Gender	Male	Female	n/a	
Age	Under 60	Over 60	17-24 25-34 35-44 45-54	55-59 60-64 65-74 75+
Qualifications	Higher level qualifications (see right 1,2,3,4,5)	Lower level qualifications (see right 6,7,8,9)	1. A Doctorate or equivalent 2. Master's Degree or equivalent 3. Bachelor's Degree or equivalent 4. HNC/HND	5. A-Level or equivalent 6. GCSE/O-Level or CSE 7. Vocational qualifications 8. Other 9. No formal qualifications
Socioeconomic status	Higher socioeconomic status (see right 1&2)	Lower socioeconomic status (see right 3,4,5,6)	1. Higher managerial, administrative or professional 2. Intermediate managerial, administrative or professional	3. Supervisory, clerical and junior managerial, administrative or professional 4. Skilled manual worker 5. Semi and unskilled manual worker 6. Casual work or unemployed with state benefits

Figure 5.6 *Categorical and ordinal socio-demographic variables used for chi-square and Spearman's rho tests.*

There are similarities between the tests. Pearson's correlation coefficient is a product-moment correlation coefficient that is used to indicate the strength of the relationship between the two variables being tested, while Spearman's rho test first ranks the data before applying Pearson's correlation coefficient to the ranked scores, indicating the shared variance in the ranked order or the data (Field, 2009).

The analysis in Chapter 7 focuses on the degree of persuasion respondents feel towards the adoption of an alternative fuel vehicle and considers perceptions relating to the five characteristics of relative advantage, compatibility, complexity, trialability and observability (See Chapter 4, Table 4.1). Alongside the use of the statistical approaches outlined above and descriptive statistics, the research incorporates a qualitative element, through the analysis of the two open-format questions shown in Section 5.5.3.

Questions that elicit an unprompted response provide the respondent with an opportunity to identify other factors or influences on their attitudes that might not have previously been identified in the research. These questions were also incorporated as a means of examining knowledge in relation to technological, economic, environmental and social advantages or obstacles associated with their use.

Principal component analysis

The analysis in Chapter 8, the final analysis chapter, is centred on the individuals considered to be most innovative, based on the findings from Chapters 6 and 7. Innovativeness is the degree to which an individual is relatively earlier in adopting new ideas than other members of a system and is the behaviour that underpins the diffusion process (Rogers, 2003). In order to generate an innovativeness score for each respondent, the process begins with the use of principal component analysis (PCA), which is applied to the Likert scale questions. An example of the application of principal component analysis in an alternative vehicle acceptance study is Ozaki and Sevastyanova (2011) who also applied it to Likert scale scores.

Principal component analysis is a method of factor analysis. Factor analysis is a multivariate technique that identifies whether the correlations between observed variables stem from their relationship to one or more latent variables in the data, taking the form of a linear model (Field, 2009). The practical difference between principal component analysis and factor analysis is that there is no explicit model (Jolliffe, 2002). Principal component analysis is concerned with establishing the linear components that exist within the data and how an individual variable contributes to that component, such that it unearths factors in the data through the identification of groups or clusters of variables (Field, 2009). Two of its key uses are to understand the structure of a set of variables and to reduce a data set to a more manageable size without losing too much of the original information (Field, 2009). The correlation between variables is arranged on an R-matrix (correlation matrix) and the underlying dimensions, i.e. variables deemed to be measuring the same thing, are termed as factors, or latent variables (Field, 2009).

As part of the preliminary analysis, the correlation matrix should be examined to identify any variables that do not correlate with other variables, or those that correlate very highly with one or more variable ($r = .9$). The ease of interpreting factors can be improved through rotation, and due to the nature of the distinct constructs of the Innovation-Decision Process, it has been necessary to use orthogonal rotation, and the type of rotation selected is Varimax, due to its ability to maximise the dispersion of factor loadings within factors through loading a smaller number of variables highly onto each factor, which results in a range of more easily interpretable factors (Field, 2009).

The number of factors extracted from the data is assessed using Kaiser's criterion, which recommends retaining all factors with eigenvalues that exceed 1, and is found to be accurate when the sample size exceeds 250 and the average communality is greater than or equal to 0.6 (Field, 2009). The extracted factors are presented in a pattern matrix to identify the variables that form each factor. To determine consistency among the variables within each factor, this is achieved by calculating Cronbach's alpha (α), which is the most common measure of scale reliability (Field, 2009). The acceptable cut-off value of Cronbach's α is often considered to be above 0.7 or 0.8, however caution should be exercised when there is a large number of variables in a scale, because α naturally increases (the top half of the equation for α includes the number of items squared) as the number of items in the scale increases (Field, 2009). Another means of determining reliability is the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO), which represents the ratio of the squared correlation between variables to the squared partial correlation between variables and varies between 0 and 1 (Field, 2009). A value exceeding 0.5 is considered acceptable, while values over 0.9 are considered excellent (Field, 2009).

Factor scores can be determined from the variables for each case (respondent) allowing specific constructs to be measured. One of the most sophisticated techniques for calculating factor scores is through the use coefficients as weights rather than using factor loadings. The regression method is considered to be simplest method for calculating factor score coefficients (B) (Field, 2009). This is obtained by multiplying the matrix of factor loading by the inverse (R^{-1}) of the original correlation or R-matrix, effectively dividing the factor loadings by the correlation coefficients. The resulting factor score matrix represents the relationship between each variable and each factor, taking into account the original relationships between the pairs of variables (Field, 2009). The technique ensures that resulting scores have a mean of zero and a variance equal to the squared multiple correlation between the estimated factor scores and the true factor scores (Field, 2009).

Principal component analysis has been applied to the personality and communication behaviour variables, while also incorporating statements relating to norms of the social system and the awareness of a problem or a need that the innovation will satisfy, as shown in Table 5.6. The statements that refer to 'felt needs or problems' and 'norms of the social system' (Figure 5.1) are identified in Table 5.6 and will be referred to as contextual factors from this point forward, such that they form the context to alternative fuel vehicle consideration.

Table 5.6 *Attitude towards contextual factors (prior conditions)*

Adoption decision		Early adopter generalisation	Attitude statement	
Prior Condition	Previous practice	n/a	7h	We should continue with petrol/diesel motor car technology
	Felt needs/problems	n/a	7c	You think about the impact of your activities on the environment
			7d	Petrol/diesel motor cars emit harmful GHGs into the environment
			7e	Oil supplies are running out
			7f	Motor cars produce gases that are harmful to people's health
			7g	Petrol/diesel is likely to become too expensive to buy in the near future
			7l	New vehicle technologies, such as electric vehicles, will never be successful
			7i	Climate change does not cause you concern
			7j	Mainstream electricity production has a low environmmental impact
	Norms of the social system	n/a	7a	Having a motor car is a necessity
			7b	Having a motor car is a luxury
			7k	your motor car use
Characteristics of the Decision-Making Unit	Personality values	Less dogmatic	8b	You want to be among the first people to try a new technology
		Favourable attitude towards change	8c	You invest in new technologies soon after they become available for puchase
		Less fatalistic	8e	You often take your time before making a decision to invest in a new technology
		Able to deal with abstractions	8h	You rarely invest in new technologies
		Favourable attitude towards science	8a	You have a keen interest in new technologies
		Empathy	6f	You are often good at understanding other people's feelings
		Greater rationality	6h	You are often contemplative when you are making a decision
		Favourable attitude towards change	6i	You are often reluctant to change your routine
		Less fatalistic	6j	The future is determined by fate
		Able to deal with abstractions	6g	You often find abstract ideas confusing
		Favourable attitude towards change	8f	You are often sceptical about new technologies
		Able to cope with uncertainty and risk	8g	You tend to invest in new technology once you have been convinced about the benefits of using it
		Less dogmatic	8i	You prefer to stick to existing technologies that you are familiar with
		Able to cope with uncertainty and risk	8j	You would consider yourself willing to take a risk when it comes to investing in new technologies
		Able to cope with uncertainty and risk	8k	The uncertainty of not knowing how successful a technology will be in the long-term would make you feel uncomfortable about investing in it
	Communication behaviour	Greater social participation	6a	You regularly participate in social activities
		Highly interconnected in their social system	6b	You regularly interact with people in your local community
		Cosmopolitan - networks broader than local system	6c	You are often involved in matters that require you to interact with people outside of your local network
		Cosmopolitan - networks broader than local system	6d	You have a small network of people you know
		Greater contact with change agents	6e	People you know are often influential (through their advice or opinions) when you are considering buying a new technology
		Greater exposure to mass media communication channels	23	You try to keep up to date with what is happening in the media
		Seek information about innovations	8a	You have a keen interest in new technologies
		Greater knowledge of innovations	12	Level of knowledge of Hybrid
		Greater knowledge of innovations	12a	Level of knowledge of FCV
		Greater knowledge of innovations	12b	Level of knowledge of EV
		Greater degree of opinion leadership	8d	Friends will often use you as a point of reference for new technologies
		Greater contact with change agents	23a	You often follow the views of experts on matters that are important to you

Note: Statement numbers correspond with the statement number in the questionnaire. A copy of the full questionnaire can be found in Appendix 2.

In the case of the present research problem, the Likert scores for each statement have enabled the identification of an overall innovativeness score for each respondent.

The purchase decision is of interest in this chapter and the analysis considers the purchase decisions that have been made with respect to existing vehicles in addition to the vehicle preferences at the next purchase. The preferences of existing vehicles and future vehicles are compared with the vehicle characteristics of currently available alternative fuel vehicles that are considered to have zero tailpipe emissions. The characteristics of electric vehicles and conventional vehicles will now be explored.

5.6 An overview of the characteristics of currently available alternative fuel vehicles with zero tailpipe emissions

In Chapter 9, the analysis is focused on the decision of the most innovative to adopt or reject an alternative fuel vehicle. In order to provide context to the decision faced by potential adopters it has been necessary to undertake a short analysis of the characteristics of alternative fuel vehicles in conjunction with the characteristics of similar-sized conventional fuel vehicles. The conventional fuel vehicles that feature in this analysis are models that are owned by the survey respondents.

As of March 2014, there were eleven vehicle manufacturers with battery electric vehicles available to buy in the UK. The UK low-emissions car-buying guide, Next Green Car (2014a), predict that almost all car manufacturers will have a battery electric vehicle available for purchase within the following two years i.e. by 2016. Tables 5.7 – 5.10 detail some of the key characteristics of electric vehicles and equivalent-sized conventional vehicles. The data has been obtained from Next Green Car (2014b). The prices of all vehicles, including battery electric vehicles, are the starting price of the respective model if bought new in 2014. By presenting these figures side by side it is possible to see the purchase options that consumers face if they are to consider purchasing an electric vehicle.

Table 5.7 shows the city car class of vehicles. The two electric vehicle city cars are compared with a Peugeot 107 – a vehicle owned by a respondent that is of the city car class of vehicle. The characteristics presented in the Table show that the price of electric vehicles in the same class are almost triple the price of a conventional fuel vehicle. The two electric vehicles excel on equivalent fuel efficiency (equivalent MPG is three times as great as a Peugeot 107), the acceleration speed is faster and the indicative fuel cost is 70% lower than that of the Peugeot 107. As far as engine power is concerned, there is minimal difference and while the top speed of the electric vehicles is 20mph slower than the Peugeot 107, the current UK motorway speed limit is 70mph and therefore the electric vehicle comfortably exceed this limit. The range of both of these vehicles is just less than 100 miles.

Table 5.7 *Comparison of 'city car' characteristics*

		Electric	
Brand	Peugeot	Mitsubushi	Citroen
Model	107	iMiEV	C-Zero
Vehicle class	City car	City car	City car
Price (starting from)	£8,220	£23,554	£21,216
MPG (or estimated equivalent)	66	187	187
Engine power (HP)	68	64	64
Acceleration 0-60mph (secs)	14	16	16
Top speed (mph)	100	81	80
Indicative fuel cost pence/mile (if diesel 142p/l, petrol 137p/l and electricity 14p/kWh)	10	3	3
Emissions (CO2 g/km)	99	0	0
Battery lease cost (£/month)		n/a	n/a
Range (miles)		93	93
Standard charge time (hrs)		7	7
Rapid charge option		yes	yes

Note: data obtained from Next Green Car (2014b)

In Table 5.8 a comparison of cars in the class 'supermini' is presented, which is the next vehicle class up from the city car. There is a large difference in the price of the Renault Zoe and the BMW i3 and this is due to Renault operating a battery-leasing system, whereby the consumer owns the vehicle but hires the battery. Renault intends this to reduce the high cost of ownership as well as improve the residual value of the vehicles, while also attempting to reduce any use-anxiety by providing the owner with assistance for all breakdowns (Which?, 2014). Despite offering the battery leasing option it is £4,000-£7,000 more expensive than conventional fuel vehicles in the same vehicle class. The BMW i3 is double the price of the Renault Zoe and does not offer the battery leasing option. It does, however, offer considerably more power than the Renault as well as offering almost three times as much power as the conventional fuel vehicles in Table 5.8. The top speed of the Renault Zoe is 10mph slower than the conventional fuel vehicles, however the BMW i3 is fairly comparable to these vehicles in its top speed. Both of the electric vehicles have an acceleration speed that is around double the speed of each of the conventional fuel vehicles listed in Table 5.7. The indicative cost of fuel is 67% - 75% cheaper for the electric vehicles than the conventional fuel vehicles. The range of the BMW i3 is less than the Renault Zoe, however both can exceed 100 miles. The standard charge time of this slightly bigger class of vehicle is around 50% quicker than the city car class of electric vehicles.

Table 5.8 *Comparison of 'supermini' car characteristics*

					Electric	
Brand	Citroen	Ford	Ford	Kia	BMW	Renault
Model	C3	Fiesta	Ka	Picanto	i3	Zoe
Vehicle class	Supermini	Supermini	Supermini	Supermini	Supermini	Supermini
Price (starting from)	£10,895	£9,995	£8,795	£8,045	£30,680	£15,043
MPG (or estimated equivalent)	66	54	58	67	196	169
Engine power (HP)	68	59	68	68	170	88
Acceleration 0-60mph (secs)	14	17	13	14	7	8
Top speed (mph)	101	94	99	95	93	84
Indicative fuel cost pence/mile (if diesel 142p/l, petrol 137p/l and electricity 14p/kWh)	10	12	11	9	3	3
Emissions (CO2 g/km)	99	120	115	99	0	0
Battery lease cost (£/month)						70
Range (miles)					118	130
Standard charge time (hrs)					3	4
Rapid charge option					yes	yes

Note: data obtained from Next Green Car (2014b)

Table 5.9 shows the vehicle class 'small family'. The prices of the Nissan Leaf and Renault Fluence are not significantly different from the electric vehicles in the city car vehicle class, while the Ford Focus electric is similar in price to the BMW i3, which falls under the slightly smaller vehicle class of super mini. As can be seen in Table 5.9, there is a conventionally fuelled Ford Focus as well as a battery electric Ford Focus, which makes it much easier to compare the two technologies. The battery electric Ford Focus is more than double the price of the conventional fuel Ford Focus. For a more highly powered Ford Focus (161 HP), with a 0-60mph acceleration speed of 9 seconds and a top speed of 135mph, the price would be in the region of £21,500 (Next Green Car, 2014b) which considerably narrows the price margin between the two technology types. As with the Zoe, Renault also offers a battery leasing system with the Fluence, which reduces the purchase price of the vehicle. Despite offering battery leasing, the Fluence is more expensive than the Nissan Leaf, which offers more engine power, a higher top speed and a slightly greater range.

Again, the electric vehicles show a much lower indicative fuel price, the margin of which is increasing as the vehicle size increases. The range of the vehicle is also improving as the vehicle class size increases due to the ability of the manufacturers to put a larger (and consequently heavier) battery in the vehicles. The acceleration speed is also likely compromised by an increase in weight and size and it is possible to see more similarity between the acceleration capability of the electric vehicles and the conventional fuel vehicles. Conventional fuel vehicles, once again, outperform the electric vehicles on top speed.

Table 5.9 *Comparison of 'small family' car characteristics*

				Electric		
Brand	Ford	VW	VW	Ford	Nissan	Renault
Model	Focus	Golf	Jetta	Focus	Leaf	Fluence
Vehicle class	Small family	Small family	Small family	Small family	Small family	Small family
Price (starting from)	£13,995	£16,775	£18,075	£28,580	£20,990	£22,845
MPG (or estimated equivalent)	48	58	46	177	169	149
Engine power (HP)	84	84	120	143	108	84
Acceleration 0-60mph (secs)	15	12	13	12	16	13
Top speed (mph)	106	111	125	85	87	84
Indicative fuel cost pence/mile (if diesel 142p/l, petrol 137p/l and electricity 14p/kWh)	13	11	14	3	3	4
Emissions (CO_2 g/km)	136	113	144	0	0	0
Battery lease cost (£/month)				n/a	n/a	77
Range (miles)				130	124	115
Standard charge time (hrs)				4	4	8
Rapid charge option				no	yes	no

Note: data obtained from Next Green Car (2014b)

Table 5.10 is the final table of vehicle comparisons and includes several vehicle classes ranging from 'large family' through to 'sports utility vehicle' (SUV) and also incorporates the 'executive' vehicle class.

Table 5.10 *Comparison of larger vehicle class characteristics*

Brand	Ford	Mercedes	VW	Ford	Vauxhall	Landrover	BMW	Volvo	Electric Tesla
Model	Mondeo	C Class	Passat	S-max	Zafira	Range Rover Sport	5 series	V60	Model S
Vehicle class	Large family	Large family	Large family	MPV	MPV	SUV	Executive	Executive	Executive
Price (starting from)	£15,995	£28,085	£20,235	£23,105	£18,920	£51,550	£30,265	£24,395	£50,715
MPG (or estimated equivalent)	42	48	48	42	43	39	63	74	123
Engine power (HP)	118	154	120	158	113	258	143	181	302
Acceleration 0-60mph (secs)	12	9	10	12	13	7	10	7	6
Top speed (mph)	121	139	127	118	115	130	133	140	120
Indicative fuel cost pence/mile (if diesel 142p/l, petrol 137p/l and electricity 14p/kWh)	15	13	13	15	15	17	10	9	5
Emissions (CO2 g/km)	156	138	138	159	157	194	119	99	0
Battery lease cost (£/month)									n/a
Range (miles)									240
Standard charge time (hrs)									8
Rapid charge option									no

Note: data obtained from Next Green Car (2014b)

There are not currently (as of 2014) any electric vehicles available for purchase in the UK that are within any of these classes other than executive. Listing the conventional fuel vehicles that are within these classes is useful to understand what type of vehicle can be purchased for a similar price as the much smaller electric vehicles that have already been presented in the previous tables. The Tesla Model S is currently the only larger battery electric vehicle available for purchase in the UK. As the table shows, the price of the Tesla is over double that of a Volvo V60 (starting price) although the highest specification costs closer to £40,000 but still £10,000 shy of the Tesla Model S price. The highest specification of the BMW 5 Series Saloon costs around £58,000, which would make the price of the Tesla Model S competitive in this vehicle class. The Tesla Model S offers more than any other battery electric vehicle currently available. It is substantially faster, more powerful, and offers a range of 240 miles. This exceeds most other battery electric vehicles by at least 100 miles. The Tesla also excels above the other conventional fuel vehicles of the same class on engine power, offering 160 more horsepower than the BMW 5 Series. The lower indicative fuel cost, being 4-5 pence per mile lower than the other two executive models, may make the Tesla Model S more appealing, particularly as it offers a much more competitive range. One of the disadvantages with the Tesla Model S is that it does not enable the use of rapid charging and has a standard charge time of eight hours.

It is also possible to see from Table 5.10 is that the prices of these vehicles are only starting to show similarity to the battery electric vehicles albeit those of a much smaller vehicle class. The BMW i3 is a Supermini and priced at £30,000, while the slightly bigger electric Ford Focus ('small family') is £28,500, both of which are a similar price to the 'large family' category vehicle of the Mercedes C Class (lowest specification). When taking other brands into consideration, the Volkswagen Passat is considerably less costly than the electric Ford Focus or the BMW i3; the highest specification of a VW Passat Saloon is £27,000, which falls just below the price of the smaller vehicle class electric vehicles.

5.7 Summary

Chapter 5 introduced the research design, outlining how the research is guided by the underpinning Diffusion of Innovations theory (Rogers, 2003), specifically the Innovation-Decision Process. In Section 5.3 an introduction to the study area of Birmingham was provided, which explained the reasons for choosing this city and provided highlights of the characteristics of the city, while also outlining Birmingham City Council's 'Climate Change Action Plan' which aims to significantly reduce carbon emissions within the city, particularly those from transport. The first stage of the research, Section 5.4, detailed how Census data is used in order to identify potential early adopters of alternative fuel vehicles. Section 5.5 then explained the process that was undertaken in the main data collection for this research and the methods of analysis that are used.

In Section 5.6 an overview of the available models of electric vehicles was presented. The majority of vehicles are in small vehicle size categories. The power of these vehicles was found to be better or similar to conventional vehicles. Range however was substantially poorer for electric vehicles. There are substantial savings to be made in the cost of fuel for electric vehicles relative to conventional vehicles. There are large discrepancies between the price of electric vehicles and conventional vehicles within the same vehicle class. The price of electric vehicles only achieves parity with the SUV class (i.e. Land Rover) and high-specification executive class vehicles, although only one manufacturer (Tesla) is selling an electric vehicle in this class in the UK.

The following four chapters present the analysis in this research, shaped by the research objectives outlined in Table 5.1. Chapter 6 covers stage one of this research and identifies geographic locations of potential early adopters in Birmingham. Chapters 7, 8 and 9 cover stage two, and the analysis of this stage is focused on the questionnaire survey.

Chapter 6: The identification of potential early adopters of alternative fuel vehicles in Birmingham

6.1 Introduction

The Innovation-Decision Process begins with the 'knowledge' phase, the point at which an individual is first exposed to the existence of an innovation and begins to develop an understanding of how it works (Section 4.3.2). Rogers (2003) maintains that socio-economic characteristics are influential at the knowledge stage and a review of the literature revealed that a number of studies have been undertaken to identify the socio-economic characteristics of individuals who have so far purchased alternative fuel vehicles, or who are predicted as being most likely to purchase such vehicles.

This section constitutes stage one of the research and serves to identify the locations of individuals with early adopter characteristics in Birmingham. The purpose of this is two-fold. Firstly it is to satisfy the objective of identifying those with the socio-economic characteristics that would allow them to be in the market for an alternative fuel vehicle and thus enable further research with these individuals. Secondly, it enables the identification of sub-areas within cities and towns that can become a primary focus for promoting alternative-fuel vehicles.

In this chapter, Census data is used to identify the geographic distribution of potential early adopters of alternative-fuel vehicles in Birmingham. It was established in Section 4.6.1, that early adopters are classified as the second most innovative group, following 'innovators' and preceding the 'early majority'. These individuals are slightly ahead of the average individual in terms of innovativeness, and they help to trigger critical mass in innovation adoption (Rogers, 1995). Knowing who the potential early adopters of alternative fuel vehicles are is important in establishing a target market. It is therefore important to know where these individuals are located.

6.2 Selecting characteristics with which to identify the locations of potential early adopters

In Table 4.2 (Section 4.6.1) a series of generalisations relating to innovativeness were presented. The generalisations of early adopter socio-economic characteristics include an increased likelihood of having more years of formal education, being literate, having a higher social status, having a greater degree of upward social mobility and having larger-sized units (e.g. residence) than later adopters.

A review of the literature in Section 3.10 indicated that there is a range of socio-economic characteristics, among other socio-demographic characteristics, that are associated with the adoption of an alternative fuel vehicle by those who are, or who are predicted to be among, the earlier adopters (see Table 3.3, Section 3.10). The characteristics identified included being younger or middle-aged, having a high household income, having a high level of education, being a homeowner and being from a multiple car household. It is possible to see a degree of overlap with Rogers' (2003) generalisations about early adopters' socio-economic characteristics and the socio-economic and demographic characteristics identified for early adopters of alternative fuel vehicles in the literature.

The 2001 Census for Birmingham was used to identify the locations of individuals who met as many of these criteria as possible. The variables used in the analysis were age, socio-economic status, level of education, tenure of property (e.g. owned or rented), type of property (e.g. detached or semi-detached), number of vehicles owned and use of a vehicle to commute to work. Table 6.1 illustrates the criteria used in the selection of the variables from the Birmingham census data.

Table 6.1. *Criteria for census data variable selection (refer to Table 3.3)*

Criteria	Reason for inclusion
1. Age group 16-59	Literature review (Section 3.10)
2. Higher education	Literature review (Section 3.10)
3. Home owner	Literature review (Section 3.10)
4. Own at least two cars or vans	Literature review (Section 3.10)
5. Home is detached or semi-detached	Homes in the UK are more likely to have off-road parking (for electric charging and vehicle-to-grid infrastructure) if they are detached or semi-detached.
6. Socio-economic status ('higher professional occupations' or 'lower managerial and professional occupations')	Used in the absence of income data being available in the Census.
7. Drive a car to work	This group demonstrate a higher dependence on their motor vehicle.

In using secondary data, the choice of variables was constrained by census data variables. To determine the appropriate age category, based on the findings in Section 3.10 that indicated those most likely to purchase an electric vehicle are from the younger or middle-aged age categories, a decision was taken to focus on those who fall in the age groups 16-24, 25-44 and 45-59. Despite 16 being below the legal driving age (in the UK the legal driving age is 17), it was considered unnecessary to exclude the age category 16-24 due to the majority within this age group being eligible to drive. While drivers under the age of 24 may not have reached the necessary earning potential to purchase an alternative fuel vehicle, they may still be influential in a household vehicle purchase decision or equally may be approaching a stage in life when earning potential will allow a larger budget for a vehicle purchase.

In the UK, income data is not collected in the national census and therefore it was necessary to use an alternative indicator of income. In this case socio-economic status has been used as a proxy variable. The census classifies socio-economic status according to occupation. The two occupation categories that constitute a higher socio-economic status are higher professional occupations and lower professional and managerial occupations, such as finance manager, solicitor, account, police officer, teacher, and scientist.

In Section 3.10, the literature showed that an individual is more likely to consider an electric vehicle if they are able to install the necessary charging infrastructure and can charge a vehicle in a secure location. This was considered more likely if individuals owned their homes. In this respect, knowing the property tenure of respondents is important. In lieu of income data, homeownership is also useful as a proxy variable for income. Further, in order to identify households that are most likely to have a driveway or an off-road parking facility, a decision was taken to incorporate an 'accommodation type' variable, such that detached or semi-detached houses might be assumed more likely to have a driveway or a garage than a terrace or a flat. Additionally, the use of a vehicle to drive to work was incorporated as an indicator of vehicle dependence.

6.3 Developing population segments based on typical alternative fuel vehicle adopter characteristics

The purpose of this stage of the analysis is to produce homogeneous groups of individuals based on the criteria detailed in the previous section, so that the group that has the highest levels of all characteristics can be identified as most closely meeting the socio-economic profile of a potential alternative fuel vehicle adopter. In order to achieve this outcome, cluster analysis (see Section 5.4.3 for details) has been selected as the most appropriate analytical approach due to its ability to partition observations for a set of specified characteristics into two or more groups (Hair et al., 2010). Its use, in this particular case, is valuable for data simplification, in order to provide structure to a large data set.

Multicollinearity impacts the weighting of variables in the analysis, which affects the similarity measure, meaning it is necessary to test for its presence prior to running cluster analysis. As such, only variables that are not highly correlated should be included (Hair et al., 2010). Pearson's correlation coefficient (r) is a technique used to measure the association between two variables and the closer the value of Pearson's coefficient to '1', the greater the multicollinearity. As a rule of thumb r values that exceed 0.8 and 0.9 are considered to be very highly correlated (Field, 2009). Table 6.2 shows a correlation matrix of the variables used in this analysis, from which it is possible to see fairly high scoring r values, as expected for socio-economic characteristics. The r values show a significant correlation (r = 0.852) between socio-economic status (professional employees or managers) and higher education (level 4+ qualifications). This should be expected due to socio-economic status often being a measure of a range of socio-economic factors including education. A decision was taken to exclude education from the analysis but to keep socio-economic status due to its ability to provide an indicator of income in lieu of this characteristic not being available in the Census.

***Table 6.2** Correlation matrix of Census characteristics*

Variables	% of those aged 16-59	% of owner occupiers	% of detached and semi detached homes	% of those travelling to work by car	% of households with 2+ cars	% of professional employees or managers within ward	% of those with level 4 qualifications
% of age 16-59	1	0.441	0.37	0.499	0.413	0.573	0.33
% of owner occupiers		1	0.701	0.735	0.742	0.547	0.319
% of detached and semi detached homes			1	0.668	0.745	0.408	0.157
% of those traveling to work by car				1	0.766	0.646	0.377
% of households with 2+ cars					1	0.708	0.517
% of professional employees or managers within ward						1	0.852
% of those with level 4 qualifications							1

In order to identify the importance of the variables in terms of their effect on the differentiation on the clusters, a one-way ANOVA was conducted. The F statistic shown in Table 6.3 indicates that there is a strong degree of distinction between the variables and that each one contributes to the differences between the clusters. An F statistic of less than 1 represents a non-significant effect (Field, 2009). All of the variables used in the cluster analysis have values that exceed 1, supporting their use in providing differentiation between the clusters. Home ownership (owner occupiers), accommodation type (detached and semi-detached homes) and number of vehicles in the household (households with 2+ cars) have the strongest effect on the differences between the clusters. Age has the smallest effect on differentiation (F=160.8) between the clusters, although it still has a strong effect.

Table 6.3 *ANOVA analysis on cluster variables*

Variable		ANOVA Sum of Squares	df	Mean Square	F	Sig.
Age 16-59	Between Groups	5.397	6	0.9	160.8	0.000
	Within Groups	17.449	3119	0.006		
	Total	22.846	3125			
Owner occupiers	Between Groups	169.649	6	28.275	2661.8	0.000
	Within Groups	33.131	3119	0.011		
	Total	202.781	3125			
Detached and semi detached homes	Between Groups	232.298	6	38.716	3782.1	0.000
	Within Groups	31.928	3119	0.01		
	Total	264.226	3125			
Travels to work by car	Between Groups	26.272	6	4.379	955.54	0.000
	Within Groups	14.292	3119	0.005		
	Total	40.564	3125			
Households with 2+ cars	Between Groups	47.874	6	7.979	1689.4	0.000
	Within Groups	14.731	3119	0.005		
	Total	62.606	3125			
Professional employees or managers within ward (higher SEC)	Between Groups	19.936	6	3.323	389.36	0.000
	Within Groups	26.617	3119	0.009		
	Total	46.553	3125			

6.4 Selecting an appropriate cluster solution

The analysis is undertaken at the lowest geographic level of data provided by the Census, called Output Areas. Lower level data i.e. household level, is not publically available due to data protection. However, Output Areas are a useful classification to work with in this analysis as they were created to reflect social homogeneity (as much as possible) based on household tenure dwelling type and were built from adjacent postcode units.

Ward's method, a hierarchical clustering algorithm, was used to identify geo-demographic clusters of Output Areas containing individuals who most closely fit the profile of an anticipated alternative fuel vehicle driver. Ward's method calculates the sum of squares (distance) between an object in the first cluster and an object in the second cluster, which is then summed across all variables (Hair et al., 2010). This method optimises the production of clusters of approximately equal size.

In deciding how many clusters should be formed, there is no standard objective procedure. The procedure is, instead, subjective but guided by the 'stopping rule', which involves selecting the number of clusters which most appropriately represents the data set (Hair et al., 2010). Rogers' Diffusion of Innovations Theory (2003) has five neat adoption categories. However, it was not certain the size of clusters that would be produced in a five cluster solution in the cluster analysis, and whether the clusters would fit the normal adopter frequency distribution. Since early adopters are the key focus of the research at this stage, it was decided that in selecting the most appropriate range of clusters, there should be a distinct individual cluster that contained the highest mean values and constituted up to 13.5%. This figure is taken from Rogers Diffusion of Innovations theory (2003), which identified that early adopters tend to constitute around 13.5% of the total adopters of an innovation. As this research has been conducted at output area level, this constitutes up to 400 output areas within Birmingham.

With the purpose of identifying a cluster solution that has clear distinctions between each cluster but also contained one with the highest mean values across all five variables, a series of cluster solutions were produced. An examination of the cluster centroids (mean values) for the different cluster solutions was undertaken as a process of internal validation and showed greatest heterogeneity between cluster groups for a five-cluster solution, followed by a seven-cluster solution and then a ten-cluster solution, a pattern which is to be expected as the number of clusters increases. The cluster in the five-cluster that constituted the highest mean values across all variables contained 752 output areas but as this constitutes 24% of all output areas it was considered to be too large. The ten-cluster solution presented insufficient heterogeneity between clusters, while the seven-cluster solution had less heterogeneity between clusters than the five-cluster solution but contained a cluster with higher mean values than the remaining six that constituted 8% of the total output areas. As early adopters tend to constitute a relatively small proportion of the overall number of adopters it was the seven-cluster solution that was considered as the most suitable grouping for this application. The output for the seven-cluster solution is shown in Table 6.4.

***Table 6.4** Characteristics of the seven-cluster solution*

		% in age group 16-59	% of owner occupiers	combined % of detached and semi-detached homes	% of those travel to work by car	% of households with 2+ cars	% of professional employees or managers within ward
Cluster 1 (Early adopters)	N Valid	259	259	259	259	259	259
	Mean %	64	94	93	67	52	39
	Std. Deviation %	4	4	7	5	10	7
	Minimum %	54	76	72	53	33	22
	Maximum %	77	100	100	82	83	68
Cluster 2 (Early majority first wave)	N Valid	493	493	493	493	493	493
	Mean %	62	87	87	58	29	25
	Std. Deviation %	5	9	10	5	7	6
	Minimum %	33	46	57	35	6	7
	Maximum %	76	100	100	72	57	52
Cluster 3 (Early majority second wave)	N Valid	473	473	473	473	473	473
	Mean %	61	75	55	57	26	29
	Std. Deviation %	6	12	11	8	9	12
	Minimum %	43	47	16	37	10	8
	Maximum %	76	100	76	83	55	66
Cluster 4 (Late majority first wave)	N Valid	454	454	454	454	454	454
	Mean %	57	70	23	49	16	23
	Std. Deviation %	9	10	11	8	7	14
	Minimum %	32	28	0	28	0	4
	Maximum %	79	91	52	77	39	67
Cluster 5 (Late majority second wave)	N Valid	618	618	618	618	618	618
	Mean %	54	47	43	47	13	15
	Std. Deviation %	5	12	11	7	5	6
	Minimum %	36	3	17	25	3	3
	Maximum %	71	80	88	71	37	51
Cluster 6 (Laggards)	N Valid	531	531	531	531	531	531
	Mean %	54	40	21	42	9	15
	Std. Deviation %	8	10	8	6	4	9
	Minimum %	38	9	3	22	0	2
	Maximum %	78	62	45	63	28	56
Cluster 7 (Unlikely adopters)	N Valid	298	298	298	298	298	298
	Mean %	50	17	13	32	6	11
	Std. Deviation %	14	10	9	8	6	5
	Minimum %	5	0	0	15	0	0
	Maximum %	84	42	39	67	33	31

Note: Highest mean values are highlighted in green, while lowest mean values are highlighted in red.

6.5 Cluster Labelling

Each of the clusters in Table 6.4 has a unique profile, and assigning a label to represent their respective characteristics provides greater context and meaning while also confirming the practical significance of the variable's presence. Profiling is considered as a form of cluster group validation (Hair et al., 2010), such that if it is straightforward to assign a name to each cluster group then it demonstrates heterogeneity between groups. Given that the seven-cluster solution has been selected for this analysis, Rogers' (2003) five innovation categories cannot be precisely assigned. The theory has, however, guided the naming of the clusters in this analysis.

The clusters in Table 6.4 are listed from top to bottom in order of the stage in time the individuals within the cluster might be likely to adopt an alternative fuel vehicle. This has been done according to the mean values and justifies the second stage of the research in the subsequent chapters.

Based on socio-demographic characteristics, Cluster 1 may be representative of an 'early adopter' group. Early adopters want to be the first people to own alternative fuel vehicles and like to see themselves as role models in society.

Cluster 2 and Cluster 3 may represent two waves of the 'early majority' group – those who will spend slightly longer deliberating over buying an alternative fuel vehicle, and will first seek the advice and opinions of an early adopter before investing. This is one of the categories with the greatest number of people, and for that reason there are two waves of 'early majority' adopters in this analysis. Cluster 3 may represent the 'early majority second wave' who are those who have deliberated for slightly longer than those in Cluster 2, the 'early majority first wave'.

Similar to Clusters 2 and 3, Clusters 4 and 5 may be representative of two waves of a 'late majority' group – these adopters are slightly cautious and sceptical about buying an alternative fuel vehicle, but may have found that a point has been reached when a combination of economic conditions or social pressure mean the individual is almost compelled to buy an alternative fuel vehicle. Again, this is one of the largest categories of adopters with Cluster 5 perhaps being the 'late majority second wave' i.e. those who are most cautious or sceptical.

Cluster 6 may be 'Laggards' who will be the last to adopt an alternative fuel vehicle, as they hold traditional values and do not respond well to change. Laggards tend to lack knowledge and understanding of alternative fuel vehicles and the environmental pressures which have led to their introduction.

The final cluster, Cluster 7, may constitute the 'unlikely adopter', who, in the case of transport and vehicle ownership and a variety of factors that may be influential (such as lack of resources or a disability), may never own or use a motor vehicle.

Despite Rogers (2003) incorporating an 'innovator' category of adopter, the analysis does not include this category (Table 6.4). An assumption has been made that the socio-demographic characteristics of an innovator, particularly in terms of the application of these characteristics to the variables available in census data, may not be overtly dissimilar to those of an early adopter. There are other factors such as innovativeness and perceptions of the innovation that are also influential in the decision to adopt an innovation (Rogers, 2003), and these will be explored in the consecutive chapters.

It is therefore possible that some innovators may exist among the output areas that have been identified as potential early adopters. As Table 6.5 indicates, the cluster solution has, however, produced some results that relate closely to the size of the adopter categories identified by Rogers. However, it is not necessarily possible to distinguish between the distinct categories until the innovation completes the diffusion process.

Table 6.5 *Frequency distribution of adopters and potential adopters*

Adopter category	**Frequency distribution in Rogers (2003)**	**Frequency distribution in the analysis**
Innovators	2.5 %	n/a
Early Adopters	13.5 %	8.0 %
Early Majority	34.0 %	31.0 %
Late Majority	34.0 %	34.0 %
Laggards	16.0 %	17.0 %
Unlikely adopters	n/a	10.0 %

Note: Unlikely adopter category added in the analysis.

The early majority categories in the analysis total 31% of output areas, the late majority categories total 34%, and Laggards constitute 17%. An additional 'Unlikely Adopter' category has been added to this analysis, which is an extension of the 'Laggard' category, whereby there may still be a population that choose never to adopt an innovation. An assumption cannot be made that all of those who meet the demographic criteria of a potential early adopter of an alternative fuel vehicle will naturally become adopters.

Figure 6.1 provides a visual representation of each of the cluster profiles that are detailed in Table 6.4.

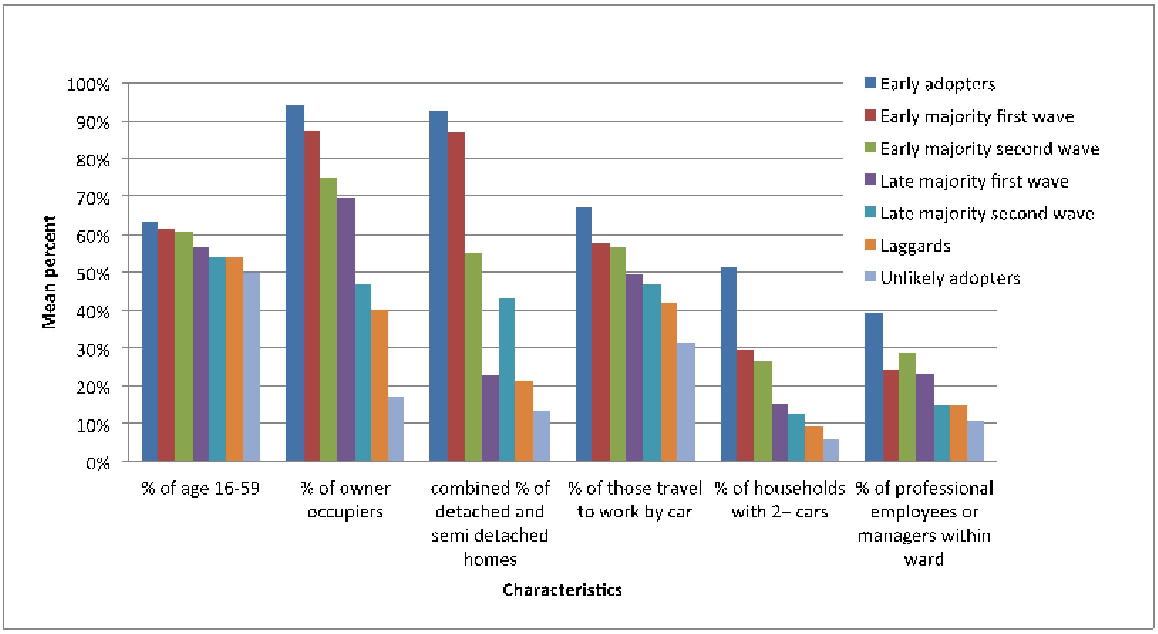


Figure 6.1 *Cluster profiles*

As Figure 6.1 further confirms, the cluster analysis was successful in producing a range of distinct clusters. The 'early adopter' cluster has the highest proportion of individuals that fit each of the criteria, while the 'unlikely adopters' cluster contains the fewest number of individuals matching the criteria.

6.6 The locations of early adopters and their characteristics

As Table 6.4 shows, the 'early adopters' cluster has the highest mean values across each of the seven variables. Within the 259 Output Areas of this cluster are 32,000 households and 85,000 residents, the latter figure equates to nine per cent of the total population of the Birmingham County Council area. The output areas are contained within wards, which are spatial units that represent electoral divisions, of which there are 40 in Birmingham. The 259 output areas are distributed across the wards shown in Table 6.6.

Table 6.6 *Ward distribution of potential early adopters*

Ward	Number of output areas	Total percent (%)
Sutton Vesey	42	16.2
Sutton New Hall	38	14.7
Sutton Trinity	37	14.3
Sutton Four Oaks	36	13.9
Hall Green	23	8.9
Quinton	10	3.9
Billesley	6	2.3
Harborne	6	2.3
Northfield	6	2.3
Bournville	5	1.9
Handsworth Wood	5	1.9
Kings Norton	5	1.9
Moseley and Kings Heath	5	1.9
Bartley Green	4	1.5
Brandwood	4	1.5
Hodge Hill	4	1.5
Weoley	4	1.5
Edgbaston	3	1.2
Kingstanding	3	1.2
Erdington	2	0.8
Longbridge	2	0.8
Sheldon	2	0.8
South Yardley	2	0.8
Springfield	2	0.8
Acocks Green	1	0.4
Perry Barr	1	0.4
Stechford and Yardley North	1	0.4

Within the 'early adopter' cluster, 94% of the population are homeowners, with 93% living in detached or semi-detached homes. Over half of the population has two or more cars and 67% of people use their cars for commuting. There are 39% of people within the output areas identified as professionals or managers.

A key finding in Table 6.6 is that 59% of the output areas in the 'early adopters' cluster are located across four wards - Sutton Vesey, Sutton New Hall, Sutton Trinity and Sutton Four Oaks, all of which form the Birmingham suburb of Sutton Coldfield. The four wards are located to the north of the city, as can be seen in the ward map in Figure 6.2. The distances of the four Sutton Coldfield wards from the city centre (located in the ward of Ladywood) are between five and seven miles. Their combined population is 95,000, constituting 9% of the total population of Birmingham Metropolitan District. These wards have the highest levels of employment, the highest percentage of the population with two or more cars and the lowest levels of people living in local authority housing.

Figure 6.2 *Ward map of Birmingham Metropolitan District.*

The census data for each of the characteristics in these wards are shown in Table 6.7 alongside the census data for the whole of Birmingham Metropolitan District.

Table 6.7 *Census data for Birmingham Metropolitan District and the four wards of Sutton Coldfield (ONS, 2001)*

Socio-demographic characteristic		Sutton Coldfield Wards								Sutton Coldfield Ward average		Birmingham Met. District	
		Sutton Four Oaks		Sutton New Hall		Sutton Trinity		Sutton Vesey					
Gender	Males	13,776	48%	15,571	48%	11,250	48%	13,871	48%	13,617	48%	473,266	48%
	Females	14,837	52%	16,792	52%	12,144	52%	14,947	52%	14,680	52%	503,821	52%
	Total population	28,613		32,363		23,394		28,818		28,297		977,087	
Age	16-24	2,248	8%	2,908	9%	2,033	9%	2,582	9%	2,443	9%	132,519	14%
	25-44	6,922	24%	9,251	29%	6,284	27%	7,366	26%	7,456	26%	276,804	28%
	45-64	8,081	28%	8,171	25%	6,007	26%	7,965	28%	7,556	27%	196,859	20%
	65+	6,143	21%	5,512	17%	4,377	19%	5,269	18%	5,325	19%	141,956	15%
	Mean Age	43		40		n/a		41		41		36	
Qualifications	Lev 3 (e.g. A Levels, GNVQ)	1,715	8%	1,823	8%	1,249	8%	1,638	8%	1,606	8%	60,291	9%
	Lev 4+ (e.g. degree level & higher)	5,849	28%	4,942	21%	4,174	25%	5,653	27%	5,155	26%	113,037	17%
EA* Socioeconomic status	Lev 1 (Higher managerial & professional)	2,864	21%	2,400	14%	1,870	16%	2,566	18%	2,425	17%	35,160	9%
	Lev 2 (Lower managerial & professional)	5,192	37%	5,576	34%	3,985	35%	5,306	36%	5,015	36%	77,424	19%
Employment status	Economically active	13,855	48%	16,621	51%	11,489	49%	14,619	51%	14,146	50%	410,558	42%
	EA* Employment rate	12,940	93%	15,535	93%	10,541	92%	13,587	93%	13,151	93%	351,120	86%
	Part-time work (incl. self employ)	3,155	23%	3,394	20%	2,455	21%	3,010	21%	3,004	21%	76,039	19%
	Full-time work (incl. self employ)	9,785	71%	11,941	72%	8,086	70%	10,577	72%	10,097	71%	275,081	67%
	EA* Unemployed	450	3%	700	4%	540	5%	497	3%	547	4%	38,826	9%
	EA* Full time students	465	3%	586	4%	408	4%	535	4%	499	4%	20,612	5%
	Retired (Economically inactive)	3,891	14%	3,444	11%	2,715	12%	3,216	11%	3,317	12%	83,311	9%
House type	Total households	12,105		13,711		9,898		11,784		11,875		390,792	
	Total detached homes	5,712	47%	4,199	31%	3,179	32%	4,421	38%	4,378	37%	44,444	11%
	Total semi-detached homes	3,818	32%	5,753	42%	3,854	39%	4,675	40%	4,525	38%	141,142	36%
Tenure	Owned (incl. with mortgage/loan)	10,457	86%	10,989	80%	7,832	79%	10,125	86%	9,851	83%	236,209	60%
	Private rented	491	4%	740	5%	532	5%	625	5%	597	5%	34,508	9%
Number of cars in household	0	1,841	15%	2,813	21%	2,112	21%	2,019	17%	2,196	19%	150,401	38%
	1	4,606	38%	5,796	42%	4,146	42%	4,726	40%	4,819	41%	163,000	42%
	2	4,458	37%	4,243	31%	2,997	30%	4,058	34%	3,939	33%	63,732	16%
	3	907	7%	680	5%	492	5%	762	6%	710	6%	10,654	3%
	4+	293	2%	177	1%	141	1%	218	2%	207	2%	3,005	1%
Travel to work	Travel by car (incl. as passenger)	9,370	72%	11,063	71%	7,320	69%	9,915	73%	9,417	72%	212,859	61%

Note: Economically Active (EA)

Sutton Coldfield has a different age distribution to that of Birmingham Metropolitan District. In Sutton Coldfield 82% of the population are over the age of 16 compared to 77% in Birmingham Metropolitan District. There are a larger proportion of those in older age groups in Sutton Coldfield with 19% over the age of 65 in comparison to 15% in Birmingham Metropolitan District. This is also supported by a higher number of retired individuals (12%) in Sutton Coldfield than in Birmingham Metropolitan District (9%).

In Sutton Coldfield, of those who are economically active, 53% of individuals have a socio-economic status that is a level one or level two (the highest levels of socio-economic status measured in the Census) compared to 27% in Birmingham Metropolitan District. There are a greater proportion of individuals in Sutton Coldfield with the highest levels of qualifications (level four and above) (26%) than in Birmingham Metropolitan District (17%). Sutton Coldfield also boasts a 7% greater employment level (93%) than Birmingham Metropolitan District (86%) and has a greater number of retirees.

Home ownership is 23% greater in Sutton Coldfield, with 83% of the population owning their homes and 5% in private rented accommodation. In Birmingham Metropolitan District, 60% of the population are homeowners and 9% are in private rented accommodation. There are also a considerably greater number of detached and semi-detached homes, constituting 37% and 38% respectively of all homes in Sutton Coldfield in comparison to 11% and 36% respectively in Birmingham Metropolitan District.

There are higher levels of car ownership in Sutton Coldfield, with 86% of the population having at least one car in the household compared to 64% in Birmingham Metropolitan District. In this analysis it is households that have at least two cars that are of particular interest, and 48% of households in Sutton Coldfield have two or more cars in comparison to 23% in Birmingham Metropolitan District. Sutton Coldfield exhibits a higher car dependency, with 72% of the population travelling to work by car in comparison to 61% of Birmingham Metropolitan District.

Of each of the four wards in Sutton Coldfield, Sutton Four Oaks has the highest proportion of those with the highest level of socio-economic status (level one) constituting 21% and the highest level of qualifications (level four and above), constituting 28% of the population. The ward with the lowest proportion of the population demonstrating these characteristics is Sutton New Hall with 14% and 21% for higher socio-economic status (level one) and higher-level qualifications (level four and above) respectively. Sutton Four Oaks also has the highest proportion of detached homes (47% of all households) in addition to being the only ward in Sutton Coldfield to contain more detached than semi-detached homes (15% more detached homes than semi-detached homes). With 47% of all households having two or more cars it also has the highest proportion of multiple-vehicle households of all four wards, with the next highest being Sutton Vesey with 43%. The proportion of multiple-vehicle ownership for Birmingham Metropolitan District is 20%. This suggests that of each of the four wards of Sutton Coldfield, Sutton Four Oaks contains a population that is perhaps more affluent than the other three wards.

These figures support the findings of the cluster analysis, suggesting that it is not unreasonable to assume that Sutton Coldfield would be a likely area in which an early adopter of an alternative fuel vehicle may reside. At the very least, it is an area with a fairly homogeneous population in accordance with the characteristics of a potential early adopter of an alternative fuel vehicle. The remaining 41% of output areas containing potential early adopters of alternative fuel vehicles are spread across a number of wards that do not share the same spatial concentration as that of the output areas in the four Sutton wards.

6.7 The locations of the least likely adopters and their characteristics

While considering the wards and output areas that contain residents who most strongly demonstrate characteristics of potential alternative fuel vehicle drivers, it is also of interest to consider the wards which have a population least likely to be early adopters of alternative fuel vehicles. The 'unlikely adopters' cluster, constituting 298 output areas, had the lowest mean values. The highest concentrations of output areas in this cluster (37%) are located in the wards enveloping the city centre, namely Aston (12%), Ladywood (11%) and Nechells (14%). These wards have the lowest levels of car ownership and are amongst the wards with the highest levels of unemployment and local authority housing. In contrast to the 'early adopter' cluster, only 17% of the population in the wards identified here are home owners. In these locations, 13% of the population live in detached or semi-detached houses, just under a third of the population travel to work by car, 6% own two or more cars and 11% are professionals or managers.

6.8 Discussion

The purpose of this chapter was to identify, from Census data, the individuals who have the potential to become early adopters of alternative fuel vehicles based on their socio-demographic characteristics.

Ward's method of hierarchical cluster analysis enabled unique labels to be assigned to seven distinct clusters that represented the potential of the population within the group to adopt an alternative fuel vehicle. The cluster with the highest mean values across the different variables was defined as constituting potential early adopters. An assessment of the location of this 'early adopter' cluster led to the identification of a strong spatial concentration in the outer wards situated towards the north of Birmingham city centre, in a suburb known as Sutton Coldfield.

The four wards of Sutton Coldfield - Sutton Vesey, Sutton New Hall, Sutton Trinity and Sutton Four Oaks - form the largest Parliamentary Constitution in Birmingham. They are located to the north of the M6 motorway, which runs from the south east of Birmingham, past Manchester and up to Carlisle, on the border of England and Scotland. The M6 motorway cuts through the wards of Hodge Hill, Tyburn, Stockland Green and Perry Barr, allowing residents from the northern wards access to a major road network without having to contend with traffic travelling from the city. Commuters travelling to the city from these northern wards can access it through an A-class arterial road. This finding is interesting for policy, marketing and infrastructure implementation.

The findings confirm the validity of the cluster analysis in conjunction with the empirical findings from the literature. A large proportion of the population living in these wards are homeowners and live in detached or semi-detached homes. Williams and Kurani (2006) found that being a homeowner was an important characteristic as it makes any necessary investment in infrastructure at the home a more viable option. Detached or semi-detached houses are more likely to have a garage or a driveway, which, according to Deloitte (2010), Ozaki and Sevastyanova (2011), and Williams and Kurani (2006), is important in providing a secure area to connect the vehicle to recharging infrastructure. Over half of the survey population own two or more vehicles; Kurani et al (1995), Ozaki and Sevastyanova (2011) Deloitte (2010) and Graham-Rowe et al. (2012) all recognise car ownership, in particular owning more than one vehicle, as an influential characteristic in the adoption of an alternative fuel vehicle.

As there was no data available for income, socio-economic status was used as an indicator of income. In the Census, socio-economic status is determined by occupation and therefore the occupation group 'professionals and managers', was used in this analysis to represent those expected to have a higher income than other occupation groups. Higher income is a key characteristic recognised by Deloitte (2010) Karplus et al. (2010) and Ozaki and Sevastyanova (2011). Just under 40% of the population are of a higher socio-economic status, a figure considerably higher than the area (Birmingham Metropolitan District) average. Education, which was considered an important factor for those considering alternative fuel vehicles (Hidrue et al., 2011; O'Garra et al., 2005), was removed from the analysis due to multicollinearity with socio-economic status. Prior to removal it was noticed in some cases that mean values across all other variables were low and yet very high for education and vehicle ownership, which may have been influenced by wards with a large student population living in high-occupancy households with multiple cars, but who are not affluent home-owners. This demonstrates that extra care needs to be taken when applying specific demographic characteristics to a given area and in the analysis of such a study, where prior knowledge of the area can prove invaluable.

Wards with a low level of potential alternative fuel vehicle owners have also been identified. There was a concentration of 'unlikely adopters' in wards close to the city centre. Low car ownership in some of these wards may, however, be due to good public transport links close to the city. Birmingham has several rail stations, with its main station, Birmingham New Street, offering direct rail links to London. The analysis showed that there is a low percentage of detached and semi-detached houses in these wards, attesting to the typical layout of a city, where one can expect to find higher density housing in inner suburbs. Inner city areas in the UK, particularly in de-industrialised cities, have been found have high levels of deprivation in contrast to outer or rural suburbs, which is evident in the levels of unemployment, social housing and education (Gripaios, 2002).

Local authorities in the UK are working towards reducing carbon emissions and are equipping themselves with the means to support electric vehicles (see Section 5.3). Knowing the locations of potential early adopters of these vehicles is valuable in the drafting of policy to facilitate their hastened adoption. While budgets are tight and electric vehicle adoption is taking some time, delivering segment-focused policies may be the most effective at this stage in offering a return on investment (e.g. infrastructure implementation). Electric vehicles are expensive to purchase and are, therefore, only likely to appeal to a small market segment at the present time. It may be that focusing on one geographic area with a fairly homogeneous group to begin with will bring about a snowball effect, with adoption spilling over into other areas of a city like Birmingham, although the social implications that may arise if one area is perceived to be favoured over others should be considered.

Focused policy has occurred on a larger scale in the US, with California becoming the focus of investment for alternative fuel vehicles, moving it ahead of other US states in terms of electric vehicle adoption rates, with an example of one policy being the city of Palo Alto, requiring every new home to be pre-wired for accommodating an electric vehicle charging point (Lavrinc, 2013). Other incentives in California include allowing electric vehicles access to High Occupancy Vehicle (HOV) lanes, making $20 million available for funding programmes that encourage 'green vehicle' purchases and making public charging points more accessible by requiring providers to allow payment by credit card, omitting the need for registration by the individual. Such policies could perhaps be implemented to encourage uptake of electric vehicles in Birmingham. For example, Birmingham city council could consider introducing a priority lane for high occupancy vehicles and alternative fuel vehicles on the arterial road that leads into the centre of Birmingham from Sutton Coldfield, and which experience congestion at peak times, particularly due to the convergence of M6 motorway traffic. Equally, Birmingham City Council could trial a policy in Sutton Coldfield, which requires new-build residential properties to fit the necessary wiring to support an electric vehicle charging point.

As one of the initial stages in product marketing is market segmentation, being able to locate potential consumers in order to allocate the appropriate resources towards the product's positioning and promotion is going to be of great interest to alternative fuel vehicle manufacturers. Knowing the location of potential consumers allows for targeted marketing campaigns, which may include advertising hoardings, local media (print and radio) as well as vehicle trial opportunities. This is going to be most effective in a place like Sutton Coldfield where there is a concentration of the target audience in one geographic location. Gärling and Thøgerson (2001) maintain that successful marketing to these early adopter market segments will pave the way for electric vehicles into the wider market for those who see electric vehicles as the new social norm, including single-car households. Activities to increase awareness of alternative fuel vehicles may also be necessary in an area like Sutton Coldfield where there is a population who may be able to afford such a vehicle, but where awareness may be poor.

Infrastructure is one of the major barriers to electric vehicle uptake, and at this early stage in the adoption of electric vehicles building a highly visible recharging infrastructure network will be critical to reducing anxiety associated with ownership and use. An ability to identify clusters of individuals who have the socio-economic characteristics to be potential adopters of electric vehicles will help to guide infrastructure programmes. With close proximity to the M6 motorway junction, Sutton Coldfield may also offer an opportunity to install a rapid-charge electric refuelling station. This would enable those who live locally to refuel electric vehicles in a shorter period of time than standard trickle charging allows, and would support the creation of a nationwide electric vehicle charging network. This would allow those travelling along the M6 motorway, from the northwest of England to the south (and vice versa), to recharge their vehicles with ease en route.

This chapter has laid the foundation for further analysis of the early adopter cluster in order to establish the additional factors affecting the adoption of alternative fuel vehicles amongst this group. The cluster of potential early adopters identified in this chapter is based on Rogers' Diffusion of Innovations theory, which now enables additional characteristics that are considered influential in the innovation-decision process to be explored. In the context of electric vehicles, the following two chapters will examine the knowledge-influencing characteristics (i.e. innovativeness) and persuasion-influencing characteristics considered to affect adoption.

Chapter 7: Knowledge of electric vehicles and the factors that influence it

7.1 Introduction

This Chapter and the two chapters that follow constitute stage two of the research and utilise survey data in the analysis. Chapter 7 is concerned with the knowledge phase of the Innovation-Decision Process and the factors that influence it, principally socio-economic characteristics, personality variables and communication behaviour, all of which are considered to be indicative of innovativeness (see Section 4.6.1). These 'decision-making unit' characteristics are depicted in Figure 7.1.

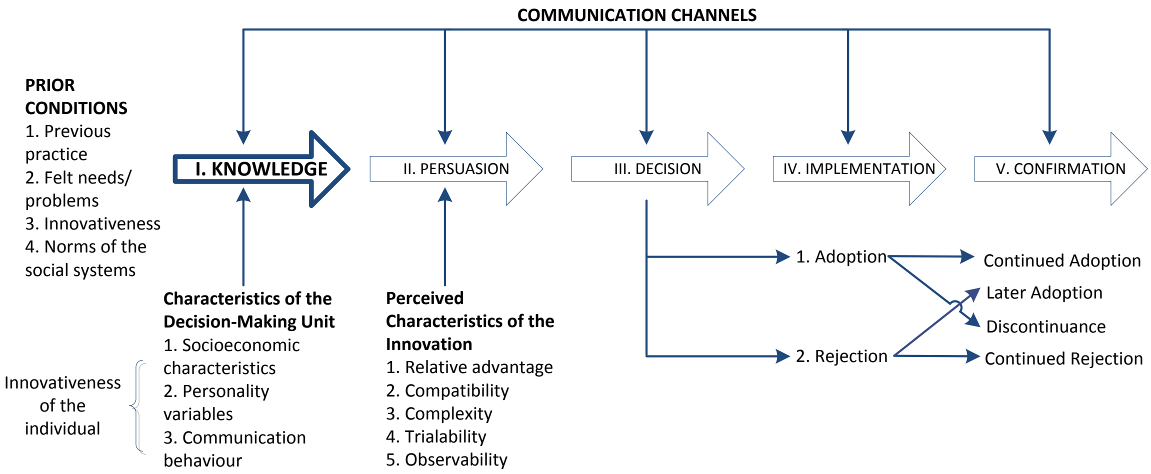


Figure 7.1 *The knowledge phase (highlighted) of Rogers (2003) Innovation-Decision Process and the characteristics of the decision-making unit is the focus of this chapter.*

In Chapter 6, a spatial cluster of potential 'early adopters' was identified, and it is from this geographic cluster within the Metropolitan District of Birmingham that the survey population has been selected (see Section 5.5.2). The analysis in this chapter serves to examine the relationship between the alternative fuel vehicle early adopter socio-demographic characteristics and the two other innovativeness characteristics of personality variables and communication behaviour. Respondent knowledge relating to the innovation and contextual factors (i.e. climate change) (refer to Section 5.5.5) will also be examined.

Section 7.2 will provide an overview of the sample and identify the key characteristics. These characteristics will be presented in the context of the socio-demographic characteristics of Sutton Coldfield and Birmingham Metropolitan District. Section 7.3 then examines the fit of the survey sample according to these socio-demographic characteristics.

In Section 7.4, knowledge, personality variables and communication behaviour are examined. The relationship between socio-demographic characteristics and personality variables and communication behaviour is analysed, in addition to contextual factors (refer to Section 5.5.5), such as the felt needs or problems that alternative fuel vehicles satisfy. Pearson's Chi-Square (X^2) test and Spearman's rho (r_s) are the two statistical techniques used for testing the effect of socio-demographic characteristics on attitudes. Both tests are used because Pearson's Chi-Square (X^2) tests for a linear relationship between two categorical variables while Spearman's rho (r_s) tests the correlations between continuous or scale data (see Section 5.5.5). In Section 7.5 the analysis presented in this chapter is discussed.

7.2 Introduction to the survey sample

The dataset consists of 413 households from four wards in the Birmingham Metropolitan District suburb of Sutton Coldfield, namely Sutton Four Oaks, Sutton New Hall, Sutton Trinity, and Sutton Vesey. The survey was undertaken in February and March in 2013, utilising the services of the survey company Research by Design in Birmingham. The households visited were selected from an address list of 1,000 addresses from each of the four wards of Sutton Coldfield (see Section 5.5.2). These were selected using postcode units that were identified in the 'early adopter cluster' in stage one (see Section 5.4.2). From Sutton Vesey there are 103 responses, 105 from Sutton Trinity, 101 from Sutton New Hall and 104 from Sutton Four Oaks.

Although guided by a pre-compiled address list, respondents were ultimately selected using two quotas - the house visited must be semi-detached or detached and it must have a driveway. House type was used as a selection criterion in stage one for the reason that a house that is semi-detached or detached is more likely to have a driveway, which would improve the ability of the household to install an electric-vehicle charging facility (an important factor recognised by Hidrue et al. 2011). Furthermore, the UK Census does not collect income data, and with semi-detached and detached homes more often being of a higher value than other home types, this aided the selection of individuals that were therefore likely to have a higher income.

Two delivery methods were utilised. There were 62% (256) of the questionnaires completed face-to-face and 38% (157) were completed using a call-and-collect method. Face-to-face was the preferred method used by the survey company due to the quality control it allows, while the call-and-collect method was used if the respondent was prepared to participate but could not spend the time at the point of the survey. In order to achieve a more representative sample, the survey was conducted on weekdays as well as evenings and weekends. It was stipulated that the respondent should be selected on the basis that they would be involved in the household decision-making process when purchasing a new vehicle.

7.2.1 Socio-demographic characteristics

Table 7.1 presents the socio-demographic characteristics for Birmingham Metropolitan District and the four wards of Sutton Coldfield (taken from the 2011 Census), alongside the details of the survey population. The 2001 Census was used to guide the selection of the survey population.

It was observed that the composition of socio-demographic characteristics of the population between the 2001 (see Table 6.7 in Section 6.6) and subsequent 2011 (Table 7.1) censuses remains largely similar, although some changes have taken place. In Sutton Coldfield there has been a 7% increase from 53% to 60% of those in the two highest socio-economic status brackets. Similarly, in Birmingham Metropolitan District, there has been an increase in the number of those with a higher socio-economic status, increasing from 28% in 2001 to 37% in 2011. There has also been a rise in the number of those with higher-level qualifications from 32% to 49% in Sutton Coldfield and in Birmingham Metropolitan District from 28% to 37%. There have been changes to the ward boundaries of the four Sutton Coldfield Wards since the 2001 census, which may have led to these changes, although, as changes have occurred for the whole of Birmingham Metropolitan District, it suggests that the increases in Sutton Coldfield are likely to be part of a wider trend. The wards have reduced in population size since the 2001 census from an average of 28,000 to 24,000 people.

Table 7.1 *Summary of the sample alongside figures for Sutton Coldfield and Birmingham Metropolitan District. Source of data: ONS (2013).*

Socio-demographic characteristic		Survey population		Sutton Coldfield Wards								Ward average		Birmingham Met. District	
				Sutton Four Oaks		Sutton New Hall		Sutton Trinity		Sutton Vesey					
Gender (Survey n=410)	Males	208	51%	11,585	48%	10,886	48%	12,227	48%	11,377	49%	11,519	48%	527,806	49%
	Females	202	49%	12,440	52%	11,569	52%	13,040	52%	11,983	51%	12,258	52%	545,239	51%
	Total population	413		24,025		22,455		25,267		23,360		23,777		1,073,045	
Age (Survey n=409)	16-24	4	1%	2,036	8%	2,033	9%	2,538	10%	2,318	10%	2,231	9%	146,445	14%
	25-34	23	6%	2,184	9%	2,252	10%	2,873	11%	2,465	11%	2,444	10%	163,025	15%
	35-54	137	33%	6,819	28%	6,501	29%	7,180	28%	6,749	29%	6,812	30%	267,415	25%
	55-64	93	23%	3,052	13%	3,420	15%	3,054	12%	3,092	13%	3,155	13%	96,048	9%
	65-74	96	23%	2,621	11%	2,177	10%	2,333	9%	2,299	10%	2,358	10%	69,471	6%
	75+	56	14%	2,718	11%	2,078	9%	2,284	9%	2,101	9%	2,295	10%	64,491	6%
Dependents (Survey n=406)	Number of dependent children	102	25%	5,245	22%	4,506	20%	5,698	23%	4,844	21%	5,073	21%	278,623	26%
Employment status (Survey n=405)	Economically active (EA) population	209	51%	11,861	49%	11,984	53%	12,971	51%	12,435	53%	12,313	52%	488,221	45%
	EA* in employment	184	88%	10,923	92%	11,041	92%	11,865	91%	11,445	92%	11,319	92%	400,679	82%
	Part-time work (incl. self employ)	64	35%	2,934	27%	2,747	25%	3,123	27%	2,909	25%	2,929	26%	114,377	29%
	Full-time work (incl. self employ)	120	65%	7,989	73%	8,294	75%	8,742	73%	8,536	75%	8,391	74%	286,302	71%
	Unemployed (seeking work)	1	1%	504	2%	523	2%	638	3%	537	2%	551	2%	54,114	5%
	Full time students	2	1%	1,119	5%	1,049	5%	1,264	5%	1,188	5%	1,155	5%	104,453	10%
	Retired	188	46%	3,027	13%	2,733	12%	2,729	11%	2,722	12%	2,803	12%	81,213	8%
Qualifications (Survey n=394)	Lev 3 (e.g. A Levels, GNVQ)	67	17%	2,263	12%	2,257	12%	2,460	12%	2,367	12%	2,337	12%	107,913	13%
	Lev 4+ (e.g. degree level & higher)	160	41%	7,372	38%	5,918	32%	6,837	34%	7,005	37%	6,783	35%	190,335	24%
Socioeconomic status (Survey n=394)	Lev 1 (Higher managerial & professional)	67	17%	3,066	26%	2,346	20%	2,588	20%	2,650	21%	2,663	22%	59,380	12%
	Lev 2 (Lower managerial & professional)	114	29%	4,739	40%	4,473	37%	4,718	36%	4,737	38%	4,667	38%	122,797	25%
House type (Survey n=413)	Total households	413		10,156		9,433		10,633		9,635		9,964		410,736	
	Total detached homes	189	46%	4,378	43%	3,854	41%	3,281	31%	3,048	32%	3,640	37%	45,419	11%
	Total semi-detached homes	224	54%	3,196	31%	3,161	36%	3,824	36%	4,116	43%	3,574	36%	143,938	35%
Tenure (Survey n=393)	Owned (incl. with mortgage/loan)	380	97%	8,321	82%	7,663	81%	7,937	75%	7,754	80%	7,919	80%	226,616	55%
	Private rented	13	3%	962	9%	883	9%	1,308	12%	1,131	12%	1,071	12%	73,405	18%
Number of cars in household (Survey n=413)	0	10	2%	1,405	14%	1,368	15%	2,081	20%	1,532	16%	1,597	16%	147,112	36%
	1	152	37%	3,852	38%	3,737	40%	4,317	40%	3,805	39%	3,928	39%	169,909	41%
	2	195	47%	3,673	36%	3,348	35%	3,329	31%	3,261	34%	3,403	34%	74,523	18%
	3	40	10%	915	9%	747	8%	721	7%	760	8%	786	8%	14,673	4%
	4	16	4%	311	3%	233	2%	215	2%	277	3%	259	3%	4,519	1%
Travel to work (Survey n=184)	Travel by car (incl. as passenger)	168	91%	7,920	73%	8,086	73%	8,043	68%	8,066	70%	8,029	71%	235,505	59%

Note: EA = Economically Active. Totals less than 413 respondents are due to missing data or not applicable (e.g. travel to work).

One further difference, although a relatively small change, is the reduction in the number of those who travel to work by car. The figure has reduced by 1% (from 72%) in Sutton Coldfield and by 2% for Birmingham Metropolitan District (from 61%). This may be due to a number of factors, such as the economic recession leading to more individuals setting up their own businesses, or improvements in communication technologies that enable more people to work remotely. Similarly, improved public transport, increased use of non-motorised modes (walking and cycling), and the promotion of these modes for health reasons, may also have been influential.

7.2.2 Gender and age characteristics

The gender split of the survey respondents is representative of the Sutton Coldfield average. The age groups in Table 7.1 are categorised according to the Census data age groups. In comparison to the age distribution of Sutton Coldfield, respondents between the age of 16 and 54 are under-represented (9% less in the survey). There is an over-representation of respondents from the age groups in the older age groups. The age group 65 and over constitutes 37% in the survey, and the average for Sutton Coldfield is 20%. The data in the Table shows that there is a higher presence of the older age groups in Sutton Coldfield than in Birmingham Metropolitan District, which may have influenced the distribution of the survey population. There are 4% more individuals aged over 55 in Sutton Coldfield than in the Birmingham Metropolitan District as a whole.

Having an older population in the survey area has, amongst other factors, led to an older survey population. Despite this observation, the proportion of respondents between the ages of 25 and 64 is 62% and, although the age structure within that category is slightly different for Sutton Coldfield, the overall proportion for Sutton Coldfield equates to 53%. Despite the survey population being relatively older than that of Sutton Coldfield, there are 4% more dependents in respondents' households than in Sutton Coldfield. Overall, almost half of respondents fall within the age category of a potential early adopter of an alternative-fuel vehicle.

7.2.3 Education and qualification characteristics

In the UK Census, qualifications fall into four categories, with the exception of a separate category for no qualifications, and range from level one (lowest level of qualifications) to level four (highest level of qualifications). Level three and four qualifications are of greatest interest in this research, and include qualifications such as A Levels, Advanced GNVQ, and BTEC upwards through to Degree (e.g. BA, BSc), Higher Degree (e.g. MA, PhD, PGCE), HND, and professional qualifications such as teaching, nursing and accountancy.

Respondents within these two qualification categories constitute 58% of the survey population, which is 11% higher than the proportion in Sutton Coldfield and 21% higher than the proportion in Birmingham Metropolitan District.

7.2.4 Socio-economic status and employment characteristics

Socio-economic status is measured in the UK Census for those aged between 16 and 74 using a range of levels between one and eight. Levels one and two constitute those whose occupations are 'higher managerial, administrative and professional' and 'lower managerial, administrative and professional' (ONS, 2013). These two levels are of the greatest interest to this research, as they are more likely to exhibit higher incomes and have achieved a higher level of education.

A total of 46% of the survey population have a level one or two socio-economic status, which is 20% greater than that of Sutton Coldfield and 31% greater than that of Birmingham Metropolitan District. The highest proportion of respondents with a higher socio-economic status is those aged 35-44 (54%). Of those who are under the age of 60, 50% are of a higher socio-economic status while for those over the age of 60, 45% are of a higher socio-economic status.

In terms of employment status, the number of economically active (EA) respondents who are in employment is 88%, which is 4% lower than that of Sutton Coldfield. However, there are a number of economically active respondents who indicated that they are unemployed but not seeking employment. The proportion of respondents employed is 6% greater than the Birmingham Metropolitan District. The proportion of retirees in the survey population is considerably higher than in Sutton Coldfield and Birmingham Metropolitan District by 38% and 42% respectively, however the figures in Section 7.2.2 show that there is an older population in Sutton Coldfield than the wider Metropolitan District, and therefore it can be expected that the number of retirees would be greater in this area.

Although it was possible to collect income data from the survey population, this information is not collected in the national census and therefore no comparisons between the survey population and the local or wider population can be drawn. Of the survey population, only 35% (145 respondents) stated their income, and the remaining 65% stated unwillingness to provide the information, or left the question unanswered. Despite the survey area having a large proportion of individuals with high socio-economic status, a high frequency of lower income households is observed among those who provided income information. In order to assess whether this was perhaps due to a higher proportion of those with lower incomes providing this information than those with higher incomes, a chi-square test was used to establish whether there is correlation between socio-economic status and income in the survey data.

Table 7.2 *Chi-Square test for household income and socio-economic status (weighted variable)*

Variable		Household annual income				Correlation coefficient	
		<£30k	£30k-£50k	£50k-£70k	>£70k	Pearson Chi-Square (X^2)	df
Socioeconomic status n=262 (weighted cases)	Higher N=138	14%	35%	28%	23%	34.095***	3
	Lower N=124	30%	50%	17%	30%		

Note: *p < .05, ** p < .01, *** p < .001

As Table 7.2 shows, a weight function has been used. A weight function, maximum-likelihood estimation, can be used to compensate for the presence of bias, which has occurred through the under-sampling of the income variable. Maximum-likelihood estimation selects coefficients that make the observed values most likely to have occurred (Field, 2009).

Just over half of those with a higher socio-economic status live in households with an income greater than £50,000 while the majority of those with a lower socio-economic status live in households with an income less than £50,000. The relationship identified here is significant at the 99% confidence interval, confirming that socio-economic status is a suitable variable to use in the absence of income data.

7.2.5 Accommodation type and tenure characteristics

A quota was in place to select only detached and semi-detached houses for the survey, meaning that all of the households in the survey fit this criteria. A decision to select semi-detached and detached houses was taken in stage one based on the assumption that the property is more likely to have a driveway or a garage for storing an electric vehicle than a terraced house or an apartment, for example.

There are 8% more semi-detached homes than detached homes in the survey. There was not strong statistical significance when comparing house type to socio-economic status or age, which confirms it was important to take both house types into consideration. Sutton Coldfield has a similar percentage of semi-detached homes to that of the Birmingham Metropolitan District (36% and 35% respectively) whereas there are considerably more detached homes (26% more) in Sutton Coldfield than there are in the Birmingham Metropolitan District. Almost all of the survey population are homeowners with only 6% living in rented accommodation. The level of homeownership in the survey population is 14% higher than that of Sutton Coldfield and 39% higher than that of the Birmingham Metropolitan District, as expected given the sampling.

7.2.6 Vehicle ownership and journey to work characteristics

A larger proportion of individuals from the survey sample have access to at least one vehicle than that of Sutton Coldfield and the Birmingham Metropolitan District. There are 61% of respondents with access to two or more cars, a factor deemed to be important when considering the purchase of an alternative fuel vehicle. However, for Sutton Coldfield the proportion of those who have access to two or more cars is 45%, while for the Birmingham Metropolitan District the figure stands at 23%.

Journey to work was used in stage one in order to identify those in the Census with a higher vehicle dependency. Those among the survey population who work showed a high vehicle dependency, with 91% travelling to work by car. This is a higher level of dependency than that of Sutton Coldfield, which is 22% lower, and of Birmingham Metropolitan District, which is 35% lower.

7.3 'Fit' of the survey respondents to the early adopter profile

In accordance with the potential early adopter profile in Chapter 6, Table 7.3 shows the proportion of respondents that fit each of the criteria. The characteristics that are highlighted are those considered to be important socio-economic characteristics in alternative fuel vehicle adoption. Due to the sampling method used to select the survey respondents (Section 5.5.2), the number of respondents meeting each of the criteria is lower than desired. However, as the sampling method was affected by the inability to link census data to specific households, it should be expected that it is not possible to entirely dictate the socio-demographic makeup of the respondents. Of the characteristics in Table 7.3, age, qualifications and socio-economic status will be used in the analysis of this Chapter to validate their use in identifying potential early adopters, as well as to provide insight into the response data. Home ownership is not used because 97% of the sample are home owners and therefore it would not indicate any meaningful relationships. Vehicle ownership is less frequently used because the analysis is focused on the characteristics of the decision-making unit. An additional characteristic of gender is used in the analysis in order to examine its effect on innovativeness and attitudes towards alternative fuel vehicles.

Table 7.3 *Respondents with matching socio-demographic characteristics*

Socio-demographic characteristic	Criteria	Proportion of respondents
1. Age	Under 60	49%
N = 405	Over 60	51%
2. Qualifications	Higher (Level 3 & 4+)	58%
N = 394	Lower (Level 1 & 2)	42%
3. Socio-economic status	Higher (Level 1 & 2)	47%
N = 387	Lower (Level 3+)	53%
4. Vehicle ownership	2+ cars	61%
N = 413	1 car or no car	39%
5. Home ownership	Home owner	97%
N = 413	Non-home owner	3%

Note: Those highlighted are potential early adopters.

As shown in Table 7.4, there are 15% of respondents who match all five of the characteristics listed in Table 6.3 above, while 37% have a minimum of four characteristics and 64% have a minimum of three characteristics.

Table 7.4 *Proportion of respondents according to total characteristics matched*

Total number of characteristics matched	Number of respondents	Proportion of respondents
0	2	<1%
1	61	15%
2	88	21%
3	110	27%
4	91	22%
5	61	15%

Despite being unable to select respondents at a level lower than postcode level, these findings confirm that the methodology for the selection of the respondents was largely successful.

7.4 The level of knowledge of alternative fuel vehicles among respondents and the influence of socio-demographic characteristics

In Section 7.4, there are two steps to the analysis. The first step is to examine the overall responses to the closed-format questions and attitude statements in order to get an indication of current levels of knowledge and current attitudes towards alternative fuel vehicles. The second step is to test for relationship between the socio-demographic characteristics of the decision-making unit and the remaining two innovativeness characteristics of personality variables and communication behaviour, (refer to Figure 7.1). These are socio-economic characteristics, personality variables and communication behaviour, all of which determine the level of knowledge that an individual has of an innovation.

In testing for a relationship, two statistical tests have been selected as appropriate. The first is Spearman's correlation coefficient (rho, r_S) (see Section 5.5.4), a method that can be used only if all variables are ordinal. For this reason it can only be applied to the characteristics of age, qualifications and socio-economic status and will provide an indication of whether an increase in one variable affects an increase in the other.

By collapsing the variables into two categories, such that the individual either possesses the characteristic that matches that of the 'early adopter' profile or does not (as per Table 7.3), enables the effect of possessing the characteristic to be tested against personality and communication behaviour variables. An alternative test must be used for categorical data and Pearson's chi-square test (see Section 5.5.5) has been selected as the appropriate test for this purpose. In this case the characteristics that will be tested are age, qualifications and socio-economic status, with the addition of gender. Vehicle ownership and homeownership will not be tested, on the assumption that these characteristics are unlikely to influence an individual's knowledge. Figure 5.6 in Section 5.5 provides detail on the socio-demographic characteristics in terms of how they will be tested as categorical variables with Pearson's chi-square test and as ordinal variables with Spearman's rho test.

Only the relationships that prove statistically significant (where $p < 0.05$) are detailed in the tables in the following analysis, although those shown to be insignificant are discussed where appropriate.

7.4.1 Knowledge of alternative fuel vehicles

This section examines the knowledge and understanding that respondents have about electric vehicles. Rogers (2003) identified that knowledge about the innovation reduced uncertainty and risk prior to adoption. In this part of the survey, respondents were asked to indicate their level of knowledge about hybrid vehicles, hydrogen fuel cell vehicles and electric vehicles on a scale of one to five, with one being the lowest and five being the highest.

Table 7.5 *Respondents' level of knowledge about alternative fuel vehicles*

Vehicle type	Perceived level of knoweldge scale					Total Lower	Total Higher
	Low 1	2	3	4	High 5	1&2	4&5
Electric vehicle N=411	51%	20%	15%	9%	5%	71%	14%
Hydrogen fuel cell vehicle N=411	64%	18%	10%	5%	3%	82%	8%
Hybrid electric vehicle N=410	46%	23%	16%	10%	5%	69%	15%

As the results in Table 7.5 show, there are very few respondents who state that their knowledge of alternative fuel vehicles is at the higher end of the scale, while the majority of respondents stated that their level of knowledge is at the lowest end of the scale. The lowest level of alternative fuel vehicle knowledge is about hydrogen fuel cell vehicles. This is to be expected, considering that they are not yet available to purchase in the UK. Of the three types of alternative fuel vehicles, the highest level of knowledge was associated with hybrid vehicles, followed closely by electric vehicles.

In Table 7.6, the correlation between knowledge and gender is highly significant for each alternative fuel vehicle technology, with the chi-square test in each case showing a correlation of $p < .001$. A larger proportion of males have a greater level of knowledge than females about each of the vehicle technologies.

__Table 7.6__ Chi square results for knowledge of alternative fuel vehicles

Statement			Correlation coefficient		
		Good/very good knowledge	Pearson Chi-Square (X^2)	df	Spearman's (r_s)
Electric vehicle knowledge					
Gender N=408	Male (N=207)	24%	51.341***	4	NS
	Female (N=201)	4%			
Qualifications N=392	Higher (N=227)	19%	17.936**	4	NS
	Lower (N=165)	11%			
Socioeconomic status N=385	Higher (N=181)	20%	36.424***	4	.237***
	Lower (N=204)	8%			
Hydrogen vehicle knowledge					
Gender N=408	Male (N=207)	4%	37.747***	4	NS
	Female (N=201)	2%			
Qualifications N=392	Higher (N=227)	11%	17.064**	4	.208***
	Lower (N=165)	7%			
Socioeconomic status N=385	Higher (N=181)	10%	20.303***	4	.196***
	Lower (N=204)	6%			
Hybrid electric vehicle knowledge					
Age N=406	N/A		NS	N/A	-.089*
Gender N=407	Male (N=206)	25%	47.523***	4	NS
	Female (N=201)	6%			
Qualifications N=391	Higher (N=226)	20%	18.27**	4	.265***
	Lower (N=165)	10%			
Socioeconomic status N=384	Higher (N=180)	21%	32.105***	4	.229***
	Lower (N=204)	10%			

Note: *p < .05, ** p < .01, *** p < .001. NS = not significant. N/A = not applicable.

Age has significant correlation in the Spearman's rho test only with knowledge of hybrid electric vehicles (p < .05) indicating that as age increases, the level of knowledge about hybrid vehicles reduces. The lack of significance of age with knowledge of electric vehicles and hydrogen fuel cell vehicles is influenced by a low overall (across all age groups) knowledge level of alternative fuel vehicle technologies.

Qualifications is significantly correlated with each alternative fuel vehicle technology in both the chi-square test (p < .01), where a greater number of those with higher qualifications perceive themselves to have a greater level of knowledge about each technology, and Spearman's rho test (p < .001), where as the number of qualifications increases, so does the perceived level of knowledge of each technology. It is expected that those with higher qualifications will know more about alternative fuel vehicle technologies.

Similarly, socio-economic status is significantly correlated with each alternative fuel vehicle technology in both the chi-square test ($p < .001$), where a greater number of those with higher socio-economic status perceive themselves to have a greater level of knowledge about each technology, and Spearman's rho test ($p < .001$), where as socio-economic status increases, so does the perceived level of knowledge of each technology.

Overall, it is possible to see that perceived knowledge of alternative fuel vehicles is greater if the individual is male, has higher level qualifications and a higher socio-economic status, while being younger was also found to be important in the case of perceived knowledge of hybrid electric vehicles.

7.4.2 Knowledge influence: awareness of the contextual factors

Prior conditions, or contextual factors (see section 5.5.4), reflect the conditions that an individual is exposed to prior to the adoption of an innovation. This section examines respondents' attitudes towards factors that form the context for alternative fuel vehicles, such as felt needs or problems. In this respect respondents were asked to indicate attitudes towards problems associated with fossil fuel depletion and climate change.

Attitudes towards, and knowledge of, contextual factors

As Table 7.7 shows, 67% (269) of respondents indicated that, to some degree, they think about the impact of their activities on the environment. However, when respondents were asked to what extent they agree that climate change does not cause them concern, 24% (98) stated they agree. When a contingency table was run for Statement 1 and Statement 2, 30% of those who showed concern about climate change stated that they do not think about the impact of their activities on the environment. There are 20% of respondents who indicated that they are not concerned about climate change and also do not think about the impact of their activities on the environment. Car ownership is seen as a necessity by 88% of respondents, a figure that indicates the high degree of vehicle dependency. With the likelihood that increased vehicle dependency will continue, and should the use of conventional vehicles become constrained (e.g. extremely high oil prices), alternative fuel vehicles may present the most sensible solution for many people.

Table 7.7 *Attitudes towards contextual factors.*

	Attitude Statement	N	Agree strongly	Agree somewhat	Neither agree/disagree	Disagree somewhat	Disagree strongly	**Total Agree**	**Total Disagree**
1	You think about the impact of your activities on the environment	401	25%	42%	17%	11%	5%	67%	16%
2	Climate change does not cause you concern	408	8%	16%	12%	39%	25%	24%	64%
3	Having a motorcar is a necessity	413	68%	20%	6%	5%	2%	88%	7%
4	Petrol/diesel motorcars emit harmful greenhouse gases into the environment	411	42%	46%	10%	2%	0%	88%	2%
5	Petrol/diesel motorcars produce gases that are harmful to people's health	406	38%	45%	15%	2%	0%	83%	2%
6	Petrol/diesel is likely to become too expensive to buy in the near future	411	37%	38%	16%	8%	0%	75%	8%
7	Oil supplies are running out	407	35%	33%	21%	8%	2%	68%	10%
8	We should continue with petrol/diesel motorcar technology	407	28%	33%	23%	13%	4%	61%	17%
9	You should not be forced by legislation to make changes to your motorcar use	408	55%	23%	12%	8%	2%	78%	10%
10	Mainstream electricity production has a low environmental impact	411	6%	28%	38%	17%	11%	34%	28%

In examining respondents' perceptions of the impact of motor cars on the environment, there are 42% who strongly agree that conventional fuel vehicles emit harmful gases into the environment and 38% who strongly agree that motor cars produce gases that are harmful to human health. This confirms that approximately 60% of respondents, who stated that they 'somewhat' agree, may be less certain of the negative externalities of transport use. This finding indicates a potential acceptance barrier for alternative fuel vehicles if the general public is not strongly convinced by the need to reduce transport's environmental impact at both a local and global level.

There is a degree of positive consensus that might support the adoption of alternative fuel vehicles, in that 68% of respondents stated they agree that oil supplies are running out and 75% agree that conventional fuel (petrol/diesel) will become too expensive to buy in the near future. Despite this, there are 61% of respondents who agree that conventional vehicle technology should be continued with. It may be that the public have made the assumption that conventional vehicle technologies will be improved so as to fully remove the environmental impact, or, perhaps, simply an assumption that science will deal with the issues so that behaviour change (perhaps perceived as sacrifice) is not necessary. There were 17% whose attitude was to the contrary, and it is this group who may be most open to the use of electric vehicles and hydrogen vehicles in the future. In order to establish the likely response to any changes to policy legislation that would affect vehicle use, the majority (78%) stated they agreed that they should not be forced by legislation to make changes to car use, confirming the challenge for policy to assist a transition to alternative fuel vehicles.

The environmental impact of mainstream electricity production remains a concern for 'well-to-wheel' emissions of electric vehicles, however the majority of respondents (38%) neither agreed nor disagreed that mainstream electricity production has a low environmental impact. There are 34% of respondents who agree that it does have a low environmental impact, while a minority, 28%, disagree. Though a poor level of knowledge of the implications of electric vehicle use on energy supply emissions may be beneficial to the sales of electric vehicles, it would seem overall that the public require clearer information on the environmental impacts of energy production.

The relationship between socio-demographic characteristics and contextual factors

The following section will analyse the contextual factors that were presented in Table 7.7 for a relationship with the socio-demographic characteristics of gender, age, qualifications and socio-economic status. Table 7.8 shows only the relationships that are found to be statistically significant, showing that all but Statement 5 of those listed in Table 7.7 demonstrated a relationship with at least one of the socio-demographic characteristics.

Table 7.8 *Spearman's rho and Pearson's chi-square results for contextual factors*

Statement			Correlation coefficient		
		Agree with statement	Pearson Chi-Square (X^2)	df	Spearman's (r_s)
1. You think about the impact of your activities on the environment					
Qualifications N=382	Higher (N=219)	73%	13.51**	4	.180***
	Lower (N=163)	58%			
Socioeconomic status N=376	Higher (N=175)	76%	12.288*	4	.128**
	Lower (N=201)	59%			
2. Climate change does not cause you concern					
Gender N=405	Male (N=205)	26%	10.317*	4	
	Female (N=200)	21%			
Age N=401	25-59 (N=194)	21%	9.504*	4	.117**
	60+ (N=207)	26%			
3. Having a motorcar is a necessity					
Age N=409	N/A		NS	N/A	-.165***
4. Petrol/diesel motorcars emit harmful greenhouse gases into the environment					
Age N=403	N/A		NS	N/A	-.120*
Qualifications N=393	N/A		NS	N/A	.125**
6. Petrol/diesel is likely to become too expensive to buy in the near future					
Qualifications N=392	Higher (N=226)	70%	7.000*	2	
	Lower (N=166)	81%			
Socioeconomic status N=385	Higher (N=181)	69%	11.242**	2	-.162**
	Lower (N=204)	82%			
7. Oil supplies are running out					
Age N=404	N/A		NS	N/A	-.085*
Socioeconomic status N=383	Higher (N=179)	65%	7.83*	2	-.111*
	Lower (N=204)	70%			
8. We should continue with petrol/diesel motor car technology					
Qualifications N=388	N/A		NS		-.120**
9. You should not be foced by legislation to make changes to motorcar use					
Qualifications N=404	N/A		NS		-.156**
10. Mainstream electricity production has a low environmental impact					
Age N=403	25-59 (N=195)	32%	11.329*	4	.099*
	60+ (N=208)	37%			
Qualifications N=392	N/A		NS		-.087*

Note: *p < .05, ** p < .01, *** p < .001. NS = not significant. N/A = not applicable. Where degrees of freedom is 2 rather than 4 the Likert scale has been collapsed to 3 categories due to expected frequency counts of less than 5, which affects the analysis.

Gender displayed a significant relationship only with climate change concern (Statement 2), with females demonstrating a greater concern for climate change than males. Age is significantly correlated with statements relating to Statement 2, 3, 4, 7 and 10. The chi-square tests show a significant relationship with concern for climate change at $p < .05$, and it is possible to see from the column in Table 7.8 that indicates the proportion of those who agree with the statement, that more of those under the age of 60 are concerned by climate change than those who are over 60.

The Spearman's rho test also supports the chi-square test finding for Statement 2 ($p < .01$), whereby as age increases, so too does the proportion of those who indicate that climate change does not cause them concern. As age increases, so does the proportion of those who: disagree that having a vehicle is a necessity (Statement 3 $p < .001$), disagree that conventional fuel vehicles emit harmful greenhouse gases into the environment (Statement 4 $p < .05$), disagree that oil supplies are running out (Statement 7 $p < .05$) but who agree that mainstream electricity production has a low environmental impact (Statement 10 $p < .05$). It would appear that older respondents are, perhaps, less concerned about environmental problems, possibly because they consider any impacts unlikely to have an effect on them during their lifetime.

The level of qualifications that respondents have correlates with Statements 1, 4, 6, 8, 9 and 10. The chi-square test shows that qualifications are highly significant in conjunction with attitude towards the environment (Statement 1 $p < .01$), where 73% of respondents with a higher level of qualifications stated that they consider the impact of their activities on the environment compared to 58% of respondents with a lower level of qualifications. There is also a significant chi-square test correlation with attitude towards petrol/diesel becoming too expensive to buy in the near future (Statement 6 $p < .05$). A greater proportion of those with lower level qualifications (81%) stated that they think the price of petrol/diesel will become too expensive to buy in the near future than those with higher level qualifications (70%).

The Spearman's rho test indicates a significant correlation also with concern for the environment (Statement 1 $p < .001$) and the harm to the environment caused by vehicle emissions (Statement 4 $p < .01$), such that as the level of qualifications increases, so too does the number of those who agree with the statement. A negative relationship was found in the attitude towards continuing with conventional vehicle technology

(Statement 8 $p < .01$), enforcement policies concerning vehicle use (Statement 9 $p < .01$) and the environmental impact of mainstream electricity production (Statement 10 $p < .01$), whereby as the level of qualifications increases, so does the number of those who disagree with the statement.

Socio-economic status is significantly correlated with three of the statements in Table 7.8. The chi-square coefficient finds correlation of this variable with concern for the environment (Statement 1 $p < .05$), with those with higher socio-economic status indicating greater concern than those with lower socio-economic status, the attitude towards future oil prices (Statement 6 $p < .05$), with more of those with a lower socio-economic status indicating they think it is likely to become too expensive to buy in the near future, and with attitude towards depleting oil supplies (Statement 7 $p < .05$), with more of those from a lower socio-economic status indicating they think oil supplies are running out.

The Spearman's rho test supported these findings, in that for Statement 1 ($p < .01$) socio-economic status increases in line with the tendency to agree, while a negative relationship was found with Statement 6 ($p < .01$) and Statement 7 ($p < .05$), where as socio-economic status increases, the tendency to agree decreases. An interesting finding here is that those of higher socio-economic status indicated that they do not think fuel prices are likely to become too expensive in the near future (Statement 6). This may be a reflection of higher fuel prices being less of a concern for high-income households, but a much greater problem for those from lower-income households.

7.4.3 Attitude towards new technologies (personality variables)

The individual's attitude towards new technologies is also indicative of their personality, which has been found by Rogers (2003) to affect individual innovativeness (i.e. how soon an individual will adopt an innovation). For example, an individual who is able to deal with uncertainty and takes risks is likely to be among the earliest adopters of an innovation ('innovators' or 'early adopters') whereas an individual who is risk averse and sceptical will be among the last adopters of an innovation ('late majority' or 'laggards').

A strongly positive response to Statements 11, 12, 13 and 14 in Table 7.9 is considered in this research to be indicative of an individual who is very innovative, whilst a strongly positive response to Statements 15, 16 and 17 Table 7.9 is considered in this research to be indicative of an individual who would likely be a much later adopter, perhaps one of the last to adopt an innovation.

Table 7.9 *Attitudes towards innovations*

	Attitude Statement	N	Agree strongly	Agree somewhat	Neither agree/disagree	Disagree somewhat	Disagree strongly	**Total Agree**	**Total Disagree**
11	You want to be among the first people to try a new technology	406	8%	19%	22%	31%	19%	27%	50%
12	You invest in new technologies soon after they become available for purchase	411	4%	15%	23%	37%	21%	19%	58%
13	You would consider yourself willing to take a risk when it comes to investing in new technologies	409	5%	17%	29%	30%	19%	22%	49%
14	Friends will often use you as a point of reference for new technologies	404	4%	14%	19%	36%	27%	18%	63%
15	You are often sceptical about new technologies	408	19%	32%	26%	18%	5%	51%	23%
16	The uncertainty of not knowing how successful a technology will be in the long-term would make you feel uncomfortable about investing in it	411	25%	37%	25%	10%	2%	62%	12%
17	You prefer to stick to existing technologies that you are familiar with	405	17%	33%	27%	20%	4%	50%	24%

As the statistics in Table 7.9 show, respondents largely state that they are not particularly innovative when it comes to investing in new technologies. The proportion of respondents who want to be among those who adopt a technology first is relatively small (27%), few tend to invest soon after a new technology becomes available (19%) and 22% consider themselves willing to take a risk when it comes to investing in new technologies. The majority of respondents do not consider themselves a reference point for new technologies with people they know (18%), while the uncertainty of a technology's long-term success appears to make the majority of respondents uncomfortable about investing in it (62%). Just over half of all respondents are sceptical about new technologies (51%) and half of respondents state that they prefer to stick to existing and familiar technologies. Table 7.10 shows a cross tabulation, or contingency table, for each of the statements in Table 7.9 according to the proportion of those who 'agree strongly' with each statement.

Table 7.10 *Contingency table of statements in Table 7.9*

Statement	11	12	13	14	15	16	17
11	-	83%	58%	65%	4%	4%	2%
12	46%	-	37%	41%	1%	2%	2%
13	33%	39%	-	24%	16%	1%	0%
14	33%	21%	29%	-	1%	3%	0%
15	9%	16%	6%	6%	-	50%	54%
16	12%	5%	18%	66%	11%	-	64%
17	3%	0%	0%	47%	42%	6%	-

Note: Contingency table shows the proportion of respondents who 'agree strongly' with each statement. The contingency tables have been processed according to the statement in the top row as opposed to the left-hand column.

There are 83% of respondents who invest in new technologies soon after they become available for purchase (Statement 12) and also want to be among the first people to try a new technology (Statement 11), which demonstrates that innovations satisfy more than a utilitarian purpose for innovative individuals. Despite this, only 33% of those who want to be among the first people to try a new technology stated they would consider themselves willing to take a risk when it comes to investing in new technologies (Statement 13). However, only 12% of those who want to be among the first people to try a technology would feel uncomfortable about investing in it if they are uncertain of its long-term success (Statement 16), and only 3% state that they prefer to stick to existing technologies that they are familiar with (Statement 17).

Of the respondents who prefer to stick to existing technologies that they are familiar with (Statement 17), none said that they are willing to take a risk when investing in new technologies (Statement 13). Similarly, none said that their friends use them as a point of reference for new technologies (Statement 14). There was a large proportion (54%) of respondents who said they are often sceptical about new technologies (Statement 15) and also a large proportion of respondents (64%) who would feel uncomfortable about investing in it if they are uncertain of its long-term success (Statement 16). The statistics in Table 7.10 largely confirm what would be expected in terms of the relationship between the personality characteristics.

There are some interesting similarities between Rogers' Diffusion of Innovation Curve (see Section 4.3.7) and the distribution of the respondents according to the extent to which they agree or disagree with the statements about adopting new technologies. For example, Statement 13 is about risk taking and characterises the innovativeness of an individual, such that the more innovative an individual is, the more likely they are to take a risk and be an earlier adopter of an innovation. In response to Statement 13, there are 5% that indicate they are strongly willing to take a risk, 17% who are somewhat willing to take a risk, 29% who are neither willing nor against taking a risk, 30% who are somewhat risk averse and 19% who are strongly risk averse.

The relationship between personality and socio-demographic characteristics

As Table 7.11 shows, there are statistically significant correlations between gender and statements 11 ($p < .01$), 14 ($p < .001$), 16 ($p < .05$) and 17 ($p < .01$). The results show more males are more likely to be among the first people to try a new technology, to find themselves used as a reference point by friends for new technologies, more likely to invest in a technology without knowing the long-term success of it and a lesser preference for sticking to familiar technologies. These results demonstrate that males are more innovative than females when it comes to new technologies.

Age is strongly correlated with all of the attitude statements shown in Table 7.11. For all but Statement 16, the chi-square test showed significant correlations (Statements 11, 12, 14 $p < .01$ and Statements 13, 15, 17 $p < .001$) which under closer examination of the results highlighted that more of those under the age of 60 state they want to be among the first to try a new technology (Statement 11), to invest in new technologies sooner rather than later (Statement 12), are willing to take a risk when investing in a new technology (Statement 13), and are often used as a reference point for new technologies by friends (Statement 14).

Table 7.11 *Chi square and Spearman's Rho results for innovativeness in conjunction with attitudes towards innovations*

Statement			Correlation coefficient		
		Agree with statement	Pearson Chi-Square (X^2)	df	Spearman's (r_s)
11. You want to be among the first people to try a new technology					
Gender N=403	Male (N=206)	35%	13.505**	4	NS
	Female (N=197)	20%			
Age N=398	25-59 (N=192)	34%	17.293**	4	-.229***
	60+ (N=206)	22%			
Qualifications N=387	Higher (N=222)	30%	9.741*	4	.189***
	Lower (N=165)	25%			
Socioeconomic status N=380	Higher (N=176)	32%	16.546**	4	.187***
	Lower (N=204)	23%			
12. You invest in new technologies soon after they become available for purchase					
Age N=403	25-59 (N=196)	25%	14.624**	4	-.193***
	60+ (N=207)	14%			
Qualifications N=392	N/A		NS	N/A	.127**
Socioeconomic status N=385	N/A		NS	N/A	.154**
13. You would consider yourself willing to take a risk when it comes to investing in new technologies					
Age N=401	25-59 (N=195)	30%	18.102***	4	-.185***
	60+ (N=206)	15%			
Qualifications N=391	Higher (N=226)	26%	13.026*	4	.138**
	Lower (N=165)	17%			
Socioeconomic status N=383	N/A		NS	N/A	.110*
14. Friends will often use you as a point of reference for new technologies					
Gender N=401	Male (N=202)	23%	20.401***	4	NS
	Female (N=199)	14%			
Age N=396	25-59 (N=191)	24%	13.886**	4	-.195***
	60+ (N=205)	13%			
Qualifications N=385	Higher (N=221)	23%	16.378**	4	.235***
	Lower (N=164)	12%			
Socioeconomic status N=378	Higher (N=176)	25%	22.606***	4	.235***
	Lower (N=202)	11%			
15. You are often sceptical about new technologies					
Age N=400	25-59 (N=195)	40%	21.464***	4	.209***
	60+ (N=205)	62%			
Qualifications N=389	Higher(N=223)	42%	18.817***	4	-.241***
	Lower (N=166)	60%			
Socioeconomic status N=382	Higher (N=178)	43%	30.694***	4	-.240***
	Lower (N=204)	57%			
16. The uncertainty of not knowing how successful a technology will be in the long-term would make you feel uncomfortable about investing in it					
Gender N=408	Male (N=207)	59%	10.397*	4	NS
	Female (N=201)	66%			
Age N=407	N/A		NS	N/A	.125**
Qualifications N=392	Higher (N=226)	58%	9.649*	4	-.146**
	Lower (N=166)	67%			
Socioeconomic status N=386	Higher (N=181)	53%	18.191***	4	-.186***
	Lower (N=205)	71%			
17. You prefer to stick to existing technologies that you are familiar with					
Gender N=402	Male (N=205)	44%	13.492**	4	NS
	Female (N=197)	55%			
Age N=397	25-59 (N=192)	40%	27.166***	4	.279***
	60+ (N=205)	59%			
Qualifications N=386	Higher (N=224)	43%	12.539*	4	-.245***
	Lower (N=162)	57%			
Socioeconomic status N=381	Higher (N=179)	39%	20.038***	4	-.272***
	Lower (N=202)	58%			

Note: *p < .05, ** p < .01, *** p < .001. NS = not significant. N/A = not applicable.

In contrast, a greater proportion of respondents over the age of 60 stated that they are often sceptical about investing in new technologies (Statement 15) and prefer to stick to familiar technologies (Statement 17). The Spearman's rho test also confirmed that, as age increases, so too does the number of those who stated they disagree with Statements 11, 12, 13 and 14, while for Statements 15, 16 and 17, as age increased, so does the number of those who stated they agree with the statements. Therefore, it is possible to see that age is highly correlated with innovativeness and younger respondents exhibit a greater level of innovativeness than older respondents.

Qualifications are also found to correlate highly with innovativeness, with all but one showing significant correlations in the chi-square test (Statements 11 $p < .05$, 13 $p < .05$, 14 $p < .01$, 15 $p < .001$, 16 $p < .05$, 17 $p < .05$). Those who have higher qualifications are found to be more innovative, with more wanting to be among the first to try a new technology, to be willing to take a risk when investing in a new technology and to be used as a point of reference with friends. In contrast more of those with lower qualifications are sceptical about new technologies, feel uncomfortable about investing in a technology with an uncertain future, and prefer to stick to familiar technologies. All statements also have significant correlations for the Spearman's rho test, all of which indicate that as qualifications increase, so does innovativeness.

A similar situation was found for socio-economic status. The chi-square test finds significant correlation between socio-economic status and statements 11 ($p < .01$), 14 ($p < .001$), 15 ($p < .001$), 16 ($p < .001$) and 17 ($p < .001$). More of those with a higher socio-economic status stated they want to be among the first to try a new technology and are used as a point of reference for new technologies by friends. In contrast more of those with a lower socio-economic status stated they are sceptical about new technologies, feel uncomfortable about investing in a technology with an uncertain future and prefer to stick to familiar technologies than those of a lower socio-economic status. All statements also have significant correlations for Spearman's rho test, all of which indicate that as socio-economic status increases, so too does innovativeness.

Overall, it is possible to see that those who exhibit greater innovativeness, thus indicating their greater propensity to adopt new technologies, are male, younger (under the age of 60), more highly qualified and have a higher socio-economic status.

7.4.4 Communication behaviour of the respondents (knowledge influence)

According to Rogers (2003) there are several generalisations that can be made about communication behaviour (Table 4.2, Section 4.6.1), which state that earlier adopters are more likely to seek information about innovations more actively, have greater exposure to interpersonal communication channels, have greater exposure to mass media communication channels, and have more contact with change agents. These aspects of communication behaviour will now be examined in Table 7.12.

Table 7.12 *Communication behaviour statements*

	Attitude Statement	N	Agree strongly	Agree somewhat	Neither agree/disagree	Disagree somewhat	Disagree strongly	Total Agree	Total Disagree
18	You have actively looked for information about electric vehicles	412	n/a	n/a	n/a	n/a	n/a	8%	92%
19	You have previously had a conversation with someone you know about electric vehicles	412	n/a	n/a	n/a	n/a	n/a	20%	80%
20	You often follow the view of experts on matters that are important to you	410	19%	55%	20%	5%	1%	74%	6%
21	The media has influenced your attitude towards fully electric vehicles	410	2%	26%	39%	23%	10%	28%	33%
22	Friends/acquaintances have influenced your attitude towards fully electric vehicles	411	1%	9%	32%	35%	23%	10%	58%
23	Your family has influenced your attitude towards fully electric vehicles	409	0%	8%	34%	36%	22%	8%	58%

Note: Statements 18 and 19 required only a "yes" or "no" response.

As Table 7.12 highlights, there are few respondents who have actively looked for information about electric vehicles, although 8% may be considered to be a relatively high proportion at this stage in the electric vehicle product lifecycle. A fifth of all respondents state that they have engaged in conversation with somebody they know about electric vehicles, while the majority (80%) indicated that they have never had a conversation about electric vehicles before.

Of each of the influences addressed in this research – media, friends and family - there is no strong evidence as to what might be influencing the attitudes towards alternative fuel vehicles. The media appears to have a greater influence over interpersonal communication channels. The majority of respondents stated they 'neither agree nor disagree', which may be due to the inability to recall a precise moment or situation that influenced their attitude. Similarly, it is unlikely that the respondents have previously been asked to consider their attitudes towards alternative fuel vehicles, and may not currently hold strong views on the subject. The likelihood of respondents having weak views on alternative fuel vehicles is supported by the low levels of knowledge about alternative fuel vehicles, as Table 7.5 showed.

There are 74% of respondents who said that they follow the views of experts on matters they consider to be important, a figure that implies the strength of 'opinion leaders' in the media. Given the low proportion of respondents (28%) who consider their attitude towards electric vehicles to have been influenced by the media, suggests 'opinion leaders', if successfully engaged in communication about alternative fuel vehicles, could possibly offer a suitable channel for reaching the disengaged (but potential) consumers.

The relationship between communication behaviour and socio-demographic characteristics

In Table 7.13, the chi-square test demonstrates that gender is significantly correlated with sourcing information on electric vehicles (Statement 18, $p < .001$), with males more likely than females to have actively sourced information about electric vehicles, and to have a conversation with someone about electric vehicles (Statement 19, $p < .01$).

Age is statistically significant for the influence of the media on attitude (Statement 21, r_s =-.160, $p < .01$) and with the influence of family on attitude (Statement 23, r_s = -.88 p < .05). The negative relationship that exists in both cases, whereby as age increases, the likelihood to agree with the statement reduces, indicates that younger respondents are more likely to have had their attitude influenced by the media or family members.

Table 7.13 *Chi square and Spearman's Rho results for innovativeness in conjunction with communication behaviour*

Statement			Correlation coefficient		
		Agree with statement	Pearson Chi-Square (X^2)	df	Spearman's (r_s)
18. You have actively looked for information about fully electric vehicles					
Gender N=409	Male (N=207)	14%	14.947***	1	NS
	Female (N=202)	3%			
19. You have previously had a conversation with someone you know about electric vehicles					
Gender N=409	Male (N=207)	27%	11.119**	1	NS
	Female (N=202)	13%			
20. You often follow the view of experts on matters that are important to you					
Qualifications N=391	N/A		NS	N/A	.142**
Socioeconomic status N=384	N/A		NS	N/A	.090*
21. The media has influenced your attitude towards fully electric vehicles					
Age N=402	N/A		NS	N/A	-.160**
Qualifications N=391	Higher (N=226)	33%	6.32*	2	.095*
	Lower (N=165)	21%			
23. Your family has influenced your attitude towards fully electric vehicles					
Age N=405	N/A		NS	N/A	-.088*

Note: *p < .05, ** p < .01, *** p < .001. NS = not significant. N/A = not applicable.

The level of qualifications is correlated with following the view of experts in the media (Statement 20, r_s = .142, p < .01) and the influence of the media on attitude towards electric vehicles (Statement 21, X^2 = 6.32, p < .05 and r_s = .095, p < .05). It is demonstrated that, as the level of qualifications increases, so too does following the view of experts in the media and the influence of media on attitude towards electric vehicles.

Socio-economic status correlates only with following the view of experts (Statement 20, r_s = .090, p < .05), suggesting that this would be more common as socio-economic status increases. Apart from socio-economic status, each of the socio-demographic characteristics is significantly correlated with at least two communication behaviour variables, suggesting that the communication behaviour of those who are male, are younger, have a higher level of qualifications and a higher socio-economic status is more in alignment with those expected to be early adopters.

7.5 Discussion

This chapter has presented the descriptive statistics of the survey data as well as providing insight into respondents' attitudes and perceptions towards alternative-fuel vehicles, particularly in the context of electric vehicles. Focusing on the cluster of individuals identified in stage one of the analysis as possessing the socio-demographic characteristics of those most likely to adopt an alternative-fuel vehicle, a target sample size of 400 respondents was established. This cluster included individuals from each of the four wards of Sutton Coldfield and was found to be of sufficient size to undertake the appropriate analysis to indicate reasons for non-adoption of electric vehicles.

There is good representation among the survey population of the characteristics identified in the early adopter profile, with 64% of respondents possessing three or more of the characteristics in the profile. This was a pleasing result given data protection rules preventing the matching of census data to household addresses. The characteristics were then tested for a relationship with knowledge and the knowledge influencing attributes of the decision-making unit (personality variables and communication behaviour). An overview of the statements and the socio-demographic characteristics that demonstrated statistical significance is presented in Table 7.13. It was confirmed that there is an overall strong relationship between the attributes, indicating the value of using the socio-demographic profile identified in Chapter 5 as a means to identify potential early adopters.

Table 7.13 *Overview of attitude statements and the socio-demographic characteristics that show statistical significance*

	Statement	Gender	Age	Qualifications	Socioeconomic status
1	You think about the impact of your activities on the environment	-	-	x	x
2	Climate change does not cause you concern	x	x	-	-
3	Having a motorcar is a necessity	-	x	-	-
4	Petrol/diesel motorcars emit harmful greenhouse gases into the environment	-	x	x	-
5	Petrol/diesel motorcars produce gases that are harmful to people's health	-	-	-	-
6	Petrol/diesel is likely to become too expensive to buy in the near future	-	-	x	x
7	Oil supplies are running out	-	x	-	x
8	We should continue with petrol/diesel motorcar technology	-	-	x	-
9	You should not be forced by legislation to make changes to your motorcar use	-	-	x	-
10	Mainstream electricity production has a low environmental impact	-	x	x	-
11	You want to be among the first people to try a new technology	x	x	x	x
12	You invest in new technologies soon after they become available for purchase	-	x	x	x
13	You would consider yourself willing to take a risk when it comes to investing in new technologies	-	x	x	x
14	Friends will often use you as a point of reference for new technologies	x	x	x	x
15	You are often sceptical about new technologies	-	x	x	x
16	The uncertainty of not knowing how successful a technology will be in the long-term would make you feel uncomfortable about investing in it	x	x	x	x
17	You prefer to stick to existing technologies that you are familiar with	x	x	x	x
18	You have actively looked for information about electric vehicles	x	-	-	-
19	You have previously had a conversation with someone you know about electric vehicles	x	-	-	-
20	You often follow the view of experts on matters that are important to you	-		x	x
21	The media has influenced your attitude towards fully electric vehicles	-	x	x	-
22	Friends/acquaintances have influenced your attitude towards fully electric vehicles	-	-	-	-
23	Your family has influenced your attitude towards fully electric vehicles	-	x	-	-

In gauging respondents' attitudes towards the contextual factors, (i.e. the issues that create the context for the need for alternative fuel vehicles) (Section 7.4.2), such as climate change and fossil fuel depletion, it was established that the majority (60%) are concerned about climate change and, equally, the majority (67%) consider the impact of their daily activities on the environment. There is also a good level of awareness about the detrimental effects of motorised transport and conventional fuels on the environment.

There is, however, evidence of a disconnect between understanding and action, a finding that concurs with those of Flynn et al., (2010), Whitmarsh (2009), Lane and Potter (2007), and Anable et al. (2006), with the majority in the Sutton Coldfield survey stating a preference for a continuation of conventional vehicle technologies. Nilsson and Küller (2000) also found that knowledge of environmental issues has a minimal impact on travel behaviour. This may be because the public has seen that vehicle manufacturers are continuously improving vehicle efficiencies and, perhaps, make the assumption that science will find a solution that does not require their current travel behaviour to be compromised. More importantly, this may be an indication of their dissonance with the problem, noted by Lorenzoni et al. (2007) and Stoll-Kleemann et al. (2001). Another possibility is that the public are not thinking about the problem of vehicle use holistically, with respect to the issues of carbon emissions and fossil fuel depletion, but rather are only able to recognise problems in isolation. Climate change concern was found to be greater among females and those who are younger and middle-aged, while those who are more highly qualified and of a higher socio-economic status are also likely to give greater consideration to the impact of their activities on the environment.

The survey population are heavily reliant on their vehicles, deeming them a necessity, with the majority using their vehicles on a daily basis. Certainly, it seems that, should vehicle use need to be curtailed as a policy response to external pressures of resource availability, the general public are not willing to compromise on their vehicle use. An assertion by Rennings (2000) is that regulatory support will be necessary in overcoming weak market demand for environmentally focused innovations. Similarly Porter and van der Linde (1995) maintain that regulation is necessary in encouraging competition and that there is a necessity to use incentives to appeal to the market.

Attitudes towards new technologies (Section 7.4.3) showed that the majority of respondents are risk averse and are less likely to be among earlier adopters of new technologies. This finding is unsurprising, however, given that the majority of adopters of an innovation adopt it later in a product's lifecycle. In fact, as should be expected, only a small proportion of respondents (4% - 8%) were confirmed to be highly innovative when it comes to new technologies. Similarity (Section 7.4.3) was recognised between Rogers' Diffusion of Innovation Curve (2003) and the distribution of respondents according to their risk aversion when adopting new technologies. Those who are most innovative are largely male, of a younger age category (<60), possess higher level qualifications and are of a higher socio-economic status, while those who are least innovative appear to be female, of an older age category (>60), possess lower level qualifications and are of a lower socio-economic status.

Scepticism and risk aversion are positively correlated with age (Section 7.4.3). Despite 27% of respondents stating that they want to be among the first people to adopt a new technology, none of the respondents have adopted an electric vehicle, which may suggest that not all technologies or innovations can be considered the same. Being among the first to adopt an 'eco-innovation' may not be as important as being among the first to adopt a technology of a different sort, perhaps one requiring a lower degree of product involvement. This supports Jansson's (2011) argument that an 'eco-innovation' is a specific type of innovation and the adoption of which is likely to be influenced by many other determinants that make it difficult to identify a uniform pattern among consumers.

Seeking information about electric vehicles (Section 7.4.3) is an activity that has been undertaken by only a small proportion of respondents (8%), although a larger proportion (20%) have had a conversation with someone about electric vehicles. However, it was demonstrated that attitudes towards electric vehicles have not been influenced by people known to the respondents (who they have perhaps had conversations with about electric vehicles) but more so by the media (Table 7.12). Many respondents seemed unsure as to what has influenced their attitudes towards electric vehicles, which may be because they have not previously been asked to consider their attitude towards an electric vehicle, or that it is difficult to recall any distinct influences. Males are more likely to have sought information (Section 7.4.3) as well as being more likely to have had a conversation with someone about electric vehicles.

The majority of respondents perceive their knowledge of alternative fuel vehicles (Section 7.4.1) to be at the lowest end of the scale (e.g. 51% of respondents state that their knowledge of electric vehicles is extremely low). Poor levels of knowledge about alternative fuel vehicles only serve to increase uncertainty among consumers and thus reduce the likelihood of adoption. Despite this finding, there are respondents who rated their level of knowledge as being towards the upper end of the scale, with 14% rating their knowledge of electric vehicles as four or five (out of five), and 15% gave the same rating for their knowledge of hybrid vehicles. For hydrogen fuel cell vehicles, the figure was considerably lower at 8%. However, this should not be surprising given that they are not yet available for public consumption. This is a common finding in hydrogen studies (e.g. Yetano Roche et al., 2010; and Mourato et al., 2004).

Hybrid vehicles have been available for purchase for many years now, yet perceived knowledge of this vehicle type is still relatively low. Age was not significant in influencing perceived level of knowledge but it was found that being male, having a higher level of qualifications and a higher socio-economic status significantly increased the likelihood of an individual having a higher perceived level of knowledge. This was also found to be the case in studies by Hackbarth and Madlener (2013) and O'Garra et al. (2005). The low levels of knowledge of alternative fuel vehicles are likely to be affecting their non-adoption. Respondents seem largely averse to moving away from conventional vehicles, a technology with which they are familiar, towards a new technology that will require them to make changes to their lifestyle. It is clear that there are clear knowledge barriers that need to be overcome in order to increase electric vehicle diffusion.

In accordance with the attitudes of respondents, this analysis has made it possible to identify a socio-economic profile of a person most likely to adopt an alternative-fuel vehicle, which supports the profile used for the selection of respondents for this survey. Using Rogers' Innovation-Decision Process (2003) to guide this analysis, the attitudes and perceptions that have been considered as important in the decision to adopt an alternative fuel vehicle have shown statistical significance with the socio-demographic characteristics. Those who have the highest levels of knowledge and are also most innovative are:

- Male
- Under the age of 60
- Have a higher level of qualifications (Level 3 and 4+)
- Have a higher socio-economic status (Level 1 and 2)

Chapter 8 will now investigate the degree of persuasion that the respondents have towards an alternative fuel vehicle. This is achieved through the examination of perceptions relating to the characteristics of the innovation: relative advantage, complexity, compatibility, trialability and observability.

Chapter 8: The degree of persuasion towards the adoption of an alternative fuel vehicle and the factors that influence persuasion

8.1 Introduction

Chapter 7 investigated the innovativeness of the respondents and their knowledge of alternative fuel vehicles. This Chapter examines the degree of persuasion that the respondents have towards electric vehicles, while also investigating the relationship of degree of persuasion with socio-demographic characteristics.

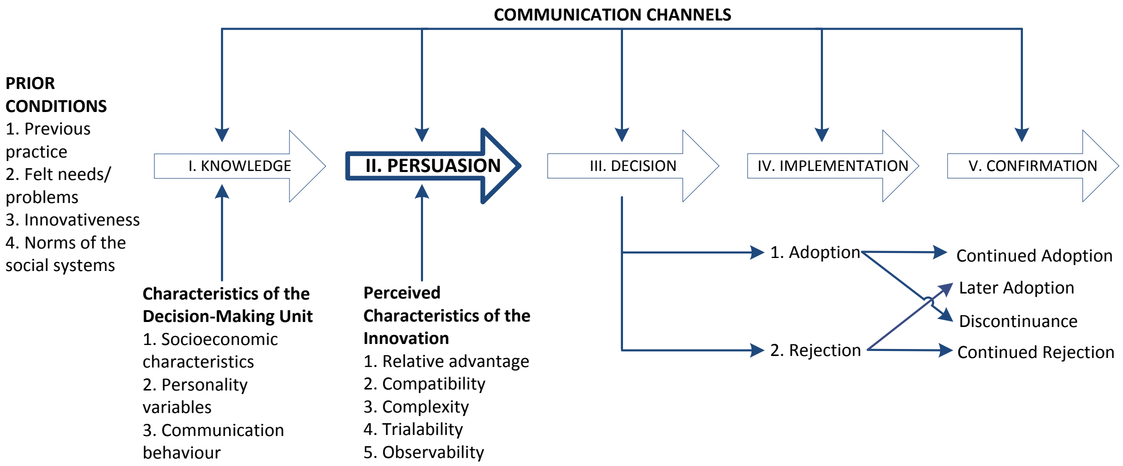


Figure 8.1 *Rogers' Innovation-Decision Process. The persuasion phase (highlighted) is the focus of this chapter.*

As depicted in Figure 8.1, the attributes that are considered by Rogers (2003) to influence an individual's degree of persuasion towards an innovation are their perceptions of the innovation's relative advantage, compatibility, complexity, trialability, and observability (refer to Table 4.1, Section 4.5 for details).

Chapter 7 focused predominantly on the characteristics of the decision-making unit (i.e. the individual), whereas this chapter focuses predominantly on the characteristics of the innovation. As with Chapter 7, this chapter also intends to validate, where appropriate, the relationship between the socio-demographic characteristics of respondents and perceptions held about alternative fuel vehicles. The nature of the data required to capture information about perceptions has led to the inclusion of qualitative analysis in this chapter, although it also draws on similar techniques to Chapter 7 for examining the relationship between socio-demographic characteristics and perceptions, where applicable.

In Section 8.2 the perceived relative advantage associated with an electric vehicle is examined, and begins by utilising two open-format questions relating to perceptions. Giving respondents the opportunity to answer questions in their own words has provided more depth and insight to the closed-format questions collected on perceptions. Section 8.3 then examines the perceived compatibility, before 8.4 analyses the perceived complexity associated with electric vehicles. Section 8.5 and 8.6 investigate the perceived trialability and observability of electric vehicles. In Section 8.8, the analysis evaluates the responses of those who stated that they have previously considered the purchase of an electric vehicle. The Chapter is discussed in Section 8.9.

8.2 The relative advantage of alternative fuel vehicles (electric vehicles)

Relative advantage is the degree to which the innovation is perceived as being better than the idea that it supersedes (Rogers, 2003). Section 8.2.1 examines the perceived advantages of owning an electric vehicle followed by the perceived obstacles of owning an electric vehicle in Section 8.2.2. As a means of gaining insight to the perceived relative advantage of electric vehicles without providing respondents with a choice of responses, respondents were also asked what they perceive the advantages to be in owning or leasing an electric vehicle, followed by what they perceive the obstacles of owning or leasing an electric vehicle to be.

The advantages and obstacles are recognised to fall under four categories; economical, environmental, technological and social elements. Social elements related to psychological, behavioural and socio-institutional motivations that are for or against electric vehicles. On occasions, respondents gave several advantages or obstacles, some of which fit more than a single category. For example, one respondent stated that an obstacle would be “too little luggage space”. It is a social obstacle because it is perceived to inhibit recreational vehicle use and technological because electric vehicle technology is currently better suited to smaller vehicles. In Section 8.2.3, the analysis considers the closed-format questions about the perceived relative advantage of specific vehicle characteristics.

8.2.1 Perceived advantages of adopting an electric vehicle

There were 233 respondents (56%, n413) who listed at least one advantage in their response. Figure 8.2 illustrates the proportion of responses that come under each of the four response categories.

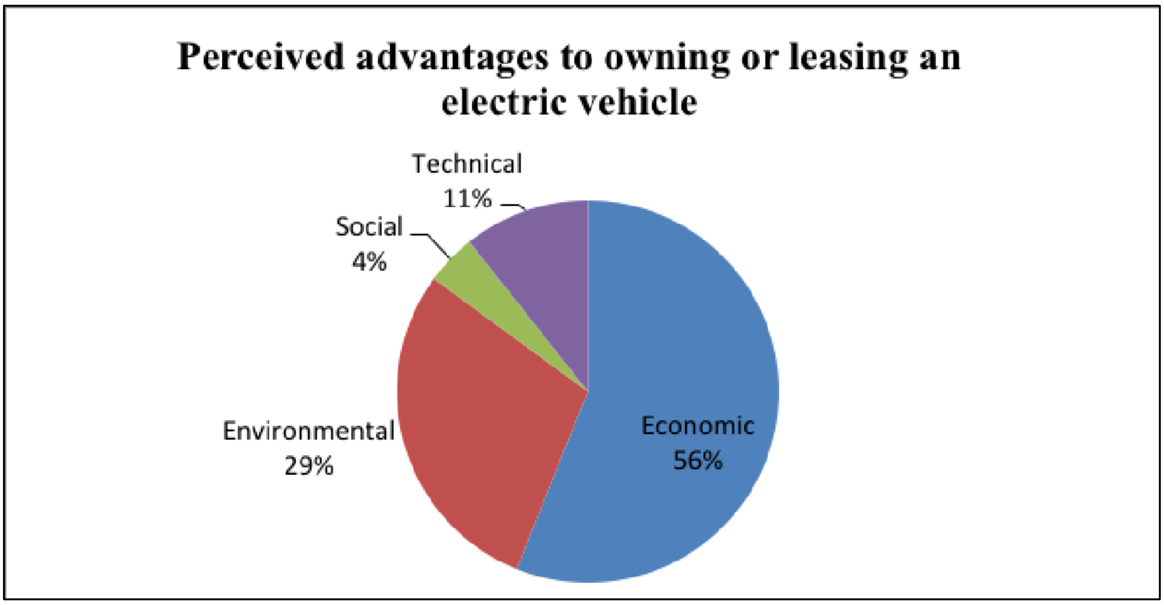


Figure 8.2 *Proportion of perceived advantages of an electric vehicle according to response category*

Many respondents provided more than one advantage, which means that the category proportions in Figure 8.2 differ to those that follow in this section, such that Figure 8.2 refers to the proportion of responses, while in the text below, the proportion refers to the number of respondents. As respondents often listed more than one obstacle, the total proportion of category responses in the analysis that follows does not equal 100%.

Of all the advantages listed, those relating to economic advantages were mentioned by 159 respondents (68%) and related to the overall running cost savings, including comments such as “no petrol costs”, “save on fuel costs”, “more economical to run” as well as “lower road tax”, “car insurance and tax would reduce”, and “reduction in exposure to fluctuations in fuel price”.

An environmental benefit was the second most frequently mentioned advantage, listed by 38% (n233) of respondents who provided a response. Many said that the use of electric vehicles would be beneficial to the environment and would help to reduce carbon emissions: “helping our carbon footprint” and “we know it would be environmentally better than petrol and diesel”. Local level environmental factors were recognised by some respondents, who said advantages would include “no smell”, “no fumes”, and “cleaner air”. It was also acknowledged that electric vehicles would offer an advantage “when oil supplies run out”. One respondent went as far as saying that an electric vehicle is “environmentally a winner for everyone!”. Interestingly, the reference to ‘green’, which is a term commonly associated with anything considered environmentally sustainable, was only mentioned by three respondents.

This is followed by technological advantages, listed by 21% of respondents (n233). One of the most frequently cited technological advantages provided was the low level of noise associated with vehicle use: “quiet and more relaxed driving”, “quiet to run”, and “the engine is silent”. There was only one performance related advantage given, which is “smoothness”, while a more frequently listed advantage is to do with its practicality as a “run-around car” making it “useful around town” and “for smaller trips, like shopping, would be ideal”. Several respondents listed the ability to charge at home as an advantage stating “charge at home instead of having to go to a garage”, “refuelling would be easier”, “able to avoid smelly, dirty garages and queues”, and “not filling up at the garage”.

There are 110 respondents (27% n413) who indicated that they cannot see any advantages associated with owning or leasing an electric vehicle, with responses such as “none at all”, “no advantages at the moment” and “none at all, and it will never take off”. A summary of some of the key perceived advantages is provided in Table 8.1.

__Table 8.1__ Examples of some of the perceived advantages, as listed by respondents

Response	Advantages of having an electric vehicle
1	"As a run-around car!"
2	"Cheaper to run. Less pollution, quieter."
3	"Don't need gear box - economise on fuel - quietness"
4	"Drive day to day shops, would be ideal and cost effective."
5	"Feel good about the environment."
6	"For smaller trips, like shopping, would be ideal."
7	"I'd use it just to work and back, I don't go far so it might be suitable for me."
8	"Local trips, small, easy parking"
9	"Low cost motoring. Quiet and more relaxed driving. Environmentally a winner for everyone."
10	"Lower emission and cheaper to run. Cheaper than petrol."
11	"Not filling up at garage. No fumes. Refuelling being less messy."
12	"Not really, I just have to sell my car and get used to the electric vehicle."
13	"Only to the environment - but then its use of electricity could be expensive."
14	"Reduced running costs. Quiet. Environmentally friendly. No annual road tax."
15	"Reduction in exposure to fluctuations in fuel price."
16	"To lower the costs of running a second vehicle for local journeys."
17	"We are lead to believe more eco friendly."

8.2.2 Perceived obstacles to adopting an electric vehicle

The proportion of obstacles according to the response categories is shown in Figure 8.3.

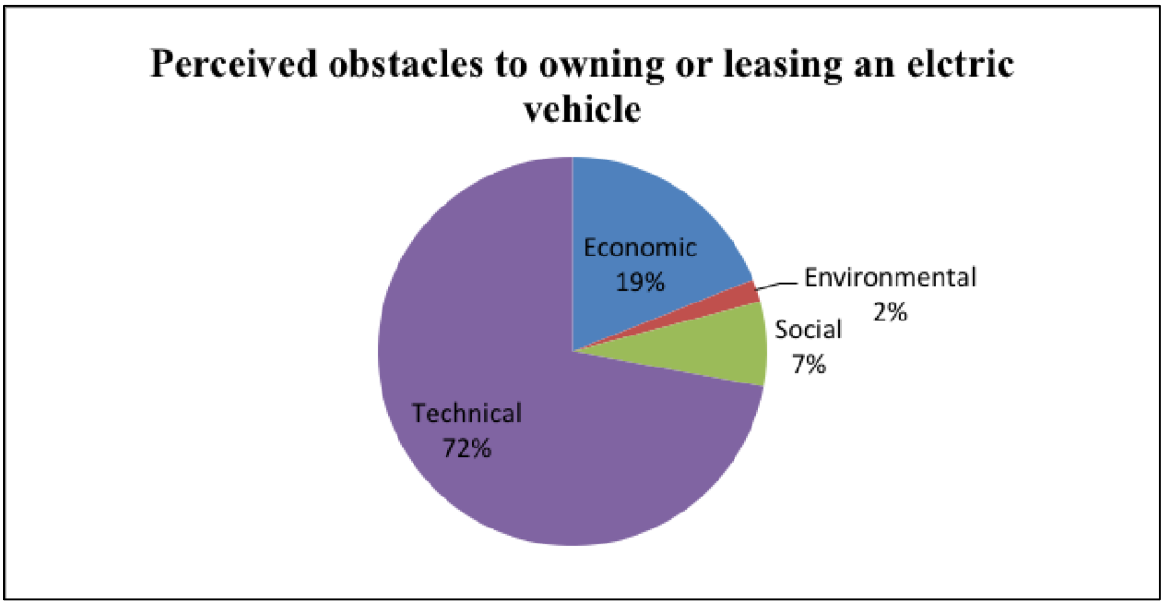


Figure 8.3 *Proportion of perceived obstacles to owning/leasing an electric vehicle according to response category*

As stated in the previous section, many respondents provided more than one obstacle, which means that the category proportions in Figure 8.3 differ to those that follow in this section, such that Figure 8.3 refers to the proportion of responses, while in the text below, the proportion refers to the number of respondents.

When asked about obstacles to purchasing or leasing an electric vehicle, 345 respondents (84%, n413) provided a response, 28% more respondents than the proportion who provided advantages to owning or leasing an electric vehicle. As respondents often listed more than one obstacle, the total proportion of category responses in the analysis that follows does not equal 100%.

Technological obstacles were mentioned by 81% (n345), and concern the vehicle itself, such as range, power/performance, image, size of the vehicle, in addition to infrastructure obstacles, such as the availability of charging points. Lack of infrastructure and limited range of the vehicles were the two most frequently cited technological obstacles. For some of the responses, it is not always possible to distinguish whether the obstacle was specific to range or the lack of supporting infrastructure. It is important to recognise that the two are perceived to be closely interlinked obstacles to electric vehicle adoption. Comments included "nowhere to refuel – always got to plan your journey around somewhere to plug in", "the distance you can travel is not enough before you have to plug it in and refuel" and "OK for a round trip into town but I do long-distance driving". Comments about infrastructural obstacles included "not enough charging points at present", "no charging points at work" and "the distance between charging facilities on long journeys". Many were also concerned about the "hassle of charging", with references made to the length of time it takes to recharge, as well as the frequency of charging: "got to keep plugging in all the time".

Obstacles relating to the battery technology are mentioned with some respondents questioning the ease of swapping batteries when they run out of power, while others were concerned about the durability and lifespan of the battery before it needs changing. Refuelling at home is seen as a potential obstacle by some who expressed concern at having to install a charging point, while others said they do not have a storage facility for the vehicle, perhaps also implying they are concerned about the security of charging the vehicle outside their house. Despite some respondents considering the low noise level associated with electric vehicles as an advantage, there were others who considered it to be an obstacle, expressing concern for pedestrian safety. There were 3% of respondents who noted performance obstacles that relate to a lack of engine power (e.g. “not powerful enough for me”).

Responses relating to economical obstacles were listed by 31% of respondents. These were predominantly in connection with the high purchase price of vehicles, with comments including “far too expensive – far out of the ordinary man’s pocket” and “it’s just too expensive to consider right now”. Some respondents expressed concern about the resale value of the vehicles and implied that there is not currently a second-hand market for electric vehicles. Running costs were frequently mentioned, with comments such as “the worry about the cost of electricity to charge vehicle battery” and “the cost of electricity will go up”, as well as some being concerned about the cost of battery replacement. Other cost concerns included the expense of installing a charging point at home and the societal costs of providing the infrastructure if there is a mass transition to electric vehicles.

As stated in Section 8.2, social obstacles related to psychological, behavioural and socio-institutional elements. The responses given indicate how such obstacles have influenced their attitude towards electric vehicles. Some of these elements, although not always explicitly expressed, are apparent in the responses that underpin almost every technological, economical and environmental obstacle listed. For example one respondent said “might not be able to travel very far before the vehicle needs charging and there might not be a point near”, which refers to the limited range of the vehicle (technological), the lack of infrastructure (technological) as well as the fact that this is a concern, and suggests that range anxiety would be associated with its use (psychological). Some were more explicit in their expression of social barriers, making references to the inability to go on holiday or visit family and friends who live long distances away, with comments such as “it would be impossible to go on holidays” and “it would not make the round trip to visit my son and his family”.

Range anxiety was made explicit in some cases, with comments including "You can't go far and constantly worry about power - you might run out of power and don't know where to refuel", "I don't know many charging points, so I would be afraid to drive very far", and "not knowing where to recharge and how far you can travel – if you were caught in a traffic jam you would use all your power". Some respondents noted the role of their vehicle to perform their jobs, stating it would compromise their ability to work: "I am a community nurse and need my car to be ready all the time and travel distances all week" and "no good for me – I'm a taxi driver". Many also expressed concern about not knowing how to use an electric vehicle, or how and where to charge. Having to learn how to use one was therefore seen as a barrier: "don't know where and how to charge", "will stay with what I know", "having to learn how to drive one", while several respondents felt they were "too old" to drive an electric vehicle.

Finally, environmental obstacles were provided by 3% of respondents and relate to the continued use of fossil fuels to supply electricity as well as environmental impacts at the point of manufacture and disposal. One respondent commented that "they would have to build more power stations to cope with demand, so it's not any better for the environment". Others spoke of concerns about battery manufacture and disposal, such as "more pollution during manufacture of batteries" and "big environmental problem with disposal of old battery units".

Within the responses, it was evident that poor knowledge is an obstacle to acceptance and adoption of electric vehicles. There were 70 responses, occasionally listed alongside advantages or obstacles, indicating that a respondent perceived their knowledge of electric vehicles to be lacking or insufficient. Such responses included "not knowing much about electric vehicles, I can't really comment" "not sure" "no idea" and "I don't know". A summary of some of the key perceived obstacles to electric vehicle ownership is provided in Table 8.2.

Table 8.2 *Examples of some of the perceived advantages, as listed by respondents*

Response	Obstacles to having an electric vehicle
1	"As I am self employed, an electric vehicle would not be an advantage due to travelling distances."
2	"Cost of car to buy. Residual loss. Battery would be expensive, no good for me."
3	"Cost of electricity. Installation of refuel point at home. Not finding fuelling point on long journey. Knowing how many hours left of fuel."
4	"Cost, and when the battery runs out. They're under-powered and looking for points to recharge and repair would be costly."
5	"Faff to charge. High electricity bills. Flat battery when need to use the car. Long charge time with short range before charging required again."
6	"I could not go on holiday in an electric car. I could not drive far, I don't
7	"I don't know many charging points, so I would be afraid to drive very far."
8	"I don't think they're practical."
9	"I haven't read much about it. I could not go far with an electric vehicle. and would have to plug at home. Cables everywhere. You should be looking at rapeseed oil technology."
10	"I think its a bad idea, they will have to build more power stations to cope with demand so it's not any better for the environment."
11	"I'm a community nurse and need my car to be ready all the time and travel distances all week. It would have to be charged up too often."
12	"Initial cost and inability for the owner to service and repair the vehicle."
13	"Lack of engine power/acceleration."
14	"Life span of the battery."
15	"Much more expensive to buy and charge up. Will stay with what I know."
16	"Not enough charging points in the areas I travel in. Got to have charging points like bike points in London and Cambridge. Too quiet."
17	"Nowhere to refuel always got to plan your journey around for somewhere to plug in."
18	"Slow and expensive, not enough power in the battery to go very far."
19	"The battery charging would be a bother."
20	"The range of travel with hours to re-charge."
21	"The range, not being able to travel far. It would have to be a second car."
22	"They have not got the range. No good for people that want to travel a long way. Where are we all going to plug in? What if you have more than one car in house?"
23	"Too little luggage space/shopping space. Lack of recharge points."

8.2.3 Relative advantage of named vehicle attributes (electric vehicles)

Respondents were asked to state from a list of vehicle attributes whether they would consider them stronger or weaker for an electric vehicle in comparison to a conventional vehicle. Figure 8.4 shows the perceptions of respondents towards the attributes. Respondents were additionally asked to select from a list the attributes that they would consider most important when purchasing a new vehicle. This question was asked simply in the context of a new vehicle purchase with no reference to electric vehicles. It is therefore assumed that respondents have answered the question in the context of a conventional vehicle.

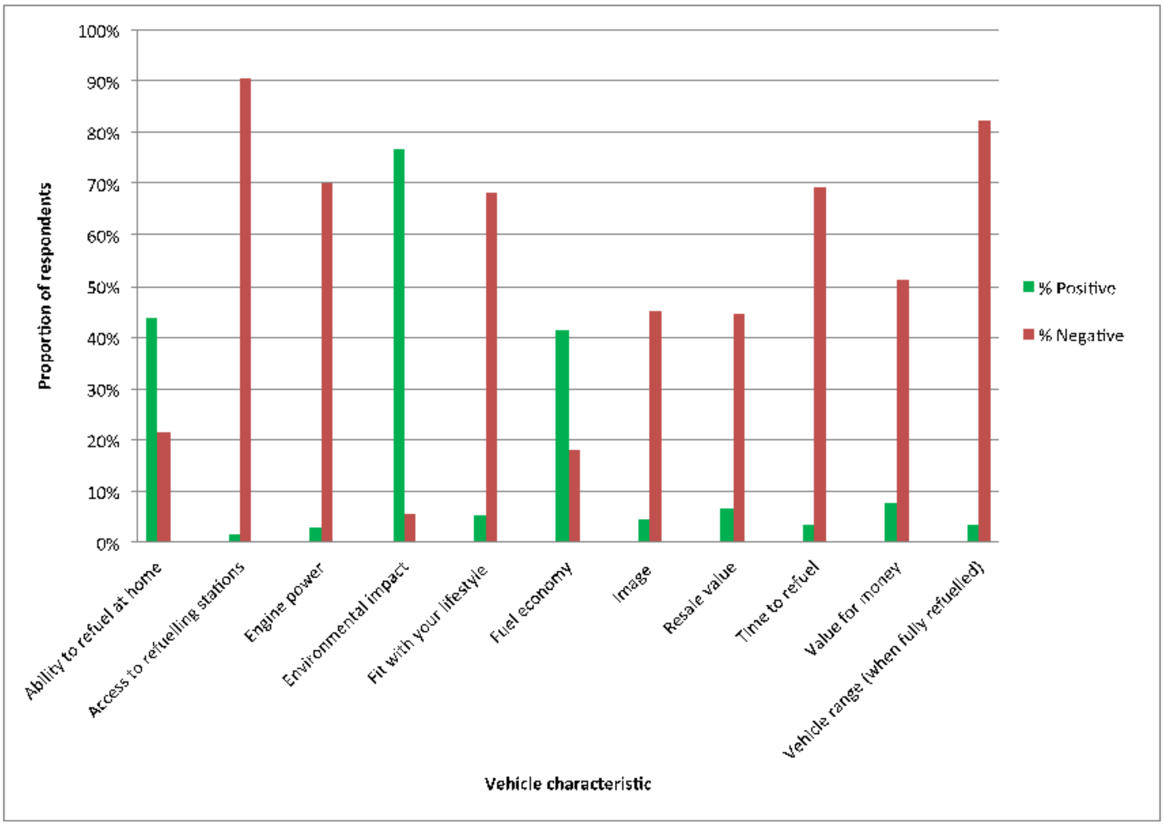


Figure 8.4 *Attitude towards the question "[...]how do you believe a fully electric vehicle compares to a petrol or diesel vehicle?"*

Overall, there are few vehicle attributes that were perceived to be better for electric vehicles than for conventional vehicles. Perceptions of attributes for which an electric vehicle does better were the ability to refuel at home, fuel economy and environmental impact. For all other attributes detailed, conventional vehicles were perceived to be better. While it is not possible to refuel a conventional vehicle at home, establishing whether the ability to undertake this particular activity at home is perceived to be a better attribute than not being able to do so is of interest. If having to go to a petrol station is perceived to be an inconvenience, then the ability to refuel at home will be a unique selling point for electric vehicles.

In order to assess how influential the perceptions of the various characteristics in Figure 8.4 are in the context of a new vehicle purchase, respondents were asked to select from a range of characteristics the three that they considered most important, and the results of which are shown in Figure 8.5.

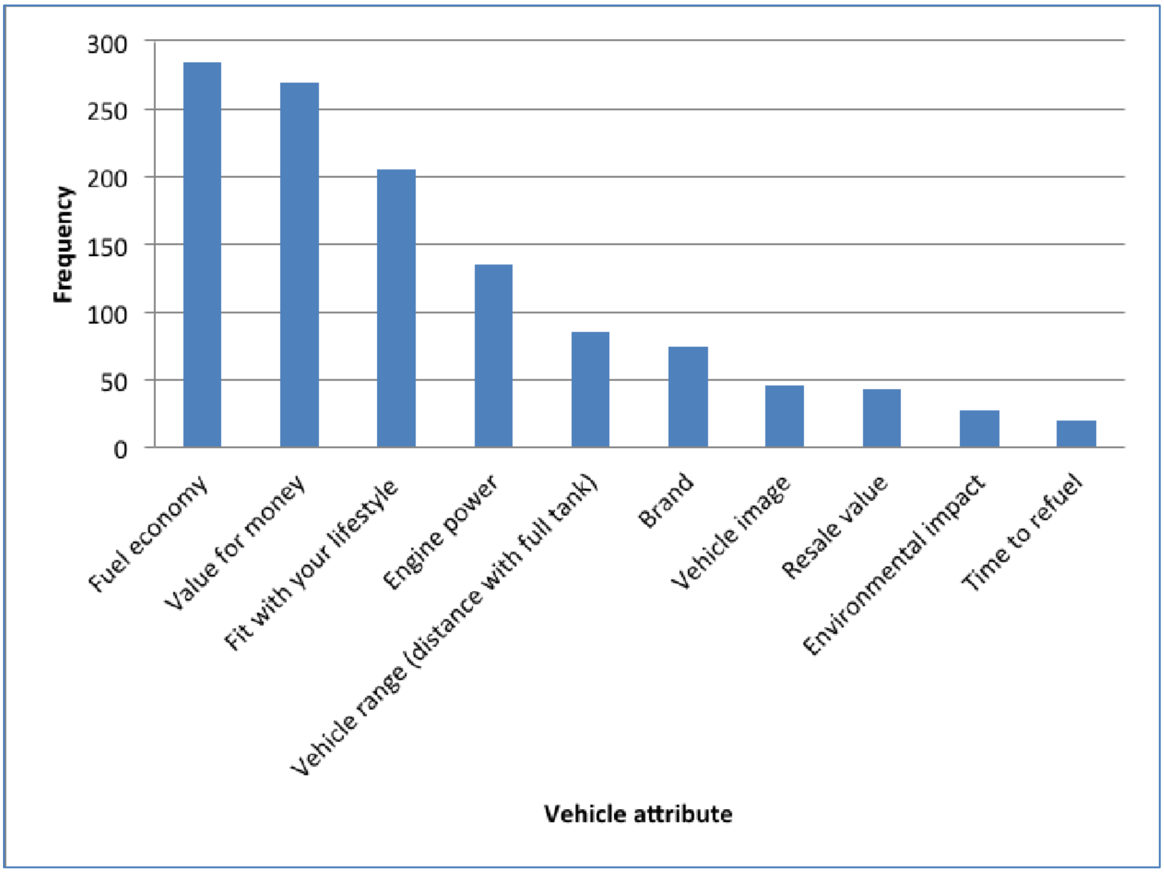


Figure 8.5 *Vehicle attributes in order of importance*

Overall, fuel economy, value for money and fit with lifestyle were the three characteristics regarded as the most important when considering a new vehicle purchase. The three least important characteristics were resale value, environmental impact and time to refuel. Brand and vehicle image were also considered to be slightly less important characteristics.

8.3 Compatibility of alternative fuel vehicles (electric vehicles)

In order for an individual to consider adopting an innovation, they must perceive it to be compatible with their needs (Rogers, 2003).

Table 8.3 *Attitude towards perceived compatibility of the innovation*

	Attitude statement	N	Agree strongly	Agree somewhat	Neither agree/disagree	Disagree somewhat	Disagree strongly	Total Agree	Total Disagree
1	An electric vehicle would require you to make impossible changes to your lifestyle	401	30%	26%	24%	14%	6%	56%	20%
2	An electric vehicle may be suitable as an additional vehicle in your household	400	7%	30%	22%	17%	25%	37%	42%

The majority of respondents (56%) indicated that an electric vehicle would require impossible lifestyle changes. Almost a quarter of respondents (24%) were unable to indicate whether or not this would be the case, perhaps demonstrating their unfamiliarity with the kind of lifestyle changes that may be required. With 20% stating that they disagreed, this may suggest that, although they are aware of differences in vehicle technologies, the changes to lifestyle that an electric vehicle would require are perceived to be manageable. As a second vehicle within the household, an electric vehicle is considered as maybe suitable by 37%, however the majority (42%) stated that it would not be suitable as a second vehicle.

Table 8.4 *Chi square and Spearman's Rho results for perceived compatibility of the innovation*

Statement			Correlation coefficient		
		Agree with statement	Pearson's Chi-Square (X^2)	df	Spearman's (r_s)
2. An electric vehicle may be suitable as an additional vehicle in your household					
Gender N=397	Male (N=202)	42%	10.144*	4	
	Female (N=195)	31%			
Age N=392	25-59 (N=189)	41%	15.468**	4	-.199***
	60+ (N=203)	33%			
Qualifications N=396					.204***
Socioeconomic status N=374					.142**

Note: *p < .05, ** p < .01, *** p < .001

The chi-square test in Table 8.4 shows a significant correlation of the perceived suitability of an electric vehicle as an additional household vehicle (Statement 2) with gender ($p < .05$) and age ($p < .01$), whereby those who are male and those who are under the age of 60 are more likely to consider an electric vehicle as suitable for this purpose.

Statement 2 also showed statistical significance in Spearman's rho test for correlations with age ($p < .001$), qualifications ($p < .001$) and socio-economic status ($p < .01$). This test proves that an electric vehicle is more likely to be considered as a suitable additional vehicle as age reduces but qualifications and socio-economic status increase.

8.4 Complexity of alternative fuel vehicles (electric vehicles)

If an individual perceives the innovation to be too complex, the likelihood of adoption is reduced (Rogers, 2003). There were at least half of the respondents who indicated that they would be confident with using an electric vehicle, which suggests that the perceived complexity associated with these vehicles is not a major barrier to their adoption.

Table 8.5 *Attitude towards perceived complexity of innovation*

Attitude statement		N	Agree strongly	Agree somewhat	Neither agree/disagree	Disagree somewhat	Disagree strongly	Total Agree	Total Disagree
3	You are confident that you would know how to drive a fully electric vehicle	391	28%	32%	22%	12%	7%	60%	19%
4	You are confident that you would know how to recharge a fully electric vehicle	392	25%	26%	28%	11%	10%	51%	21%
		N	Very easy	Somewhat easy	Neither easy/difficult	Somewhat difficult	Very difficult	Total Easy	Total Dfficult
5	How easy/difficult do you think driving an electric vehicle is?	407	41%	27%	30%	2%	0%	68%	2%
6	How easy/difficult do you think recharging an electric vehicle at home is?	407	25%	24%	32%	14%	5%	49%	19%
7	How easy/difficult do you think recharging an electric vehicle away from home is?	407	10%	7%	15%	27%	42%	17%	69%

As shown in Table 8.5, in the case of driving an electric vehicle and recharging an electric vehicle, the majority of respondents (60% and 51% respectively) stated that they are confident they would know how to do both of these activities.

Respondents were also asked how easy or difficult they perceive it would be to recharge an electric vehicle at home and to recharge away from home. Recharging at home was considered somewhat or very easy by 49% of respondents. Recharging away from home was considered a more challenging activity, with 68% stating that they would find this activity somewhat difficult or very difficult.

Table 8.6 *Chi square and Spearman's Rho results for perceived complexity of an electric vehicle*

Statement			Correlation coefficient		
		Agree with statement	Pearson's Chi-Square (X^2)	df	Spearman's (r_s)
3.You are confident you would know how to drive an EV					
Gender N=388	Male (N=197)	73%	35.223***	4	
	Female (N=191)	47%			
Age N=383	25-59 (N=185)	64%	15.761**	4	-.180***
	60+ (N=198)	56%			
Qualifications N=372	Higher (N=217)	68%	12.103*	4	.207***
	Lower (N=155)	50%			
Socioeconomic status N=365	Higher (N=172)	72%	22.313***	4	.204***
	Lower (N=193)	49%			
4. You are confident you would know how to recharge an EV					
Gender N=389	Male (N=198)	66%	37.812***	4	
	Female (N=191)	36%			
Age N=384	25-59 (N=185)	56%	11.41*	4	-.175***
	60+ (N=199)	46%			
Qualifications N=374	Higher (N=219)	59%	14.109**	4	.192***
	Lower (N=155)	40%			
Socioeconomic status N=366	Higher (N=172)	63%	21.516***	4	.167***
	Lower (N=194)	41%			

Note: *$p < .05$, ** $p < .01$, *** $p < .001$

The chi-square test in Table 8.6 shows that there are significant correlations between gender and confidence when it comes to using an electric vehicle (Statement 3 $X^2 = 35.223$, $p < .001$ and Statement 4 $X^2 = 37.812$, $p < .001$), and males have significantly more confidence than females. Those who are under the age of 60 (Statement 3 $p < .01$ and Statement 4 $p < .05$), those with higher qualifications (Statement 3 $p < .05$ and Statement 4 $p < .01$), and those with a higher socio-economic status (Statement 3 $p < .001$ and Statement 4 $p < .001$) are significantly more confident than those who are over the age of 60, have lower qualifications and a lower socio-economic status.

Table 8.7 *Spearman's Rho results for perceived complexity of an electric vehicle*

Statement	Correlation coefficient
5. How easy/difficult do you think driving an electric vehicle is? (Scale of 1(low) to 5(high))	Spearman's (r_s)
Age N=406	-.151**
Qualifications N=391	.253***
Socioeconomic status N=385	.199***

Note: *p < .05, ** p < .01, *** p < .001

In Table 8.7, the Spearman's rho test demonstrates significant correlations between age, qualifications and gender and Statements 3 and 4 ($p < .001$). Confidence reduces as age, level of qualifications and socio-economic status increases. In Table 8.7, the same result is associated with perceived ease of driving an electric vehicle (Statement 5), with age ($p < .01$), qualifications ($p < .001$) and socio-economic status ($p < .001$). These results confirm that the perceived complexity element that influences the degree of persuasion towards the adoption of an electric vehicle correlates highly with socio-demographic characteristics. Those who are male, younger, have a higher level of qualifications and a higher socio-economic status are more likely to have a reduced perception of electric vehicles being complex to use.

8.5 Trialability of alternative fuel vehicles (electric vehicles)

Having the ability to trial an innovation positively influences the adoption of an innovation (Rogers, 2003).

In the case of alternative fuel vehicles, very few of the respondents have experienced ever travelling in one. Out of all alternative fuel vehicles, respondents have had the most exposure to hybrid vehicles. There are 53 respondents (13%) who have previously travelled in a hybrid vehicle. There are 25 (6%) who have travelled in an electric vehicle and, despite not being available to the public for purchase, 6 respondents (1.5%) indicated that have previously travelled in a hydrogen fuel cell vehicle.

Table 8.8 *Chi square results for trialability of the innovation.*

Statement			Correlation coefficient	
		"yes" response	Pearson's Chi-Square (X^2)	df
6. Have you ever travelled in a hybrid vehicle?				
Gender N=404	Male (N=207)	16%	4.781*	1
	Female (N=197)	9%		
Socioeconomic status N=382	Higher (N=179)	18%	9.476**	1
	Lower (N=203)	8%		
7. Have you ever travelled in an electric vehicle?				
Gender N=404	Male (N=207)	9%	6.540*	1
	Female (N=197)	3%		
8. Have you test-driven an electric vehicle?				
Gender N=410	Male (N=208)	5%	7.300**	1
	Female (N=202)	1%		

Note: *p < .05, ** p < .01, *** p < .001

The questions in Table 8.8 are closed-format questions with "yes" or "no" response categories, which means that the Spearman's rho test cannot be used to examine the relationship with socio-demographic characteristics. However, the chi-square test demonstrates the presence of significant correlations. Previous exposure to a hybrid vehicle correlates with gender ($p < .05$) and socio-economic status ($p < .01$), whereby males and those of a higher socio-economic status are more likely to have previously travelled in a hybrid vehicle. The use of an electric vehicle correlates only with gender, where, again, males are more likely to have travelled in an electric vehicle than females.

When respondents were specifically asked if they had test driven an electric vehicle, 11 respondents stated they have done so. As Table 8.8 shows, there is a significant relationship between statement 8 and gender. Ten of the eleven respondents who have test driven an electric vehicle are male. There was a significant relationship between having travelled in an electric vehicle and having test-driven an electric vehicle ($p < .001$), however the relationship shows that only 6 out of the 25 respondents who have travelled in an electric vehicle have actually test-driven an electric vehicle.

8.6 Observability of alternative fuel vehicles (electric vehicles)

An innovation that is perceived as having greater observability (i.e. visibility of the results of the innovation) is associated with a greater likelihood of adoption (Rogers, 2003).

Overall, visibility of electric vehicles and the supporting infrastructure was relatively low. There were 3% (n412) of respondents who knew somebody who uses an electric vehicle, although 10% (n410) have seen somebody using one. Electric vehicles are not currently widely owned or used, so it is to be expected that visibility is relatively low.

Table 8.9 *Chi square results for observability of the innovation.*

Statement			Correlation coefficient	
		'"yes" response	Pearson's Chi-Square (X^2)	df
9. Have you ever seen anybody using an electric vehicle?				
Gender N=407	Male (N=206)	15%	13.461***	1
	Female (N=201)	4%		
10. Have you seen any recharging points in public spaces in Birmingham or Sutton Coldfield?				
Age N=398	25-59 (N=193)	17%	11.253**	1
	60+ (N=205)	6%		

Note: *p < .05, ** p < .01, *** p < .001

Charging points in public spaces in the local area (Birmingham and Sutton Coldfield) have been observed by 11% (n406) of respondents. At the time of the questionnaire, there were two points available in a public car park in Sutton Coldfield in addition to 13 of Birmingham's city centre car parks. Poor observability suggests that insufficient marketing is being done to promote these charging points.

As with the questions associated with innovation trialability in Section 8.5, being closed-format questions with only two response categories ("yes" or "no"), Statements (questions) 9 and 10 cannot be used in conjunction with Spearman's rho, however the chi-square test shows the presence of some significant correlations. Observation of electric vehicles is correlated with gender ($p < .001$), with significantly more males than females having seen electric vehicles in use. The observation of electric vehicle charging infrastructure in the local area is correlated with age ($p < .01$), with those under the age of 60 far more likely to have seen a charging point than those over the age of 60.

Very few females (4%) have previously seen anybody using an electric vehicle. This may be caused by unfamiliarity with electric vehicle brands and models, and an inability to distinguish an electric vehicle from a conventional vehicle. As observation is considered an important influence on the adoption of an innovation, it may be that electric vehicle manufacturers need to make these vehicles more easily distinguishable from conventional vehicles. However, making electric vehicles more distinctive may affect their image, possibly making them less desirable.

The influence of age on the observation of charging points in public spaces in Birmingham may be caused by older respondents' unfamiliarity with electric vehicle infrastructure.

8.7 Perceptions of the long-term success of alternative fuel vehicles

When respondents were asked to indicate their attitude towards the long-term success of new vehicle technologies, such as electric vehicles, just over half (53%) stated that alternative fuel vehicles do have a future, although 21% indicated that they do not think alternative fuel vehicles will be successful in the long-term. Interestingly, when this statement was examined against the question "have you ever test-driven an electric vehicle?", 9 of the 11 respondents who have test-driven an electric vehicle disagreed with Statement 11. However, one respondent who has test-driven an electric vehicle stated that they 'agree strongly' with Statement 11. Similarly, there were 19 out of 24 respondents who have travelled in an electric vehicle who disagreed with Statement 11. There were three who 'neither agree nor disagree', suggesting that, following exposure to these vehicles, they were uncertain about the future success of electric vehicles. However, overall, it seems that exposure to electric vehicles leads to a positive attitude towards them.

Table 8.10 *Attitude towards future success of new vehicle technologies.*

	Attitude statement	N	Agree strongly	Agree somewhat	Neither agree/disagree	Disagree somewhat	Disagree strongly	Total Agree	Total Disagree
11	New vehicle technologies, such as electric vehicles, will never be successful	407	10%	11%	26%	26%	27%	21%	53%

As illustrated in Table 8.11, age has an influence on the perception of whether or not electric vehicles will be successful in the future and it was confirmed that a greater number of those under the age of 60 have the perception that electric vehicles will be successful in the future. The Spearman's rho results show that that as age increases, so too does the likelihood that the individual perceives alternative fuel vehicle technologies will be unsuccessful in the future.

Table 8.11 *Chi square and Spearman's Rho results for attitude towards future success of new vehicle technologies.*

Statement			Correlation coefficient		
		Agree with statement	Pearson's Chi-Square (X^2)	df	Spearman's (r_s)
11. New vehicle technologies, such as electric vehicles, will never be successful					
Age N=399	25-59 (N=192)	58%	12.501**	4	.132**
	60+ (N=207)	48%			
Qualifications N=388					-.107*

Note: *p < .05, ** p < .01, *** p < .001

There were 37% of respondents in the age groups 65-74 and 74+ who think electric vehicles will never be successful, whilst only 14% of those under the age of 40 agreed. Qualifications have a negative relationship with this statement (r_s = -.107, $p < .05$) indicating that as the level of qualifications increases, the perception that new vehicle technologies will be successful also increases.

8.8 Consideration given to the adoption of an electric vehicle

According to Rogers (2003), the non-adoption of an innovation falls into two categories. The first type of non-adoption is called 'active rejection', which is where an individual considers adopting an innovation but then decides not to adopt it, and the second type of non-adoption is 'passive rejection', which is where the individual has never really given any consideration to using the innovation.

In order to understand the type of non-adoption among the respondents, they were asked whether they have, at any stage, given consideration to the purchase or lease of an electric vehicle. At the time of the survey, none of the respondents owned or leased an electric vehicle but 5% (21 respondents) stated that they have at some stage considered the purchase or lease of an electric vehicle. Of these individuals, 14 are male, 12 are under the age of 60, 14 have higher-level qualifications, 10 have a higher socio-economic status and 16 own two or more vehicles. Given that none of those who had considered the purchase or lease of an electric vehicle currently own or lease one, the non-adoption by these individuals is likely to be 'active rejection' at this point in time.

As Table 8.12 illustrates, eight respondents who have previously considered an electric vehicle intend to purchase an alternative fuel vehicle. There were five respondents, however, who have previously considered purchasing an electric vehicle but intend to purchase a conventional fuel (petrol or diesel) vehicle at the next purchase, which would confirm that these individuals are actively rejecting alternative fuel vehicles. A further eight respondents were not certain of their next vehicle purchase, suggesting, perhaps, that they have not completely decided against the purchase of an alternative fuel vehicle.

Table 8.12 *Cross-table of past and future consideration of an alternative fuel vehicle*

"Which of the following vehicle types best describes your probable next vehicle?"	"Have you at any stage considered the purchase/lease of an EV?"		
	"Yes"	"No"	Total
Hybrid vehicle	6	7	13
Fully electric vehicle	2	2	4
Petrol vehicle	4	127	131
Diesel vehicle	1	86	87
Other	0	1	1
Unsure	8	143	151
Total	21	366	387

Of the 21 respondents who have given consideration to purchasing an electric vehicle, the perceived obstacles they stated are shown in Table 8.13 (20 of the 21 respondents named a barrier). From the reasons presented in the table, it is possible to deduce the reasons for active rejection of an electric vehicle. They largely relate to three problems: purchase price, limited range, and poor infrastructure availability. There were two respondents who had given consideration to purchasing an electric vehicle and who still intend to purchase one; one of whom could not see any obstacles to adopting an electric vehicle, while the other noted that range was a concern. There are those who may want to purchase a more environmentally sustainable vehicle technology, but who have identified obstacles in the case of electric vehicle adoption, and have therefore decided that their next vehicle purchase will be a hybrid vehicle. This was the case for the six respondents shown in Table 8.13.

Table 8.13 *Obstacles to the adoption of electric vehicles among those who have given consideration to an electric vehicle purchase, and their likely next vehicle choice*

Respondent	Potential obstacle to adoption of an electric vehicle	Next vehicle choice
1	"At the moment, where to refuel. Ok for round trip into town, but I do long distance driving."	Hybrid
2	**"Electric charge points on a day out."**	**Petrol**
3	"Existing batteries are too big and too heavy. Hopefully, battery development will improve so that smaller, lighter, higher capacity batteries can be developed."	Hybrid
4	**"I would not be able to travel far and won't know the places for getting charged up."**	**Petrol**
5	**"Initial cost, not enough plug-in points."**	**Unsure**
6	**"It is just too expensive to consider right now."**	**Unsure**
7	**"Lack of power - speed, acceleration. Range of travel. Battery charging. Storage facility."**	**Petrol**
8	**"No charging points, how can I charge it?"**	**Unsure**
9	"None."	Electric
10	**"None."**	**Unsure**
11	**"Not having enough points to charge."**	**Unsure**
12	**"Price of electricity to charge."**	**Unsure**
13	**"Price to buy. The distance I travel daily. Also the batteries. Impact on environment."**	**Petrol**
14	"Price. Charging points. Break down when out of charge."	Hybrid
15	**"Purchasing price."**	**Diesel**
16	"Range."	Electric
17	"Recharging may be a problem as I have a serious back problem. Recharge in own home?"	Hybrid
18	"Recharging time, low fuel range on longer journey."	Hybrid
19	**"The mileage - how far will it travel on a full charge?"**	**Unsure**
20	**"Too expensive to buy."**	**Unsure**
21	(none provided)	Hybrid

Note: Alternative fuel vehicle choices are highlighted.

The obstacles outlined in Table 8.13 illustrate the reasons that hybrid vehicles are stated as the next likely vehicle purchase choice. Hybrid vehicles may serve as a bridging technology between conventional vehicles and electric vehicles, such that they do not face many of the obstacles that the respondents have indicated are stopping them from purchasing an electric vehicle.

The obstacles may become less problematic in time as the technology in electric vehicles develops and more charging infrastructure becomes available. In Table 8.14, five of the respondents who were unsure about the type of vehicle (technology) they will choose, do not intend to purchase their next household vehicle within the next three years. It may be that these individuals will choose to wait and see what advances take place with the technology and the price of the vehicles. These individuals may become 'later adopters' (refer to Figure 8.1), or if they still perceive obstacles to their adoption, it may be a case of 'continued rejection' (refer to Figure 8.1).

Table 8.14 *The next household vehicle purchase/lease and vehicle type.*

Vehicle type	Next household vehicle purchase or lease						Total
	Next 12 months	1-2 years	2-3 years	3-4 years	4 years+	Unsure	
Hybrid vehicle	1	1	2	0	0	2	6
Fully electric vehicle	1	0	1	0	0	0	2
Petrol vehicle	1	1	0	0	0	2	4
Diesel vehicle	0	0	1	0	0	0	1
Unsure	1	2	0	1	1	3	8
Total	4	4	4	1	1	7	21

The majority of the respondents who have considered an electric vehicle (12) stated they intend to purchase their next household vehicle within the next three years, but it is unlikely that the obstacles listed in Table 8.13 will have all been overcome in such a short space of time.

8.9 Discussion

In listing the advantages of ownership of electric vehicles (Section 8.2.1), there was mention of tax exemption as an advantage, but no other Government incentives were mentioned, such as the Plug-In Car Grant of £5,000 towards the cost of the vehicle (see Section 2.4). Despite some evidence of awareness of exemption from vehicle excise duty, it would seem overall awareness of the range of incentives available to consumers is relatively unknown. Although Hackbarth and Madlener (2013) maintain that incentives such as purchase grants, tax exemption and free parking will be important in encouraging uptake of these vehicles, these incentives are already available in the UK but perhaps there is insufficient emphasis being placed on informing consumers of their existence, particularly consumers who are considered as potential adopters.

It was mentioned by 23 respondents that an advantage of an electric vehicle would be the reduced noise, with some even noting how this would contribute to the relaxation of driving. The noise characteristic could be a useful attribute to focus on in marketing to a segment with a need for a more relaxing driving experience.

The greatest barriers to the adoption of electric vehicles (Section 8.2.2) are technological and include vehicle range, length of charging time, frequency of charging and lack of recharging infrastructure, which supports the findings in the literature (Shears, 2007; Ziegler, 2012; Graham-Rowe et al., 2012). A recent survey by the Department for Transport (DfT, 2014b) also identified recharging and the distance travelled on a battery to be obstacles.

The social obstacles mentioned by respondents emphasised a strong concern for the lack of range of the vehicle and the inability to locate charging stations, a finding that is perhaps akin to 'range anxiety' (e.g. Pearre et al., 2011). Despite safety being identified as a concern in some alternative fuel vehicle acceptance studies (Jansson, 2011; EPRI, 2010), there was little mention of vehicle safety being an obstacle to their adoption. However, Ricci (2006) notes that public safety concerns for alternative fuel vehicles can be more of a preoccupation of researchers than the public themselves.

Economic barriers were mainly related to the cost of the vehicle but also included concerns about the rising costs of electricity and how much it would cost to charge the vehicles. Similarly, cost minimisation was found to be the main concern for respondents in a study by Graham-Rowe et al. (2012). A further concern about the cost of battery replacement is raised by several respondents, although it is not clear whether the respondents are referring to battery replacement at the end of the battery's life or battery exchange as an alternative refuelling approach. Assuming the former, battery leasing is an approach currently used by the vehicle manufacturer, Renault, for its electric vehicles to reduce the associated risk. However, a study by Lane (2006) suggests that battery leasing costs would likely cancel out any savings on fuel.

A high frequency of responses including 'no idea' or 'not sure' are indicative of a low level of knowledge of electric vehicles, which further supports the findings in Chapter 7 of poor knowledge of alternative fuel vehicles. A recent Department for Transport study into attitudes towards electric vehicles also reported that lack of knowledge was a significant factor in putting drivers off purchasing electric vehicles (DfT, 2014b).

It was identified in Section 8.2.3 that several vehicle characteristics are perceived as better for electric vehicles than for conventional vehicles. These included the ability to refuel at home, fuel economy and environmental impact. Importantly, fuel economy was ranked as one of the most important vehicle characteristics when making a new vehicle purchase. Despite previous studies having identified consumers and the marketplace becoming increasingly environmentally conscious (e.g. Laroche et al. 2001), environmental impact is considered as one of the least important characteristics, a characteristic not highly valued by Graham-Rowe et al. (2012). Therefore, it stands to reason that if the adoption of alternative fuel vehicles is to increase, environmental attributes are not important enough to consumers for it to be a marketing focus. The importance placed on fuel economy indicates that this attribute could be rather more influential in the marketing of electric vehicles than environmental attributes

There appears to be a distinct barrier to adoption when it comes to compatibility, with few of the respondents considering an electric vehicle as compatible with their lifestyle. Only 20% indicated that they would not have to make changes to their lifestyle to accommodate an electric vehicle. 'Fit with lifestyle' was also ranked as one of the most important characteristics considered in a new vehicle purchase, inferring that compatibility is of great importance in satisfying consumer needs. This supports the value of this perception in influencing the degree of persuasion towards an innovation (Rogers, 2003).

An opportunity for compatibility was established (Section 8.3) when respondents were asked to consider the possibility of having an electric vehicle as a second household vehicle. It was noted by Kurani et al. (1995) that an electric vehicle was more likely to be considered if it was incorporated into the existing household fleet, such that a conventional vehicle is always available for long-range journeys. A relatively large proportion of the sample (just under 40%) recognised this as a possibility, which indicates that compatibility of these vehicles may increase if they are marketed as 'run-around' vehicles. Likewise, Graham-Rowe et al. (2012) found that an electric vehicle was considered better suited as a second vehicle for short, local journeys. The analysis in this Chapter demonstrates that males and those who are younger to middle-aged are more likely to consider an electric vehicle as being suitable as a second vehicle.

The associated complexity (Section 8.4) of use with alternative fuel vehicles is not well evidenced in the literature. Survey results show that perceived confidence when driving and recharging an electric vehicle does not appear to be problematic to most respondents. In both cases over half of respondents stated that they would be very confident that they would know how to drive and recharge an electric vehicle. Approximately a fifth of all respondents stated that they would not be confident with knowing how to undertake these activities. Those who stated lower levels of confidence are females, those who are from an older age group (>60), those with lower level qualifications and those of a lower socio-economic status. Confidence was found to reduce as age increases. In the open-format question, several individuals remarked that they are too old to learn how to use an alternative fuel vehicle, which also reinforces the need to target a younger audience.

Relatively few respondents have had exposure (Section 8.5) to alternative fuel vehicles. Only 6% have previously travelled in an electric vehicle, while 13% have travelled in a hybrid vehicle. Only 11 of the respondents have actually test driven an electric vehicle, and of the 25 individuals who have travelled in an electric vehicle, only 6 of these have test driven one. Rogers (2003) found that being able to trial an innovation played a significant role in its adoption and, in the case of hydrogen vehicles, Altman and Gräsel (1998) confirmed that direct contact with the vehicles had a positive influence on acceptance.

It is interesting then that only 6 out of 25 individuals (Section 8.7) who have travelled in an electric vehicle have also test driven one, perhaps suggesting that the initial exposure was sufficient in influencing the decision of the majority that an electric vehicle is not suitable for them. On the other hand, 9 out of 11 respondents who have test driven an electric vehicle (Section 8.7) stated that they disagreed with Statement 11, so indicating that they think electric vehicles will be successful in the future. There is little evidence in the literature about the effect of trialability on the adoption of alternative fuel vehicles and there is scope for further work in this area. It may be necessary to create better access to trial opportunities, such as through road-shows or similar events, particularly as the technology develops.

Less than 5% knew somebody who uses an electric vehicle and only 10% had seen an electric vehicle being used (Section 8.6). The latter may be affected by an inability to recognise an electric vehicle but may also be affected by the inability to distinguish between an all-electric vehicle and a hybrid vehicle. Considerably more males than females have seen somebody using an electric vehicle, an incidence that may be influenced by males having expressed a greater interest than females in electric vehicles and therefore are more likely to recognise one. Charging points in Birmingham and Sutton Coldfield have been seen by just over 10% of people. Public charging points in this area are currently limited, which will certainly have influenced the likelihood of respondents having seen any. However, there are a number of limited access points (i.e. not public charging points) that may have been observed by respondents. The visibility (Section 8.6) of electric vehicles is likely to be one of the current major barriers to their adoption and affecting perceptions of these vehicles. Without being able to observe their use by others in society sends messages of uncertainty about whether or not to adopt them. Equally, observing that there is supporting infrastructure for electric vehicle recharging will be important in reducing uncertainty, as is recommended by Egbue and Long (2012). The more charging infrastructure that is visible to the public, the less uncertainty there will be associated with running out of power (i.e. range anxiety) and not having anywhere to recharge the vehicle's battery.

When asked whether any consideration had been given to the purchase or lease of an electric vehicle (Section 8.8), there were 5% of respondents (21) who said they have.

The majority of these respondents (in the Sutton Coldfield survey) were male, under the age of 60, had a higher level of qualifications and owned two or more vehicles. Results from a 2014 survey into public attitudes towards electric vehicles undertaken by the Department for Transport (DfT, 2014b), identified that 19% of those surveyed have given consideration to the purchase of an electric vehicle. The Department for Transport survey also confirmed that older age groups, in particular those over the age of 65, were less likely to consider an electric vehicle, while those with a higher level of education were more likely to consider an electric vehicle. Half of the Sutton Coldfield survey respondents also have a higher socio-economic status. None of these respondents have converted consideration into the adoption of an electric vehicle, however two stated that their next vehicle purchase will be an electric vehicle and six stated that their next vehicle will be a hybrid. This confirms that 19 out of 21 respondents who have given consideration to an electric vehicle are *actively* rejecting it at this stage.

The large proportion of respondents who have not given consideration to an electric vehicle confirms that these individuals are *passively* rejecting electric vehicles. The confirmed low levels of knowledge about electric vehicles (Section 7.4 and 8.2) are likely to be responsible for the low level of consideration given to the purchase of an electric vehicle (passive rejection). Equally, the largely poor perceptions of electric vehicles in addition to their technological inferiority (relative to conventional vehicles) is creating substantial barriers for consumers and leading to active rejection. Therefore, major barriers need to be overcome in order to enhance perceptions of electric vehicles that will lead to faster diffusion.

The perceptions analysed in Chapter 8 continue to support the socio-demographic profile identified in Chapter 6, while also noting a significant relationship with gender (as also established in Chapter 8). Accordingly, the profile of an individual most likely to be among the earlier adopters will be male, under the age of 60, have a higher level of qualifications, and have a higher socio-economic status. The subsequent chapter, Chapter 9, concerns the decision phase of the Innovation-Decision Process, which is the next phase in the process.

Chapter 9 Examining the vehicle purchase preferences of the most innovative respondents as a means to understanding 'passive rejection' of electric vehicles

9.1 Introduction

In Chapters 7 and 8, relationships were established between socio-economic characteristics and knowledge and persuasion attributes in the context of alternative fuel vehicles. The innovativeness of respondents, their knowledge towards alternative fuel vehicles and their perceptions of these vehicles were also presented. The third phase of the Innovation-Decision Process is the 'Decision' phase, which is presented in Figure 9.1. At this stage in the Innovation-Decision Process, an individual chooses whether to adopt or reject the innovation.

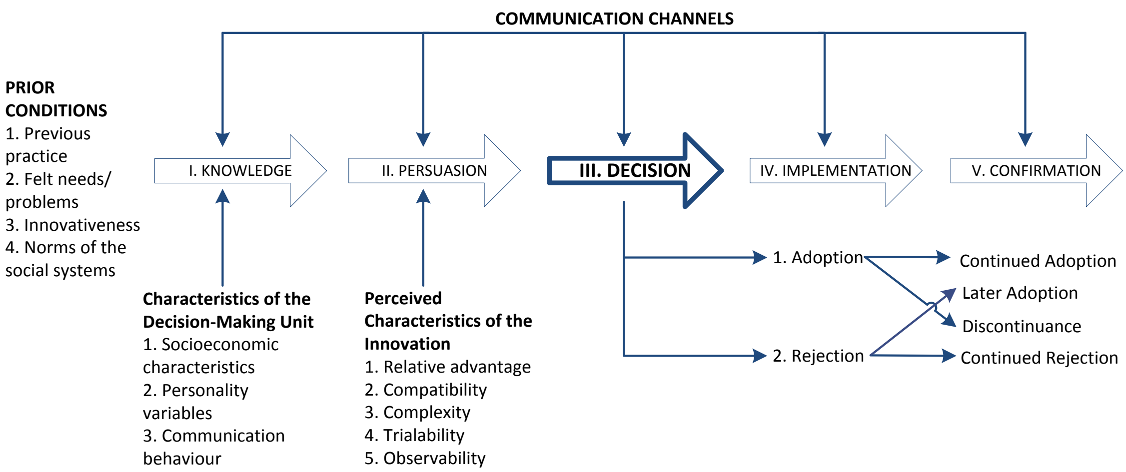


Figure 9.1 *The Innovation-Decision Process. The decision phase (highlighted) is the focus of this chapter.*

While it has not been possible in this research to undertake a longitudinal study of the innovation-decision process with respondents, this Chapter considers decisions about vehicle purchases that may ultimately affect whether the respondent will purchase an alternative fuel vehicle or not. It has been shown that none of the respondents currently own an alternative fuel vehicle that is considered to be zero emissions (i.e. a battery electric vehicle), and are therefore, so far, non adopters of these vehicles. Non-adoption, or 'rejection' as it is referred to by Rogers (2003) in the Innovation Decision Process (Figure 9.1), may not necessarily be long term. The innovation may be reconsidered at a later stage and lead to its adoption. The analysis of vehicle purchase decisions in this chapter identifies opportunities for the adoption of battery electric vehicles at a later stage, while also highlighting opportunities for marketing to increase their adoption. The vehicle purchase decisions investigated relate not only to vehicles that are presently owned but also to preferences regarding a future household vehicle purchase.

In Section 9.2, the analysis begins by reducing the number of respondents to those who are most innovative. As established in Section 4.6.1, innovativeness is the "bottom-line behaviour in the diffusion process" (Rogers, 2003, pg 267) and is determined by socio-economic characteristics, personality variables and communication behaviour.

To identify the most innovative respondents, this is achieved firstly through the use of factor scores for personality variables and communication behaviour characteristics to identify those with the highest scores, reducing the total number of respondents to 160. A further step is then taken to eliminate those with fewer than four of the 'early adopter' socio-demographic characteristics from Chapter 6, which reduces the number of respondents to 50. Section 9.3 provides an overview of the characteristics of these 50 'most innovative' respondents, while Section 9.4 examines their knowledge and perceptions towards alternative fuel vehicles.

In Section 9.5 the analysis considers two of the most frequently listed obstacles listed by respondents to electric vehicle adoption – purchase price and range. It therefore investigates the vehicle purchase decision by considering driving distance characteristics of the most innovative respondents and the purchase choices that have been made for existing vehicles. The preferences for the next vehicle purchase are also examined. In addition, vehicle size preferences are considered in order to establish the practicability of electric vehicles. The purchase preferences are examined with respect to models of electric vehicles that were available in the UK in early 2014.

In Section 9.6 the analysis then goes a step further to identify among the most innovative respondents those who have a vehicle purchase budget that meets the price of an alternative fuel vehicle. This Section constitutes a qualitative analysis of the vehicle usage of these individuals and their purchase preferences in order to establish the alignment between expectations of vehicle characteristics and the characteristics of currently available models (as at 2014) of alternative fuel vehicles. A diagram to show the process for reducing the number of respondents in the analysis is provided in Figure 9.2.

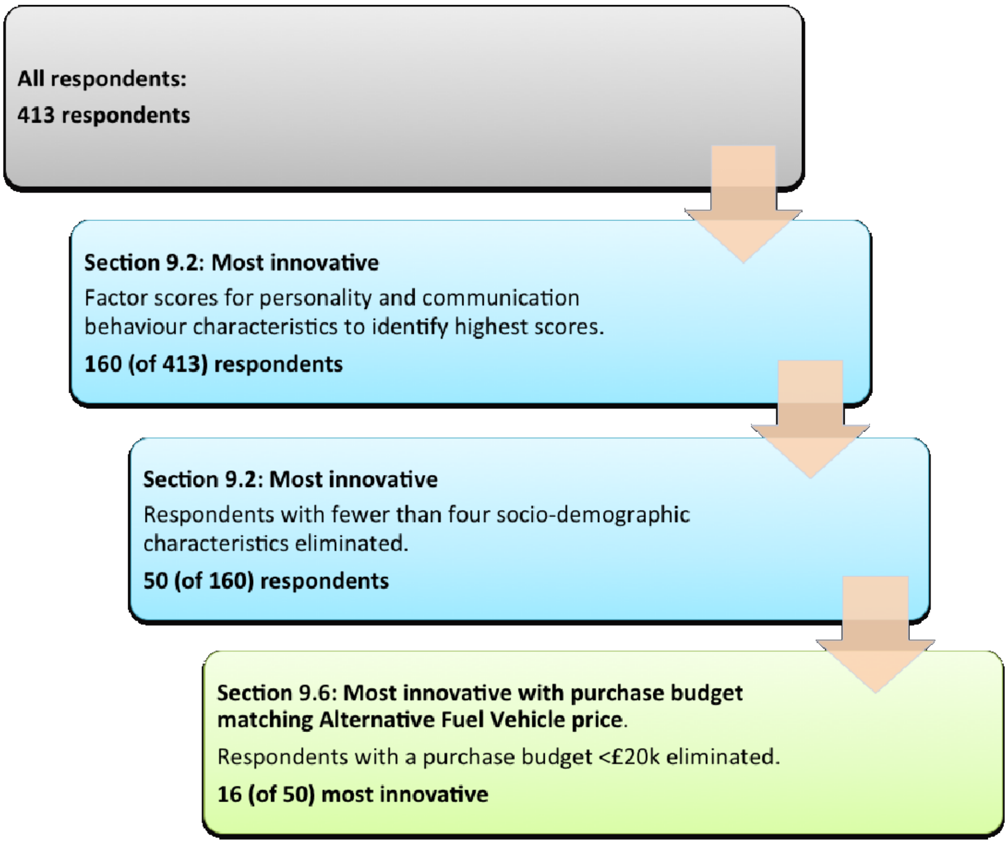


Figure 9.2 *Elimination process to reveal respondents with greatest potential to purchase an alternative fuel vehicle.*

9.2 Identifying those who are most innovative

The first step of this analysis is to identify and select the most innovative respondents. Chapters 7 and 8 revealed that the characteristics in socio-demographic profile identified in Table 3.3 (Section 3.10) were associated with higher levels of innovativeness in the respondents. It is therefore necessary to turn to personality and communication behaviour to identify respondents with the highest levels of innovativeness across these characteristics. Concerns were raised in the literature about innovation-specific innovativeness and eco-innovations being different to any other innovation (e.g. Jansson, 2011; Hellström, 2007). To manage this concern, variables relating to the prior condition 'felt needs or problems' (Figure 9.1), such as contextual factors (refer to Section 5.5.4), are also incorporated to compensate for any scores which may be high on innovativeness but low on knowledge or attitudes towards contextual factors (e.g. low scores for awareness of environmental impacts of vehicles use and low scores for pro-environmental attitudes).

A principal component analysis (PCA) (refer to Section 5.5.4 for details) was conducted on 38 personality and communication behaviour items with orthogonal rotation (varimax). The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis, KMO = 0.84 ('great' according to Field, 2009), and all the KMO values for individual items are > 0.5 which is an acceptable limit (Field, 2009). Bartlett's test of sphericity X^2 (528) = 3576.64, $p < 0.001$, demonstrates that correlations between items were sufficiently large for PCA. An initial analysis was run to obtain eigenvalues for each component in the data. Nine components had eigenvalues over Kaiser's (1960) criterion of 1 and, in combination, explained 61% of the variance. Given the large sample size this is the number of components that were retained in the final analysis.

Table 9.1 shows the factor loadings after rotation. The items that cluster on the same components suggest the following: Component 1 = Aversion to risk, Component 2 = Affective reasoning, Component 3 = Contextual awareness, Component 4 = Communication behaviour, Component 5 = Expectations for vehicle use, Component 6 = Awareness of environmental impact of energy generation, Component 7 = Inter-connectedness, Component 8 = Vehicle demand, and Component 9 = Media awareness. Components 1, 2 are representative of personality, while Components 4, 7 and 9 represent communication behaviour. The remaining Components (3, 5, 6, 8) represent the variables that have been incorporated to align innovativeness scores with attitudes towards, and awareness of, the contextual factors (i.e. the societal problem or need that alternative fuel vehicles satisfy).

__Table 9.1__ The characteristics of the decision-making unit grouped into nine factors

Statement	Component score	Factor	Eigenvalues	% of variance
You want to be among the first people to try a new technology	0.867	Risk aversion	4.833	14.65
You invest in new technologies soon after they become available for purchase	0.83			
Friends will often use you as a point of reference for new technologies	0.827			
You have a keen interest in new technologies	0.735			
You would consider yourself willing to take a risk when it comes to investing in new technologies	0.672			
You rarely invest in new technologies	-0.62			
You prefer to stick to existing technologies that you are familiar with	-0.609			
You tend to invest in new technology once you have been convinced about the benefits of using it	0.478			
You are often contemplative when you are making a decision	0.719	Affective reasoning	2.728	8.27
You often take your time before making a decision to invest in a new technology	0.657			
You are often reluctant to change your routine	0.6			
You often find abstract ideas confusing	0.589			
The uncertainty of not knowing how successful a technology will be in the long-term would make you feel uncomfortable about investing in it	0.582			
You are often sceptical about new technologies	0.463			
Petrol/diesel motor cars emit harmful greenhouse gases into the environment	0.722	Context awareness	2.53	7.67
Motor cars produce gases that are harmful to people's health	0.711			
Petrol/diesel is likely to become too expensive to buy in the near future	0.681			
Oil supplies are running out	0.606			
You think about the impact of your activities on the environment	0.483			
You regularly interact with people in your local community	0.857	Communication behaviour	2.515	7.62
You regularly participate in social activities	0.844			
You are often involved in matters that require you to interact with people outside of your local network	0.702			
We should continue with petrol/diesel motor car technology	0.655	Vehicle usage expectations	1.92	5.82
New vehicle technologies, such as electric vehicles, will never be successful	0.599			
You should not be forced by legislation to make changes to your motor car use	0.586			
Mainstream electricity production has a low environmental impact	0.7	Environmental impact of	1.51	4.58
The future is determined by fate	0.499			
You have a small network of people you know	0.628	Inter-connectedness	1.501	4.56
You are often good at understanding other people's feelings	0.621			
People you know are often influential (through their advice or opinions) when you are considering buying or trying a new technology	0.521			
Having a motor car is a necessity	0.758	Vehicle requirement	1.438	4.36
Having a motor car is a luxury	-0.581			
You try to keep up to date with what is happening in the media	0.765	Media awareness	1.228	3.72

Using the regression scores generated for each of the factors in Table 9.1, it was possible to identify the mean scores for respondents. From a total of 413 respondents, there are 321 valid cases following the exclusion of respondents with any missing factor scores. The minimum regression score is -11.26 and the maximum of 9.7, and the mean score is 0 with a standard deviation of 3. In order to identify the most innovative respondents, those whose scores exceeded the mean score were extracted to produce a data set of 160 respondents.

There is a further step to identifying the most innovative, and that is the influence of socio-demographic characteristics. To represent this characteristic, this research relies upon the socio-demographic profile outlined in Chapter 6 and validated in Chapters 7 and 8. From the 160 cases identified as being most innovative, based on their personality and communication behaviour, those that meet a minimum of four of the socio-demographic criteria (with one compulsory criterion of owning more than one vehicle) have been extracted to produce a data set of 50 cases. It is these 50 cases that represent the most innovative respondents. The sum of the factor scores for the 50 most innovative respondents ranges from 0 to 7.78, with a mean score of 2.1 and a standard deviation of 1.93. These individuals will now be referred to as 'the most innovative' respondents.

9.3 Characteristics of the most innovative respondents

This section introduces the characteristics of the most innovative respondents. Table 9.2 details the demographic characteristics of the 50 respondents who are considered to be the most innovative and the vehicle use characteristics of the most innovative are illustrated in Table 9.3. There are eight more males than females, and 27 (just over half) of the respondents were aged between 35 and 54. Twenty-six of the most innovative respondents had a qualification equivalent to a Bachelor's degree or above, and 39 were of a higher socio-economic status (higher or intermediate managerial level). Only one of the most innovative respondents lived in a one-person household. The majority (30) of the most innovative respondents lived in households constituting more than two occupants. This may be an indication that the majority of the most innovative respondents were living as a family unit.

Table 9.2 *Demographic characteristics of the most innovative*

Variable	Category	Frequency
Gender n=50	Male	29
	Female	21
Age n=50	25 - 34	4
	35 - 44	12
	45 - 54	15
	55 - 59	2
	60 - 64	6
	65 - 74	9
	75+	2
Qualifications n=50	A Doctorate or equivalent	1
	Master's Degree or equivalent	6
	Bachelor Degree or equivalent	19
	HNC/HND	8
	A-level or equivalent	13
	GCSE/O-level or CSE	1
	Vocational qualifications	1
	No formal qualifications	1
Socioeconomic status n=50	Higher managerial, administrative or professional	17
	Intermediate managerial, administrative or professional	22
	Supervisory, clerical and junior managerial, administrative or professional	7
	Skilled manual work	4
Number of people in household n=50	1	1
	2	19
	3	10
	4	17
	5+	3

The majority of the most innovative respondents were from Sutton Vesey (22), followed by Sutton Four Oaks (13), Sutton Trinity (11), and finally, Sutton New Hall (4). In the cluster analysis in Chapter 6, Table 6.6, showed how the majority of those with early adopter socio-demographic characteristics are in Sutton Vesey. This finding confirms that these individuals also display a high degree of innovativeness and may constitute a strong target market for alternative fuel vehicles.

Table 9.3 *Number of household vehicles and vehicle use characteristics*

Variable	Category	Frequency
Number of driving licences in household n=50	1	2
	2	40
	3	6
	4	2
Number of cars in household n=50	2	42
	3	5
	4	3
Car is main mode of transport n=50	Daily	46
	Weekly	2
	Monthly	2
Commute to work n=41	Commutes by car	25
Frequency driving distance >100 miles in a single day n=50	Daily	4
	Weekly	14
	Monthly	15
	Less frequently	17
Frequency second household vehicle driving distance >100 miles in a single day n=48	Daily	3
	Weekly	7
	Monthly	8
	Less frequently	30

Forty-eight of the most innovative respondents were from households that have two or more people who hold a driving license. The majority (42) owned two cars, while eight owned more than two. Of those who worked (41), 25 commuted to work by car and 46 of the 50 respondents used a car as their main mode of transport on a daily basis. Only four stated that they used their car less frequently. The driving distance covered on a regular basis was important in understanding the suitability of a limited-range vehicle, such as its suitability to an individual's routine. Despite the majority of the most innovative respondents using their car on a daily basis, there were four who drive a distance greater than 100 miles in a single day on a daily basis. Thirty-two of the most innovative respondents stated that they do not drive 100 miles in a single day more frequently than on a monthly basis. A similar pattern was also true for the second vehicle within the household, with 38 respondents stating that it was not driven more than 100 miles in a single day more frequently than on a monthly basis.

The most innovative respondents exhibited a high degree of vehicle dependency and present an ideal target market for alternative fuel vehicles, particularly should a situation arise where the use of conventional vehicle technology has to be curtailed (e.g. in the event of an oil crisis).

9.4. Knowledge and perceptions of vehicle characteristics of the most innovative respondents

Section 9.4 examines the knowledge and awareness of the most innovative respondents and their perceptions of vehicle characteristics, including use characteristics, such as mileage.

9.4.1 Knowledge and awareness of electric vehicles

The majority of the most innovative respondents perceived they have a low level of knowledge of electric vehicles, however there was a relatively large proportion who perceived their knowledge level to be high. There were 17 respondents who perceived their level of knowledge to be high (score = four or five out of five) in comparison to 22 respondents who perceived their level of knowledge to be low (score = one or two out of five). In Chapter 7, the perceived level of knowledge of all respondents constituted 14% for a high level of knowledge. This confirms that there is a strong link between innovativeness and knowledge of alternative fuel vehicles, such that the 17 respondents with a high knowledge here equates to 34% of the most innovative respondents.

The level of knowledge of the most innovative respondents is likely to be limited by almost none of them having previously test-driven an electric vehicle; only one of the most innovative respondents had previously done so. There were 17 of the most innovative respondents who stated that they were interested in test-driving one, although only three respondents had seen or heard any advertising for electric vehicles promoting an opportunity to test-drive a vehicle. A fifth of the most innovative respondents were able to name a vehicle manufacturer that has produced an electric vehicle. These results confirm that marketing of electric vehicles is ineffective in reaching potential adopters.

9.4.2 Perceptions of electric vehicles and standard vehicle characteristics

In the context of a new vehicle purchase, this section aligns vehicle characteristics and the importance placed on them with the perceptions of the most innovative respondents towards these characteristics in the context of electric vehicles.

When considering a new vehicle purchase, the most innovative stated that fuel economy, value for money and fit with lifestyle were some of the most important characteristics they looked for. Time to refuel and vehicle image were among the least important characteristics, along with brand, resale value and environmental impact. No vehicle technology was specified to the respondent when answering this question, but it can be assumed that it was answered in the context of a conventional fuel vehicle. As such, in the context of 'time to refuel', where there is little difference between conventional vehicles in the time taken to refuel the vehicle itself, it is likely that this would be given greater importance if the question was asked in relation to alternative fuel vehicles.

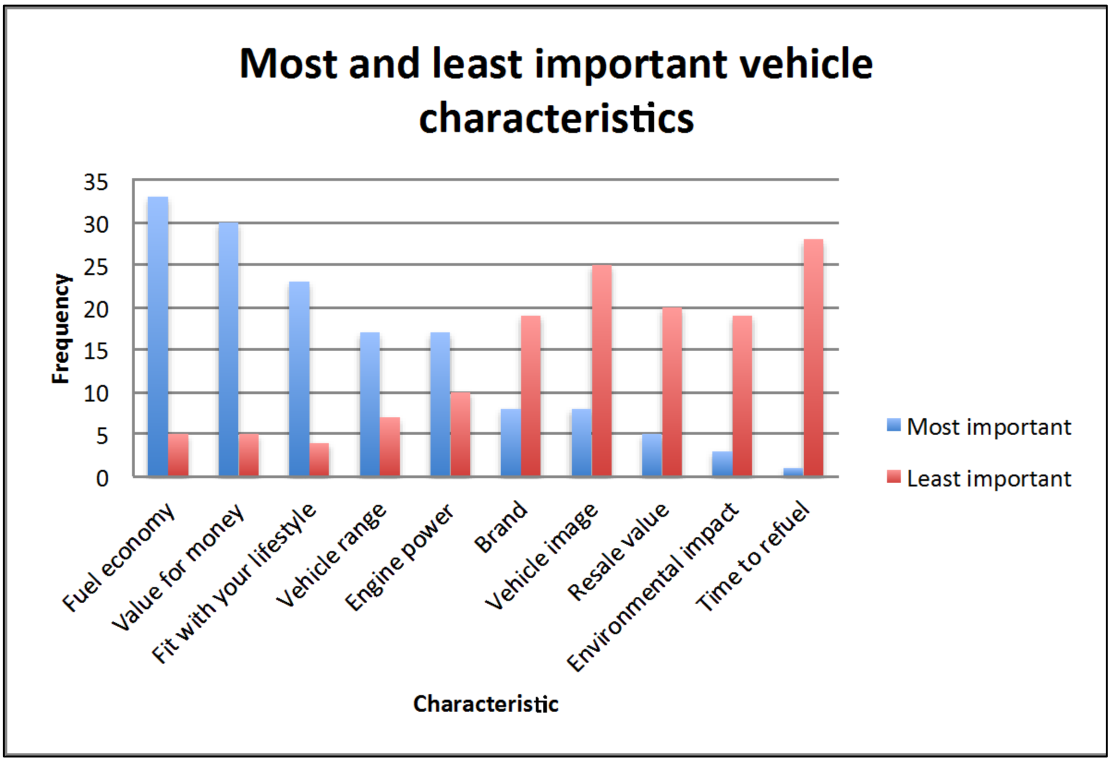


Figure 9.3 *Vehicle characteristics perceived to be most and least important in a new vehicle purchase.*

When the characteristics in Figure 9.3 are considered in the context of electric vehicles, some important observations can be made that will be useful in determining which characteristics to focus on in the marketing of electric vehicles. Firstly, fuel economy is considered one of the most important characteristics when purchasing a vehicle. A comparison of electric vehicle and conventional fuel vehicle characteristics in Section 5.6 shows that fuel economy is much better for electric vehicles than conventional vehicles. Of the electric vehicles that are currently available, they have an indicative fuel cost of 3-5 pence per mile, whereas the fuel cost for conventional vehicles is approximately 9-17 pence per mile. The average annual mileage of respondents is 12,000 miles, and the equivalent annual costs, according to vehicle type, are demonstrated in Table 9.4. The values in the Table confirm that there would be a substantial difference in running costs for many of the respondents. The best scenario would mean annual savings of just over £1,500. There were 27 of the most innovative respondents who stated that they think the fuel economy of an electric vehicle is better than a conventional vehicle, while only five respondents stated they think it is worse.

Table 9.4 Fuel economy comparison based on respondents' average mileage

	Electric vehicle	Conventional vehicle
Best fuel economy	£360	£1,080
Worst fuel economy	£600	£2,040

Note: The values relate to that of the electric vehicle and the conventional fuel vehicles identified as having the best and worst fuel economy in Tables 5.7 - 5.10.

Value for money was also considered as being very important in a new vehicle purchase. In an open-format question (refer to Section 5.5.3), sixteen of the fifty most innovative respondents expressed concern about the cost of the vehicle or the cost of electricity to charge an electric vehicle. When it comes to understanding what actually constitutes 'value' with respect to vehicle ownership, a complex problem is faced due to the many factors that may be influential (e.g. affective-symbolic factors as in Section 3.6). However, other characteristics in Figure 9.3, such as the importance placed on fit with lifestyle, or vehicle image in a new vehicle purchase, are characteristics from which value can be derived.

Fit with lifestyle was considered very important, and, in the case of electric vehicle adoption, lifestyle may be compromised relative to conventional vehicles in terms of trip length and trip frequency. It was apparent that a number of the most innovative respondents came from four-person households, suggesting that fit with lifestyle might lead to the preference of a family car over a sports car, for example. The effect of the 'fit with lifestyle' characteristic on electric vehicle adoption became more apparent in the qualitative responses. One of the most innovative respondents owned a caravan and stated "I would not be able to use it for holidays, I tow a caravan". Another stated how "fully electric vehicles don't currently have sufficient range to allow either of us to do our jobs".

Vehicle range was relatively lower down the list in order of importance, but this may be indicative of standards for conventional vehicles that have guided consumer expectations of vehicle range. The open-format responses implied that vehicle range would become more of a concern if it fails to meet these expectations. For example, in the case of obstacles to electric vehicle adoption, responses included "the distance you can travel is too limited" and "long charge time with short range before charging required again".

Engine power was also among the most important characteristics when considering a new vehicle purchase. In the comparison of characteristics of electric vehicles and conventional vehicles in Section 5.6, almost all electric vehicles have an engine power that is equivalent to or better than conventional vehicles. However, when asked to indicate whether they perceived an electric vehicle to be better or worse than a conventional vehicle with respect to engine power, only two of the most innovative respondents stated that they think electric vehicles are better, while 34 stated that they think electric vehicles are worse. It seems that there is a misperception among some of the most innovative respondents about engine power in electric vehicles.

Brand was considered relatively unimportant to the most innovative respondents. While there are few electric vehicles on the market, this may be important for manufacturers who are trying to gain custom from those who may not have had previous experience of their brand. There were 19 of the most innovative respondents who perceived the image of an electric vehicle to be worse than a conventional vehicle, however 28 respondents stated they think it is neither better nor worse. Despite the high number of those who perceived vehicle image to be poor for electric vehicles, vehicle image was one of the least important characteristics considered by the most innovative respondents in a new vehicle purchase.

Resale value was also considered relatively unimportant relative to the other characteristics when purchasing a new vehicle. In the context of electric vehicles, resale value is still a relatively unknown quantity and, so far, the second-hand market for these vehicles is virtually non-existent. Eighteen of the most innovative respondents stated that they think electric vehicles compare poorly to conventional vehicles on this attribute, however half indicated that they think there is likely to be no difference between the two vehicle types (although this may be an indicator that they do not know). In the open-format responses, "resale value" and "residual value" were mentioned by two of the most innovative respondents as an obstacle to the purchase or lease of an electric vehicle.

Environmental impact was rated as being of low importance in a new vehicle purchase decision. This is, perhaps, a particularly noteworthy finding with respect to the marketing and advertising of electric vehicles. Marketed as 'eco-innovations' with an emphasis on green attributes, it is possible that marketers of electric vehicles may be missing out on potential consumers. Despite environmental impact not being considered as a particularly important attribute, only two of the most innovative respondents perceived the environmental impact of electric vehicles to be worse than conventional vehicles. One of the most innovative respondents indicated concern about the environmental impact of electric vehicles and stated "still use fossil fuel to produce electricity". As consumers become develop more environmental awareness, this may become an important consideration for electric vehicle marketers.

Time to refuel was considered as the least important of the characteristics, however it is most likely that the responses to this characteristic were given in the context of a conventional vehicle. Similarly, with vehicle range, there is an expected standard by consumers for conventional vehicles. In the context of electric vehicles, time to refuel was considered to be worse than a conventional vehicle by 43 respondents and was also listed as an obstacle by several who made comments including, "charging them up would be too time consuming" and "faff to charge".

9.4.3 Vehicle use perceptions

Despite the majority of the most innovative demonstrating a low level of perceived knowledge of electric vehicles (Section 9.4.1), only four stated that they would not be confident in knowing how to drive an electric vehicle. The perceived complexity of an innovation is found to be associated with the rate of adoption (Rogers, 2003), and with 44 out of 50 of the most innovative respondents having stated that they are confident they would know how to drive a fully electric vehicles, as shown in Figure 9.4, this confirms that using an electric vehicle is not perceived to be a complex activity by the most innovative respondents.

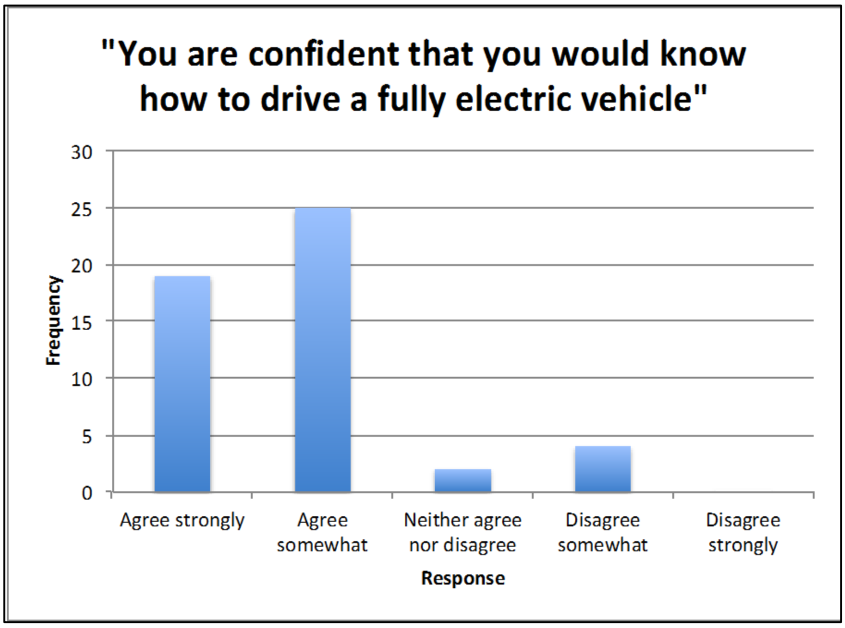


***Figure 9.4** Confidence of the most innovative respondents in driving an electric vehicle*

Similarly, as shown in Figure 9.5, there were 38 of the most innovative respondents who stated that they do not perceive charging an electric vehicle as a difficult activity.

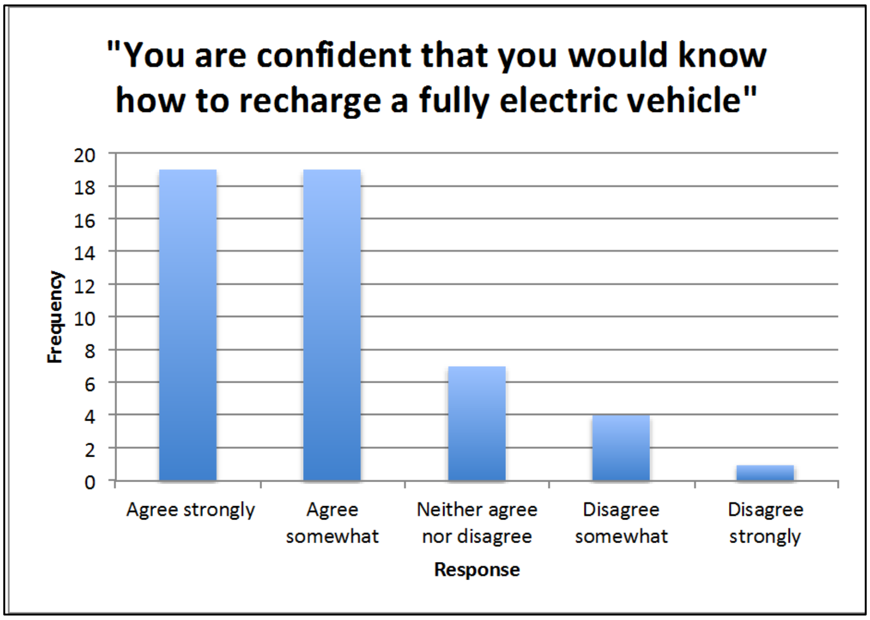


Figure 9.5 *Confidence of the most innovative respondents in knowing how to recharge an electric vehicle*

There were mixed opinions regarding the compatibility element of electric vehicles, such that there are 22 who perceived an electric vehicle would require impossible lifestyle changes, and 15 who perceived this not to be the case. There were 13 who neither agreed nor disagreed, which may be a sign of unfamiliarity with electric vehicles. Electric vehicles must be perceived as having compatibility in order for adoption of the innovation to occur (e.g. Rogers, 2003). Despite electric vehicles perhaps not offering compatibility at first consideration, when asked whether it might be suitable as an additional household vehicle (e.g. for shorter, regular journeys), the response towards them was far more positive. Figure 9.6 shows the responses stated by the most innovative respondents when asked to consider the suitability of an electric vehicle as an additional household vehicle.

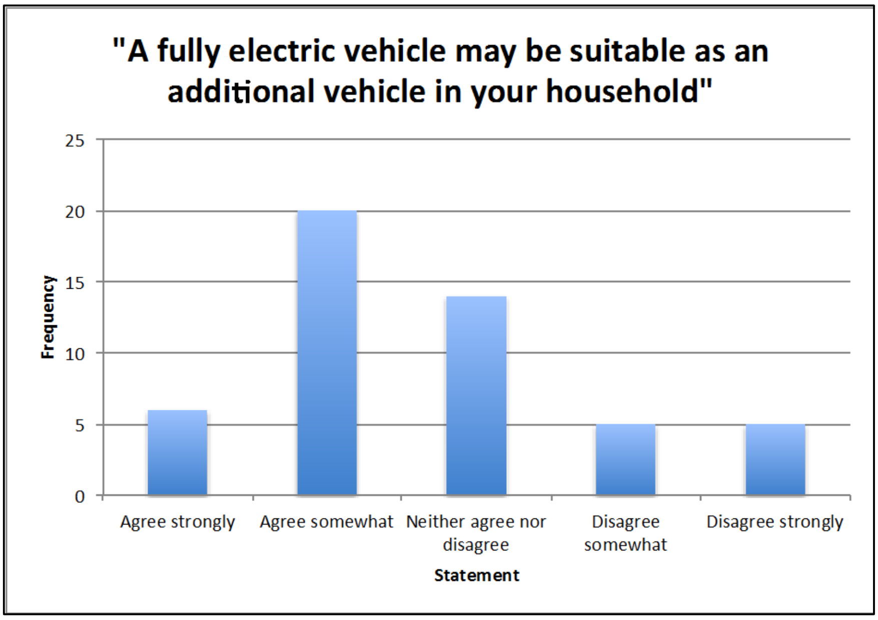


Figure 9.6 *Perceived compatibility of an electric vehicle as a second household vehicle by the most innovative respondents*

Fewer of the most innovative respondents disagreed than agreed that an electric vehicle may be suitable as an additional vehicle in the household. It can therefore be deduced that there may be a place for electric vehicles within households where there is already an existing vehicle, which is most likely to be a conventional vehicle.

9.5 Price and driving-distance characteristics of the most innovative respondents

Price and range are two of the most frequently stated obstacles by respondents to adopting electric vehicles. This Section will consider the characteristics of the first two listed vehicles owned by each of the most innovative respondents.

Only eight of the most innovative owned more than two vehicles, which is why a decision has been made to consider only the first two listed vehicles. Respondents were not asked to list their vehicles in order of priority of use and so it cannot be assumed that vehicle one was necessarily the primary household vehicle but it was more likely to be the vehicle most commonly used by the respondent. Therefore, vehicle two is assumed more likely to be a vehicle used by a different individual within the household.

9.5.1 Price and driving-distance characteristics of the most innovative respondents' (first named) vehicles

The maximum spent by one of the most innovative respondents on a vehicle was £60,000, while the minimum was £1,500. The average vehicle price of respondents' vehicles was £13,300. Thirty-eight of the most innovative respondents owned vehicles that were purchased for less than £16,000, a price below the minimum asking price of any of the currently available battery electric vehicles, with the exception of the Renault Zoe that offers a battery leasing system (refer to Section 5.6). Four vehicles were purchased by the most innovative respondents for a price that exceeds £21,000, a price similar to a Nissan Leaf or Citroen C-Zero (see Table 5.7, Section 5.6). Two of the most innovative respondents spent over £40,000 on their current vehicle, which would comfortably cover the cost of most electric vehicles that are available in the UK in 2014.

The average age of the first listed vehicle owned by the most innovative respondents was 5 years, and vehicles ranged from new through to 17 years old, although the most common age was 3 years. Twenty-nine vehicles were purchased within the last 5 years and 14 were purchased within the last two years. The highest annual mileage covered by respondents (first named vehicle) was 70,000 and the lowest was less than 1,000 miles. The average mileage was 12,000 miles. There were 8 respondents who stated that they drive an annual mileage greater than the average mileage of and 30 who drive 10,000 miles or less in a year. If these 30 respondents drove a similar mileage each day, then split across the number of days in a year, this would equate to 27 miles per day and would comfortably within the capability of all currently available models of electric vehicle.

Twenty-two of the respondents' vehicles were purchased as new, however the majority of vehicles (28) had been purchased second hand. It is unlikely that purchasing a second hand electric vehicle will be possible for some time with so few being available. Eight of the respondents' vehicles (first named vehicle) were company cars, five were leased, but the majority (37) were owned outright. As far as vehicle make is concerned, 13 of the respondents' vehicles were made by Ford. Volkswagen is the second most popular vehicle brand, owned by five of the most innovative respondents, followed by

Honda, Kia, Peugeot and Volvo owned by three respondents. Of these vehicle manufacturers, Ford, Volkswagen, and Peugeot have battery electric vehicles available on the UK market in 2014 (see Section 5.6) and brand familiarity could aid their uptake.

9.5.2 Price and driving distance characteristics of the second household vehicles

It is important to consider the characteristics of a second household vehicle in order to recognise the expectations that would be placed on an alternative fuel vehicle should it be adopted as a second household vehicle. The maximum spent by the respondents' household on the second vehicle was £33,500, while the minimum was £1,900. The average vehicle price was £9,000. Four (n=29) spent more than £16,000 on this vehicle and three spent £23,000 or more on this vehicle. The age of vehicles ranged from new to 20 years, with the average vehicle age being six years. Twenty-six of the vehicles were purchased within the last five years and 12 (n=46) were purchased within the last two years. This suggests the second household vehicle is often purchased for a lower purchase price and replaced less frequently than the first household vehicle.

The annual mileage covered by the second vehicle ranged from 100 miles to 15,000 miles, and the average mileage is 6,600 miles. Thirty-seven (n=42) vehicles have an annual mileage that does not exceed 10,000 miles, while 16 vehicles do not exceed 5,000 miles. A greater proportion of the second household vehicles were purchased second hand, with only 13 (n=48) newly purchased. Forty-three vehicles are owned outright (n=47) while one is leased and three are company cars.

As with the respondent's own vehicle, the most popular vehicle brand for vehicle two is Ford constituting 13 of the vehicles followed by Audi, Hyundai, Vauxhall and Volvo which each constituted three vehicles.

9.5.3 Comparing driving range and purchase price characteristics of the first and second household vehicles

There is a weak relationship (r^2 = 0.020) between the purchase price paid for the two household vehicles. A higher purchase price paid for one vehicle does not relate to a high purchase price paid for a second vehicle, for example, the most expensive vehicle purchased (listed as the first vehicle) had a purchase price of £60,000, yet the purchase price of the second household vehicle was £10,000. The next most expensive purchase price paid for a vehicle (listed as the first vehicle) was £33,500 and the purchase price of the second household vehicle in this case was £14,500. An issue that may arise is whether consumers are prepared to pay a higher price for a second household vehicle that is perceived as only being suitable for shorter, local trips.

Figure 9.8 illustrates the combined purchase price of the first and second household vehicles (n=27). The mean combined purchase price was £23,000, which only just meets the cost of an electric vehicle, and would leave little budget for purchasing a conventional vehicle for longer-range journeys. There were 23 out of 27 respondents who had spent up to £27,000 on both vehicles. There is then a jump to the next combined purchase price of £41,000, and there were four out of twenty seven respondents who had purchased both vehicles at a combined price of £41,000 or more. Realistically, only these four respondents may be able to consider the purchase of an electric vehicle as a second household vehicle.

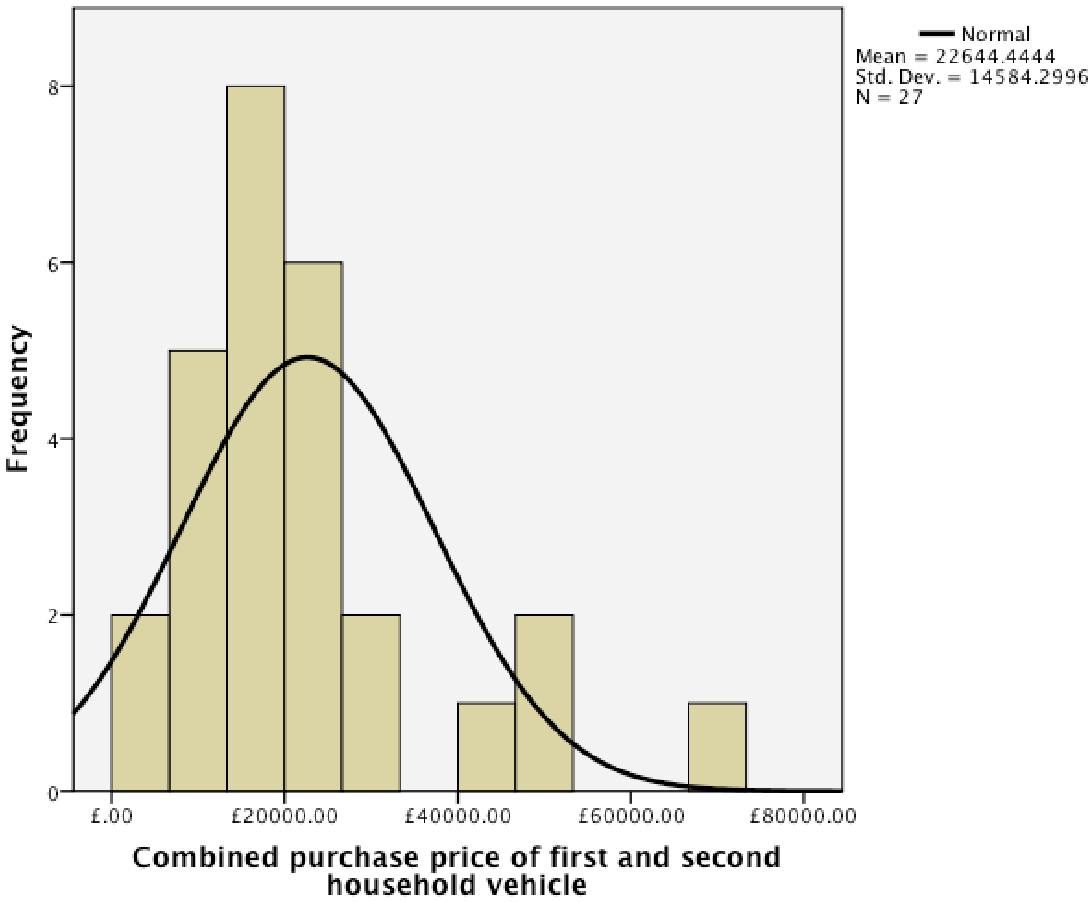


Figure 9.8 *Graph to illustrate the combined purchase price of the first and second household vehicle.*

There is a weak relationship between the average annual mileage of the two household vehicles, ($r^2 = 0.007$), such that a high annual mileage driven by one household vehicle is not related to a high annual mileage driven by a second household vehicle. This is a good sign that multi-vehicle households can accommodate an alternative fuel vehicle that has a more restrictive range than a conventional fuel vehicle.

9.5.4 Preferred characteristics of the next vehicle purchase

Looking ahead to the next vehicle purchase preferences of the group, there were 29 (n=50) respondents who stated that their household's next vehicle purchase is likely to be within the next three years and 18 respondents stated they were likely to purchase a new rather than a second hand vehicle.

Five of the most innovative respondents (n=48) stated that they intend to purchase an alternative fuel vehicle. Four stated they are likely to buy a hybrid vehicle next, while one is likely to purchase an electric vehicle. Only one of the most innovative respondents stated that they know somebody who uses an electric vehicle, and the same individual stated their next vehicle choice will be a hybrid electric vehicle. Although this may confirm that 'observability' and communication will be important in the adoption of alternative fuel vehicles, four of the most innovative respondents who intend to purchase a hybrid or electric vehicle had not observed anybody using an electric vehicle. The same four individuals had also not seen any recharging points in public places in Birmingham or Sutton Coldfield.

As may be expected, petrol and diesel were the preferred fuel options for the next vehicle, however there were 17 respondents who were unsure as to which fuel option they will consider. This may be an indication that alternative fuel vehicles are not necessarily going to be overlooked by these individuals.

When asked to indicate the vehicle class (vehicle size) they would choose for their next vehicle, the majority (13) of the most innovative respondents selected the vehicle class 'large family', while the next most popular was 'small family' (9) followed by 'super mini' (7). There are no 'large family' sized battery electric vehicles available for purchase in the UK (in 2014), however there are electric vehicles within the 'super mini' and 'small family' class, as shown in Table 5.8 and 5.9 in Section 5.6.

There were 12 respondents who stated the purchase price of their next vehicle is likely to be over £20,000 (n=50), although 16 respondents were unsure as to the likely purchase price of their next vehicle.

9.6 The ability of the most innovative respondents to afford an electric vehicle

Section 9.6 identifies the most innovative respondents who have spent, or intend to spend, the amount required to purchase an alternative fuel vehicle and then examines the purchase preferences of these individuals.

9.6.1 Identifying the most innovative respondents with a vehicle purchase budget that matches the price of an electric vehicle

As of 2014, the starting price of a battery electric vehicle is approximately £20,000 with the exception of those with two seats, such as a Smart (city car), which can be purchased for £15,000, or the Renault Zoe (super mini) and the Renault Twizzy (one-seat quadricycle) which offer a battery leasing system (refer to Section 5.6 for further details of electric vehicle characteristics). Of the most innovative respondents, there are 12 individuals who stated that the price of their next vehicle is likely to be greater than £20,000 (price of an electric vehicle). The intended expenditure of the next vehicle is detailed in Table 9.4.

Table 9.4 *Next vehicle expenditure of the most innovative individuals who will spend over £20,000*

Vehicle price range	Frequency
£20,000 - £25,000	6
£25,000 - £30,000	4
£30,000 - £35,000	1
£35,000 - £40,000	0
£40,000 - £45,000	1
Total	12

In addition to the respondents shown in Table 9.4, there were four respondents who have previously spent £20,000 or more on a current household vehicle. Two of whom were unsure as to the purchase price of their next vehicle, while the other two respondents intend to spend less than £20,000 on their next vehicle purchase. Having shown a propensity to spend an amount greater than £20,000 on a vehicle, it is possible that the purchase price of an electric vehicle would not be prohibitive to these four individuals.

9.6.2 Purchase preferences

The preferences of all 16 individuals identified in 9.6 will now be examined. Eleven of the individuals stated they intend to purchase a new rather than used vehicle, and only one stated they have previously given consideration to a battery electric vehicle. The majority of the individuals (seven) stated they would opt for a diesel vehicle, three for a petrol vehicle and one stated they are likely to purchase a hybrid electric vehicle. Five were unsure as to what fuel type they will choose for their next vehicle.

The most popular vehicle size preference of the 16 respondents was a 'large family' size vehicle, stated by seven individuals, while only three stated a preference for a smaller vehicle (i.e. a vehicle class for which there are electric vehicle models). The other vehicle preferences were for 'sports utility' (two) and 'executive' (two) and two were unsure. There is not an electric vehicle in the UK in 2014 (refer to Section 5.6) that would meet the vehicle size preference of the majority of these individuals. However, three of these respondents stated they will choose either a 'small family' or 'super mini' class of vehicle next and there are several battery electric vehicle options in this category. Two selected an 'executive' class of vehicle. In this vehicle class, there is only one battery electric vehicle option in 2014, which is the Tesla. When the class of vehicle is compared to the preferred price of the next vehicle purchase, as in Table 9.5, it confirms the incompatibility of electric vehicles for these individuals.

Table 9.5 *Preferences for next vehicle purchase price and size*

Vehicle price	Super mini	Small family	Large family	Sports Utility	Executive	Unsure	**Total**
£10,000 - £15,000	1	0	0	0	0	0	1
£15,000 - £20,000	0	1	0	0	0	0	1
£20,000 - £25,000	0	0	5	0	0	1	6
£25,000 - £30,000	0	1	1	1	1	0	4
£30,000 - £35,000	0	0	0	1	0	0	1
£35,000 - £40,000	0	0	0	0	0	0	0
£40,000 - £45,000	0	0	0	0	1	0	1
Unsure	0	0	1	0	0	1	2
Total	1	2	7	2	2	2	16

Those who stated they wish to purchase an executive vehicle intend to spend less than £30,000 in one case and less then £45,000 in the other case. A budget of up to £30,000 was being considered for a small family car by one individual, which would comfortably cover the cost of all currently available models of battery electric vehicle in that class. The other individual considering a small family car between £15,000-£20,000 would have to stretch their budget to £21,000 to cover the price of the Nissan Leaf. It is likely

that more battery electric vehicle models will be available in time and therefore it may be possible to purchase a 'large family' electric vehicle within the next few years.
There is, perhaps, a greater issue for six of these individuals who indicated that they drive a distance that exceeds 100 miles in a single day on a daily or weekly basis. The majority, however, indicated that this would occur monthly or even less frequently. Depending on how much the driving distance exceeds 100 miles, it may be that the Ford Focus electric vehicle, with a range of 130 miles, or the Nissan Leaf, with a range of 124 miles, would be suitable.

Of the 16 individuals, there were four who drive a distance exceeding 100 miles in a single day either daily or weekly who come from a household where a second vehicle also covers a distance that exceeds 100 miles in a single day on a daily or weekly basis. Having two vehicles within a household where one exceeds 100 miles in a single day infrequently confirms the suitability of an electric vehicle within the household, such that the electric vehicle can be used for all journeys that fall within its range capability. A conventional vehicle can then be used for journeys beyond the range of an electric vehicle.

Only one of these individuals had previously considered the purchase or lease of an electric vehicle. For the other fifteen respondents, not having ever given any consideration to the purchase or lease of a battery electric vehicle is indicative of what Rogers (2003) describes as passive rejection. While the evidence detailed above showed that for some of these individuals there are practical barriers to battery electric vehicle adoption, this is not the case for all respondents. The perceived advantages and obstacles to owning an electric vehicle stated by these 16 individuals are shown in Table 9.6. It is clear that these individuals have poor perceptions of electric vehicles; five individuals stated that they perceive no advantages to owning an electric vehicle (highlighted in red).

Table 9.6 *The 16 respondents' perceived obstacles and advantages to owning an electric vehicle*

Respondent	Perceived obstacles	Perceived advantages
1	**Charging point** density.	-
2	**Charging points** - location locally and nationally. **Residual values, reliability** issues.	Reduction in **emissions**.
3	**Charging stations** (lack of)	-
4	**Cost (Initial), resale value, range,** difficulty in finding **charging points**.	None
5	**Electricity bill** increasing. Increasing costs from electricity companies	None
6	**Expensive to charge.**	**Cleaner air.**
7	Fully electric vehicles don't currently have sufficient **range** to allow either of us to do our jobs.	None
8	I have no garage to store a vehicle and would see **security** as an issue.	**Less destructive to the environment.**
9	I would **not be able to use it for holidays**, I tow a caravan. It would not make the round trip to visit my son and his family.	-
10	I would **not be interested** in owning an electric vehicle.	As I am self employed, an electric vehicle would **not be an advantage** due to travelling distances.
11	**Installation of the charger** and how much it would cost. **Cost of electricity** to charge.	**Don't know.**
12	It's still **too expensive.**	It might be **cheaper to run,** who knows?
13	**Recharging** and **can't drive too far.**	Nope, I **would not change**
14	**Recharging time,** low fuel **range** on longer journey.	**Lower driving costs,** lower **environmental impact.**
15	The **cost** of purchase!	Better fuel consumption (.ie. more **economical**). Less negative impact on **environment**. **Car insurance and tax** would reduce.
16	Too **difficult to keep charging**	None.

Note: Key words are in **bold** font. The red highlights five respondents who perceive there to be no advantages in electric vehicle ownership. An empty box denotes a non-response.

Despite the practical barriers that exist for some, such as range, vehicle size availability and cost of vehicle, it was possible to identify ways of how these might be overcome. It may, therefore, be that perceptions are the overriding factor in the case of passive rejection of battery electric vehicles, because it is the perceptions of the innovation's characteristics that influences whether the individual develops a positive or negative attitude towards it (Rogers, 2003).

9.7 Discussion

The analysis in this Chapter demonstrates the need for an individual to be not only innovative, but, in order to adopt the innovation in question, they must also have a positive attitude towards it (shaped by their perceptions of the characteristics of the innovation). As the results showed, even those who demonstrate the highest degree of innovativeness do not have wholly positive attitudes towards alternative fuel vehicles (Section 9.4.2). Despite identifying the 50 most innovative individuals (Section 9.2), 16 of these respondents stated that cost was a concern. It was also identified that only 16 respondents have purchased or intend to purchase a vehicle that is a similar price to electric vehicles that are currently available for purchase. This confirms that in the early stages of alternative fuel vehicle adoption, socio-economic status is one of the most important factors influencing alternative fuel vehicle adoption.

A high degree of vehicle dependency was identified among the most innovative respondents, with almost all relying on their vehicle as their main mode of transport on a daily basis. If at any stage the curtailment of conventional vehicles is enforced, perhaps through policies to reduce carbon emissions or reduced oil availability, then alternative fuel vehicles may present an attractive substitute for those who are heavily reliant on their cars. The most innovative respondents stated that they are fairly knowledgeable about electric vehicles and are confident that they would know how to drive and how to charge one.

One of the least important characteristics considered in a new vehicle purchase was the environmental impact. As an eco-innovation, an electric vehicle may need to be repositioned in terms of marketing and concentrate on fuel economy and engine power as its main selling points if it is to appeal to the most innovative individuals. With a limited number of manufacturers selling electric vehicles in the UK, it does not seem as though this is a significant problem for the most innovative respondents who indicated that brand is not one of the most important characteristics they consider when purchasing a new vehicle. Despite that, it was found that several respondents owned two vehicles made by the same manufacturer. Interestingly the car manufacturer, Ford, is the most popular brand of vehicle owned by respondents. Ford have produced a small family class electric vehicle model (Ford Focus) (refer to Section 5.6), however none of the respondents seemed aware of this when asked to name any vehicle manufacturers they know to be currently producing electric vehicles. If brand loyalty is present among the most innovative respondents, then it seems that marketing opportunities are being missed by vehicle manufacturers.

In the tables showing electric vehicle characteristics against conventional vehicle characteristics (Tables 5.7 - 5.10 in Section 5.6), the engine power of electric vehicles was better, or at least comparable to, conventional vehicles in the same class. It seems that there is a misperception held by these individuals that electric vehicles are not as powerful as conventional vehicles and, given that image is perceived to be worse for electric vehicles than for conventional vehicles, this may be an important characteristic for electric vehicle manufacturers to promote in order to enhance the image of electric vehicles.

Poor range, frequency of refuelling, length refuelling time, and lack of refuelling points were among the most frequently stated obstacles to purchasing a battery electric vehicle. Concerns about how the vehicle would allow longer trips to take place were evident. Resale value was mentioned as a concern by two of the individuals, while this was a factor that was also perceived as a weaker characteristic for battery electric vehicles than for conventional vehicles. One particular problem that is likely to affect resale value of battery electric vehicles is the lifetime of the battery, which is an expensive part to replace. It is estimated that batteries will last approximately six to eight years before they need replacing (Gerssen-Gondelach and Faaij, 2012) and, given the cost is likely to be around £8,000 for a new battery, this may significantly affect the ability to sell a used electric vehicle, a concern also raised by Graham-Rowe et al. (2012). For Renault, a manufacturer that offers battery leasing on its battery electric vehicles, this may help reduce the anxiety.

The cost of installing the charging point was a concern for some as well as security of the vehicle while it is charging. It may be that on-street parking with access to charging points would help to overcome this concern and encourage the uptake of these vehicles. An effective remuneration strategy to cover the cost of on-street charging points would have to be implemented if such an approach is to be financially viable.

A fairly large number (18 out of 50) of the most innovative respondents exceed the average range of an electric vehicle (~100 miles) on a daily or weekly basis, which confirms that for such individuals concerns about range are not unfounded. For these individuals it is likely that an electric vehicle will not be considered unless it could be easily charged at a mid-point and for the length of time required, or if electric vehicle range is improved. Within the households of these 18 individuals, the second household vehicle exceeds 100 miles far less frequently, which may mean that an electric vehicle could be incorporated to the household if there is a conventional vehicle available that can do longer journeys. However, Egbue and Long (2012) identified that there is a gap between expectations of driving range of an electric vehicle and the driving range actually covered on a daily basis. Most respondents intend to make their next household vehicle purchase within the subsequent three years, offering opportunities for marketers to reach these individuals, but at the same time not necessarily leaving time for significant improvements to electric vehicle technology and infrastructure that overcome the social barriers to adoption. However, it is possible that within the next three years the price of the vehicles will begin to fall as more vehicles are purchased.

The leasing of an electric vehicle is a business model that can reduce the risk associated with their purchase (e.g. Lane, 2006). However, very few of the most innovative respondents currently lease their vehicle, and have instead purchased outright. Battery leasing for electric vehicles is offered by Renault to reduce the risk for electric vehicle consumers, although unfamiliarity with leasing may not bring about the desired increase in uptake. This may also be attributable to the fact that most respondents purchase second-hand and leasing may not be available in the same way for used vehicles.

In the case of company cars, it is the fleet owners who may need to be encouraged to incorporate electric vehicles, but equally the user must also want to opt for an electric vehicle over any other available options. The risk associated with their adoption, in terms of capital outlay, would be reduced for the user and therefore research into how fleet vehicle owners or operators could be encouraged to incorporate electric vehicles would be of value. Commonly offered as a company car, is a vehicle that falls into the executive class. In terms of electric vehicle models, a Tesla Model S electric vehicle would fit this description. It is comparable in price to conventional vehicles in the same class, and also offers the consumer a range of 240 miles, which is much higher than the range available from electric vehicles in smaller vehicle classes.

In addition, the majority of vehicles owned by the most innovative respondents were purchased second-hand, which would not be possible for electric vehicles at present given that the market for electric vehicles is not sufficiently established for there to be a second-hand car market. If these individuals are purchasing second-hand vehicles, this may be a sign that innovativeness is innovation specific (e.g. Jansson, 2011; Goldsmith and Hofacker, 1991) and the purchase of a product that requires a large capital outlay (i.e. high-level involvement) is likely to require different consideration to an innovation that does not. When the vehicle preferences of the most innovative respondents were examined, vehicle class, or vehicle size, poses a threat to the uptake of battery electric vehicles in that the majority of the most innovative respondents stated that their next vehicle purchase would be of a size that exceeds the vehicle class of currently available battery electric vehicle models. There were, however, 16 respondents who stated their next vehicle size preference is for 'small family' or 'super mini', for which there is a limited but steadily increasing range of battery electric vehicle options available.

An alternative fuel vehicle was likely to be the next purchase choice for four of the most innovative respondents. In this case the alternative fuel vehicle preference related to a hybrid vehicle rather than a battery electric vehicle. However, this is an encouraging sign for alternative fuel vehicle acceptance. Hybrid vehicles are also considered by some (e.g. Karplus et al., 2010) to be an important stepping-stone in the transition from conventional vehicles to battery electric vehicles. It may be that these individuals become adopters of battery electric vehicles in the mid-term. When it comes to the purchase price of their next vehicle, 12 respondents indicated it would be £20,000 or more, which is the approximate starting price of small-family size battery electric vehicles. The mean price of all currently owned vehicles (both listed vehicles) was £11,400 with few having purchased a vehicle over £21,000.

There were 16 individuals among the most innovative respondents who have purchased, or who intend to purchase, a vehicle that meets the price of an electric vehicle. A new vehicle was the preference for most of these respondents. The most popular vehicle size preference was 'large family', although three stated a preference for a smaller vehicle. There were also two who indicated a preference for an executive class of vehicle. However, when preferences for vehicle purchase price were considered, it was possible to see there would be incompatibility with the purchase price of a battery electric vehicle.

In all but one case, matching vehicle size and purchase price preferences would require budgets to be stretched considerably in order to afford a battery electric vehicle that also met vehicle size criteria. This confirms the necessity for there to be a greater range of choices available to consumers, also noted by EPRI (2010). To broaden this research, collecting information from respondents on the upper limit of their budget for a vehicle purchase would be useful to establish whether consumers might be persuaded to purchase a battery electric vehicle if it satisfied sufficient purchase criteria. All but one of the sixteen respondents had not previously considered the purchase of a battery electric vehicle, which according to Rogers (2003) would suggest that an electric vehicle has been 'actively rejected' by this individual.

The perceptions of the characteristics of battery electric vehicles highlighted some misperceptions, but also confirmed some of the practical reasons that respondents consider battery electric vehicles not to be suitable. As far as having a relative advantage over a conventional vehicle, only a small number of the sixteen individuals were able to provide a response that relates to savings on fuel and reduced environmental impact associated with battery electric vehicle use. A great deal of negativity was expressed by most of the respondents in their responses.

A key obstacle that would have to be overcome for several of these 16 individuals is vehicle range as almost half of the respondents drive a distance that exceeds 100 miles in a single day on a daily or weekly basis. As maintained by Graham-Rowe et al. (2012) and Kurani et al. (1995), battery electric vehicles may only be suitable in two-car households where it can become the primary vehicle used for short journeys, and a conventional vehicle is used only for journeys beyond the range of the electric vehicle. An electric vehicle would be suitable for two-car households where a second household vehicle is infrequently used for journeys of around 100 miles. In this instance, there were four individuals from a household where two vehicles cover a distance in excess of 100 miles on a daily or weekly basis, and the arrangement of having one battery electric vehicle and one conventional vehicle in a household would likely be impractical. For the other 12 respondents this situation was not the case and it may be that a scenario of two household vehicles with one being a battery electric vehicle has not been considered. When asked, very few disagreed that a battery electric vehicle could have a place in the existing household vehicle fleet as a second vehicle.

If an electric vehicle is perceived to be only suitable as a second household vehicle (i.e. not the main household vehicle), then it may be a challenging prospect to encourage consumers to purchase an alternative fuel vehicle that commands a higher price than an equivalent conventional fuel vehicle, which, at this stage in time, is more likely to be the main household vehicle.

Chapter 10: Conclusions

10.1. Introduction

This chapter draws together the findings of this research to demonstrate how the research aim, objectives and the gaps in the literature have each been addressed (Section 10.2). It then highlights the original contributions to knowledge (Section 10.3). The limitations of the research are discussed in Section 10.4, and the chapter concludes in Section 10.5 with recommendations for further research in this area.

10.2 Addressing the research objectives

Objective 1: To understand the key consumer acceptance issues of alternative fuel vehicles.

A review of the literature in Chapter 3 highlighted that one of the key problems is changing behaviour. In Section 3.10, the high price, limited range and limited infrastructure were determined to be significant factors in the acceptance of alternative fuel vehicles. Individual barriers relating to scepticism and distrust of information, particularly with respect to climate change, mean that consumers are less willing to change their behaviour to adopt more sustainable practices (Section 3.6). Awareness of climate change issues was, however, identified as failing to translate into changing car use behaviour (Section 3.8). Levels of knowledge and awareness of the general public about alternative fuel vehicles are poor (Section 3.9.2 and 3.9.3), and when given the opportunity, consumers have requested more information to better inform their attitudes on these technologies. The literature stated that for those who had purchased alternative fuel vehicles, the potential for cost minimisation rather than concern for the environment was the main motivation.

Alternative fuel vehicles were also recognised as being high-involvement products, due to the high cost of the product (Section 3.7), meaning that extensive problem-solving is undertaken before the product is purchased. This highlights why it is easier for consumers to stick to familiar products (e.g. conventional fuel vehicles) in the case of high-involvement purchases.

Objective 2: To identify the socio-demographic characteristics of early adopters of alternative fuel vehicles and the locations of such individuals.

To address this objective, the literature review determined the socio-demographic characteristics that have so far been found to be associated with adopters of alternative fuel vehicles or those who have indicated that they will become an adopter of an alternative fuel vehicle (Section 3.10). Those who are most likely to be among early adopters of alternative fuel vehicles are younger to middle-aged, highly educated, have a high household income, are home-owners and own more than one vehicle. This enabled a socio-demographic profile of an early adopter to be established (Table 3.3, Section 3.10). Establishing a profile early on in the research allowed for targeted research, so as to be able to examine the possible reasons for why individuals already considered as most likely to be among the early adopters have not adopted an alternative fuel vehicle. In the interest of understanding attitudes in the context of vehicles with zero tailpipe emissions (in line with targets for decarbonisation of the transport sector by 2050, see Section 2.2) it was necessary to predominantly focus on electric vehicles.

In Chapter 6, the first stage of the research, the application of cluster analysis to Census data for the Metropolitan District of Birmingham revealed a strong spatial cluster of 'potential early adopters' (almost 60% of the potential early adopters) in the suburb of Sutton Coldfield. This suburb is located on the periphery of the Birmingham Metropolitan District and is made up the four wards of Sutton Four Oaks, Sutton Trinity, Sutton Vesey and Sutton New Hall. These wards have the highest levels of employment, the highest percentage of the population with two or more cars and the lowest levels of people living in local authority housing. Areas with the fewest potential early adopters were located in wards that surrounded the city centre – areas that have high levels of deprivation.

The findings in Chapter 9 confirmed that this spatial cluster does contain individuals who are more likely to adopt alternative fuel vehicles, with five out of the 50 most innovative individuals stating that their next vehicle purchase will be an alternative fuel vehicle. Four of these individuals intend to purchase a hybrid vehicle and one intends to purchase an electric vehicle and it is likely that these individuals will be considered to be early adopters. It may be that many of the most innovative individuals identified in this research will not be among the early adopters, but there is potential for them to be among the early or late majority.

Objective 3: To investigate the relationship between potential early adopters' socio-demographic characteristics and innovativeness.

The early adopter characteristics were verified in Chapter 7. A significant relationship was demonstrated between these socio-demographic characteristics and the two innovativeness characteristics of personality and communication behaviour. There were also significant relationships between the socio-demographic characteristics and knowledge of alternative fuel vehicles, knowledge and attitudes towards contextual factors (e.g. climate change). Those with a higher socio-economic status, higher level of qualifications and who were younger in age (under 60) were the most knowledgeable about electric vehicles and contextual factors. An additional socio-demographic characteristic of gender was found to be significant. Males were identified as being more knowledgeable and more innovative (in terms of personality and communication behaviour. In Chapter 8, the same characteristics were found to be present in those who expressed the highest degree of persuasion towards electric vehicles. These individuals perceived electric vehicles to be less complex and more compatible with their lifestyles, and they were also more likely to have observed others using electric vehicles.

In support of these findings, the majority of those who had considered the purchase of an electric vehicle were male, under the age of 60, have higher-level qualifications and own more than two vehicles. Half had a higher socio-economic status, which may be a key reason for which consideration of an alternative fuel vehicle has not been converted into adoption (i.e. an alternative fuel vehicle is unaffordable).

Objective 4: To examine potential early adopter's knowledge of alternative fuel vehicles and the factors that influence it.

The knowledge characteristics examined in Chapter 7 demonstrated that there is a low level of knowledge of alternative fuel vehicles. There is no difference in the proportion of those who know about hybrid vehicles than electric vehicles, and considering hybrid vehicles have been available for purchase for a longer period of time, this is rather surprising. Hydrogen vehicles are not well understood. Poor knowledge of electric vehicles was further supported in Chapter 8, when a large proportion of individuals indicated in open-format responses that they did not know of any advantages or obstacles to electric vehicle ownership. There was also poor awareness of the incentives available for their adoption. Some were aware that electric vehicles are exempt from vehicle excise duty but there was little evidence of awareness of other savings that can be made, such as the Plug-In Car Grant.

It was established that there is generally a good level of awareness of the environmental impacts associated with transport use. However, this was not always the case. Despite the majority of survey respondents having awareness of the environmental impacts of transport, a relatively high proportion of these individuals stated that they are not concerned about climate change and want to continue with conventional vehicle technology. Many also considered the long-term prospects for electric vehicles to be poor. If such issues are not of concern, then it may be unlikely that such individuals would consider learning about environmentally sustainable innovations like alternative fuel vehicles. Similarly, it is unlikely that they would make behaviour changes to reduce their environmental impact.

Objective 5: To examine potential early adopters' perceptions of alternative fuel vehicles

The characteristics of electric vehicles considered to be advantageous include fuel economy and environmental benefit. Many respondents recognised that there are money-saving opportunities through the use of an electric vehicle in terms of fuel cost savings and also the savings that can be made through not having to pay vehicle excise duty. The environmental advantages refer to an improvement in local and global pollution. In support of the perceived low environmental impact of electric vehicles, there were over a third of individuals who considered the production of mainstream electricity to also have a low environmental impact. The technical advantages of an electric vehicle focused on its use for shorter, local trips and also the convenience of being able to 'refuel' at home rather than having to go to a fuel station.

The environmental impact of electric vehicles was considered to be better than for conventional fuel vehicles although this characteristic is listed as one of the least important when making a new vehicle purchase. This suggests that branding electric vehicles based on their environmental attributes is likely to be unsuccessful in speeding their diffusion. Fuel economy, on the other hand, is considered as one of the most important characteristics in a new vehicle purchase and therefore offers an opportunity for improved branding and marketing.

It was identified that there are far more perceived obstacles to owning an electric vehicle than there are advantages to owning one. Technological is the most commonly listed obstacle to ownership and refer principally to the restricted range and difficulties associated with charging, which include the frequency of charging, the duration of charging and unavailability of recharging stations. Power and performance were also considered to be problematic. The cost of acquiring an electric vehicle is considered to be prohibitive by many, but there are also concerns relating to rising utility costs and how this would affect the costs of charging an electric vehicle. This may indicate that the public is not well informed about the potential cost savings relative to conventional vehicle fuel cost. Despite safety being recognised as a concern in the literature (Section 3.9), there was little mention in the open-format responses (Chapter 8) of safety being an obstacle to their adoption.

In terms of compatibility, the majority of survey respondents perceived impossible lifestyle changes to be required in the case of electric vehicle use. Concern in this respect relates to the utility that the vehicle provides as a means of transport for going on holiday (including a need to tow a trailer) and as a means to fulfil job expectations, making it difficult for certain occupation, such as taxi drivers or on-call medical staff.

An electric vehicle is considered by just over a third of survey respondents to have potential as a second household vehicle. Electric vehicle use (both driving and recharging) was not perceived to be a complex activity by most and similarly the majority expressed that they were confident they would know how to use and drive an electric vehicle.

There was evidence of misperceptions about the power of electric vehicles, which may also be affecting the image of these vehicles. Power is, in many cases, the same or better than a similar equivalent of conventional vehicle (Section 5.6), although the majority perceive it to be worse. Engine power was considered as one of the more important characteristics in making a new vehicle purchase and therefore this misperception is likely to be having some level of impact on the adoption of electric vehicles.

Objective 6: To evaluate the alignment of private transport expectations and alternative fuel vehicle characteristics

In Chapter 9, characteristics of current vehicle ownership and use as well as the likely decision relating to the next vehicle purchase were examined. This led to some interesting and relevant observations as far as the suitability of electric vehicles is concerned.

There was a lack of alignment between the characteristics sought in a new vehicle and what is available from the current range of electric vehicles. Almost all of the currently available electric vehicle models are of the small family or city car class and those who currently own a vehicle of the same class or intended to buy a vehicle in this class did not have the budget for an electric vehicle. A large family car was the preferred size option for a new vehicle among those who are most innovative and considered to be potential early adopters of an electric vehicle. Those who had a purchase budget that would cover the price of an electric vehicle stated that their vehicle size preference would be a large family car or an executive class of vehicle.

A further problem, as highlighted in Chapter 9, is the propensity to purchase second-hand vehicles rather than new vehicles. There is a greater demand for second-hand vehicles for private use than for new vehicles. As there is not an established second-hand market for electric vehicles, it is likely to take a while to generate interest for electric vehicles among many consumers. The resale value of electric vehicles is also a concern and is likely to be a factor in influencing non-adoption.

It was also found in Chapter 9 that the purchase budget and other vehicle criteria only become compatible with an electric vehicle in the executive class. The high cost of electric vehicles, particularly in smaller classes of vehicle means that compromises have to be made. However, with an executive class of vehicle that already commands a higher price tag, it is possible to enhance the features that would not make economic sense in a smaller class of vehicle. Tesla is currently the only electric vehicle manufacturer pursuing the executive market, and it may be that this business model would work for other manufacturers, with the purpose of making electric vehicles aspirational vehicles at this stage.

Chapter 8 identified 'fit with lifestyle' as one of the most important characteristics considered in a new vehicle purchase, however it was perceived that the adoption of an electric vehicle would require impossible lifestyle changes. When exploring compatibility options for an electric vehicle, it was asked whether an electric vehicle might be suitable as a second household vehicle. In Chapter 8, it was found that around 40% consider that an electric vehicle might be suitable as a second vehicle. Chapter 9 further emphasised this opportunity - despite the limited range being a concern expressed by many, the majority of individuals live in a household where, even if one household vehicle regularly exceeds the range of an electric vehicle, there is an additional household vehicle that does so much less frequently. The average annual mileage driven by the most innovative is 12,000 miles, which, on average, would mean that the daily driving distance could be within the capabilities of an electric vehicle. The public needs to be better informed about how an alternative fuel vehicle can be compatible with their lifestyles.

In a marketing context, the difficulty faced by alternative fuel vehicles is that the consumer decision-making process begins with need recognition or problem awareness (Jobber, 2001). However, at a utilitarian level conventional vehicles are already satisfying a need. It is perhaps the psychological or emotional needs that need to be better addressed by marketing to create a need for alternative fuel vehicles. This may be through appealing to perceived needs for more technologically advanced vehicles (e.g. higher power and better acceleration), or through image (e.g. representing the pro-environmental attitude of the individual). It became clear in Chapter 8, when establishing perceptions of alternative fuel vehicles, that, certainly in the case of electric vehicles, they are perceived not to have as much power as conventional vehicles and some mentioned in the open response section that they perceive electric vehicles to be slow and not powerful enough. As such, there is a marketing opportunity for targeting a different market segment to the environmentalist segment that seems to have been the target market so far. The Tables in Section 5.6 showed that engine power is comparable with or better than conventional vehicles in many cases, indicating that the perception of poor engine power is actually a misperception.

Fuel economy, considered as one of the most important characteristics when purchasing a new vehicle was, in many cases, perceived to be better for electric vehicles than conventional vehicles. Here there is an opportunity to satisfy a need, that of saving money. Attributes, particularly those that are economic or technological may provide for a stronger marketing focus than any environmental attributes, which is considered to be among the least important vehicle characteristics in a new vehicle purchase.

Objective 7: To make recommendations for policy that will support the adoption of alternative fuel vehicles.

Regulation, such as increasing vehicle excise duty on conventional fuel vehicles and increasing fuel duty, may provide a solution, particularly in the early stages, to speed up the diffusion of alternative fuel vehicles. Following in the footsteps of Denmark with a much higher car tax on conventional vehicles for a limited period of time (e.g. in Green et al., 2014) may help to stimulate demand as it makes the cost of an electric vehicle more comparable with a conventional vehicle. Policies at a national and international level that improve the market conditions for alternative fuel vehicles will be necessary in stimulating demand for these vehicles.

Providing free parking, which is currently offered by some councils, may go some way to encouraging adoption but only as part of a range of incentives. “Easier to park” was perceived to be an advantage of having an electric vehicle by only one respondent, although it is not clear whether this refers to the size of the vehicle or access to free parking.

In reducing the associated risk of adoption, existing policies that reduce the financial commitment such as the Plug-In Car Grant and exemption from vehicle excise duty, are likely to aid adoption but only with those who have already considered the purchase of an alternative fuel vehicle. The Grant should be attracting new and potential adopters to alternative fuel vehicles, but the evidence of a lack of awareness of its existence became clear in Chapter 8 when it was not stated as an advantage of adopting an electric vehicle. Long-term policies should be drawn up to ensure plans are in place for phasing out any subsidies and incentives once vehicle adoption has reached a certain stage in the diffusion process. This point will largely be determined by budget forecasting.

Policies that focus on educating the public about alternative fuel vehicles would be an essential part of increasing their adoption. It was evident that knowledge about alternative fuel vehicles is relatively poor. It was also evident in the open response questions in Chapter 8 that, given the opportunity to express their views, the public has many unanswered questions about electric vehicles and better provision of information will largely help to answer these as well as address any misperceptions. It was found in Chapter 6 that few have actively sought information about alternative fuel vehicles, and this means that an approach delivering the information to the general public with minimal perceived effort on their part is likely to be necessary. This might be achieved through the electric vehicle showcasing events including opportunities to test-drive electric vehicles. With respect to Birmingham City Council, it may be necessary to work with local vehicle dealerships and create opportunities for exposure at as many public events as possible. In Chapter 9 it was also evident that the public is unaware of how an electric vehicle could be incorporated with minimal interference with lifestyle, such that in many households there was only one vehicle that was required for journeys exceeding the range of an electric vehicle on a regular basis. Policies in this respect need to focus on demonstrating the compatibility of alternative fuel vehicles with lifestyles.

In order to reduce uncertainty for every part of electric vehicle, or other alternative fuel vehicle, ownership it may be necessary to produce a guide to ownership, such as:

- Where to buy an electric vehicle, including a list of models available.
- Electric vehicle running costs (with examples of conventional vehicle costs).
- How to obtain the Plug-In Vehicle Grant.
- How and where to install charging infrastructure at home.
- Local and national charging points.
- How to use and access public charging points (i.e. registration and costs).

Car clubs present an opportunity to give the public access to alternative fuel vehicles without the financial commitment. The expense of electric vehicles makes them less desirable to car clubs, and so it may be necessary to offer incentives to car clubs to incorporate them into fleets, whereby the car club is able to offer their use to customers at a rate no more expensive than conventional vehicles. This will provide an opportunity to increase 'observability' of the practice of using alternative fuel vehicles.

In the earlier market stages of alternative fuel vehicle adoption, and in the interest of speeding up diffusion, policy should perhaps focus on those who are most likely to be among the earlier adopters of alternative fuel vehicles i.e. those who fulfil the early profile characteristics. Social obstacles (in terms of social inclusion) may arise in this instance, but transport policies must also satisfy economic objectives and untargeted policies at this stage may not be cost effective. Targeted policies may include the establishment of a network of recharging points, such as a focus on providing infrastructure in the Sutton Coldfield suburb of Birmingham. This would enable those who do not have a driveway to charge their vehicles. It would make less financial sense to install charging points in the areas enveloping the city centre that have high levels of deprivation and were identified (in Chapter 6) as having the lowest level of potential early adopters.

Installing charging points in the four wards of Sutton Coldfield that were identified as having the highest number of potential early adopters may satisfy several objectives – the first is accessibility to a range of charging points, particularly rapid charging points that can recharge a vehicle within 20 minutes, and which would reduce the anxiety of running out of power. The second is visibility of charging points. Rogers (2003) notes visibility is an important factor in the innovation-decision process, and, in this case, non-adopters may be more interested in the adoption of electric vehicles if they can see that they would be able to recharge them without difficulty. The third is that Sutton Coldfield is located next to a major road network that includes the M6 motorway and is the main route between the Northwest and the Midlands of England, and could provide motorway users with an opportunity to stop and recharge. Birmingham is located halfway between London and Manchester, which are 200 miles apart, and therefore provides Birmingham with an opportunity to be a vanguard city in the establishment of a nationwide network of charging points. In this case it would be necessary for local transport policy in Birmingham to consider the installation of rapid charging points in Sutton Coldfield, and therefore close to the M6 motorway.

Rapid charging points should be considered as a priority for public installations. The "hassle of charging" was highlighted in the open response questions that were analysed in Chapter 8, and is likely to be considered as less of a problem if the speed of recharging vehicles can be greatly reduced. Raising awareness and continually updating a nationwide map, such as Zap Map (Zap Map, n.d.) is essential to reducing range anxiety. Smart phone applications, such as Charge Map (Charge Map, n.d.), will also allow for better interaction enabling the user to identify charging points that are available, which will be necessary to avoid any uncertainty in being able to recharge the vehicle.

To support any grants for purchasing alternative fuel vehicles or for building supporting infrastructure that will speed up their diffusion will likely require better allocation of tax revenues. This may involve increased emphasis on redirecting tax revenues obtained from activities that rely on the combustion of fossil fuels, while also making resources available for research and development of energy generation from renewables. Finally, there is evidence of concern among the public over the use of fossil fuels to generate the electricity to supply electric vehicles, and for this to be overcome there also needs to be a focus of policies that encourage utility companies to increasingly pursue renewable sources.

10.3 Contributions to knowledge

The contributions of this research covers three main areas:

1. A means of identifying the characteristics and location of earlier adopters;
2. The recognition of reasons for non-adoption of alternative fuel vehicles; and
3. The application of Rogers' Decision-Innovation Process to alternative fuel vehicles.

Firstly, despite recent research into consumer acceptance of alternative fuel vehicles, gaps remain in the understanding about who will be among the earlier adopters of alternative fuel vehicles and when they will adopt. Using a targeted approach, this research enabled the identification of those who were more likely to be able to afford an electric vehicle and be among the earlier adopters of alternative fuel vehicles. The analysis identified the socio-demographic profile of an early adopter of an alternative fuel vehicle to be:

- Young/middle-aged;
- Well educated;
- Higher socio-economic status (high household income);
- Home owner; and
- Owner of two or more vehicles.

The cluster analysis of Birmingham census data was successful in identifying spatial concentrations of such individuals. This approach therefore presents broader applicability to other towns and cities, that will enable targeted policies and marketing. In the early stages of diffusion, it may also indicate suitable locations for charging infrastructure.

Secondly, the findings add to knowledge through the confirmation that there is misalignment between consumers' vehicle (and use) preferences and the characteristics offered by alternative fuel vehicles, that lead to their non-adoption. However, some of this misalignment is shaped by misperceptions and a lack of information rather than incompatibility. While previous research has focused on purchase intentions with respect to alternative fuel vehicles, the research in this thesis considered choices that have already been made with respect to current household vehicle characteristics, in addition to the preferences for a future vehicle purchase. These observations have then been studied with respect to electric vehicle attributes.

Thirdly, an important contribution is made through the application of Rogers' theory to an 'eco-innovation'. There are few applications of Rogers' theory for such innovations, particularly in the case of the Decision-Innovation Process being applied holistically. Through the incorporation of need-recognition and broader context-knowledge related attributes, innovation-specific concerns were overcome and the theory was successful in identifying those who are most likely to consider an alternative fuel vehicle, such that five of the most innovative respondents indicated that their next household vehicle purchase will be an alternative fuel vehicle.

Methods of data gathering in the application of Rogers' theory largely occur post hoc. However, there is little evidence of studies that have used a research design that gathers data at different stages in the diffusion process. The application of the theory at this stage in innovation diffusion overcomes the concern for diffusion theory contributions being undertaken at the post-diffusion stage and therefore leading to a pro-innovation bias. The application of the theory has enabled the identification of potential earlier adopters and some of the obstacles that need to be addressed in order to speed up diffusion.

A further contribution overcomes the gap in contributions to Rogers' theory with regard to the rejection of innovations and, in particular, whether the rejection is active or passive. The findings in this thesis have highlighted how it is largely passive rejection that is inhibiting the diffusion of alternative fuel vehicles. Low levels of knowledge and understanding of alternative fuel vehicles were found to cause passive rejection.

10.4 Limitations of the research

The research presented in this thesis is bounded by a number of limitations. However, the recognition of such limitations provides an indication of how future work can extend the findings of this research.

One concern in this research was the length of the questionnaire, such that too long a questionnaire can lead to fatigue among some respondents who, by which stage, begin to tick boxes or answer questions with less care in order to complete the questionnaire as quickly as possible. This was overcome by conducting the majority of questionnaires face-to-face. A larger budget for data collection would have allowed for a much greater number of responses and thus provided additional robustness to the research and the identification of more adopter segments.

A further difficulty was that of identifying those who exactly matched the socio-demographic profile outlined in Chapter 6. Firstly, Census data does not contain information on income, which led to the reliance on socio-economic status as a proxy variable for income. Secondly, because data from the 2011 Census was not available in its entirety until 2013, the first stage in this research was reliant on the 2001 Census. Since the 2001 Census, the Birmingham Metropolitan District ward boundaries have experienced some changes, which meant that in matching Output Areas to postcodes for the main data collection, some Output Area codes no longer exist. Data protection prevented the identification of individuals at a level lower than postcode level, which also meant that it was not possible to accurately locate those who exactly matched the socio-demographic profile. Despite these difficulties, the majority of those in the survey population matched at least three out of the five socio-demographic characteristics, as shown in Chapter 7. It may be advisable to undertake the profiling of respondents using a three-stage approach, such that, in the first stage, Census data is deployed in a similar fashion to its use in this thesis. In the second stage, a large-scale survey could be used simply as a means of identifying those who can be confirmed as having the demographic characteristics of potential early adopters. The third stage would then allow for a more detailed and targeted questionnaire that is completed by individuals that have already been confirmed as potential early adopters. A three-stage approach may be effective in improving data quality.

The application of Rogers' theory is also limited in its approach in the research contained within this thesis due to its application at a stage in time when it is not known exactly what stage of diffusion alternative vehicles are at. As such, those who purchase an electric vehicle in the near future may still be among the innovators, or they may even be the beginning of the early majority. It is not possible to obtain a full understanding of the diffusion of alternative fuel vehicles, or a clear distinction between adopter categories, until a much later stage in the diffusion process, by which point it will be known whether the innovation has been successful or not. Rogers' theory is also a theory for which the application is not clearly specified, or consistently applied across disciplines. How it is applied very much relies on the interpretation of the user. The broad scope of the theory enhances its flexibility, although it can also make it challenging for the user to ensure it is consistently applied.

10.5 Further avenues of research

There are a number of opportunities to extend this research.

Firstly, focusing on those who are most likely to adopt in other towns and cities in the UK and other developed economies, such as the US and Europe, will allow for a better understanding of the reasons for non-adoption at this early stage in the diffusion of alternative fuel vehicles.

Secondly, an understanding of the role of opinion leaders could be better developed. There was evidence in Chapter 7 that the public follow the view of experts on matters that are important. There are public figures who may have the ability to shape opinions on alternative fuel vehicles and identifying these individuals may prove advantageous in speeding up the diffusion of new vehicle technologies.

Finally, future studies must continue to monitor the diffusion of alternative fuel vehicles, such that they may prove to be an innovation that is distinct from other innovations (e.g. as an eco-innovation) that have been previously studied. They create an opportunity to study an innovation that may or may not prove to be successful in the long-term, thus avoiding a pro-innovation bias. Longitudinal studies of alternative fuel vehicles and other eco-innovations will enable contributions to the Diffusion of Innovations theory at all stages of the diffusion process. For eco-innovations there are gaps in knowledge in the Innovation-Decision Process relating to the implementation and confirmation phases. Further applications of the theory would be suited to studying the diffusion of other eco-innovations, such as photo-voltaic panels and vehicle-to-grid technology. Similarly, undertaking research with the same methodology used in this thesis in a country like Norway, which is experiencing some of the highest levels of alternative fuel vehicle adoption, may be particularly insightful, particularly in the interests of policy development.

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Appendix 1: Questionnaire survey cover letter to respondents

February 2013

Dear Sir/Madam,

Survey of Electric Vehicle perceptions

Birmingham City Council is currently implementing a network of electric vehicle charging points across the City to help support the take up of electric vehicles. The Council is committed to supporting new vehicle technologies which can help reduce the impact of transport on the environment and in particular reducing the City's Carbon emissions and improving local air quality.

To support our strategy development and help with our understanding of the emerging electric vehicle market and how the public perceive it we are now working with Loughborough University and Research By Design (RBD) to conduct research into car purchase decisions particularly in the context of new vehicle technologies.

We would be extremely grateful if you were able to help us with this research by sparing a few minutes to help with completing the research questionnaires.

Thank you very much for your time and assisting us. If you have any questions please do not hesitate to contact me.

Yours sincerely,

David Harris
Projects Leader, Transportation Policy

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Appendix 2: Questionnaire Survey

New vehicle technologies

We are conducting research for Birmingham City Council and Loughborough University about car purchase decisions, particularly in the context of new vehicle technologies, to assist with Birmingham's Transport Strategy. We would like to ask you how you make decisions when it comes to purchasing a new vehicle. We would be very grateful if the person who makes the main decisions about a new car purchase in your household could spare a few minutes to fill in this questionnaire. Thank you.

Interviewer: **House type**

❑ Semi-detached house with drive	❑ Semi-detached house without drive (CLOSE)	❑ Detached house with drive	❑ Detached house without drive (CLOSE)

Q1	**How many cars are there in your household?**	**0**	**1**	**2**	**3**	**4**	**5+**
Q2	**How many people are there in your household?**	**-**	**1**	**2**	**3**	**4**	**5+**
Q3	**Of these, how many are aged 17 or over?**	**0**	**1**	**2**	**3**	**4**	**5+**

Q4 **Do you hold a full UK driving license?**

❑ Yes	❑ No

Q5	**How many people in your household hold a full driving license, including yourself?**	**0**	**1**	**2**	**3**	**4**	**5+**

Q6 **The following statements are concerned with your personality and opinions.**
To what extent do you agree or disagree with these statements? (Interviewer: SHOWCARD 1)

	1. Agree strongly	*2. Agree somewhat*	*3. Neither agree nor disagree*	*4. Disagree somewhat*	*5. Disagree strongly*
You regularly participate in social activities	❑	❑	❑	❑	❑
You regularly interact with people in your local community	❑	❑	❑	❑	❑
You are often involved in matters that require you to interact with people outside of your local network	❑	❑	❑	❑	❑
You have a small network of people you know	❑	❑	❑	❑	❑
People you know are often influential (through their advice or opinions) when you are considering buying or trying a new technology	❑	❑	❑	❑	❑
You are often good at understanding other people's feelings	❑	❑	❑	❑	❑
You often find abstract ideas confusing	❑	❑	❑	❑	❑
You are often contemplative when you are making a decision	❑	❑	❑	❑	❑
You are often reluctant to change your routine	❑	❑	❑	❑	❑
The future is determined by fate	❑	❑	❑	❑	❑

Q7 **The next set of statements focus upon your attitudes towards driving and the environment. To what extent do your agree or disagree with the following? (Interviewer: SHOWCARD 1)**

	1. Agree strongly	*2. Agree somewhat*	*3. Neither agree nor disagree*	*4. Disagree somewhat*	*5. Disagree strongly*
Having a motor car is a necessity	❑	❑	❑	❑	❑
Having a motor car is a luxury	❑	❑	❑	❑	❑
You think about the impact of your activities on the environment	❑	❑	❑	❑	❑
Petrol/diesel motor cars emit harmful greenhouse gases into the environment	❑	❑	❑	❑	❑
Oil supplies are running out	❑	❑	❑	❑	❑
Motor cars produce gases that are harmful to people's health	❑	❑	❑	❑	❑
Petrol/diesel is likely to become too expensive to buy in the near future	❑	❑	❑	❑	❑
We should continue with petrol/diesel motor car technology	❑	❑	❑	❑	❑
Climate change does not cause you concern	❑	❑	❑	❑	❑
Mainstream electricity production has a low environmental impact	❑	❑	❑	❑	❑
You should not be forced by legislation to make changes to your motor car use	❑	❑	❑	❑	❑
New vehicle technologies, such as electric vehicles, will never be successful	❑	❑	❑	❑	❑

Q8 **The following statements focus upon how you respond to new technologies. To what extent do you agree or disagree with the following? (Interviewer: SHOWCARD 1)**

	1. Agree strongly	*2. Agree somewhat*	*3. Neither agree nor disagree*	*4. Disagree somewhat*	*5. Disagree strongly*
You have a keen interest in new technologies	❑	❑	❑	❑	❑
You want to be among the first people to try a new technology	❑	❑	❑	❑	❑
You invest in new technologies soon after they become available for purchase	❑	❑	❑	❑	❑
Friends will often use you as a point of reference for new technologies	❑	❑	❑	❑	❑
You often take your time before making a decision to invest in a new technology	❑	❑	❑	❑	❑
You are often sceptical about new technologies	❑	❑	❑	❑	❑
You tend to invest in new technology once you have been convinced about the benefits of using it	❑	❑	❑	❑	❑
You rarely invest in new technologies	❑	❑	❑	❑	❑
You prefer to stick to existing technologies that you are familiar with	❑	❑	❑	❑	❑
You would consider yourself willing to take a risk when it comes to investing in new technologies	❑	❑	❑	❑	❑
The uncertainty of not knowing how successful a technology will be in the long-term would make you feel uncomfortable about investing in it	❑	❑	❑	❑	❑

Q9 **For your household car/s driven most often (at least once per week), please provide the following information (please insert a question mark '?' if unsure of the answer).**

	Motor car 1	Motor car 2	Motor car 3	Motor car 4
What was the year of purchase?				
What is the make/manufacturer?				
Model				
What was the approximate purchase price?	£	£	£	£
Is the car owned, leased or a company car?	❑ Owned ❑ Leased ❑ Company car	❑ Owned ❑ Leased ❑ Company car	❑ Owned ❑ Leased ❑ Company car	❑ Owned ❑ Leased ❑ Company car
Is the car new or second-hand?	❑ New ❑ Second-hand	❑ New ❑ Second-hand	❑ New ❑ Second-hand	❑ New ❑ Second-hand
Type of fuel e.g. petrol/diesel	❑Petrol ❑Diesel ❑LPG ❑Electric ❑Other	❑Petrol ❑Diesel ❑LPG ❑Electric ❑Other	❑Petrol ❑Diesel ❑LPG ❑Electric ❑Other	❑Petrol ❑Diesel ❑LPG ❑Electric ❑Other
What is the average mileage per year?	miles	miles	miles	miles

Q10 **When considering a new vehicle purchase, which three of the following are most important and which three are least important? (Interviewer: SHOWCARD 2)**

		1. Most Important	*2. Least important*
1.	Brand	❑	❑
2.	Vehicle image	❑	❑
3.	Value for money	❑	❑
4.	Vehicle range (distance with full tank)	❑	❑
5.	Time to refuel	❑	❑
6.	Engine power	❑	❑
7.	Fuel economy	❑	❑
8.	Environmental impact	❑	❑
9.	Resale value	❑	❑
10.	Fit with your lifestyle	❑	❑

Q11 **Please can you answer 'yes' or 'no' to the following questions:**

	Yes	*No*
Do you know the current price of fuel?	❑	❑
Do you know the MPG of your main vehicle?	❑	❑
Do you know the range of your main vehicle on a full tank of fuel?	❑	❑

Q12 How much do you know about each of these vehicle technologies? Please use a scale from 1 to 5 where 1 is low knowledge and 5 is high knowledge. (Interviewer: SHOWCARD 3)

	1 (Low level of knowledge)	*2*	*3*	*4*	*5 (High level of knowledge)*
Hybrid electric vehicle	❑	❑	❑	❑	❑
Hydrogen fuel cell vehicle	❑	❑	❑	❑	❑
Fully electric vehicle	❑	❑	❑	❑	❑

Q13 Have you previously had a conversation with someone you know about electric vehicles?

❑ Yes ❑ No

Q14 Have you actively looked for information about fully electric vehicles?

❑ Yes ❑ No

Q15 Have you ever travelled in any of the following?

	Yes	*No*
Hybrid electric vehicle	❑	❑
Hydrogen fuel cell vehicle	❑	❑
Fully electric vehicle	❑	❑

Q16 The following questions relate to electric vehicles. To what extent do you agree or disagree with the following statements? (Interviewer: SHOWCARD 1)

	1. Agree strongly	*2. Agree somewhat*	*3. Neither agree nor disagree*	*4. Disagree somewhat*	*5. Disagree strongly*
A fully electric vehicle would require you to make impossible changes to your lifestyle	❑	❑	❑	❑	❑
A fully electric vehicle may be suitable as an additional vehicle in your household	❑	❑	❑	❑	❑
You are confident that you would know how to drive a fully electric vehicle	❑	❑	❑	❑	❑
You are confident that you would know how to recharge a fully electric vehicle	❑	❑	❑	❑	❑

Q17 Please use the space below to list any advantages you think you (or your household) might experience by owning or leasing a fully electric vehicle.

Q18 Please use the space below to list any obstacles you (or your household) might experience by owning or leasing a fully electric vehicle.

Q19 How easy or difficult do you think the following activities are for fully electric vehicles? (Interviewer: SHOWCARD 4)

	1. Very easy	*2. Somewhat easy*	*3. Neither easy nor difficult*	*4. Somewhat difficult*	*5. Very difficult*
Driving	❑	❑	❑	❑	❑
Recharging at home	❑	❑	❑	❑	❑
Recharging away from home	❑	❑	❑	❑	❑

Q20 A fully electric vehicle has a range of around 100 miles before it needs to be charged, which can take several hours. In order to understand whether an electric vehicle might suit your lifestyle, please answer the following questions. (Interviewer: SHOWCARD 5)

	1. Daily	*2. Weekly*	*3. Monthly*	*4. Less frequently*	*5. Never*	*6. n/a*
How often is a car your main mode of transport?	❑	❑	❑	❑	❑	-
How often does your driving distance exceed 100 miles in a single day?	❑	❑	❑	❑	❑	-
How often do you spend away from home (where you might not be able to recharge an electric vehicle battery)?	❑	❑	❑	❑	❑	-
If there is an additional vehicle in the household, how often is it used for trips that involve driving over 100 miles in a single day?	❑	❑	❑	❑	❑	❑

Q21 **Considering each of the following vehicle characteristics, how do you believe a fully electric vehicle compares with a petrol or diesel vehicle? (Interviewer: SHOWCARD 6)**

	1. Fully electric vehicle is much stronger	*2. Fully electric vehicle is somewhat stronger*	*3. Neither stronger nor weaker*	*4. Fully electric vehicle is somewhat weaker*	*5. Fully electric vehicle is much weaker*
1. Image	❑	❑	❑	❑	❑
2. Value for money	❑	❑	❑	❑	❑
3. Vehicle range (distance with full tank)	❑	❑	❑	❑	❑
4. Access to refuelling stations	❑	❑	❑	❑	❑
5. Ability to refuel at home	❑	❑	❑	❑	❑
6. Time to refuel	❑	❑	❑	❑	❑
7. Engine power	❑	❑	❑	❑	❑
8. Fuel economy	❑	❑	❑	❑	❑
9. Environmental impact	❑	❑	❑	❑	❑
10. Resale value	❑	❑	❑	❑	❑
11. Fit with your lifestyle	❑	❑	❑	❑	❑

Q22 **Hydrogen fuel cell vehicles are a different vehicle technology that may become available to the public within the next 5-10 years. What is your reaction to the possibility of buying or leasing these vehicles in the future?**

Q23 **To what extent do you agree or disagree with the following statements? (Interviewer: SHOWCARD 1)**

	1. Agree strongly	*2. Agree somewhat*	*3. Neither agree nor disagree*	*4. Disagree somewhat*	*5. Disagree strongly*
You try to keep up to date with what is happening in the media	❑	❑	❑	❑	❑
You often follow the views of experts on matters that are important to you	❑	❑	❑	❑	❑
The media has influenced your attitude towards fully electric vehicles	❑	❑	❑	❑	❑
Your family has influenced your attitude towards fully electric vehicles	❑	❑	❑	❑	❑
Friends/acquaintances have influenced your attitude towards fully electric vehicles	❑	❑	❑	❑	❑
Fully electric vehicles receive mostly positive coverage in the media	❑	❑	❑	❑	❑

Q24 **When is your household's next vehicle purchase or lease likely to be?**

❑ In the next 12 months	❑ In 2-3 years	❑ In 4 years or more
❑ In 1-2 years	❑ In 3-4 years	❑ Unsure

Q25 **Is this vehicle likely to be new or used?**

❑ New ❑ Used

Q26 **Have you at any stage considered the purchase or lease of a fully electric vehicle?**

❑ Yes ❑ No

Q27 **Which of the following vehicle types (by the amount of fuel used) best describes your probable next vehicle for purchase or lease? (Interviewer: SHOWCARD 7)**

❑ 1. Hybrid vehicle	❑ 4. Petrol vehicle	❑ 7. Unsure
❑ 2. Fully electric vehicle	❑ 5. Diesel vehicle	
❑ 3. Hydrogen fuel cell vehicle	❑ 6. Other	

Q28 **Will this vehicle be lease or purchase?**

❑ Lease ❑ Purchase ❑ Unsure

Q29 **Which of these vehicle types best describes the size of your probable next vehicle for purchase or lease? (Interviewer: SHOWCARD 8)**

❑ 1. Car City car e.g. Fiat 500/Smart	❑ 1. Large family or estate vehicle e.g. Ford Mondeo	❑ 7. Executive e.g. BMW 5 Series
❑ 2. Small e.g. Ford Fiesta	❑ 2. Multi-purpose e.g. Vauxhall Zafira	❑ 8. Sports/Cabrio e.g. Audi TT Roadster
❑ 3. Small family e.g. Ford Focus	❑ 3. Sports utility e.g. Land Rover Freelander	❑ 9. Small van e.g. VW Caddy
		❑ 10.Unsure

Q30 **Do you know anybody who uses a fully electric vehicle?**

❑ Yes ❑ No

Q31 **Have you seen anybody using a fully electric vehicle?**

❑ Yes ❑ No

Q32 **Have you seen any recharging points in public spaces in Birmingham or Sutton Coldfield?**

❑ Yes ❑ No

Q33 **What do you think the purchase price of your next vehicle will be? (Interviewer: SHOWCARD 9)**

❑ 1. Less than £5,000	❑ 4. £30,000 - £35,000	❑ 13. £60,000 - £65,000
❑ 2. £5,000 - £10,000	❑ 5. £35,000 - £40,000	❑ 14. £65,000 - £70,000
❑ 3. £10,000 - £15,000	❑ 6. £40,000 - £45,000	❑ 15. £70,000 - £75,000
❑ 4. £15,000 - £20,000	❑ 7. £45,000 - £50,000	❑ 16. Over £75,000
❑ 5. £20,000 - £25,000	❑ 8. £50,000 - £55,000	❑ 17. Unsure
❑ 6. £25,000 - £30,000	❑ 9. £55,000 - £60,000	

Q34 **Have you test-driven a fully electric vehicle?**

❑ Yes ❑ No

Q35 **(ASK IF NO TO Q34) Would you be interested in driving a fully electric vehicle?**

❑ Yes ❑ No

Q36 **Have you seen or heard any advertisements inviting you to test-drive a fully electric vehicle?**

❑ Yes ❑ No

Q37 **(ASK IF YES TO Q36) What was the source? (Please be specific e.g. Mitsubishi website or The Daily Telegraph newspaper etc.)**

Q38 **Would you know which vehicle manufacturers to approach if you wanted to test-drive a fully electric vehicle?**

❑ Yes ❑ No

Q39 **(ASK IF YES TO Q38) Which manufacturers produce fully electric vehicles?**

Q40 **Do you have solar or photo-voltaic panels fitted to your house?**

❑ Yes ❑ No

Q41 **To which age group do you belong?**

❑ 17 - 24	❑ 45 - 54	❑ 65 - 74
❑ 25 - 34	❑ 55 - 59	❑ 75+
❑ 35 - 44	❑ 60 - 64	

Q42 **What is the highest level of formal education you have completed?**

❑ A Doctorate or equivalent	❑ HNC/HND	❑ Vocational qualifications
❑ Master's Degree or equivalent	❑ A-level or equivalent	❑ Other
❑ Bachelor Degree or equivalent	❑ GCSE/O-level or CSE	❑ I have no formal qualifications

Q43 **What is your employment status?**

❑ Working full time (30+ hours)	❑ Unemployed - seeking work	❑ Not working - in education
❑ Working part time (9 - 29 hours)	❑ Unemployed - not seeking work	❑ Not working - invalid/disabled
❑ Voluntary work	❑ Not working - retired	

Q44 **Which of the following best describes your current occupation (or previous occupation if you have retired)? (Interviewer: SHOWCARD 10)**

❑ 1. Higher managerial, administrative or professional	❑ 3. Supervisory, clerical and junior managerial, administrative or professional	❑ 5 Semi and unskilled manual workers
❑ 2. Intermediate managerial, administrative or professional	❑ 4 Skilled manual workers	❑ 6. Casual work or unemployed with state benefits

Q45 **If you are currently employed, do you commute to work by car?**

❑ Yes ❑ No

Q46 **Which figure in the table below most accurately represents your household income (before tax and other deductions)? (Interviewer: SHOWCARD 11)**

	WEEKLY	MONTHLY	YEARLY
❑ 1.	Less than £625	Less than £2,500	Less than £30,000
❑ 2.	£626 - £833	£2,501 - £3,333	£30,001 - £40,000
❑ 3.	£834 - £1,042	£3,334 - £4,167	£40,001 - £50,000
❑ 4.	£1,043 - £1,250	£4,168 - £5000	£50,001 - £60,000
❑ 5.	£1,251 - £1,458	£5,001 - £5,833	£60,001 - £70,000
❑ 6.	£1,459 - £1,667	£5,834 - £6,667	£70,001 - £80,000
❑ 7.	£1,668 - £1,875	£6,668 - £7,500	£80,001 - £90,000
❑ 8.	£1,876 - £2,083	£7,501 - £8,333	£90,001 - £100,000
❑ 9.	More than £2,084	More than £8,334	More than £100,000
❑ 10.	Prefer not to say		

Q47 **Are you the main income earner in this household?**

❑ Yes ❑ Joint
❑ No ❑ Prefer not to say

Q48 **Do you own or rent this property?**

❑ Own ❑ Rent

Q49 **What is your gender?**

❑ Male ❑ Female

Q50 **As part of this important study we may recontact a small proportion of respondents to acquire additional information concerning their attitudes to vehicle technologies. If this is necessary, would you be happy for us to recontact you?**

❑ Yes ❑ No

Q51 **As part of our quality control procedures it is possible that you will receive a call from Research by Design. If they do call they will simply be checking that this interview was conducted professionally and that your answers have been recorded accurately. Is that okay?**

☐ Yes ☐ No

If you are willing to be recontacted to acquire additional information and/or are happy to be called for quality control purposes, please provide your contact details below, thank you.

Name:	
Address:	
Telephone number:	

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I confirm that I have carried out this interview face-to-face with the above named person and that I asked all the relevant questions fully and recorded the answers in conformance with the survey specification and within the MRS Code of Conduct.

Interviewer name:	
Date of interview:	
Time of interview:	
Signature:	
Ward:	
Street:	

Appendix 3: Publications, Conferences and Training Courses

Publications

Campbell, A.R., Ryley, T.J. and Thring, R.H. (2012) Identifying the early adopters of alternative fuel vehicles: A case study of Birmingham, United Kingdom, Transportation Research Part A, 46, 1318-1327.

Campbell, A.R., Ryley, T.J. and Thring R.H. (2012) Identifying the early adopters of alternative fuel vehicles: a case study of Birmingham, United Kingdom. Paper presented at the 91st Annual Meeting of the Transportation Research Board, Washington, DC, 22-26 January 2012.

Campbell, A.R., Ryley, T.J. and Thring R.H. (2014) Identifying the reasons for consumers' non-adoption of zero-emissions vehicles. Paper presented at Universities' Transport Studies Group 46th Annual Conference, Newcastle 6th-8th January 2014.

Conference presentations

Dec 2011 International Hydrogen Conference, Mexico
Jan 2012 TRB International Conference in Washington DC, US
Apr 2014 University of California Transportation Conference in LA, US

Training courses completed

Dec 2012 Introduction to Linear Regression and Correlation
May 2013 Introduction to Analysis of Variance (ANOVA)
May 2013 Introduction to the Design of Multifactor Experiments
Jan 2014 Viva – What Happens?

Skills/Modules Completed as part of CDT PhD programme

Year	Module Title	Marks	Credits
2011	Effective Project Management	76%	10
2011	Marketing and TQM	80%	10
2010	Materials for Hydrogen and Fuel Cell Technologies	75%	10
2010	The Energy System	60%	10
2012	Business Methods	65%	10
2012	Exploring Science and Technology in Society	70%	20
2012	From the Bench to the Bank	68%	20
2013	Consultancy Skills	69%	10
2013	Transferable Skills	Pass	10
2014	Public engagement and awareness in energy	TBC	TBC

Appendix 4: Journal paper: Campbell, A.R., Ryley, T.J. and Thring, R.H. (2012) Identifying the early adopters of alternative fuel vehicles: A case study of Birmingham, United Kingdom, Transportation Research Part A, 46, 1318-1327.

Transportation Research Part A 46 (2012) 1318–1327

Contents lists available at SciVerse ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

Identifying the early adopters of alternative fuel vehicles: A case study of Birmingham, United Kingdom

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ARTICLE INFO

Article history:
Received 25 November 2011
Received in revised form 29 March 2012
Accepted 16 May 2012

Keywords:
Alternative fuel vehicles
Electric vehicles
Early adopters
Driver characteristics
Cluster analysis

ABSTRACT

The transport sector has been identified as a significant contributor to greenhouse gas emissions. As part of its emissions reduction strategy, the United Kingdom Government is demonstrating support for new vehicle technologies, paying attention, in particular, to electric vehicles.

Cluster analysis was applied to Census data in order to identify potential alternative fuel vehicle drivers in the city of Birmingham, United Kingdom. The clustering was undertaken based on characteristics of age, income, car ownership, home ownership, socio-economic status and education. Almost 60% of areas that most closely fitted the profile of an alternative fuel vehicle driver were found to be located across four wards furthest from Birmingham city centre, while the areas with the poorest fit were located towards the centre of Birmingham. The paper demonstrates how Census data can be used in the initial stages of identifying potential early adopters of alternative vehicle drivers. It also shows how such research can provide scope for infrastructure planning and policy development for local and national authorities, while also providing useful marketing information to car manufacturers.

1. Introduction

There is global concern about climate change which is commonly linked to anthropogenic impact on the environment stemming from greenhouse gas emissions. In recognition of the dangers of climate change, national and international governments have sought to develop and set policies to tackle greenhouse gas emissions, with transport identified as one of the high-emissions sectors. The United Kingdom (UK) Climate Change Act 2008 (DECC, 2008) set a legally binding target for the UK of an 80% reduction in greenhouse gas emissions by 2050. The UK Government is targeting carbon reduction and decarbonisation of the transport system by 2050 as one of its policy objectives. Its strategy for doing so is designed 'to avoid dangerous levels of climate change in an economically efficient way' (DfT, 2009).

In addition to climate change, there is also a very real risk surrounding energy security and the future oil supplies. Vehicle manufacturers are increasingly recognising their role in contributing to the objective of decarbonising the economy and reducing oil dependency. New vehicle technologies such as plug-in hybrid electric vehicles, battery electric vehicles and hydrogen fuel cell vehicles, collectively termed 'alternative fuel vehicles' in this paper, are being promoted as securing the future of mobility. There are technological, infrastructural and behavioural hurdles that first need to be overcome before

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0965-8564/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.tra.2012.05.004

such vehicles can penetrate the mass market. New vehicle technologies also require Government support to succeed (Romm, 2006; Stevens, 2010). The focus of support from the UK Government has been on electric vehicles, which has been demonstrated in two ways. Firstly transport taxes have been used in a way to support the Government's environmental objectives whereby battery electric vehicle owners pay no excise duty (a tax on ownership) and are subject to the minimum level of company car tax (OLEV, 2011). Secondly, it has provided £250 million (USD 380 million) for consumer incentives, launching a 'Plug-in Car Grant' scheme which provides subsidies of 25% of the price of a vehicle up to a maximum value of £5000 (USD 7500) from 2011. These grants are available to both private individuals and commercial consumers. The £250 million budget also includes the allocation of £30 million (USD 46 million) to a scheme called 'Plugged-in-Places', which has been operational since 2010, for electric vehicle charging infrastructure. The scheme focuses on trialling the infrastructure in a small number of 'lead' cities and regions in the UK, including Birmingham.

The aim of the paper is to identify the geographic distribution in a major metropolitan district of individuals who most closely fit the profile of anticipated early adopters of alternative fuel vehicles, using a technique known as hierarchical cluster analysis. This paper is a case study of Birmingham, the second largest city in the UK, which is located in the West Midlands region of the United Kingdom. The typical demographic characteristics of people who are most likely to adopt an alternative fuel vehicle have been identified in a literature review; clusters of people with the identified characteristics were then located within the city of Birmingham. The next step involved geographically mapping the results of the cluster analysis to identify any trends that may be present and their proximity to the city centre. Doing so may provide a useful indication for the location of vehicle refuelling (hydrogen) stations and also recharging points for electric vehicles which may be of particular importance for homes that do not have the luxury of off-road parking. The information in this study may also be useful for vehicle manufacturers in identifying market segments. Finally, the findings from the study have been used to make policy recommendations.

2. The case study of Birmingham, United Kingdom

The focus of this paper is on Birmingham, United Kingdom and considers the area of Birmingham which falls under the Birmingham City Council authority. This area is called a Metropolitan District, which is a form of single-tier local authority found in some of the larger areas of England (ONS, 2011); in Birmingham the Metropolitan District constitutes 40 wards. The Office for National Statistics (ONS, 2011) defines a ward as being, 'the base unit of UK administrative geography, being the areas from which local authority councillors are elected'. Population is the primary determinant of a ward and boundaries are often easily identifiable at ground level, demarcated by rivers, major roads and railways for example (ONS, 2011). The total population of the 40 wards is one million people, as recorded in 2001(ONS, 2001), although the population of the wider metropolitan area is around four million people (ESPON, 2007).

Car dependency is lower than many other authorities in England and Wales, suggesting that a larger than average proportion of the population travel to work by public transport in Birmingham. Thirty-eight per cent of households in Birmingham do not own a car or a van and 20% of households own two or more cars/vans. Although home ownership in Birmingham is 60%, this is a much lower percentage than in many other authority areas in England and Wales. The employment level of those who are 'economically active' is 61% which is 7% lower than that for the West Midlands region and almost 10% lower than that for the United Kingdom. 'Economically active' refers to those between the ages of 16 and 74 and in work, and therefore this figure does not take into account those who do unpaid work, are retired, in education, unable to work or those who choose not to work.

Road transport accounts for almost 24% of Birmingham's carbon emissions (Birmingham City Council, 2011). In 2010 Birmingham City Council published a 'Climate Change Action Plan' (Birmingham City Council, 2010) in recognition of the changes the city needs to make in order to reduce its impact on the environment and to create a more sustainable economy. The Action Plan follows closely on the Council's 2015 Birmingham Declaration (Birmingham City Council, 2009) and outlines the steps the city will need to take in order to meet a 60% reduction in carbon emissions by 2026. One of the 'Early Actions' it sets down as a key priority is 'Reducing the environmental impact of the city's mobility needs through "Low Carbon Transport"'.

Projected carbon emissions per capita from transport are expected to reduce as a result of the mitigation measures Birmingham is introducing. Between 1990 and 2026, the actual and predicted levels are as follows (Birmingham City council, 2010):

1990: 1.25 tonnes
2005: 1.57 tonnes
2007: 1.54 tonnes
2011: 0.89 tonnes
2026: 0.66 tonnes

One of the targets in the Council's 2015 Birmingham Declaration is to have at least 500 electric vehicles on the streets of Birmingham as the city develops the electric vehicle charging infrastructure. Plugged-In-Places funding will therefore contribute to reaching this target by ensuring electric vehicle charging points are installed before 2015.

3. Literature review

Research into profiling the early adopters of alternative fuel vehicles is rather limited, with a strong leaning towards electric vehicles. This paper attempts to consider a range of alternative fuel vehicles, although it is predominantly research in electric vehicles that guides the methodology.

Following a study of consumer awareness and purchase barriers of vehicle owners in the US, along with interviews with executives from automotive original equipment manufacturers (OEMs), car dealers and energy companies, Deloitte (2010) was able to establish a 2011–2020 early adopter profile (electric vehicles) for the US: young, very high income individuals with an average household income of $114,000 who have a perception of electric vehicles being ‘green and clean’, are influenced predominantly by the reliability of the vehicle, who live in an urban or suburban location with access to a garage and power, who already own one or more vehicles and who drive an average of 100 miles per week. It expects that early adoption will be predominantly in California where electric vehicle infrastructure is ready to support electric vehicle users. In the same study Deloitte also revealed a predicted profile of ‘non adopters’, constituting those who have low household incomes and are price sensitive. The majority of ‘non adopters’ do not have a garage, creating a challenge for secure home charging. Nemry and Brons (2010) suggest that a lack of charging infrastructure will inhibit market penetration until 2020 at the earliest.

Price is likely to be a major factor in determining who the early adopters of alternative fuel vehicles will be. A recent survey of 1000 car owners conducted by Low CVP (2010) found that the median car price paid by those who had recently bought a new or nearly-new car was between £11,000 (USD 17,000) and £15,000 (USD 23,000), which falls significantly below the price of an electric vehicle. The high cost of alternative fuel vehicles was found to be a prohibitive factor for individuals considering plug-in hybrid electric vehicles in research by Karplus et al. (2010), who suggest that price premiums need to be significantly reduced to make them commercially viable. Price was also noted as top of purchase criteria in an opinion survey undertaken by Musti and Kockelman (2011) in Austin, Texas.

Hidrue et al. (2011) undertook a nationwide (US) survey, part of which looked at the demographics of electric vehicle drivers. Variables which increased a respondent’s electric vehicle orientation include: being younger to middle aged; having a Bachelor’s or higher degree; expecting higher gasoline prices in the next five years; having made a shopping or lifestyle change to help the environment in the last five years; having a place they could install an electric vehicle electrical outlet at home; being likely to buy a small or medium-sized passenger car on next purchase; and having a tendency to buy new products that come onto the market. They also found that the number of vehicles per household and the type of residence are important variables in electric vehicle choice. With respect to education, O’Garra et al. (2005) also found that being highly educated is strongly linked to an individual’s likelihood of having prior knowledge of new vehicle technologies.

In the early phase of electric vehicles, Gärling and Thøgersen (2001) suggest targeting three market segments; public sector organizations, eco-conscious companies and multi-car households, constituting an early adopter market of over 2.5%, arguing that multi-car households may offer significant opportunities for electric vehicle sales because the household possesses one or more conventional vehicles that can be used for journeys which are currently beyond the range of electric vehicles. This research supports the work of Kurani et al. (1995) who, in their Neighbourhood Electric Vehicle Drive Trials study 17 years ago, found that many households would consider an electric vehicle if they incorporated it into their existing ‘household vehicle fleet’ so that there was always an option of an internal combustion engine vehicle for long-range journeys. In a more recent study, Graham-Rowe et al. (2012) found the same attitudes still remain; consumers find the range of current battery electric vehicles too restrictive to have the electric vehicle as the only household vehicle, but rather as a second vehicle that can be used to make short, local journeys.

The age characteristics of a hybrid-electric vehicle driver in research undertaken by Ozaki and Sevastyanova (2011), in collaboration with Toyota GB involving a survey of buyers of the Toyota Prius, contrasts with both Deloitte’s (2010) predicted ‘early adopter’ age profile and also the age characteristics identified in a study of electric vehicle drivers by Hidrue et al. (2011). The majority of Toyota Prius vehicle owners in their survey were men aged 50 and over, which was found to be a true representation of Toyota GB’s hybrid customers. The survey results also showed household composition of hybrid vehicle owners tends to be a retired couple or single, with a net monthly household income of over £4000 (USD 6000) and who own more than one vehicle. The contrast may have been influenced by other factors, such as branding of the Toyota Prius, perhaps leading to its appeal to a slightly older market.

With the exception of Williams and Kurani (2006), there has been very little research into profiling who the early adopters of hydrogen vehicles are likely to be. Williams and Kurani (2006) conducted a study looking at Californian residents to estimate the early market potential for hydrogen fuel cell vehicles. They identified the target customers most likely to benefit from ‘Mobile Energy’ innovations, such as vehicle-to-grid technology to create ‘Mobile Electricity’. The authors suggest that consumers will be more likely to make supporting modifications and investments in the required infrastructure if they own their homes and have parking facilities close by. They also recognise the initial price premiums associated with new vehicle and mobile energy technologies and therefore choose not to consider consumers from completely unemployed households or from households with no income as target consumers.

4. Methodology

The Census used in this study took place in 2001 (ONS, 2001). Although a more recent Census has taken place (March 2011), the data collected in this Census is not yet publically available. The data used is therefore over 10 years old, so any demographic changes that have taken place in Birmingham over the course of the past 10 years will not be reflected in this paper. In 2004 the ward boundaries in Birmingham changed, however the Census data collected in 2001 has been manipulated by the Office for National Statistics to take this change into account. The dataset constitutes 3126 Census super output areas which are within the 40 Census wards of Birmingham City Council. A super output area is defined as 'a geographical area designed for the collection and publication of small area statistics' (Local Government Improvement and Development, 2009).

The demographic profile of an anticipated alternative fuel vehicle driver has been determined by the literature review and used as a guide to collate the appropriate local census data, which will indicate the locations of potential early adopters of alternative fuel vehicle drivers in Birmingham. The variables that will be used are: location, car ownership, education, home-ownership, age, socio-economic status, and journey (mode) to work. The Census does not collect data on income; this is because it is believed that it would prejudice the completion rates and, for small areas, income can be estimated using other variables (House of Commons Public Administration Select Committee, 2011). In this research, socio-economic status and home ownership will be used as a guide to the wealth of inhabitants of the different wards and their sub areas.

In order to identify locations of potential alternative fuel vehicle drivers, it is necessary to establish homogenous groupings in the data. Working with such a large volume of information, as the dataset presents, it is appropriate to classify the information into manageable subgroups. Cluster analysis has been selected as the most suitable approach to classifying the data as it performs objective data reduction and recognises the inter-relationships between the variables (Hair et al., 2005). Using an appropriate algorithm, a sample of entities is sub-divided into a small number of mutually exclusive groups based on the similarities (or differences) among the entities. Unlike discriminant analysis the groups are not pre-defined. Due to the nature of cluster analysis, as a non-parametric test, there are not strict assumptions, although the variables must be independent. Analysis should be undertaken without any pre-conceptions of the user, but the results do depend on their judgement. It is acknowledged that the cluster analysis technique generates suggested groups for review rather than definite solutions. Previous examples applying cluster analysis to transport applications, in order to determine market segments, include Ryley (2006), who identified households in Edinburgh with the greatest propensity to use non-motorised travel modes and Anable (2005), who used cluster analysis to identify six distinct travel behaviour segments.

5. Developing population segments based on typical alternative fuel vehicle driver characteristics

Cluster analysis was applied to the 3126 super output areas within Birmingham (Birmingham City Council area). The super output areas vary in size, constituting between 53 and 259 households with an average of 125 households. This translates into an average super output population size of 312 individuals.

A hierarchical technique of clustering was applied as it is the only one to permit categorical data. Ward's method, a hierarchical clustering algorithm, has been used to identify geo-demographic clusters of super output areas containing individuals who most closely fit the profile of an anticipated alternative fuel vehicle driver. Ward's method calculates the sum of squares (distance) between an object in the first cluster and an object in the second cluster, which is then summed across all variables (Hair et al., 2005). This method optimises the production of clusters of approximately equal size. The variables that could be input into a cluster analysis have been identified from the literature as characteristics of individuals who most closely fit the early adopter profile, and are shown in Table 1. An examination of the relationships between these seven

Table 1
Variables included in the analysis.

Variable	Reason for inclusion
Age group 25–59	Literature review: Deloitte (2010) and Hidrue et al. (2011). Census age categories have been combined (25–44 and 45–59) to create a younger to middle-aged variable
Home owner	Literature review: Williams and Kurani (2006). The variable also provides an indication of levels of income which is not available from the Census
Home is detached or semi-detached	Homes in the UK are more likely to have off-road parking (for electric charging and vehicle-to-grid infrastructure) if they are detached or semi-detached
Drive a car to work	This group demonstrate a higher dependence on their motor vehicle
Own at least two cars or vans	Literature review: Deloitte (2010), Ozaki and Sevastyanova (2011), Kurani et al. (1995), and Graham-Rowe et al. (2012)
Socio-economic status ('higher professional occupations' or 'lower managerial and professional occupations')	The Census classifies socio-economic status according to occupation groups. These two occupation groups have been combined on the assumption that these groups are of a higher income level
Higher education	Literature review: Hidrue et al. (2011), O'Garra et al. (2005)

variables identified strongest correlation between the socio-economic status and higher education variables. Therefore, one of these variables, higher education, was not included in the cluster analysis.

In deciding how many clusters should be formed, there is no standard objective procedure; the procedure is, instead, subjective but guided by the 'stopping rule', which involves selecting the number of clusters which most appropriately represents the data set (Hair et al., 2005). Rogers (1995) has shown that early adopters constitute up to around 10% of total product adopters of innovations. It was, therefore, considered desirable to identify the top 5–10% of super output areas (between 150 and 300 super output areas) with a population who most closely fit the profile of an anticipated early adopter of an alternative fuel vehicle.

6. Identifying super output areas with a population that contains the characteristics of potential alternative fuel vehicle drivers

Cluster analysis was undertaken on the six variables (age, home owner, detached/semi-detached house, drive a car to work, car/van ownership and socio-economic status) to produce a range of five, seven and 10 clusters, to generate an early adopter cluster of between 150 and 300 super output areas. The cluster run that best fit this criterion was the seven-cluster solution. An examination of the cluster centroids (mean values) for each of the three cluster solutions, as a process of internal validation, showed greatest heterogeneity between cluster groups for the five-cluster solution, followed by the seven-cluster solution and then the 10-cluster solution. However, given that the five-cluster solution generated too large a number of observations (752 super output areas) to fit the early adopter profile, and the 10-cluster solution did not display as much heterogeneity between clusters as the seven-cluster solution, the seven-cluster solution was deemed the most suitable grouping for this application.

The output for the cluster run of seven is shown in Table 2 and a visual representation of the data is provided in Fig. 1. Each of the seven clusters shown in Fig. 1 has a unique profile. Assigning a name to each cluster that represents its characteristics provides greater context and meaning, and is considered a form of cluster group validation (i.e. if it is straight-forward to assign a name to each cluster group then it demonstrates clear heterogeneity between groups). The clusters in Table 2 are listed from top to bottom, based on their mean values in order of adoption, ranging from 'early adopter' through to 'unlikely adopters'. The highest mean values in the Table 2 are highlighted in bold, while the lowest mean values are highlighted in italic. As the focus of this research is to identify early adopters, which are recognised by Rogers in the Diffusion of Innovations Theory (1995), other adopter categories used in this theory have guided the naming of each of the clusters presented here.

The number of super output areas identified in the 'early adopter' cluster constitutes 8% of the total number of super output areas and therefore satisfies the criteria for identifying early adopters. The 'early adopters' want to be the first people to own alternative fuel vehicles and like to see themselves as role models in society. The 'early majority' represents those who will spend slightly longer deliberating over buying an alternative fuel vehicle, and will first seek the advice and opinions of an early adopter before investing. This is one of the categories with the greatest number of people, and for that reason there are two waves of 'early majority' adopters in this analysis. The 'early majority second wave' represents those who have deliberated for slightly longer than those in the 'early majority first wave'. The 'late majority' adopters are slightly cautious and sceptical about buying an alternative fuel vehicle, but may have found that a point has been reached when a combination of economic conditions or social pressure mean the individual feels compelled to buy an alternative fuel vehicle. Again, this is one of the largest categories of adopters and the 'late majority second wave' represents those who are most cautious or sceptical. 'Laggards' will be the last to adopt an alternative fuel vehicle, as they hold traditional values and do not respond well to change. They may lack knowledge and understanding of alternative fuel vehicles and the environmental pressures which have led to their introduction. The final category which has been introduced here is 'unlikely adopter', which constitutes those who may lack the resources to be in the position to own a vehicle.

As can be seen in Table 2, the 'early adopters' cluster has the highest mean values across each of the six variables. Within the 259 super output areas of this cluster are 32,000 households and 85,000 residents, which equates to 9% of the total population of the Birmingham County Council area. The 259 super output areas are distributed across the wards shown in Table 3.

Within the 'early adopter' cluster, 94% of the population are homeowners, with 93% living in detached or semi-detached homes. Over half the population has two or more cars and 67% of people use their cars for commuting. Thirty-nine per cent of people within the super output areas identified are professionals or managers.

Fifty-nine per cent of the super output areas in the 'early adopters' cluster are located across four wards (Table 3): Sutton Vesey, Sutton New Hall, Sutton Trinity and Sutton Four Oaks. These wards form the suburb of Sutton Coldfield. The distances of these wards from the city centre are approximately between five and seven miles. They have the highest levels of employment, the highest percentage of the population with two or more cars and the lowest levels of people living in houses owned by the Local Authority. The four wards are located to the north of the city as can be seen in the ward map in Fig. 2. Birmingham City Centre is located in the ward of Ladywood.

While considering the wards and super output areas that contain residents who most strongly demonstrate characteristics of potential alternative fuel vehicle drivers, it is also of interest to consider the wards which have a population least likely to be early adopters of alternative fuel vehicles. The 'unlikely adopters' cluster, constituting 298 super output areas, had the

Table 2
Output for cluster run of seven in order of likely adoption.

Ward method			% of age 25–59	% of owner occupiers	Combined % of detached and semi detached homes	% of those travel to work by car	% of households with 2 + cars	% of professional employees or managers within ward
Early adopters	N	Valid	259	259	259	259	259	259
	Mean (%)		**64**	**94**	**93**	**67**	**52**	**39**
	Std. Deviation (%)		4	4	7	5	10	7
	Minimum (%)		54	76	72	53	33	22
	Maximum (%)		77	100	100	82	83	68
Early majority first wave	N	Valid	493	493	493	493	493	493
	Mean (%)		62	87	87	58	29	25
	Std. Deviation (%)		5	9	10	5	7	6
	Minimum (%)		33	46	57	35	6	7
	Maximum (%)		76	100	100	72	57	52
Early majority second wave	N	Valid	473	473	473	473	473	473
	Mean (%)		61	75	55	57	26	29
	Std. Deviation (%)		6	12	11	8	9	12
	Minimum (%)		43	47	16	37	10	8
	Maximum (%)		76	100	76	83	55	66
Late majority first wave	N	Valid	454	454	454	454	454	454
	Mean (%)		57	70	23	49	16	23
	Std. Deviation (%)		9	10	11	8	7	14
	Minimum (%)		32	28	0	28	0	4
	Maximum (%)		79	91	52	77	39	67
Late majority second wave	N	Valid	618	618	618	618	618	618
	Mean (%)		54	47	43	47	13	15
	Std. Deviation (%)		5	12	11	7	5	6
	Minimum (%)		36	3	17	25	3	3
	Maximum (%)		71	80	88	71	37	51
Laggards	N	Valid	531	531	531	531	531	531
	Mean (%)		54	40	21	42	9	15
	Std. Deviation (%)		8	10	8	6	4	9
	Minimum (%)		38	9	3	22	0	2
	Maximum (%)		78	62	45	63	28	56
Unlikely adopters	N	Valid	298	298	298	298	298	298
	Mean (%)		*50*	*17*	*13*	*32*	*6*	*11*
	Std. Deviation (%)		14	10	9	8	6	5
	Minimum (%)		5	0	0	15	0	0
	Maximum (%)		84	42	39	67	33	31

lowest mean values. The highest concentrations of super output areas in this cluster (37%) are located in the wards enveloping the city centre, Aston (12%), Ladywood (11%) and Nechells (14%). These wards have the lowest car ownership levels and are amongst the wards with the highest levels of unemployment and Local Authority housing. In contrast to the 'early adopter' cluster, only 17% of the population in the wards identified here are home owners. Thirteen per cent of the population live in detached or semi-detached houses, just under one third of the population travel to work by car, 6% own two or more cars and 11% are professionals or managers.

7. Discussion

Using the cluster analysis technique, distinct population segments have been identified, making it possible to clearly distinguish wards with a large proportion of the population possessing the characteristics of potential early adopters.

The main finding was a strong spatial cluster in the outer wards situated towards the north of Birmingham city centre. The four wards of Sutton Vesey, Sutton New Hall, Sutton Trinity and Sutton Four Oaks, form the largest Parliamentary constituency in Birmingham. They are located to the north of the M6 motorway, which runs from the south east of Birmingham, past Manchester and up to Carlisle, on the border of England and Scotland. The M6 motorway cuts through the wards of Hodge Hill, Tyburn, Stockland Green and Perry Barr, allowing residents from the northern wards access to a major road network without having to contend with traffic travelling from the city. Commuters travelling to the city from these northern wards can access it through an A-class arterial road. It may make sense to locate a rapid-charge electric refuelling station on this arterial road, which is close to a motorway junction, to enable those who live locally to refuel electric vehicles in a shorter period of time than trickle charging allows. Such a location would also support the creation of a nationwide electric vehicle recharging network, allowing those travelling from north to south and vice versa along the M6 motorway, to recharge

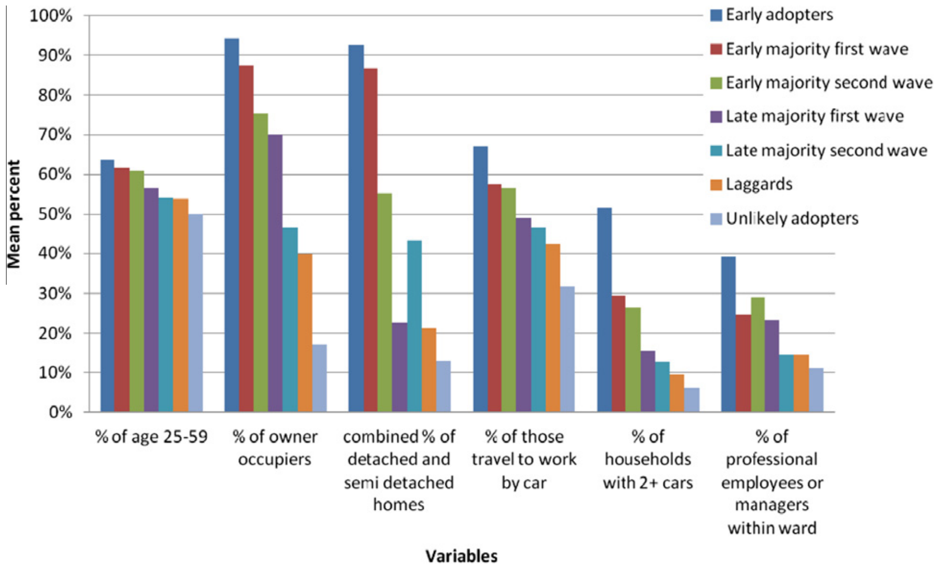

Fig. 1. Clusters in the cluster run of seven.

Table 3
Ward distribution of population showing characteristics of potential alternative fuel vehicle drivers.

Ward	Number of super output areas	Total percent (%)
Sutton Vesey	42	16.2
Sutton New Hall	38	14.7
Sutton Trinity	37	14.3
Sutton Four Oaks	36	13.9
Hall Green	23	8.9
Quinton	10	3.9
Billesley	6	2.3
Harborne	6	2.3
Northfield	6	2.3
Bournville	5	1.9
Handsworth Wood	5	1.9
Kings Norton	5	1.9
Moseley and Kings Heath	5	1.9
Bartley Green	4	1.5
Brandwood	4	1.5
Hodge Hill	4	1.5
Weoley	4	1.5
Edgbaston	3	1.2
Kingstanding	3	1.2
Erdington	2	0.8
Longbridge	2	0.8
Sheldon	2	0.8
South Yardley	2	0.8
Springfield	2	0.8
Acocks Green	1	0.4
Perry Barr	1	0.4
Stechford and Yardley North	1	0.4

their vehicles with ease en route. In the case of hydrogen vehicles, it may be pertinent to locate one of the first hydrogen filling stations on this arterial road for the same reasons.

The findings confirm many of the empirical findings from the literature. A very high percentage of the population in these wards was found to be home owners and live in detached or semi-detached homes. Williams and Kurani (2006) found that being a home owner was an important characteristic as it makes any necessary investment in infrastructure at the home a more viable option. Detached or semi-detached houses are more likely to have a garage or a driveway, which according to

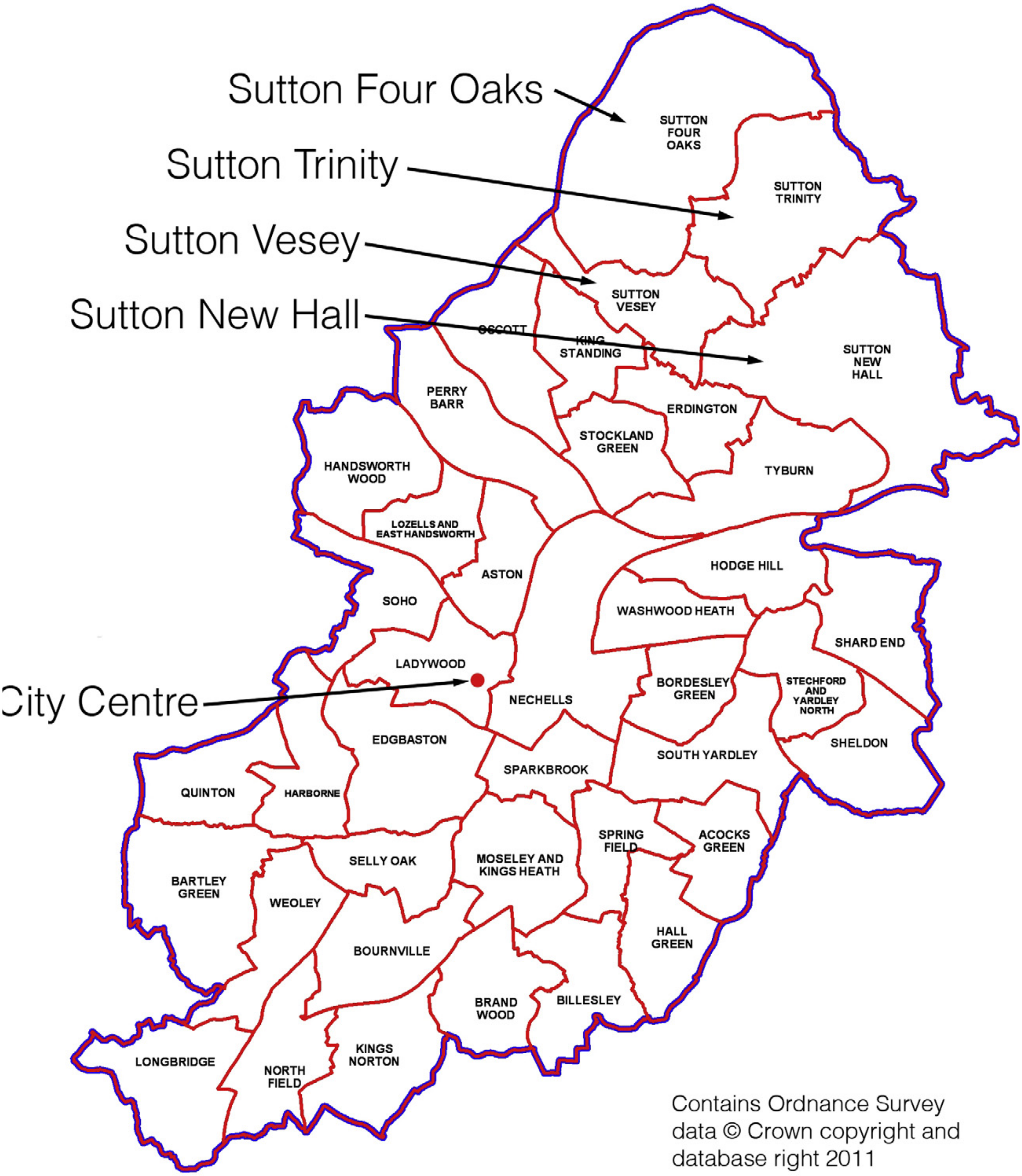

Fig. 2. Ward map of Birmingham.

Deloitte (2010), Ozaki and Sevastyanova (2011) and Williams and Kurani (2006) is important for providing a secure area to connect the vehicle to recharging infrastructure. Over half of the population own two or more vehicles; Kurani et al. (1995), Ozaki and Sevastyanova (2011), Deloitte (2010), and Graham-Rowe et al. (2012) all recognise car ownership, in particular owning more than one vehicle, as an influential characteristic with respect to owning an alternative fuel vehicle. As there was no data available for income, socio-economic status was used as an indicator of income. In the Census, socio-economic status is determined by occupation and therefore the occupation group 'professionals and managers', was used in this research to represent those expected to have a higher income than other occupation groups. Higher income is a key characteristic recognised by Deloitte (2010), Karplus et al. (2010), and Ozaki and Sevastyanova (2011). Almost 40% of the population are professionals or managers, a figure that is, perhaps, not as high as expected for this cluster. However, education, which was considered an important factor for those considering alternative fuel vehicles (Hidrue et al., 2011; O'Garra et al., 2005), affected the cluster results when used as one of the variables. In some cases, the mean values across all other variables were low and yet very high for education. This may have occurred in wards where there is a high student population, who are well-educated but are not affluent home-owners, yet having multiple cars in the household. This demonstrates that extra care needs to be taken when applying specific demographic characteristics to a given area and in the analysis of such a study, where prior knowledge of the area may prove invaluable.

Wards with a low level of potential alternative fuel vehicle owners have also been identified. There was a concentration of 'unlikely adopters' in wards close to the city centre. Low car ownership in some of these wards may, however, be due to good public transport links; Birmingham has several rail stations, with its main station, Birmingham New Street, offering direct rail links to London. The analysis showed that there is a low percentage of detached and semi-detached houses in these wards, attesting to the typical layout of a city, where one can expect to find higher density housing in inner suburbs. Inner city areas in the UK, particularly in de-industrialised cities, have been found to have high levels of deprivation in contrast to outer or rural suburbs, which is evident in the levels of unemployment, social housing and education (Gripaios, 2002).

With regard to policy development, the results of the analysis showed that the 'early adopter' cluster identified in Fig. 1, constituted a population with a large proportion owning two or more vehicles and showed high car dependency. A concerted policy effort is required to bring about a shift in behaviour towards alternative fuel vehicles such as electric cars. This could be achieved through greater promotion of Government incentives for the adoption of electric vehicles in the wards with high concentrations of potential alternative fuel vehicle owners. Providing the identified wards with the necessary refuelling infrastructure may help pave the way to a transition from a standard vehicle to an alternative fuel vehicle. Gärling and Thøgersen (2001) make the point that successful marketing to these early adopter market segments will pave the way for electric vehicles into the wider market for those who see electric vehicles as the new social norm, including single-car households. However, policy makers must remain aware of the social implications of installing infrastructure only in certain areas, and ensure that implementation is non-discriminatory. Increasing the visibility of refuelling stations may also help to increase awareness of alternative fuel vehicles and also help to reduce 'range anxiety', a fear that the vehicle may not reach its intended destination.

Clearly the infrastructure for electric vehicles and hydrogen vehicles, for example, is going to be very different through a centralised hydrogen distribution system, although through a decentralised hydrogen production system, such as a move to vehicle-to-grid technology, there may be the requirement for similar refuelling facilities.

In ongoing discussions with Birmingham City Council, and following the results of this research, the Council has stated that it will endeavour to provide a basic level of publically available charging points across the wards of Sutton Vesey, Sutton New Hall, Sutton Trinity and Sutton Four Oaks. It also intends to target workplace parking, Park and Ride sites, retail areas and leisure facilities as locations for installing charging points. Providing incentives for electric vehicle users through traffic management schemes, such as priority lanes, and free parking for electric vehicles, is also being considered.

Although wards with the highest number of potential early adopters of alternative fuel vehicles have been identified, this research is primarily concerned with determining the locations of these potential early adopters. The next step in the research will be a primary data collection to validate the results presented in this paper. An in-depth survey, conducted in the locations identified will also delve into the attitudes and travel behaviour of the population.

A further challenge for researchers, policymakers and vehicle manufacturers alike, is to identify and provide the necessary support and infrastructure for the 'mass market', once early adopters have bought and used alternative fuel vehicles.

8. Conclusions

This research has highlighted that it is possible to use Census data to investigate the locations of potential early adopters of alternative fuel vehicles. This is a novel, yet simple approach, with no evidence of such a study having been undertaken previously. A strong spatial cluster was identified to the north of Birmingham City centre, representing a cluster of people with greater affluence, higher car ownership, higher home ownership and higher socio-economic status than the areas of Birmingham that were identified with the lowest potential of becoming an early adopter of an alternative fuel vehicle. A concentration of these clusters was identified in areas located close to the city centre. This research provides a stepping stone to identifying the locations of different consumer segments of the population who, at the next stage, can be surveyed to reveal more in-depth information on behaviours and attitudes towards alternative fuel vehicles. This same methodology could be applied in other towns and cities, where detailed census data is available, as the first step to identifying potential alternative fuel vehicle drivers.

Vehicle manufacturers are also undoubtedly interested in the location of potential consumers. This research can, therefore, provide guidance for targeted marketing campaigns, such as product advertising on billboards in the identified wards, or in the local media.

Acknowledgements

The Engineering and Physical Sciences Research Council has provided funding for this work through the Doctoral Training Centre for Hydrogen and Fuel Cells Technology, and is gratefully acknowledged. The authors would like to thank George Bailes at Birmingham City Council for his support and help with providing data. Further thanks must also go to the two anonymous referees for their helpful comments.

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