An exploration of household response to personal travel carbon reduction targets

AN EXPLORATION OF HOUSEHOLD RESPONSE TO PERSONAL TRAVEL CARBON REDUCTION TARGETS

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ABSTRACT

Transport is currently responsible for around a quarter of the UK's total anthropogenic CO_2 emissions and this proportion is projected to increase. The transport sector will undoubtedly need to play a significant role in achieving carbon reductions if the Government is to meet its ambitious long term goal of a 60% reduction by 2050. This paper examines current carbon use by households for personal land-based transport and considers how feasible it would be to change that use over the period up to 2050 in the UK. It provides a unique insight into how much and in what way households and individuals may be willing to adapt their transport behaviour to achieve carbon reductions.

A computer based transport carbon calculator was developed to investigate individual households' CO_2 emissions from various modes based on travel diary information. This formed the focus of a series of interactive interviews in which participants were asked to consider how their future low carbon transport strategy could look. Households' views on various abatement measures were explored, including technological change in vehicle design or fuel source and behavioural change through, for instance, traffic restraint and investment in public transport.

Overall, a 40% reduction in carbon emissions was seen to be feasible through a combination of behavioural change measures and a realistically achievable degree of technological improvement, falling well short of the UK government's goal of a 60% reduction. Through changes in behaviour alone the households involved could only achieve around a 20% cut in carbon emissions – seemingly a threshold beyond which further reductions will be difficult and may necessitate significant lifestyle change.

1. INTRODUCTION

The role of transport is significant in terms of global warming abatement. The transport sector is currently the second largest source of UK end user greenhouse gas emissions. As emissions from all other sectors are set to decline, transport emissions are predicted to continue to increase (DEFRA, 2004). Greater economic activity, higher incomes and growth in population have all led to mounting car ownership and an inexorable rise in car traffic (Lenzen et al, 2003), often at the expense of other more sustainable forms of transport (DfT, 2005). Between 1980 and 2003 travel by car in the UK has increased from 403 billion passenger kilometres to 678 billion - an increase of 68% (DfT, 2004a). The increased demand for personal mobility, and the freedom and independence it affords has, however, come at a cost to the environment. Road transport is the principal source of greenhouse gas emissions from the transport sector and responsible for around one quarter of the UK's total end user CO_2 emissions (DfT, 2004b).

If the UK Government is to achieve its goal of a 60% reduction in CO_2 emissions by 2050 (DTI, 2003), then these trends must change and need to do so in the near future. The transport sector and personal land based transport in particular, will undoubtedly have to play a crucial role in moving towards a low carbon economy. This paper examines how much change might be brought about through behavioural and lifestyle adaptations and adds new insights into the ways in which people might choose to adjust their current transport patterns and dependencies.

The specific aims of the work reported here were to:

- calculate the CO_2 emissions produced by a sample of households as a result of their personal land-based transport and to compare this to the levels implied by the UK governments long term goal of a 60% reduction in CO_2 emissions by 2050;
- determine what behavioural changes could be made under current circumstances in order to reduce carbon emissions;
- investigate the policy and technological mitigation measures most likely to be accepted and implemented to reduce carbon emissions in the future;
- analyse household responses and adaptive strategies and how they may relate to individuals' environmental attitudes;
- develop an appropriate computer based interview tool to enable the above to be done.

In this paper, section two presents an overview of previous research examining the means by which large scale change in transport may be brought about in order to significantly influence greenhouse gas emissions. Section three describes the methodology used to carry out the research, detailing the novel interactive computer based tool used to undertake the in-depth interviews. The findings of the household interviews are presented and analysed in section four, whilst final conclusions are given in section five.

2. THE POTENTIAL FOR DEEP CUTS IN TRANSPORT CARBON EMISSIONS

It is clear from the literature that there is relatively little work which has examined the need for deep cuts in carbon emissions from transport and how best such cuts might be achieved. One recent study which has looked at this question is the VIBAT study (Hickman and

Banister, 2005) which examined the feasibility of a 60% cut in UK transport emissions by 2030, using a backcasting approach. They conclude that such a target is hugely ambitious, may not be possible to achieve and may be an underestimate of the scale of the change required. Achievement of such targets will require imaginative use of both technology and behavioural change strategies. Similarly, Tight et al (2005), on the basis of a review of relevant work, conclude that technology alone is unlikely to be sufficient to bring about the required improvements in personal land-based transport by 2050. They also suggest that such technology may not actually materialise as expected for a number of reasons: firstly improvements may continue to be offset by mileage increases; secondly the size and weight of vehicles is increasing as is the uptake of in-vehicle devices such as air-conditioning (Zachariadis, 2006); thirdly technology may not develop as quickly as expected; fourthly renewable sources of energy required for alternative energy carriers such as hydrogen may not become available; and finally increased efficiency will result in lower costs of travel per kilometre and hence could lead to an increase in demand – the so-called rebound effect (Greening et al, 2000), though recent research (Small and Van Dender, 2005) has indicated that this effect may not be as large as initially thought.

Bristow et al (2004a) conclude that by 2050 we could reasonably easily achieve a 25% improvement in vehicle efficiency for personal land-based transport with current technology measures alone. A 60% improvement in efficiency through technology is just conceivable, however it would require immediate action, dramatic change to the vehicle stock and concerted effort from government, vehicle and fuel manufacturers. The offsetting effects of transport growth mean that a solely technical solution would have to deliver considerably greater reductions in vehicle emissions to achieve a 60% reduction overall. It is most likely that a substantive cut in transport emissions can only be achieved by a combination of technological and behavioural change, at least over the timeframe up to 2050. The success of such measures ultimately lies in how effective they are in persuading individuals to alter their travel patterns or lifestyles, to adopt new technologies and the effectiveness of those technologies. Research investigating the underlying factors that influence individuals' travel behaviour is therefore important in gaining an insight to public attitudes towards both technological and policy measure options. Bristow et al (2004a and b) assess various methods to achieve a 60% and an 80% cut in carbon emissions from personal transport by 2050. Changes of such magnitude are clearly going to be very difficult to achieve and will involve unpopular measures. Testing a range of scenarios for different available measures showed that the most stringent targets could only be reached by a combination of a high level of technical innovation, pricing measures to encourage take-up of such technologies and to reduce dependence upon motorised transport, government investment in 'soft' measures to encourage behavioural change and achievement of carbon zero public transport by 2050. Potter (2007) reaches similar conclusions through application of a simple environmental impact formula where he states that technical measures alone are likely to be ineffective and a combined strategy with demand management measures to address trip length, generation and mode share is the only viable approach.

Most studies to date have not looked in detail at the specific measures which might bring about deep cuts in carbon use in the transport sector and what they will mean to individual transport users, in particular, few have considered the lifestyle impacts of such changes. The approach followed here sought to fill that gap using a novel interview technique to explore with a sample of households their current transport behaviour and ways in which it might be changed.

3. METHODOLOGY

3.1 Introduction

This research was innovative in that respondents were requested to assess the likely impact of transport policy measures on their transport behaviour in both the short and long-term future and to consider ways of making substantive changes in their transport activity. "*The time horizon to which individuals relate in the process of adjusting their behaviour is important because, depending on how far away that horizon is, very different responses may be considered*" (Saloman & Mokhtarian, 1997). The study was also unusual in that it took account of policy measures aimed at promoting behavioural and lifestyle change in addition to technological advancements, to investigate how they affected respondents' travel behaviour and carbon emissions. There is clearly a methodological issue involved with asking people how they might change their behaviour at some point a long way into the future and it is unclear whether many people would ever normally make decisions related to transport on such timescales. However, for the purposes of this research it was considered important to get some idea of how respondents felt their behaviour could change both in the immediate future and if they were given greater time in which to adapt their lifestyles. For climate change many of the targets currently being considered are 40-50 years into the future and some of the possible technological solutions only start to have significant impacts over the same kinds of timescales.

Studies such as Fujii and Taniguchi (2005) have shown that provision of personalised feedback about travel opportunities and encouraging people to develop their own behavioural plans to reduce transport are effective approaches to promote behavioural change. Garling et al (1998) showed that an interactive interview procedure following on from collection of travel diary information made respondents consider their travel patterns and alternatives thoroughly with the result that predictive ability is improved. Interactive programmes such as HATS, the Household Activity Travel Simulator (Jones, 1979) or CUPIG, the Car Use Patterns Interview Game (Lee-Gosselin, 1989,1990), which encourage participants to analyse their current travel behaviour and to formulate their own adaptive travel plans, are much more effective in terms of behavioural intention and increase the likelihood of behavioural changes being subsequently implemented. Both the HATS and CUPIG methods of exploring household travel behaviour, by engaging participants in an interactive interview, made use of visual aids to communicate to respondents. This was found to facilitate their comprehension of how various policy measures or scenarios impacted on their travel behaviour.

The current research focused on travel behaviour and carbon emissions at a household level, since decision-making concerning travel behaviour is largely carried out at a household level. By gaining an insight into these decision-making processes, the research facilitates a better understanding of the factors influencing household choices relating to transport behaviour and their reactions to policy and technological measures.

The technique used involved an interactive interview procedure using a computer-based tool developed for this study for calculating transport carbon emissions. The tool used travel information collected from household travel diaries to establish how far participants were able and willing to go to change their transport behaviour in order to reduce their emissions of carbon. Participants' potential behavioural adaptations and responses to various measures were recorded by the tool, allowing for a quantitative assessment of carbon emissions savings to be made according to different transport strategies. The information provided by the in-depth interviews not only gave an insight into the reasons behind individuals' travel patterns, but also what conditions would be required in the future, to facilitate the success of low carbon measures.

3.2 The Computer Tool

The computer tool developed for this research had the ability to summarise household travel behaviour in some detail and to estimate resulting changes in emissions from changes in behaviour.

3.2.1 Information requirements. The principal input data for the computer tool was derived from travel diary information. Each household member was asked, for every trip made:

- time of departure and arrival
- trip purpose
- mode of travel
- distance travelled
- for private vehicles: the number of passengers and whether they were from the household or external e.g. friends or neighbours
- vehicle details including: make, model, engine size, age and fuel.

They were also asked for information on the number of people in the household and the name, age and gender of each person.

Information from the completed diaries was entered into the computer survey tool prior to the interviews and formed the base data to enable calculation of a household's transport carbon emissions over the course of an entire week. This base scenario could then be scrutinised by the household members to determine how they might modify their travel behaviour over time.

3.2.2 Calculation of Carbon Emissions from Cars. Average carbon dioxide emissions (g/km) were obtained from the Society of Motor Manufacturers and Traders (SMMT, 2005) website which provided information for different vehicle models, from January 1997 onwards. These figures take no account of factors such as vehicle maintenance and hence there is almost certainly an underestimate of actual emissions. For vehicles manufactured prior to 1997, emissions were established using the most similar model of vehicle covered by the SMMT database. It was concluded that emissions figures for 1997 models could reasonably be used for the small number of older vehicles since efficiency gains from technological developments in internal combustion engines over the previous decade had tended to be offset by a range of factors such as better safety standards and air conditioning (Bristow, 1996). If anything this may result in a slight underestimate of total emissions, but should not seriously affect the degree of change in emissions that households are capable of making.

Figures from the National Atmospheric Emissions Inventory (NAEI, 2003) were used to modify the results from the SMMT database to correspond to emissions for rural and motorway driving. Adjustment factors were derived for rural and motorway driving compared to urban driving, for petrol and diesel fuelled cars (shown in brackets in table 1). These factors were applied to SMMT figures for household vehicle CO_2 emissions.

Table 1 about here

All carbon dioxide emissions were converted to carbon by multiplying by 0.273. A factor of 1.15 was then applied to take account of emissions from the supply and manufacture of fuel (Bristow et al, 2004a). This provided figures for the ‘well-to-wheel’ carbon emissions which include the exhaust emissions created from driving the car and also those that are created in the production and distribution of the fuel (Foley, 2003). The computer tool worked out the emissions of other modes of transport internally, based on figures and assumptions formulated by Bristow et al (2004a).

3.3 Interview procedure

A sample of 35 households was drawn from within the City of Leeds in England. The sample was drawn from two groups, firstly a group of 15 who were from relatively high mileage households and drawn mostly from staff at the University of Leeds and two other large employers in the city and secondly a group of 20 from within the Transport and Environment Departments of Leeds City Council. Within both sub-samples participants were selected from a cross-section of different age ranges and backgrounds in an attempt to produce a sample that contained a broad spectrum of responses. The sample was not intended to be representative of the population as a whole, but rather to draw from a group of people who are likely to be reasonably environmentally aware and responsible and hence more open to making changes to their behaviour in order to reduce their impact on the environment. As such the results probably represent something approaching a best case scenario. Recent and ongoing survey results from the Department of Environment, Food and Rural Affairs (DEFRA) in the UK (DEFRA, 2001) shows that awareness of climate change is variable amongst different groups of the population, though growing. Nationally in 2001, 63% of 18-25 year olds and 78% of 45-64 year olds had heard of the term climate change, as had 91% of those educated to degree level. In 2005 a survey for the Department for Transport (DfT, 2006) shows around 80% of the UK population between 26 and 74 years are very concerned or fairly concerned about climate change, with a slightly higher level of concern amongst non-car users. Despite high levels of concern and awareness, there still appears to be a fairly poor level of understanding of the causes and implications of climate change (DEFRA, 2005).

The principal objective of the computer based software used was to permit households to examine their transport carbon emissions as a whole and to interactively experiment with different ways of reducing their emissions. The software presented the households with their current emissions of carbon and two personalised targets which they were asked to try to achieve or get as close to as possible. The two targets were:

- Target 1: A simple 60% reduction from the households' current level of carbon emissions from transport.
- Target 2: A 60% saving in carbon emissions in the UK to be met from all sectors, with transport's contribution permitted to increase from present levels. For this target it is also assumed that emissions are allocated equally across the population, producing a target for transport of 3.63 kg carbon per week on a per capita basis. This target was derived from a review of five key studies focussing on future low carbon scenarios for the UK (Bristow et al, 2004a).

These targets reflect two approaches which could be used to achieve the required carbon reductions and present varying levels of difficulty to households, depending very much on their existing levels of emissions. Target 1 is a straightforward 60% reduction of current emissions which might be particularly difficult to meet for households already having low carbon emissions, while Target 2, which is perhaps a more equitable approach, is based on an equal allocation of carbon emissions across the population and allows higher levels of emissions from transport.

On the basis of their input travel diary information the computer tool presented respondents with a number of different screens giving a range of personalised information about their household travel and carbon emissions. The initial screen shows details of each trip, identified by purpose, and represented by a bar on the screen, which is colour coded according to mode. Carbon emissions are denoted by the height of the bar, and duration of trip indicated by the width. Where household members shared the same trip, for example in the same car, these were interlinked and indicated by a white line on the screen. By interlinking the two trips, the emissions produced are only counted once and shared between those travelling.

The visual representation of emissions proved very effective in communicating to participants their current carbon emissions from transport in relation to the two targets and the effect of any changes made to their travel activity. It enabled different travel strategies to be explored by participants and quickly calculated and redisplayed any subsequent changes in their carbon emission levels (e.g. they could easily see the carbon impact of changing a specific trip from, say, car to bus). Participants were encouraged to analyse how and why they currently travel and to plan their trips more carefully with carbon reduction as the ultimate goal. This heightened people's awareness of what other modes or options could be available to them.

Given resource constraints and practical problems around a half of the interviews were conducted on a one-to-one basis with one household member representing the entire household, whilst the others involved more than one member of the household and opened up the possibility of discourse between those members. The interviews typically took around half an hour to complete, though involved considerable preliminary work including obtaining completed travel diaries from households, input and analysis of this data, as well as the process of setting up appropriate times and venues for the interviews.

At the start of each interview the participants were given a brief explanation detailing the aims and objectives of the research project. They were then introduced to the interactive computer-based tool. A visual comparison was made of their base transport carbon emissions against the two prescribed targets. A discussion was instigated concerning the reasons for their current travel behaviour and of any constraints that inhibit their travel choices. Participants were then asked to consider each day in turn by studying their current travel patterns, and to describe what changes they would be willing and able to make to reduce their carbon emissions under present circumstances. Any agreed changes were then recorded using the computer model. Possible changes included mode of travel, distance travelled, whether a trip is made and trip chaining.

By requiring participants to view their existing travel behaviour in detail a day at a time, the validity of the data could be crosschecked, reducing any errors incurred. This also ensured that the discussions which followed regarding behavioural response and adaptations would be based on modifying their ‘real’ travel patterns, rather than an optimistic assessment of the effects of the policy measure, separate from their actual behaviour (Jones, 1979, Fujii and

Taniguchi, 2005).

Once all possible emissions reductions had been made under current circumstances, the interview moved on to focus on longer term behavioural changes which household members may be able and willing to make (the behavioural scenario). Efforts were made to encourage interviewees to quantify the future conditions needed to bring about behavioural change. For example, what frequency and quality of bus provision would be required to instigate a modal shift from car to bus. Future policy measures were looked at in turn, and the discussion led on to how various supportive strategies were envisaged to influence their travel behaviour. Again, the software displayed the changes in carbon emissions relating to any transport changes made, including any additional amounts from, say, increased bus use (emissions from an additional bus passenger were based on vehicle emissions per kilometre and average bus occupancy levels for Leeds). Once all change options had been explored, the interview proceeded to the final technology based scenarios.

Two technology scenarios were considered: firstly a straightforward 25% reduction of each households' final carbon emission output (relative to the behavioural scenario) was made (technology (25%)); secondly a 60% reduction of each households' final carbon emission output (technology (60%)). These simulated future emissions reductions from use of new technology – the former relatively easily achievable given changes in purchasing behaviour (for example SMMT (2005) estimate this reduction could be more than achieved if all consumers chose best vehicle in class for CO_2 emissions), the latter at the top end of what might be achievable. The emissions reductions from the technology scenarios were imposed on the respondents by simply automatically reducing the emissions achieved in the behavioural scenario. The aim was to take some account of likely technological gains and to see whether these enabled more households to achieve their targets.

The final output screen for each household shows how well they are doing according to the targets. They are presented with their initial baseline emissions, the two targets set, their current scenario showing how they might make immediate changes to their emissions, the longer term changes they felt they could make under the behavioural scenario and finally their carbon output once improvements due to technological change had been added.

4. RESULTS

Participating households provided trip data for 87 individuals travelling a total of 28,381 kilometres over the one week sample period. Two thirds of the sample of individuals within the households were between 20 and 59 years, one fifth under 20 years and the remainder 60 years or above. There were on average 2.49 persons per household.

4.1 Base Travel Patterns

Of the 35 households sampled all but one recorded car travel over the course of the week. The single household with no journeys made by car did not contain a member holding a driving licence. Total distance travelled by car varied widely from household to household, from as little as 30 kilometres per week, up to 2,433 kilometres. All but two households made some trips by foot and just under half made some trips by cycle. Public transport was the second most common form of transport with twenty households making trips by bus, and thirteen using the train. Least utilised transport modes were taxi (6), underground[1] (3) and motorcycle (2).

Table 2 shows that the biggest distance travelled per household was by car. Public transport accounts for a lower proportion of household distance travelled and, as expected, cycling and walking mostly account for shorter journeys.

4.2 Changes in Mode Use

Table 2 shows the mode choice adopted by participants under current conditions and in response to future measures assisting behavioural change. The percentage change in kilometres compared to the base data is shown in brackets. A reduction of almost 8% in car kilometres was predicted to be achieved under current conditions, largely from participants substituting short distance car journeys by walking or bus. Under the forward looking behavioural scenario, a 28% decrease in car journeys was accomplished, with many households switching to bus and train instead. Under these conditions, journeys made by walking grew by 29% and cycling increased by nearly 60%, though from a lower base.

Table 2 about here

4.3 Carbon Emissions Savings

[1] Leeds does not have an underground railway system – these trips arise from at least one member of 3 households travelling to London during the travel week. Such travel, while not unusual, does not normally take place at such frequency and probably reflects a chance occurrence due to the small sample size, though it may be assumed that the kinds of people involved – professional, in employment – are more likely to make such trips than most.

Table 3 shows the number of households achieving each target and both targets together for the base and each of the scenarios – current, behavioural and technology. All households failed to meet a 60% reduction in emissions (Target 1) under base and current circumstances. However, Target 2 was achieved by two households, prior to any adaptations being made. Both these households were similar in that they were the only participating households that consisted of two adults, and two or more children under the age of 12. It can be argued that Target 2 would be easier for these households to achieve since it assumes emissions are allocated on a per capita basis and young children are unlikely to make many independent journeys.

Table 3 about here

Changes made under current conditions enabled a further household to reach Target 2. Only once policies aimed at evoking behavioural change were introduced, was Target 1 achieved by a household, with another achieving both emission reduction targets. Applying the 25% reduction to final carbon emissions outputs to take account of future advancements in technology, enabled a further five households to reach one or both targets. A 60% reduction in final carbon emissions enabled all households to meet at least target 1 (as would inevitably be the case), though only 60% of households achieved both targets even with this very large technological boost. With the more feasible 25% technology improvements, less than one-third of households achieved one or both targets.

It is worth noting that base average carbon emissions per person per week were 9.2 kilograms. This was more than 2.5 times greater than the Target 2 figure of 3.63 kilograms, assuming that emissions are allocated equally across the population, illustrating the difficulty of achieving such a target.

4.4 Travel Adaptations under Current Conditions

Under current circumstances, with no policy interventions, only a small reduction in carbon emissions (-3.5% on average) was achieved. This reduction is lower than the reduction in car kilometres as household strategies included a degree of transfer from car to other carbon emitting modes. The types of changes households were willing to make included:

- Public transport instead of car (14)
- Cycle instead of car (7)
- Walk instead of car (9)
- Telecommute (4)
- Use of household's most efficient car (2)

It should be noted that there were some caveats which came with these choices, for example some would only cycle if there were less traffic, whilst reliability would be a key factor in public transport use.

The majority of short-term adaptations to travel behaviour made by households to reduce their emissions, were in terms of their leisure activities, for instance shopping, visiting friends, sport and the pub were all journey purposes presently being made by car, but were altered to be made by foot, public transport or cycle. Some households said that laziness was primarily the reason for choosing to use the car for very short journeys to the local shops and that they rarely gave their carbon emissions a second thought.

Households were rather more rigid in resisting alterations to their work journeys and such travel remained largely unaltered under current circumstances, though some did consider the possibility of going to meetings by bus rather than by car.

Fifteen households (43%) made no changes to their travel behaviour under the ‘current’ travel scenario. Three principal reasons relating to the current situation emerged as to why behavioural adaptations could not, or would not be made:

- five households where one member commuted to work by car were unwilling to substitute their car use due to the incentive of free parking currently provided by their employer;
- three households were unable to make any emission savings under current conditions since they already had very low carbon emissions;
- three households were tied into their current behaviour due to specific circumstances, for instance, physical disability or lack of alternative provision.

It seems that in the short term households are willing and able to make some changes at the margins to reduce their carbon emissions, but crucially, they are very much restricted in what they could change by existing lifestyle decisions, which effectively limit their choice of alternatives to car use. More major lifestyle changes would take rather longer to implement.

4.5 Travel Adaptations under Future Policies

An average saving of roughly 21% in carbon emissions was achieved under policy measures that favoured behavioural change. Three households failed to make any changes under the behavioural scenario, though all of these started from a fairly low base and hence reductions may have been difficult to achieve. Only two additional households achieved either target compared to current conditions.

Qualitative analysis of the results from the in-depth interviews provided an insight into how these carbon savings are likely to be achieved in the future, and included transfer of trips from car to public transport, cycling and walking, trip chaining, car share and telecommunications replacing trips. Key policy instruments were promotion of public transport and car clubs and implementation of pricing regimes for parking and car use. The majority of respondents currently using their car were only willing to reduce their car use if ‘stick’ measures were to be introduced such as parking charges or congestion charging. ‘Carrot’ measures alone, such as improved public transport were not seen to be enough for participants to switch car journeys to public transport. Some form of pricing to restrain traffic demand was thought to be an effective method for encouraging a modal shift to more sustainable forms of transport. These findings conform with the kinds of results found in a range of other surveys looking at the effectiveness of travel demand management strategies, which suggest that to successfully make significant changes to behaviour requires use of measures which force change rather than simply encouraging it (see for example the overview by Meyer, 1999). Interestingly such studies also tend to show that milder encouragement based measures are more popular with the public and decision makers than measures which enforce change, given the controversy that such measures may raise (Hodgson and Tight, 1999, Garling et al, 2002).

4.6 The Technology Scenarios

The 25% technology scenario brought about an average reduction in carbon emissions compared to the base of just over 40%. The 60% technology scenario resulted in an average reduction of nearly 70% compared to the base.

When questioned on the main decision criteria in their choice of current vehicle the crucial aspect influencing the decision was found to be cost, though practicality and to a certain extent fun were also important. The importance of fuel economy varied considerably with around half the households rating it as important, whilst others failed to give it much consideration. One householder said "*fuel costs would have to double before fuel consumption became an issue for me*". The connection between fuel consumption and carbon emissions was not widely understood, with most households only considering cost savings in fuel instead of the benefits for the environment.

Participants were open to the idea of new vehicle technologies with many willing to pay a price premium for lower carbon vehicles, though it was notable that most of these came from the sample of 20 drawn from the city council, rather than from the more general sample. Amounts varied from £500 more (10), up to £1000 more (3). Many were more receptive to the idea of a price premium if linked to increased efficiency and fuel savings. The initial expense of new technologies was a deterrent.

Households not willing to pay a price premium for a lower carbon vehicle included many with second hand cars. For instance one household said they would only consider new technology vehicles if in 10 years' time they were on the second hand market. Low mileage car users were also found to be willing to pay less because many of them did not want to pay a high price for a vehicle that is rarely used.

Factors influencing a household's future decision to purchase a hybrid or fuel cell vehicle in one case included possible exemption from charges for car use. Similarly, another household said that by the time they come to change their car, more will be known about what form road user charging will take. They will then be able to make a more informed decision as to whether purchasing a hybrid or fuel cell vehicle will work out cheaper in the long run, or if they will be charged regardless.

In terms of potential new fuels such as biofuels and hydrogen, households generally welcomed their future development and would be happy to use them should they become widely available, affordable and with adequate refuelling infrastructure. One household said they felt empathy for the environment and so they would like their vehicle to be run on more sustainable fuels. However, they said that the cost implications would influence any future choice.

One household was wary of new biofuel technology, citing extensive land take and intensive farming procedures using pesticides and poisons as reasons against their widespread use. Most importantly they disagreed with the way in which new technologies perpetuate the idea that personal mobility will be possible in the future, whereas efforts should be focussed on actually reducing travel demand.

Households' responses to the various policy measures and new technologies were found to be predominantly dictated by cost, supporting the findings of Loukopoulos et al (2004).

Households would weigh up their choice of adaptations with the purpose of minimising the costs incurred, both in terms of time and money.

5. CONCLUSIONS

The computer-based tool proved very effective in communicating to households their current transport carbon emissions in relation to reduction targets and aided in exploring ways in which carbon emissions could be reduced. Some participants were surprised at just how challenging the UK government's 60% goal was to meet when related to their transport behaviour. For households currently using sustainable forms of transport with a low base level of emissions a 60% reduction (target 1) was considered very difficult to achieve. Such participants thought that it was unfair to expect everyone to reduce their emissions by 60% as it bears no relation to whether they are currently high carbon emitters or low. It was therefore felt that target 2 was the fairer of the two targets, being based on an equal allocation of carbon emissions on a per capita basis.

It is recognised that respondents stated behavioural changes in response to the targets set may not reflect what they would actually do and that their stated behaviour probably represents a best case scenario. However, the method used to obtain the data, where respondents are presented with personalised journey specific information, makes them think in a non-abstract way about their behaviour and carefully consider the options open to them to reduce their carbon emissions. It is also notable that the changes households are willing to make are actually quite minimal, probably reflecting a considered response about what is actually acceptable and feasible.

Under current conditions, taking account of changes respondents felt they could put in place immediately, only small changes in travel behaviour were found which reduced carbon emissions by around 3.5%, with an 8% reduction in car kilometres. All households failed to meet a 60% reduction in CO_2 emissions under current circumstances and 15 out of the 35 were unwilling or unable to make any changes to their travel at all. Participants listed increased time, inconvenience and cost as reasons for why they were unwilling to switch their car journeys to more sustainable transport modes such as public transport. In many cases households rarely gave carbon emissions a second thought in relation to their travel behaviour and it is clearly not currently a major driver of behavioural change.

Under the behavioural scenario, where households were asked to consider changes they might make in future conditions, a 21% reduction in carbon was achieved and a 28% reduction in car use, though it was notable that only four households managed to meet target 2. Respondents clearly had some difficulties considering changes over long time periods, however, the in-depth discussions helped to clarify their thoughts and drew out in general terms the kinds of strategies they would consider. Overall, this figure of roughly a one-fifth reduction in carbon resulting from longer term behavioural change might represent a 'threshold of pain', beyond which the kinds of changes required of most households will be difficult to achieve and will start to mean significant changes to their lifestyles. This finding is similar to Lee-Gosselin (1989) who concluded that households could afford to reduce their travel by up to 20% without serious loss of quality of life.

For both the current and behavioural scenarios cost minimisation was the principal factor dictating households' adaptive responses to policy measures. Participants tended to weigh up the cost effectiveness of various options (in terms of both time and monetary savings) and would continue to use their cars up until the point when cost became too high. Only through pricing mechanisms such as the abolition of free parking permits provided by their employer, or the introduction of road user charging, were households incentivised to reduce their car use.

Applying a 25% reduction to take account of efficiency gains from technology delivered a 40% cut in emissions from transport, overall still falling well short of the government's 60% goal. Only when a 60% cut was made to the behavioural scenario figures to take account of further efficiency gains from technology were just under two-thirds of the households able to achieve target 2. Current evidence suggests that such a large efficiency gain from technology is very much at the top end of what is possible and is unlikely to be realistic.

Although only a small sample of households was interviewed, a great deal of information was obtained, giving valuable insights into their decision-making processes and factors influencing their travel behaviour. The sample, while not intended to be representative, consisted of a group who were reasonably environmentally aware and hence likely to be willing to consider changes to their behaviour in order to reduce their carbon emissions. Much more entrenched behaviours are likely to exist amongst other groups of the population and hence the behavioural change reported here is likely to be towards the top end of what might be achieved voluntarily. Results found that short-term adaptations tended to be made to leisure activities such as shopping or visiting friends. For some journeys such as trips to a hospital, it was often impossible to substitute car use with any more sustainable modes and individuals had only a limited degree of control over their behavioural choices. There were also locational differences in the choice of transport modes available, for example trips in rural areas tended to have relatively poor public transport provision.

This research suggests that for the UK government's aspiration of a 60% cut in CO_2 emissions to be achieved (even allowing for an increase in the current contribution of transport relative to other sectors), the majority of households will be required to make substantial changes to their current travel behaviour. Critically, this assessment of household emissions does not consider future increases in transport demand, which will make the achievement of targets even more difficult. Evidence showed that people are unlikely to voluntarily choose to alter their travel behaviour or to adapt their lifestyles in order to reduce their carbon emissions and that this would be difficult to do. Even where voluntary changes were made in the absence of policy interventions, few emissions savings were made. The findings of this research highlight the need to obtain considerably more than a 25% reduction in emissions through technology in the period to 2050. They also show that it will be necessary to give serious consideration to a range of other measures to complement technological change in order to bring about significant behavioural change. Such measures might include pricing or the implementation of some kind of emissions quota. However, it should be noted that the scale of change required is likely to mean that such measures will at best be difficult to implement and potentially very unpopular with both transport consumers and with those responsible for implementing the measures. More work is certainly required on the acceptability and perceived equity of such measures and on how best to educate people on why they are necessary – it was noticeable from this research that few households are aware of the scale of the changes required.

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Figure and Table Captions

Table 1: Fleet weighted emissions of CO_2 (grammes per km) using different fuels under different driving conditions (ratios to urban emissions in brackets)

Table 2: Household travel (kilometres) by mode per week (percentage change compared to base)

Table 3: Changes in total Carbon emissions (kilograms) by scenario and numbers of households achieving targets

Table 1: Fleet weighted emissions of CO_2 (grammes per km) using different fuels under different driving conditions (ratios to urban emissions in brackets)

	Rural	***Urban***	***Motorway***
Diesel	118 (0.72)	165	144 (0.87)
Petrol	177 (0.84)	211	245 (1.16)

Source: adapted from NAEI, 2003 by Bristow et al, 2004a.

Table 2: Household travel (kilometres) by mode per week (percentage change compared to base)

Mode	***Base***	***Current***	***Percent change***	***Behavioural***	***Percent change***
Car	18609	17168	-7.74	13430	-27.83
Walk	1067	1186	+11.15	1378	+29.15
Bus	1528	2571	+68.26	3217	+105.37
Train	5795	5337	-7.90	7130	+23.04
Taxi	341	307	-9.97	288	-15.54
Cycle	590	687	+16.44	926	+56.95
Motorcycle	375	386	+2.93	351	-6.40
Underground	76	76	0.00	76	0.00
Total	28381	27718	-2.34	26796	-5.58

Table 3: Changes in total Carbon emissions (kilogrammes) by scenario and numbers of households achieving targets

Scenario	**Total Carbon emissions (kg)**	**% reduction relative to Base**	**Number of households achieving targets (total 35 households)**		
			Target 1	Target 2	Both targets
Base	804	-	0	2	0
Current	776	-3.5	0	3	0
Behavioural	635	-21.0	2	4	1
Technology (25%)	477	-40.7	3	8	1
Technology (60%)	254	-68.4	35	21	21