Identifying the early adopters of alternative fuel vehicles: A case study of Birmingham, United Kingdom

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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.

Keywords
Alternative fuel vehicles
Electric vehicles
Early adopters
Driver characteristics
Cluster analysis

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 recognizing their role in contributing to the objective of decarbonising the economy and reducing oil dependency. New vehicle technologies such as 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 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 electric vehicle owners pay no excise duty (a tax on ownership) and are subject to the minimum level of company car tax (DfT, 2011). Secondly, it has provided £250 million (USD 400 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 £5,000 (USD 8,000) 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 50 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, a city 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 (Office for National Statistics (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 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 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 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 (USD24,000), 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 on to 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 Thøgerson (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 an 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 £4,000 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 it appealing 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 recognize 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 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 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 3,126 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, 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 was necessary 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 recognizes 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

The cluster analysis was applied to the 3,126 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 optimizes 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 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 ten per cent of total product adopters of innovations. It was, therefore, considered desirable to identify the top five to ten per cent 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.

Table 1
Variables included in the analysis

Variable	**Reason for inclusion**
Age group 25-59	Literature review: Deloitte (2010), 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), 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).

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 ten 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 ten-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 ten-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 Figure 1. Each of the seven clusters shown in Figure 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’. 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.

Table 2
Output for Cluster run of seven in order of likely adoption

Statistics

Ward Method			% of age 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
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%

Table 2 shows the highest mean values highlighted in green, while the lowest mean values are highlighted in red.

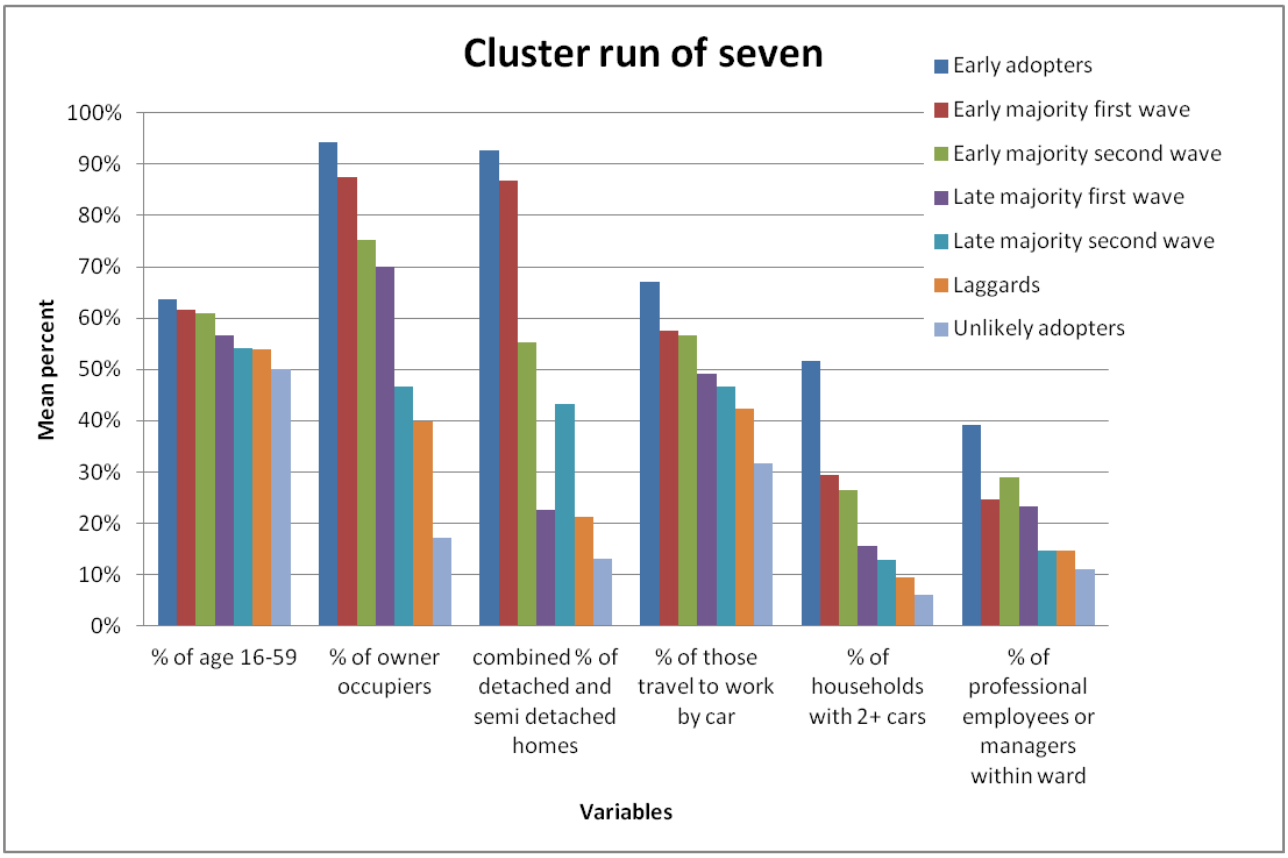

Figure 1. Clusters in the cluster run of seven

The number of super output areas identified in the 'early adopter' cluster constitutes eight per cent 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 category 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 is almost compelled to buy an alternative fuel vehicle. Again, this is one of the largest categories of adopters and the 'late majority second wave' is 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 nine per cent 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.

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%

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, 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 Figure 2. Birmingham City Centre is located in the ward of Ladywood.

Figure 2. Ward map of Birmingham

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 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 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. 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 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 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 recognize 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 recognized 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-industrialized 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).

With regard to policy development, the results of the analysis showed that the 'early adopter' cluster identified in Figure 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 Thøgerson (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 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

In conclusion, 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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