Analysing rail travellers' desire for reducing carbon emissions from personal travel

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ABSTRACT

Rail is generally regarded to be more environmentally friendly than other forms of transport. Indeed, it is hypothesised that at least a small proportion of rail trips are made due to the relative environmental benefits of rail over competing modes. This paper reports on a recent study carried out in the United Kingdom which surveyed over 3,000 rail users, asking a series of questions to investigate baseline understandings of environmental issues as they relate to rail travel and the extent to which rail demand is currently influenced by environmental concerns. The study then investigates respondent's desire for reducing carbon emissions by fitting discrete choice models to data collected through a stated preference survey. The study highlights important variations across the population in their valuations of reductions in carbon emissions. Crucially, these variations retrieved in the modelling analysis align very closely with the environmental attitudes retrieved in earlier stages of the survey.

1 INTRODUCTION

Rail travel is an environmentally friendly form of transport compared to its chief competitors of road and air transport. In the UK, where at present only 40% of the network is electrified, rail has lower per passenger kilometre emission figures for CO_2 than car and air travel (cf. CfiT, 2001), and this is likely to decrease in the future given the recent announcement of further electrification of key rail routes (DfT, 2009). Rail currently contributes only around 1% of total UK carbon emissions, compared with 17% for road transport (cf. DfT, 2007). As well as comparatively good environmental performance on such objective measures, the general public also believes that trains do little to contribute to climate change, with only 1% of respondents to the national British Social Attitudes Survey believing that trains contribute most to climate change relative to other modes (cf. DfT, 2008).

It might therefore be hypothesised that some journeys will be taken by rail as a result of its environmental advantages. The literature suggests however that determining how demand for travel might change in the future if the public becomes more pro-environmental is a difficult task. There are several key issues:

1. Asking questions about the environment is difficult as the phenomena are complex and quantitative methods may be superficial (cf. Poortinga et al., 2006),

2. The relationship between what people know about the environment and how this affects their attitudes is not well understood (cf. Anable et al., 2006),

3. The relationship between attitudes and actions is also complex and travel behaviour is strongly affected by factors such as cost, convenience and reliability which can have a higher weighting to travellers (cf. Marsden et al., 2009).

The aim of this study of rail demand in light of environmental concerns was to use a mixed methods approach to consider demand for rail from different perspectives, and thus acknowledge the issues above in our methodology. To overcome the first issue a series of focus groups were used to scope out the understanding of some key environmental concepts amongst a sample of rail and non-rail users. This qualitative understanding provided the basis for development of our questionnaire, which incorporated both psychometric and econometric aspects. We discuss this further in the methods section (Section 2).

Current research into environmental awareness and attitudes suggests that a moral norm (the morals and responsibilities that guide what individuals believe they should do in a given situation) to take action to help the environment is important in forming intentions to make travel behaviour

changes which reduce carbon (Eriksson et al., 2008; King et al., 2008). We might therefore expect the rail user population to exhibit a stronger overall moral norm to help the environment than the average traveller.

The relationship between attitudes and actions is perhaps the most complex and difficult to collect data on. There is clear evidence in the literature to suggest that many issues mediate between people's actions and their intentions to behave in a particular manner (e.g. Nilsson and Küller, 2000). A variety of approaches can be used to understand the relationship between attitudes and actions, and these are discussed further under methods. The approach that this paper goes on to focus on though is a form of stated preference survey. Such surveys offer a means of people trading off between different attributes as a means of understanding preferences (see e.g. Louviere et al., 2000). It is therefore of interest to explore the way in which rail travellers may be willing to sacrifice reductions in travel time in return for reductions in CO_2 emissions.

The research reported here builds on and adds to the growing body of work looking at public willingness to pay for environmental benefits, in particular in an air travel context. Here, recent work has looked at the willingness of air travellers to pay for carbon offsets for their air travel (e.g. Brouwer et al., 2008; Mackerron et al., 2009; Collins et al., 2009). Brouwer et al. (2008) found that three-quarters of all air travellers questioned stated that they would be willing to pay an additional offset charge in addition to the price of their current ticket. They applied a "double bounded (DB) dichotomous choice" (p306) contingent valuation question which identified the approximate values people stated they would pay. The resultant average valuation was "60 eurocents per 100 km they fly …with an average WTP of about 25 euros per tonne CO_2-eq" (p307), which is low compared to the Stern review (Stern et al., 2006) estimate of the social damage costs of carbon of $85 per tonne. It is well known that contingent valuation approaches are likely to be affected by significant levels of strategic bias (cf. Louviere et al., 2000), and have in fact been completely discarded in some contexts. An alternative is to infer (rather than directly ask for) the valuations of carbon reductions by including them in a more general stated choice survey where respondents are asked to choose between different alternatives made up of a number of attributes. Here, Collins et al. (2009) recently included a carbon tax as one of the attributes in a stated choice experiment for air travel and found that the sensitivity to the carbon tax is roughly half as high as the sensitivity to air fares, suggesting that travellers clearly have a lower reluctance to pay for what is deemed to be a good environmental cause.

The remainder of this paper is organised as follows. The next section describes the survey work carried out for this study. This is followed by a discussion of the two main parts of the analysis; looking first at the environmental attitudes coming out of the early parts of the survey before turning our attention to the analysis of the stated preference data. Finally, we present the conclusions of the work and outline areas for future research.

2 SURVEY WORK

As set out in the introduction, the survey methods for this study were a mix of qualitative and quantitative approaches. There were two key phases to the data collection, firstly a series of focus groups, and secondly a number of on train and at platform surveys.

Four focus groups were held in UK cities in September 2008. The focus groups explored what people understood about the environmental impacts of rail use and if and how environmental concerns feature when choosing whether to travel by train. Participants with differing amounts of rail use were recruited according to how they are classified in an official UK government pro-environmental behaviour segmentation model (DEFRA, 2008). Two groups were recruited that had high potential and willingness to act (Positive Greens and Concerned Consumers), and two groups that had

potential to act but lower willingness (Waste Watchers and Cautious Participants). The data from the focus groups provided an in-depth understanding of people's perceptions about rail and the environment, and this was used to help design the questionnaire survey, in particularly to word questions such that they were meaningful to respondents at the same time as collecting the data needed for the research. In particular, when asking about the importance of 'the environment' relative to other attributes of travel, we used the umbrella term 'environment' rather than breaking this down into different components, as the focused groups revealed considerable confusion regarding the different components, but an understanding that climate change per se was perhaps the major environmental issue. Further, in the stated preference exercise, when asking people to trade off journey time savings with environmental benefits we used the percentage change in 'greenhouse gas emissions', since the focus groups suggested that participants are familiar with this term even if they have a poor understanding of which emissions are included within it. For example, talking about kilograms of CO_2 was relatively meaningless to most people. We also drew on the focus group findings to support the analysis and interpretation of the questionnaire data.

As mentioned above, the questionnaire survey was administered on trains and at rail stations. Six long-distance services were selected for on-train surveys covering a range of UK national circumstances, including routes which had strong modal competition especially from air. The on-train methodology was predominantly 'distribute & collect' in that questionnaires were distributed to rail travellers during the course of their journey, and completed questionnaires were collected at the end of the trip. Surveys were carried out throughout the day with the majority of services surveyed between 7am and 4pm to ensure a wide profile of passengers. Such methods are not feasible however on commuter routes to London and other major cities and so mailback copies of the same survey were distributed at four stations in London and at stations in both Manchester and Birmingham. The survey teams worked at the stations all day (7am untill 6pm).

The questionnaire was used to collect data on rail use in general and more specifically, for the day of the survey (e.g., frequency, ticket price and perceptions of reliability). In addition, the survey collected data on socio-demographics, attitudes both generally and specifically based on the Theory of Planned Behaviour (Ajzen, 1988), segmentation, and stated preference techniques. The research was thus mixed methods in two respects; it mixed qualitative and quantitative approaches, as well as bringing together psychometric and econometric techniques. The psychometric data collection utilised the Theory of Planned Behaviour, which states that behaviour (in this case catching the train to help the environment) is a result of intentions. Those intentions are in turn based on attitudes, social norms (in this case the influence of significant others and people the respondents know more generally), and perceived behavioural control (perceived ability to do something taking into consideration opportunities and impediments, in this case catch the train). In this study, moral norms were also added as a fourth antecedant to intentions. This area of the research was dealt with by four questions in the survey asking respondents to indicate how much they agreed or disagreed with a series of statements as outlined in Table 1.

The moral norm data was used with the other antecedents of intentions specified by the Theory of Planned Behaviour to explain intentions to catch the train to be environmentally friendly, and in conjunction with the rail use data and focus group findings establish whether those intentions explained actual behaviour, or whether other factors mediated between intentions and behaviour. The moral norms were also integrated into the discrete choice modelling as explained in Section 4, to assess the link between key attitudinal factors and actions. A full explanation of the psychometric aspects of this research, including the results, is provided in Shires et al (2009).

Table 1: Questions to assess moral norms

	Strongly agree						Strongly disagree
It is my responsibility to take action to be environmentally friendly.	1	2	3	4	5	6	7
I am morally obliged to take action to be environmentally friendly.	1	2	3	4	5	6	7
It is my responsibility to catch the train more to be environmentally friendly.	1	2	3	4	5	6	7
I am morally obliged to catch the train more to be environmentally friendly.	1	2	3	4	5	6	7

The stated preference section of the questionnaire centred upon a ranking question as outlined in Table 2. The rankings were based upon the current train journey time and the key tradeoffs involved reductions in journey time and reductions in greenhouse gases. Journey time was preferred to fares in this context because evidence from the focus groups suggested that it was considered a less contentious attribute, potentially avoiding strategic bias. In addition, it was felt that offering reductions in journey time was more realistic than offering reductions in fares. An additional feature of the ranking exercise was an attempt to mask the intentions of the exercise by introducing two dummy choice that were always presented to the respondents but never used in the analysis: these being (1) The chance of a getting a seat; and (2) The chance of a train arriving at its destination on time. When presented with the ranking experiment the respondents were asked to consider a number of potential changes to their current rail journey and rank them in order of preference. A specific request was made to ensure that respondents did not allow for any ties in their ranking of alternatives.

Table 2: Ranking experiment

Changes to Your Current Rail Journey	**Ranking (1 to 8) *where*** 1 - most preferred change & 8 - least preferred change
Time spent travelling on the train is reduced by 5%	
Amount of greenhouse gases generated by your trip is reduced by 20%	
Amount of greenhouse gases generated by your trip is reduced by 10%	
Time spent travelling on the train is reduced by 15%	
There is a higher chance of getting a seat than currently	
Amount of greenhouse gases generated by your trip is reduced by 30%	
Time spent travelling on the train is reduced by 10%	
There is a higher chance of your train arriving at your destination station on time than currently	

3 ANALYSIS OF ENVIRONMENTAL ATTITUDES

This section presents the findings coming out of the study of the early parts of the survey, relating to environmental attitudes and intentions. It was immediately clear that train travel was perceived to be an environmentally friendly mode. Survey respondents ranked five transport modes according to how environmentally friendly a journey of 100 miles would be relative to the other modes. Overall respondents ranked electric train as the most environmentally friendly mode followed by diesel train, coach, car with passengers and finally, car with driver only.

The perception of train as the most environmentally friendly mode appears to be broadly unsupported by knowledge. Based on our journey of 100 miles, carbon comparators suggest that coach is in fact more environmentally friendly than electric train. As such, none of the survey respondents gave the correct ranking of modes. This uncertainty was reflected in the focus groups:

> *"You imagine it [train] to be more effective but like you say, you do not know, you are just sort of thinking that way I think." [Concerned Consumer, female]*

The environmental performance of each respondent's current rail journey was rated highly relative to other trip attributes. During the survey, respondents rated a list of statements relating to their current rail journey according to how much they agree or disagree with the statement. This was again done using a 7 point Likert scale with 1 being strongly agree and 7 being strongly disagree. For all statements, the average ratings varied from 2.5 for "I can make productive use of time spent travelling" to 4.0 for "The fare structure is simple," indicating that no factors were considered unimportant. "The train service is environmentally friendly" received an average rating of 2.9 and was ranked third in the list of statements, with making productive use of travelling time and the journey being safe in terms of personal security ranked first and second respectively.

Set against this positive environmental image of rail is a reality which suggests that for most people in most journey contexts, the environment is not amongst the most highly rated features in the decision making process. Indeed, when asked to consider which factors are important when travelling by train (using the same Likert scale) "the train service is environmentally friendly" was rated lowest (average of 2.6) whilst the highest was "the train service is reliable" (average 1.6) followed by getting a seat and train fares being good value for money.

A breakdown of the rankings by sociodemographics and pro-environmental segment revealed that Positive Greens, females, those aged 60 years and over, and commuters gave greater importance to train travel being environmentally friendly than other subsets, though they still ranked it as being of less importance than most other factors.

Similarly, the focus group participants placed other factors ahead of the environment when considering travel by train.

> *"if I am travelling somewhere, you know, I look at cost first and time, and then I would eventually get down to whether it affects on the environment." [Positive Green, female]*

In order to investigate the potential for response bias (e.g. respondents saying they use train for environmental reasons because they believe that this is the "correct" answer), two versions of the questionnaire were produced. Respondents were asked to select from a list of options the main reasons they had chosen to travel by train instead of using alternative means on the day of the survey. "Train being environmentally friendly" was presented as an option on half of the questionnaires, but omitted from the other half. In these questionnaires, an "other" option was

included with a space to specify the "other" reason. Responses to this were then compared with the number checking the environmentally friendly option in that version of the questionnaire.

A total of 15.5% of respondents selected the environmentally friendly option as a reason for their current trip being by rail when this was presented, but just 0.6% of respondents used the "other" option to state that they had chosen train for environmental reasons when the option was not presented. Of the latter a quarter stated that their companies had policies in place to encourage environmental travel. This finding seems to reinforce those above that whilst the environment is relevant and important, it is not foremost in respondents' decisions to travel by rail. This corroborates previous research into climate change and travel choices, which suggested that a journey being environmentally friendly was an added bonus, rather than a key deciding factor (King et al, 2008).

The results of the psychometric analysis (which used multiple regression with intention as the dependent variable, and the Theory of Planned Behaviour antecedents of intention as the independent variables (Shires et al, 2009)) further support this finding. Approximately 50% of rail users intended to catch the train to be environmentally friendly in the future, and it was possible to explain 56% (adjusted Rsq 0.56) of intentions per se (i.e., regardless of direction of intention). The explanatory factors in order of contribution to explanation were moral norms (t 17.82, sig at 95%), social norms (t 12.73, sig at 95%), perceived behavioural control (t 11.22, sig at 95%) and attitudes (t -2.25, sig at 95%). It is clear therefore that norms are highly significant in forming intentions to travel by rail for environmental reasons, and further, the research (Shires et al, 2009) suggested that business travel policies may contribute to the importance of social norms. The significance of norms in explaining intentions is unusual and sheds new light on understanding of rail demand, and potentially mode choice in relation to environmental factors per se.

Previous mode choice and the environment research using the Theory of Planned Behaviour (King et al, 2008; Jopson et al, 2009; Jopson, 2003; Forward, 1998) suggested an important role for norms in forming intentions, but it has always been second to the influence of perceived behavioural contol as illustrated in Table 3. Further, it is surprising that control and attitudes are not higher in the list of explanatory factors given the evidence above regarding issues that are important when travelling by train. However, if users have sufficient experience of rail travel (or any other mode) to feel confident about catching the train (or bus, or walking etc), control and attitudes may be less central to forming intentions. The implication being that if you can take it for granted that the important factors such as value for money and reliability are in place, then norms will be deciding factors. This is an important conclusion for the promotion of environmentally friendly modes. However, if important factors such as cost etc are found not to be in place, intentions will not be translated into actions. This is supported by the fact that in this case it was not possible to explain behaviour (train travel) based on intentions to catch the train because cost and other practical issues did not support rail use. Taken together with the evidence above, and that from previous research (King et al, 2008), the lack of explanation of behaviour suggests that whilst respondents may have a moral goal to travel in an environmentally friendly manor, issues such as cost and reliability intervene between intentions and behaviour. For example, an intention to save money may prove stronger than that to be environmentally friendly. Nevertheless, it is crucial to build on pro-environmental intentions given that they are the precursor to behaviour that will contribute to reducing carbon emissions (when other contextual issues such as cost also support pro-environmental behaviour). Consequently, the most significant fact in explaining intentions (moral norms) was taken forward into the willingness to pay modelling as described below.

Table 3: Factors explaining intentions in Theory of Planned Behaviour mode choice and the environment research

	King et al, 2008; Jopson et al, 2009	Jopson, 2003	Forward, 1998
Antecedents of intentions to choose pro-environmental travel options significant at 95%	PBC* (t 5.35) Moral norms (t 4.05)	PBC* (t 4.84) Social norms (t 2.31)	PBC* (Beta 0.39) Social norms (Beta 0.16) Attitudes (Beta 0.13)

*** PBC: perceived behavioural control**

4. ANALYSIS OF STATED PREFERENCE DATA

4.1. Methodology

As set out in Section 2, each respondent was presented with a ranking experiment. From this, we obtained the ranks for the three options involving a reduction in travel time, and the three options involving a reduction in CO_2 emissions. The resulting data was then rank exploded so that for each respondent, we obtain data on five choices. Here, the first choice involves selecting the highest ranked alternative out of the full set of six options, the second choice involves selecting the second ranked alternative out the five options remaining after removing the highest ranked option, etc. The final choice involves selecting the fifth ranked alternative out of the two lowest ranked options.

The resulting data thus contained 8,390 choices collected from 1,678 respondents. A discrete choice model[1] was used in the analysis of the data. In a discrete choice model, we analyse the choice between a number of mutually exclusive alternatives, where the probability of choosing a specific alternative is a function of an estimate utility (or attractiveness) for that alternative. This utility is a function of the attributes of the alternatives and the estimated sensitivities (or tastes) of the respondent. In the present context, the utility is given as a function of the savings in CO_2 and travel time, while we also incorporate interactions with gender, overall journey time, and four moral norm indicators The moral norm indicators were responsibility (norm1) and moral obligation (norm2) to take action to be environmentally friendly, and responsibility (norm3) and moral obligation (norm4) to catch the train to be environmentally friendly. Each of these was assessed using a 7 point Likert scale in the questionnaire, 1 representing strong agreement and thus a strong moral norm to act in favour of the environment, and 7 representing strong disagreement.

Specifically, the utility of an alternative involving a reduction in travel time was specified as:

$$V = \beta_{time} * time\text{-}red$$

where *time-red* gives the reduction in travel time (in %) obtained by choosing that alternative, and β_{time} gives the marginal utility (to be estimated) of a 1 percent reduction in travel time.

For the alternatives leading to a reduction in CO_2 emissions, a more complex specification was used[2], as follows:

[1] See Train, 2003, for a thorough introduction to discrete choice modelling methodology.

[2] Note that due to the specific nature of the design (i.e. an alternative always leads to a reduction in only one of the two attributes, time or CO_2), the interaction terms could obviously only be included for one of the two types of alternatives.

$$V = \delta_{CO2} + \beta_{CO2} * CO_2\text{-red} * [(norm1 / 2)^{\lambda norm1} * (norm2 / 2.5)^{\lambda norm2} * (norm3 / 3.4)^{\lambda norm3} * (norm4 / 3.7)^{\lambda norm4} * (jtime / 150)^{\lambda jtime}] + \beta_{female,CO2} * \textit{female} * CO_2\text{-red} + \beta_{env\text{-}reasons,CO2} * \textit{env-reasons} * CO_2\text{-red},$$

where δ_{CO2} is a constant for the three alternatives that involve CO_2 reductions. The parameter β_{CO2} gives the marginal utility of a 1% reduction in CO_2. Here, this is interacted continuously with the four moral norm variables as well as with journey time (jtime). As an example, λ_{norm1} gives the elasticity of the β_{CO2} parameter in relation to a change in norm1. Here, the expected negative estimate for λ_{norm1} would mean that an increase in the value of norm1 (and hence a reduction in the pro-environment norm) would lead to a reduction in the marginal utility of a reduction in CO_2. The division of norm1 by 2, which is the sample average for norm1 means that the estimate for β_{CO2} gives the marginal sensitivity to CO_2 reductions at the sample average moral norms. A corresponding approach was used for the interactions with the three remaining norm variables as well as with the journey time. Finally, $\beta_{female,CO2}$ and $\beta_{env\text{-}reasons,CO2}$ give additional increments to the marginal utility that are estimated only for female respondents, respectively respondents who make trips for environmental reasons. Attempts to include other socio-demographic attributes, such as age and income, did not reveal any significant effects. Our a priori expectations would be that we obtain positive estimates for β_{time} , β_{CO2} and $\beta_{env\text{-}reasons,CO2,}$ along with negative estimates for λ_{norm1}, λ_{norm2}, λ_{norm3} and λ_{norm4}, with no preconceptions for the signs of $\delta_{CO2,}$ $\beta_{female,CO2}$ and λ_{jtime}.

Some readers may express concern at the incorporation of attitudinal indicators in the modelling of individual choices, given endogeneity issues. In the present context, this specific approach was motivated by the desire to investigate the link between attitudes and actions.

Two further important points need to be discussed before presenting results. Firstly, it is a well known fact that asking respondents to rank alternatives is significantly more complex than asking them to state their most preferred options (see e.g. Louviere et al., 2000). From this perspective, the expectation would be that the modelled component of utility (i.e. not the random component) has a relatively bigger impact for the first of our choices (which equates to choosing the highest ranked alternative). In a random utility modelling context, this phenomenon is referred to as scale differences, where the scale is inversely proportional the variance of the random component of utility and where higher scale means a greater weight for the modelled component. To account for such scale differences, we explicitly estimated the scale for the five choice sets, where the scale was normalised to 1 for the first choice set (to enable identification). Taking such scale differences into account is important with a view to avoiding biased coefficient estimates.

The second point that needs addressing is that each respondent in our data now has five choices, and this repeated choice nature of the data potentially has impacts on the standard errors produced during a purely cross-sectional approach (see e.g. Ortúzar et al., 1997), i.e. when treating each choice as if it came from a separate respondent. Tests were carried out in this context[3] which showed that taking into account the correlation across choices for the same respondent did not lead to any significant drops in parameter significance.

All models presented in this section were estimated using BIOGEME (Bierlaire, 2005).

[3] Detailed results available on request.

4.2. Estimation results

The estimation results for the discrete choice model are presented in Table 4, where it should be noted that the t-ratios for the scale parameters are given in relation to a base value of 1 rather than 0.

Table 4: Estimation results for discrete choice model

Number of individuals:	1678
Number of observations:	8390
Final log-likelihood:	-7071.38
adj. ρ2:	0.358

	est.	t-rat. (0)
δ_{CO2}	1.82	14.52
β_{CO2}	0.175	30.8
$\beta_{female,CO2}$	0.00987	2.05
$\beta_{env\text{-}reasons,CO2}$	0.0566	8.26
βtime	0.584	38.75
λ_{norm1}	-0.152	-4.22
λ_{norm2}	-0.138	-3.75
λ_{norm3}	-0.0811	-1.71
λ_{norm4}	-0.0519	-1.08
λ_{jtime}	0.0422	2.2

	est.	t-rat. (1)
Scale1	1	-
Scale2	0.45	-27.04
Scale3	0.0266	-63.25
Scale4	1.01	0.23
Scale5	1.42	5.56

Our analysis of the results shows that there is an overall preference for the CO_2 reducing options (as captured in δ_{CO2}). As expected, the estimates for β_{CO2} and β_{time} are both positive, showing that reductions in CO_2 and travel time have a positive impact on the utility of an alternative. Here, this is slightly higher marginal utility for CO_2 reductions for female respondents and respondents who travel by rail for environmental reasons, reflected in the positive signs for $\beta_{female,CO2}$ and $\beta_{env\text{-}reasons,CO2}$.

Additionally, the estimates for the four interaction terms λ_{norm1}, λ_{norm2}, λ_{norm3} and λ_{norm4} are all negative. The negative sign of these interaction terms shows that with decreasing environmental norms (i.e. as the value of norm1 to norm4 increases), the marginal utility of CO_2 reductions is decreased. We can also observe decreasing magnitude and statistical significance when moving from norm1 to norm4, where the final two are no longer significant at the usual levels of confidence. This gives a strong indication that the responsibility and moral obligation to be environmentally friendly per se are stronger than the responsibility and moral obligation to catch the train to be environmentally friendly. This is also supported by the descriptive statistics for the four moral norm questions (note the mean values for norm1 to norm4 discussed in Section 4.1), and fits with the findings that people want to do something for the environment, but when it comes to catching the train issues such as cost etc intervene, i.e. are potentially more important. There is also a suggestion

that within each frame the two moral norm questions are asked (environment per se, and catching the train to be environmentally friendly), perceived responsibility is stronger than moral obligation (i.e. $\lambda_{norm1} < \lambda_{norm2}$, and $\lambda_{norm3} < \lambda_{norm4}$). In other words, people accept the environment as their responsibility but see it as a moral issue to a lesser extent. Again this is supported by the descriptive statistics for the four moral norm questions.

Finally, there is a small positive estimate for λ_{jtime}, showing that the marginal utility of CO_2 reductions increases with journey time. Even though the effect is small, this is an interesting finding given that we are already working on the basis of percentage changes. What this suggests is that the marginal utility of a one percent reduction in CO_2 increases more rapidly with distance than is the case for the marginal utility of a one percent reduction in journey time.

Turning our attention to the scale parameters, we observe the expected reduction in scale when moving from the first to the second and especially the third choice set, showing the increasing difficulty for respondents to perform the rankings in the midfield. However, for the later rankings, the scale increases once more, where this indicates for example that choosing the lowest ranked option is relatively easy.

4.3. Interpretation of results

The easiest way to interpret the estimation results is in the form of a trade-off between reductions in CO_2 and reductions in travel time. In other words, the output of such a calculation would be an indication as to the relative value of a 1% reduction in CO_2 and a 1% reduction in travel time. In the absence of interaction terms, this would simply be calculated as $r = \beta_{CO2}/\beta_{time}$, where the value of r would show how much a 1% reduction in CO_2 is worth in comparison to a 1% reduction in travel time. In the presence of the interaction terms, this calculation is more complicated, and we now have:

$$r = 1 / \beta_{time} * [\beta_{CO2} * (norm1 / 2)^{\lambda norm1} * (norm2 / 2.5)^{\lambda norm2} * (norm3 / 3.4)^{\lambda norm3} * (norm4 / 3.7)^{\lambda norm4} * (jtime / 150)^{\lambda jtime} + \beta_{female,CO2} * female + \beta_{env\text{-}reasons,CO2} * env\text{-}reasons]$$

i.e. dividing the full marginal utility for CO_2 reductions by the full marginal utility for travel time reductions.

The above shows that a different value for the trade-off is obtained when looking at male or female respondents, when looking at respondents with different attitudes and/or respondents making trips for environmental reasons, and when varying the journey time. As an illustration, we present here the trade-offs for a range of different types of respondents and different journey times.

The first observation that can be made is that a 1% reduction in CO_2 is always values less highly than a 1% reduction in travel time. However, there are significant variations arise, where, for the ranges presented here, the lowest valuation for a 1% reduction in CO_2 is a 0.18% reduction in travel time, while the highest is a 0.57% reduction. There is a very small increase in valuations as journey time increases, along with a small increase in valuations for female respondents, and a more marked increase for respondents who make trips by rail for environmental reasons. The most important variations however arise when taking into account the moral norm indicators, which show that when looking only at those respondents that expressed the strongest moral norms to change versus those that expressed the strongest disagreement with this moral norm, the relative value of CO_2 reductions increases is more than twice as high for the former group.

Thus far, we have solely talked about valuations in terms of percentage changes. However, these valuations can also be monetised. Indeed, with the average rail journey length being 40.3km, and

405 the average journey time:length ratio being 1.9km/min (source Transport Watch[4]), we obtain an
406 average journey time of 21.2mins. With an average CO_2 emission of 61g/km (ATOC, 2007), this
407 journey would thus on average produce 0.0024583 tonnes of CO_2, meaning that a 1% saving in CO_2
408 would equate to 0.000024583 tonnes.

409 **Table 5: Relative valuations for reductions in CO_2 emissions and travel time by type of respondent**

						relative value of 1% reduction in CO2 in terms of % travel time reductions at journey times of					
First moral norm indicator	**Second moral norm indicator**	**Third moral norm indicator**	**Fourth moral norm indicator**	**Gender**	**Trips made for environmental reasons**	**30 mins.**	**60 mins.**	**120 mins.**	**150 mins.**	**180 mins.**	**240 mins.**
average	average	average	average	Male	NO	0.28%	0.29%	0.30%	0.30%	0.30%	0.31%
average	average	average	average	Male	YES	0.37%	0.38%	0.39%	0.40%	0.40%	0.40%
average	average	average	average	Female	NO	0.30%	0.30%	0.31%	0.32%	0.32%	0.32%
average	average	average	average	Female	YES	0.39%	0.40%	0.41%	0.41%	0.42%	0.42%
strong pos.	strong pos.	strong pos.	strong pos.	Male	NO	0.42%	0.43%	0.44%	0.45%	0.45%	0.46%
strong pos.	strong pos.	strong pos.	strong pos.	Male	YES	0.51%	0.52%	0.54%	0.54%	0.55%	0.55%
strong pos.	strong pos.	strong pos.	strong pos.	Female	NO	0.43%	0.45%	0.46%	0.46%	0.47%	0.47%
strong pos.	strong pos.	strong pos.	strong pos.	Female	YES	0.52%	0.54%	0.56%	0.56%	0.56%	0.57%
strong neg.	strong neg.	strong neg.	strong neg.	Male	NO	0.18%	0.19%	0.19%	0.20%	0.20%	0.20%
strong neg.	strong neg.	strong neg.	strong neg.	Male	YES	0.27%	0.28%	0.29%	0.29%	0.30%	0.30%
strong neg.	strong neg.	strong neg.	strong neg.	Female	NO	0.20%	0.20%	0.21%	0.21%	0.21%	0.22%
strong neg.	strong neg.	strong neg.	strong neg.	Female	YES	0.29%	0.30%	0.31%	0.31%	0.31%	0.32%

410

411 Using the same group of respondents as in Table 5, but at the average journey length of 21.2
412 minutes, we can calculate valuations as shown in Table 6. Here, we start by calculating the relative
413 value of a 1% reduction in CO_2 compared to reductions in travel time. From this, and for the given

[4] http://www.transport-watch.co.uk/

journey time, we can calculate the actual time saving that is equivalent to a 1% reduction in CO_2, from which, when using the average value of travel time savings of £8.29 per hour (WebTAG, 2009), we can calculate the monetary value of the 1% reduction in CO_2 (equating to 0.000024583 tonnes).

If grossing up of marginal changes were acceptable, then these results could be used to calculate valuations for one tonne reduction in CO_2 ranging from £215.11 to £614.80. These values are very high when compared to the current shadow price of carbon which is set to £26.5/tonne of CO_2 (DEFRA, 2009), but need to be put in context by noting that, for the current trip, the value for the total CO_2 emissions would range between 53 pence and £1.51, where the average fare for such a journey in the UK can vary widely, ranging from under £3 to over £10. This again assumes that marginal rates can be grossed up, which may be more realistic at the level of an individual trip, and in this case would give the willingness to pay for a carbon neutral trip.

Table 6: Willingess-to-pay for reductions in CO_2 emissions by type of respondents

First moral norm indicator	Second moral norm indicator	Third moral norm indicator	Fourth moral norm indicator	Gender	Trips made for environmental reasons	relative value of 1% reduction in CO2 in terms of % travel time reductions	Time saving equivalent to 1% reduction in CO_2 (mins)	Value of 1% reduction in CO_2 for given trip (pence)
average	average	average	average	Male	NO	0.28%	0.0585	0.81
average	average	average	average	Male	YES	0.37%	0.0774	1.07
average	average	average	average	Female	NO	0.29%	0.0618	0.85
average	average	average	average	Female	YES	0.38%	0.0807	1.12
strong pos.	strong pos.	strong pos.	strong pos.	Male	NO	0.41%	0.0872	1.20
strong pos.	strong pos.	strong pos.	strong pos.	Male	YES	0.50%	0.1061	1.47
strong pos.	strong pos.	strong pos.	strong pos.	Female	NO	0.43%	0.0905	1.25
strong pos.	strong pos.	strong pos.	strong pos.	Female	YES	0.52%	0.1094	1.51
strong neg.	strong neg.	strong neg.	strong neg.	Male	NO	0.18%	0.0383	0.53
strong neg.	strong neg.	strong neg.	strong neg.	Male	YES	0.27%	0.0572	0.79
strong neg.	strong neg.	strong neg.	strong neg.	Female	NO	0.20%	0.0416	0.57
strong neg.	strong neg.	strong neg.	strong neg.	Female	YES	0.29%	0.0605	0.84

5. DISCUSSION

Train travel is perceived to be an environmentally friendly mode and those travelling by train (whether or not they are motivated by environmental reasons) rate the environmental performance of their journey highly relative to other trip attributes such as cost and reliability. Train travel is perceived to be more environmentally friendly even than coach travel although carbon comparators show this not the case. Twenty-four percent of people in our survey reported having used train partly or purely for environmental reasons in the past six months. We estimate that this corresponds to around 3.4% of all trips although it was higher (4.4%) for business trips. There may be some positive response bias associated with this figure. However, the analysis of the stated preference data supports the notion that some journeys will have an environmental motivation as there is a consistency between those stating that they travel by train for environmental reasons and those that have higher preference for carbon savings.

Set against this very positive environmental image of rail is a reality which suggests that, for most people, in most journey contexts, the environment is not a feature in the decision-making process. However, it can be a deciding factor where other attributes are similar across modes and some businesses also promote train travel.

From the estimates of our discrete choice models, and in conjunction with generally accepted value of travel time savings measures, it was possible to calculate an estimate of the willingness to pay for reductions in CO_2 emissions. Grossed up to the level of a tonne, these valuations were significantly higher than those produced in previous research (Brouwer et al., 2008; Mackerron et al., 2009) and which, were they to be adopted, would imply a much greater responsiveness to carbon saving initiatives than is seen in practice. In general, one would however not expect that these values can be grossed up to the level of a tonne as they relate to a single journey. However, another potential reason for the high values could be the actual approach used in the present study, in which respondents were asked to trade off between reductions in CO_2 and in time, rather than money, where our approach may in fact avoid some strategic bias resulting from asking more directly for monetary valuations.

Independently of the absolute values, the experiment provides very interesting insights as the relative valuations appear to be consistent with other aspects of the questionnaire and with the expectations from the literature. In particular there is a higher willingness to pay for climate change emission reductions amongst those that say they travel by train for environmental reasons compared with those that do not and for those that have stronger moral norms for travelling by train. This supports the notion that those with pro-environmental intentions and behaviours, on average, have a higher willingness to pay for them. The very high degree of consistency between the statistics on the four norms and their role in explaining choices is a strong endorsement for the notion that in this case, the retrieved valuations are consistent with the stated attitudes.

Finally, throughout the study, females expressed a slightly higher valuation than males and this was the only socio-economic variable which emerged. This too is consistent with previous research (King et al, 2008) which showed that women reported stronger feelings than men of personal responsibility to reduce car use to improve the environment and their quality of life.

Over time, if the population does exhibit a greater level of concern for the environment and, critically, assumes more personal responsibility to tackle environmental problems, then this will encourage greater use of rail. To benefit from any pro-environmental shift, rail will have to continue to maintain its actual (and perceived) environmental benefits over other forms of transport. In the UK context it seems that such shifts in mode use are likely to remain 'at the margins' for the foreseeable future. One important reason for this is the mis-match between the fare structure

(which is largely based around managing route congestion) and the relative environmental benefits of rail (which are largely independent of time of travel). There will remain a large proportion of trips for which the cost of the journey acts as a disincentive to choose an environmentally friendly option.

Our research suggests that there are a number of potential future areas for further investigation:

- The study reinforces the previous noted difficulties in conducting closed question format investigations about the environment. In particular it would be interesting to examine how the willingness to pay estimates varied with different question formats and terminology.

- The study captures understanding in late 2008 and it would be interesting to trace the changes in underlying attitudes over time and the extent to which this feeds forwards into estimated valuations, thus providing a more dynamic understanding of the speed with which underlying environmental motivations might affect rail demand.

- Greater understanding needs to be developed of what the population thinks a 'green' or 'environmentally friendly' train service is. There is little awareness of the actions of operators to promote their environmental benefits and carbon calculators appear not to be used as part of the decision-making process. Whilst the valuation work suggests that there may be a part of the population willing to pay for carbon offset schemes for example, there is little understanding of these schemes and how they work.

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References

Ajzen I (1988) *'Attitudes, Personality, and Behaviour',* Open University Press, Buckingham.

Anable, J. Lane, B. and Kelay, T. (2006) An evidence base review of public attitudes to climate change and transport behaviour, Final Report for Department for Transport, www.dft.gov.uk

Bierlaire, M., 2005. An introduction to BIOGEME Version 1.4. biogeme.ep.ch.

Brouwer, R., Brander, L. and van Beukering, B. (2008) "A convenient truth": air travel passengers' willingness to pay to offset their CO2 emissions, *Climatic Change*, **90**, 299-313

CfiT 2001 A comparative study of the environmental effects of rail and short-haul air travel, Commission for Integrated Transport, www.cfit.gov.uk

Collins, A.T., Rose, J.M. & Hess, S. (2009), Search based internet surveys: airline stated choice, paper presented at the 88th Annual Meeting of the Transportation Research Board, Washington, D.C.

DEFRA (2008) A Framework for Pro-Environmental Behaviours, Department of Environment, Food and Rural Affairs, London, January.

DfT (2007) Low carbon transport innovation strategy, Department for Transport, www.dft.gov.uk

DfT (2008) Attitudes to climate change and the impact of transport (2006 and 2007), Department for Transport, www.dft.gov.uk

DfT (2009), http://www.dft.gov.uk/pgr/rail/pi/rail-electrification.pdf.

Eriksson, L., Garvill, J. and Nordlund, A. M. (2008) Acceptability of single and combined transport policy measures: The importance of environmental and policy specific beliefs, *Transportation Research Part A*, **42**, 1117-1128

Forward, S. (1998) *Behavioural Factors Affecting Modal Choice,* Swedish National Road and Transport Institute, Linkoping, Sweden.

Jopson, A., Marsden, G. and Harwatt, H (2009) Climate Change Attitudes and Car Use Reductions: the intention-behaviour gap, *forthcoming.*

Jopson, A. (2003) *Reducing Car Use: the role of The Theory of Planned Behaviour.* PhD. Leeds: University of Leeds

King, S., Marsden, G., Dyball, M., Jopson, A., Harwatt, H. and Kimble. M. (2008) *Exploring public attitudes to climate change and the barriers and motivators to behaviour change: Final Report*, Report to Department for Transport, www.dft.gov.uk (October 2008)

Louviere, J.J., Hensher, D.A. and Swait, J.D. (2000), Stated Choice Methods—Analysis and Application, Cambridge University Press, UK.

Mackerron, George J. MacKerron, G.J., Egerton, C., Gaskell, C., Parpia, A. and Mourato, S. (2009) Willingness to pay for carbon offset certification and co-benefits among (high-)flying young adults in the UK, *Energy Policy*, **37**, 1372-138

Marsden, G., Kimble, M., Jopson, A., Harwatt, H. and King, S. (2009) What does the public want to know about climate change and what difference does it make? Transport Practitioners Annual Meeting, Reading, July 2009

Nilsson, M. and Küller, R. (2000) Travel Behaviour and Environmental Concern, *Transportation Research Part D*, **5**, 211-234

Ortúzar, J de D., Roncagliolo, D.A., and Velarde, U.C., (1997), Interactions and Independence in Stated Preference Modelling, PTRC Perspectives, London.

Poortinga, W., Pidgeon, N. and Lorenzoni, I. (2006) Public Perceptions of Nuclear power, Climate Change and Energy Options in Britain: Summary Findings of a Survey Conducted during October and November 2005. Understanding Risk Working Paper 06-02. Norwich Centre for Environmental Risk.

Shires, J., Marsden, G., Muir, H. and Jopson, A. (2009), The impact of environmental awareness on rail demand, report prepared for the Association of Train Operating Companies.

Stern, N., S. Peters, V. Bakhshi, A. Bowen, C. Cameron, S. Catovsky, D. Crane, S. Cruickshank, S. Dietz, N. Edmonson, S.-L. Garbett, L. Hamid, G. Hoffman, D. Ingram, B. Jones, N. Patmore, H. Radcliffe, R. Sathiyarajah, M. Stock, C. Taylor, T. Vernon, H. Wanjie, and D. Zenghelis (2006), Stern Review: The Economics of Climate Change, HM Treasury, London.

Train, K.E. (2003), Discrete Choice Methods with Simulation, Cambridge University Press, Cambridge, MA.

Webtag (2009), TAG Unit 3.5.6: Values of Time and Operating Costs, Transport Analysis Guidance, UK DfT, http://www.webtag.org.uk/webdocuments/3_Expert/5_Economy_Objective/3.5.6.htm