IMPACT OF EMISSIONS INFORMATION ON MODE CHOICES IN DUBLIN: A STATED PREFERENCE EXPERIMENT

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Abstract

The rise of smartphone applications within the transport sector has created new and exciting opportunities to provide users with a wide range of previously unavailable information services. The combination of journey planning applications and carbon calculators, allows for the provision of trip specific information regarding the potential environmental impact of personal transport options. While these applications are readily available in the market place, little in terms of scientific research has been undertaken to examine their influence on users. This paper presents the results of a stated preference experiment examining influence of carbon dioxide emissions information on user mode choice, as part of a survey undertaken in the Greater Dublin Area in November 2012. Acknowledging research findings arising from the field of behavioural economics, this study recognizes that mode choices are also influenced by factors other than the attributes presented to the user. In addition to standard socioeconomic considerations, the influence of the respondents' habitual transport behaviour was incorporated into the multinomial logit model. Moreover, due to the issue of information presentation inherent in smartphone applications, the effect of the respondents' process of information assimilation was examined. Results indicate that, for all non driving modes, emissions play a significant role in the respondents' mode choice, with reduced associated emissions contributing to enhanced mode utility. The inclusion of habitual and information processing variables was found to greatly improve upon the initial model in terms of predictive power.

Introduction:

Climate change resulting from the emission of greenhouse gases associated with human economic activities has the potential to create an unstable global climatic future. A considerable portion of these emissions arise as a result of the transport decisions made by everyday individuals in everyday situations. In line with Hardin's Tragedy of the Commons [1], the seemingly insignificant actions undertaken by unexceptional individuals, in this case numbering in the billions, sum together to drastically impact upon the fragile environmental balance of the global commons. Ordinary individuals are making unsustainable transport choices that imperceptivity erode away the stability of the planet's ecosystem.

Without access to quantifiable and comparable trip specific information, how can individuals be asked to make informed choices between available alternatives? Even individuals who possess sustainable aspirations have, up until very recently, not had the ability to make informed choices in line with their personal beliefs. Conversely individuals may engage in relatively inconsequential acts that they perceive to be contributing to climate change mitigation.

While it may be beyond this research to suggest what actions individuals should or should not take, it seems appropriate that they should at least be provided with enough information to informed choices in line with their personal environmental beliefs. This approach is not without recent precipitant in terms of the provision of information. Nutritional information is now mandated on food products sold within the European Union [2], and retailers display calorific information in tandem with prices on in store displays. Similarly alcoholic beverages are required display their relevant alcohol content and tobacco products must to provide information on their ingredients. In each case the individual is free to make their choice, in line with their person beliefs, but cannot reasonably claim that they were not in some way aware of the consequences of their actions.

While carbon calculators have existed in an online format for a number of years, it is their incorporation into journey planners that may enable them to make emissions more relevant to individuals' when choosing between modes. If emissions information is not actively sought after or its provision legally required, one solution is to incorporate it into services that individuals consult for other purposes. While it is questionable as to whether an individual would consult a carbon calculator when planning a trip, the inclusion of emissions calculators into journey planning applications enables the provision of emissions estimates at a time, or "touchpoint", when the individual is making their route/ mode choices. By providing information at the moment when the decision is made it is more likely that the role of environmental concerns in the decision making process will become more prominent. Integration of smartphone applications with carbon calculators also allows for the provision of trip specific emissions estimates rather that generalised averages. If the individual is able to input other details such as the make and model of their car, then the accuracy of emissions predictions can be further improved.

Discrete Choice Modelling:

Discrete choice modelling refers to an experimental approach where a respondent is presented with a number of options or "alternatives" and asked to make a choice. Unlike other modelling methods such as alternative ranking, the discrete choice approach aims at replicating real world situations where consumers choose one good or service over another.

Random Utility Theory (RUM) is an economic theory that states that a consumer will seek to choose an alternative from a choice set that maximises his/her "utility". Utility is a latent property of the alternative and is a function of the attributes associated with that alternative. In the case of this study the alternatives under examination are the five mode choice (Drive, Rail, Bus_Rail, Bus, Park and Ride) and the relevant attributes are the trip time and the carbon dioxide emissions associated with each available mode. RUM states that given a finite set of alternatives, the individual will choose the alternative from which he/she derives the greatest level of utility. Utility is assumed to be composed of both deterministic (V) and a random component (ε).

$$U_i = V_i + \varepsilon_i$$

The random element cannot be measured be the analyst and it is therefore assumed to be set to a probability distribution defined by the model used to analysis the data. The probability that an individual will choose one alternative over another is therefore the probability that he/she derives more utility from that alternative.

Multinomial Logit Model

Often considered to be the "workhorse" of the choice modelling world, the Multinomial Logit (MNL) model has been used in a large number of choice studies in the transport sector. The model assumes that the unobserved error component of the utility function is Gumbell distributed and hence the probability of picking a given alternative is as:

$$P_i = \frac{e^{v_i}}{\sum_{j=1}^{J} e^{v_j}}$$

Where Pi is the probability that the individual will choose alternative *i, Vi* is the deterministic component of utility for alternative *i* and *J* is the number of alternatives in the choice set.

Survey Methodology:

Survey Distribution

The stated preference experiment formed part of a broader survey that was conducted via a number of large governmental agencies and departments in late 2012. Care was taken to include organisations outside the Dublin CBD to ensure that on radial commuters were also included in the survey sample.

Table 1: Sample Properties

Gender	Male	Female	(No Answer)			
	42.8 (34.8)	57.2 (46.5)	(18.7)			
Age	15-24	25-34	35-44	45-54	55+	(No Answer)
	15.7 (12.3)	25.5 (20.1)	24.7 (19.5)	25 (19.7)	9.1 (7.2)	(21.3)
Education	High School	Diploma	Bachelors Degree	Higher Degree	(No Answer)	
	25.4 (20.5)	17.7 (14.3)	22.9 (18.5)	34 (27.4)	(19.3)	
Income	€0-24K	€25-49K	€50-74K	€75-99K	€100k +	(No Answer)
	22.2 (17.9)	44.6 (36)	20.9 (16.9)	6.4 (5.2)	2 (1.6)	(22.5)

Experimental Design

Alternatives: Respondents were presented with a hypothetical 10km commuter/trip to education in the Greater Dublin Area. Five alternatives were made available: Drive, Rail. Bus-Rail, Bus, and Park and Ride. These modes were chosen to reflect both the majority of trips undertaken in the Greater Dublin Area [3, 4], and the trip types likely to be recommended by journey planning applications. Specifically Bus-Rail and Park and Ride were chosen to represent multimodal options that, although infrequently undertaken, represent sustainable alternatives for individuals with non CPB origin-destination pairs or with limited access to high quality public transport.

Attributes: To reflect the nature of existing journey planners and smartphone applications, it was decided to include trip time and emissions as the only scenario attributes. While cost was considered for inclusion as an attribute, difficulties in calculating trip cost due to factors such as complex public transport ticketing structures and the sunk cost of driving, make comparisons unsuitable for this experiment.

Carbon Budget: As individuals are likely to have little in terms of internal references to compare emissions estimates with, it was decided to provide them with a trip specific carbon budget. This budget was defined with 1.25kg/km or 12.5kg carbon dioxide emissions representing one hundred per cent of the user's allowance. This is in line with transport projections under Ireland's commitment to the Kyoto protocol and previous research conducted on carbon budgeting in Ireland [5]. As research indicates that individuals have varying preferences with regard to the presentation of emissions information [6], it was decided to provide a traffic light inspired colour coding scheme in tandem with the percentage figures. Emissions falling between 0-50 percent were displayed in green text, those falling between 50-100 percent in orange text and those exceeding 100 percent in red.

Table 2: Scenario Attributes

Alternative	Emissions (kg CO_2)			Time (Minutes)		
Driving	1.2	1.5	1.8	20	35	50
Rail	0.3	.475	.65	25	30	35
Bus_Rail	.21	.34	.47	20	35	50
Bus	.15	.35	.55	30	45	60
Park and Ride	.75	1	1.25	20	35	50

Decision rule

Analysis of Discrete Choice models can often be complex and while significance of terms can be extrapolated, it is difficult to be sure of the exact role the respective attributes played in the respondents stated choice. When presented with similar tasks individuals often quickly develop decisions rules to help them process their choices with as little cognitive strain as possible. As the scenarios presented contained only two attributes, it was decided to ask respondents select a decision rule that best summarised how they had processed the information contained in the scenarios. Respondents were asked to select from the following four choices:

- First look at time and then consider emissions
- First look at emissions and then consider time
- Only consider time
- Only consider emissions

Results:

Table 3 displays the results of the initial model in terms of the coefficients associated with each mode. From the purpose of this model only the influence of the time and emissions attributes for each of the modes is considered.

$$U = \beta const + \beta t * time + \beta e * emisssions$$

Where:

U= Utility of the Mode, βconst=Constant term, βt=Time coefficient, βe= emissions coefficient.

Base Model

Examination of the base model coefficients reveals that all terms, with exceptions of emissions for Driving and Park and Ride, are statistically significant at 95% confidence level. All coefficients of statistical significance display negative signs suggesting that decreases in both trip cost and associated emissions increases the utility of the mode. In terms of travel time, this is as expected, both from the literature and on an intuitive level. The negative signs associated with the emissions levels indicate, that for public transport journeys at least, the utility associated with the alternative decreases with respect to rises in emissions. The Rho

Squared w.r.t constants has a value of 0.097 suggesting that the model does a poor job at explain the variances seen in the data.

Table 3: Base Model

Observations N=1189				
Drive=152	Rail=495	Bus_Rail=275	Bus=225	P&R=42

Variable	Coefficient	Z Stat
Drive Time	-.031***	-4.08
Drive Emissions	.15725	.42
Rail Time	-.03305**	-2.18
Rail Emissions	-2.245***	-5..04
Bus_Rail Time	-.07067***	-10.65
Bus_Rail Emissions	-5.159***	-3.94
Bus Time	-.043***	-7.03
Bus Emission	-3.97***	-7.36
Park and Ride Time	-0.027**	-2.07
Park and Ride Emissions	-1.25	-1.58
Log Likelihood	-1655.23	
Rho Squared Constants only	0.097	
Rho Squared No Coefficients	0.271	

Table 4 displays the results of the expanded model. A wide range of socio economic variables were tested, and this model includes only those that proved statistically significant for their respective modes. To account for respondents' travel habits and any biases that might arise from this source, habitual terms have been included in the model. For the Bus_Rail option, the frequency with which respondents took both modes was examined, however only the Bus Habits term for the Bus_Rail alternative proved significant. For both socio economic and habitual variables, the Park and Ride option was held as the reference option. No additional variable proved statistically significant for this mode. Results indicate that the more frequently a respondent uses a given mode, the more likely the greater utility they accord it. Gender was coded as 1 for male and -1 for female, resulting in females being more likely to take the Bus_Rail option. Respondents' residence was coded 1-5, with higher values indicating increased distance from the city centre. Somewhat counter-intuitively results indicate that individuals living closer to the city would be more likely to drive than those residing in more peripheral locations. Perceived access to modes was only observed to be significant for the Bus mode, where stated access to that mode increased its utility.

Expanded Model

Table 4: Expanded Model

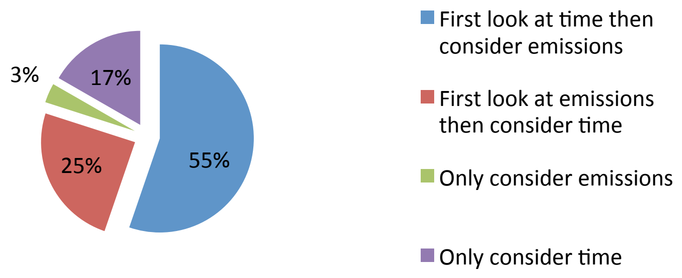
Observations N=1029					
Variable	Coefficient	Z Stat	Variable	Coefficient	Z Stat
Drive Time	-.03***	-3.51	Bus_Rail Emissions	-7.06***	-4.79
Drive Emissions	.23	.54	Bus_Rail Bus_Habit	.355***	3.18
Driving Habit	.718***	6.15	Bus_Rail_Gender	-.331***	-3.87
Drive Age	-.03***	-2.78	Bus Time	-.05***	-7.15
Drive Live	-.154*	.093	Bus Emission	-4.64***	-7.37

Rail Time	-.033*	-1.87	Bus Habit	.316***	3.11
Rail Emissions	-2.40***	-4.69	Bus Bus_Acc	.3415***	3.11
Rail Habit	.33**	5.28	Bus Rail_Habit	-.1932	-2.04
Rail Age	-.0193***	-2.97	Park and Ride Time	-.0328**	-2.32
Rail Edu	.212***	3.53	Park & Ride Emissions	-1.00	-1.21
Bus_Rail Time	-.077***	-10.42			
Log Likelihood		-1172.23			
Rho Squared Constants only		0.1765			
Rho Squared No Coefficients		0.333			

Decision Rule

The inclusion of the decision rule was intended to provide a simple guide to the respondents decision process in the case that both time and emissions variables proved to be significant. As respondents completed three scenarios it is assumed that they quickly established a decision rule with regard to the processing and weighting of the information they were presented it with. This would represent a cognitive shortcut where the user would discard information that he/she deemed irrelevant or less important, and concentre upon the primary attribute of interest. While this rule must be treated as a rough guide, as it does not account for random error, such as the latent variables not included in the experiment, it provides an insight into the respondents' consideration of the two attributes. It is clear that time is the dominant variable as it is either the primary or only attribute considered by 72% of the sample. It is also notable that only 3% of respondents stated that they only considered emissions when choosing a mode.

Figure 1: Decision Rule



Decision Rule Model

Table 5 presents the results of the Decision Rule model. This model involved the incorporation a variable based upon the responses stated method of processing the information displayed in scenarios. Responses were coded as follows: (1) Only look at time, (2) First look at time then emissions, (3) First look at emissions then time, (4) Only look at emissions.

The decision rule variables were added to the Drive, Rail, Bus_Rail and Bus utility equations as linear terms. These terms are labelled as Drive_Drule, Rail_Drule, Bus_Rail_Drule, and Bus_Drule respectively. Decision rule coefficients were found to be statistically significant for all modes at either 95 % of 99% significance. The Park and Ride alternative was held as the reference mode and therefore there is no decision rule coefficient associated with it. The sign of the coefficients associated with the Rail, Bus_Rail, and Bus alternatives were observed to be positive in sign. Given the coding approach applied to the decision rule variable, these coefficients would indicate that the more attention individuals pay to emissions information, the more the utility of these modes increases. Conversely the coefficient for the decision rule associated with the driving alternative is positive in sign, suggesting that individuals who ignore or accord little attention to emissions information are more likely to choose the Drive option.

Table 5: Decision Rule Model

Observations N=960					
Variable	Coefficient	Z Stat	Variable	Coefficient	Z Stat
Drive Time	-.04362***	-4.28	Bus_Rail Emissions	-8.31***	-5.26
Drive Emissions	.0653	.13	Bus_Rail Bus_Habit	.365***	5.19
Driving Habit	.588***	4.77	Bus_Rail_Gender	-.241***	-2.64
Drive Age	-.023*	-1.81	Bus_Rail D_Rule	1.68***	5.67
Drive Live	-.249**	-2.34	Bus Time	-.0541***	-7.25
Drive D_Rule	-.638**	-1.98	Bus Emission	-5.33***	-7.65
Rail Time	-.028	-1.55	Bus Habit	.362***	4.5
Rail Emissions	-2.50***	-4.57	Bus Bus_Acc	.237**	2.02
Rail Habit	.295***	4.55	Bus Rail_Habit	-.205**	-2.05
Rail Age	-.016**	-2.31	Bus D_Rule	1.6***	5.29
Rail Edu	.214***	3.37	Park and Ride Time	-0.035**	-2.45
Rail D_Rule	.679**	2.43	Park & Ride Emissions	-.987	-1.17
Bus_Rail Time	-.083***	-10.7			
Log Likelihood		-1009.46			
Rho Squared Constants only		0.2379			
Rho Squared No Coefficients		.381			

Goodness of Fit of Models

For studies examining mode choice experiments within the transport sector, models are regarded to be good fits for the data given rho squared (with respect to constants) values of between 0.2-0.4.[7]. The initial model displayed a value of 0.097 which can be considered poor, although the inclusion of habitual and socioeconomic variables rises this to 0.1765. The further incorporation of variables reflecting the respondents' decisions rule brings this vale to 0.2379 which falls within the expectable bounds of a good model. Random utility theory is based upon the premise of the rational individual who assesses all the attributes presented in an equal manner before making a choice. However, in real world situations individuals often engage in cognitive shortcuts, ascertaining essential information and discarding or ignoring any information they deem superfluous. The marked improvement in model fit result from the inclusion of the decision rule highlights how variables arising from behavioural economics can improve upon standard random utility models, at least in the area of information provision.

Discussion:

Carbon dioxide emissions associated with transport can often be considered a latent attribute of any trip, as it very unlikely that it will be considered by an individual in the normal course of events. The results of this experiment would suggest that by displaying the emissions associated with public transport, especially in comparison to driving, the perceived utility of these modes can be increased. Smartphone applications represent a method of including emissions information as part of a value added service. If applications can be designed in such a fashion that emissions information can be displayed, without detracting from the primary functionality of the application, it seems logical that developers, particularly public transport providers, should facilitate its inclusion. This paper touched upon some of the behavioural and habitual issues and demonstrated the importance of incorporating these into any further analysis.

Acknowledgements

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