PEACOX – Persuasive Advisor for CO2-reducing cross-modal trip planning

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D3.3 Development of the Behavioural Model

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Abstract

The behavioural model is designed to reflect the role that the provision of CO_2 emissions information plays in the users' decision making processes. This is achieved through the application of Random Utility Theory (RUT) and is implanted via the multinomial logit model. The model will incorporate factors including the trip attributes that the PEACOX application provides to the user as well as other trip specific attributes such as cost or weather conditions, the socio-economic characteristics of the decision maker, and users' access to travel alternatives. The model will utilise approaches such as model segmentation and the creation of nested models.

Table of Contents

1. Introduction

1.1 Background

The purpose of behavioural modelling is to provide a simplified representation of the factors affecting the observed behaviours that individuals undertake. Many factors both internal and external impact upon the decisions that individuals make every day. While it is impossible to understand the exact workings of an individual's mind when they are under taking a decision, behavioural modelling attempts to explain their choices in terms of factors which the analyst considers important. These factors are often specific to the choice in question and may vary between individuals. For example in the case of the transport sector an individual with small children undertaking a shopping trip is likely to have a different set of priorities than a student travelling to college with a similar array of modes available. A large number of studies have utilized this approach to predict individuals' route/mode choices. Commins and Nolan (2011) used Irish census data to identify the determinants of mode choice in the Greater Dublin Area. Johansson et al (2006) used this method to examine the role of time cost and comfort, as well as environmental attitudes, in terms of influence on mode choice. Menghini et al (2010) looked at the route choices of cyclists in Zurich, while Caulfield and Brazil assessed how the provision of information on health benefits and carbon emissions could influence mode choice for short non work based trips. Further examples can be found in Louviere et al (2000) and Hensher et al (2005).

1.1.1 Scope of This Deliverable

This task will develop the behavioural choice model. This choice model will be based upon a discrete choice modelling approach. This approach will enable the isolation of trip characteristics to ascertain how they impact upon mode choice. The key trip characteristic that will be examined in the model will be the information on CO_2 emissions. The choice model developed will be able to demonstrate the influence of this information upon the mode choice. This exercise will the relative importance of emissions on trip choice compared to trip cost, travel time, and a number of other characteristics. The choice will be designed around the field trials and model individuals' responses when they are presented with CO_2 and if it impacts upon their travel behaviour.

2. Discrete Choice Modelling

Discrete choice modelling is concerned with activities where an individual is forced to make a decision between products and services. This is in contrast to methods such as ranking where individuals can assign ranks or scores to indicate preference. Discrete choice modelling has the advantage of mirroring many of the situations that confront consumers in everyday live. For an example, in the case of the real world application of PEACOX, individuals will not provide a ranked listed of alternatives revealing their preference; rather they will make a discrete choice to take one mode or route over another.

In order to create a workable model that has the ability to isolate some, if not all, of the likely factors in a mode choice decision, we turn to Random Utility Theory.

3. Random Utility Theory

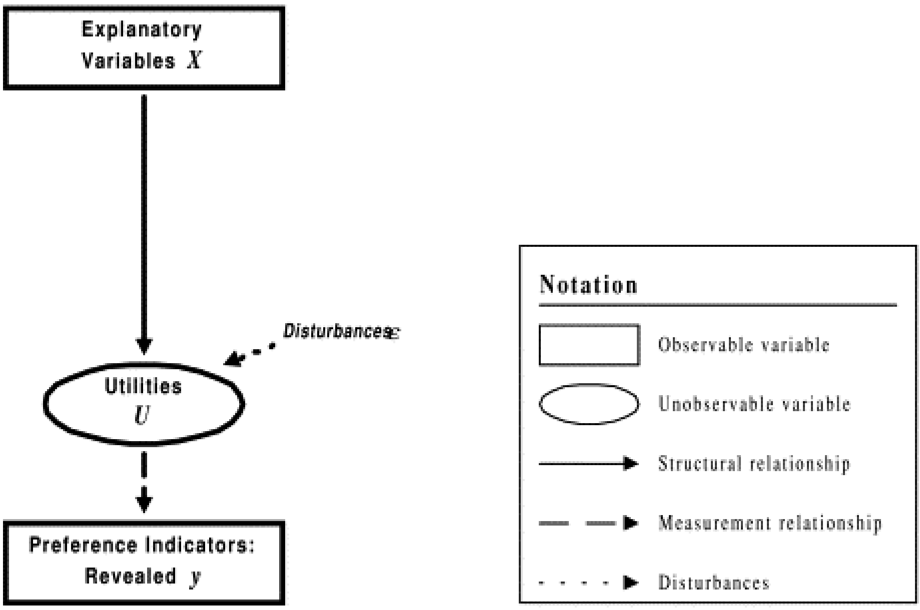

Figure 1 Utility Model (Walker and Ben-Akiva 2000)

Random Utility Theory (RUT) is an economic theory which states that an individual derives a certain level of "utility" (*U)* from each of the alternatives available to him or her in a choice scenario. . In the case of the PEACOX project a choice scenario is likely to be the choice between transport modes or routes presented to users by the application. Utility is a theoretical economic construct of the individual's preferences and is not a measureable quantity. According to RUT the individual compares the amount of utility they estimate that they will receive from each alternative and chooses the alternative *i,* which provides the greatest level of utility.

$$U_{in} > U_{ij} \forall j \neq i$$

Equation 1

While it is possible to estimate the impact of certain attributes upon the choice maker, it is impossible to identify all the factors that influence the decision making process. This reflects the idiosyncrasies of individuals varying circumstances, upbringing and personal opinions/attitudes, and the fact that no two individuals are the same. To reflect the two distinct components of the utility, the utility equation contains a deterministic term V_i and an error term ε_i, which is assumed to be randomly distributed across the population, hence the "Random" section of the theory.

$$U_i = V_i + \varepsilon_i$$

Equation 2

The deterministic component of the utility of each of the alternatives available to the individual is assumed to be a product of the "attributes" of that alternative. An attribute of an alternative is a characteristic of the alternative such as the cost of a bus journey or the level of comfort experienced when undertaking a train trip. The equation for deterministic component of the utility *(V_h)* is a combination of attribute levels (X_h), attribute coefficients (β_{2h}) and an alternative specific constant (β_{1h})

$$V_h = \beta_{1h} + \beta_{2h} X_h$$

Equation 3

In the case of transport research these attributes commonly include items such as trip time, trip cost, levels of comfort etc. In the case of the PEACOX model extra attention will be given to identifying the impact of environmental information upon the decision making process. If the levels of the attributes vary it is assumed that the level of utility produced by the alternative also alters. For example if the travel time attribute of a given mode decreases the utility of mode should increase and therefore the mode will become more attractive.

Similarly as the cost attribute of a mode increases it is likely that the mode will become less attractive to the decision maker. In the case of the PEACOX field trials the impact of changes to the level of emissions produced will be assessed. It is at this time assumed that users wish to reduce their emissions and therefore a reduction in the emissions attribute will increase the attractiveness of the mode. However, it is possible that the influence of emissions information may be insignificant in comparison to other attributes such as time and cost. It is impossible to know before the trials whether the additional information that PEACOX provides will be significant in the choice process of users.

As with all experimental models the behavioural model is subject to potential Type 1 and 2 errors.

Type 1 Error: this is a false positive where the model appears to detect the influence of a factor which is in fact statistically insignificant in the decision process.

Type 2 Error: This is where the factor does have a significant role in the decision making process but is not detected by the model.

Random Utility Theory deals with probabilities, and the probability of a probability of an individual choosing a given mode is probability that the utility of that mode is greater than the other modes in the choice set.

$$P_i = \Pr ob(U_i > U_j) \forall j \neq i$$

Equation 4

4. Multinomial Logit Model (MNL)

The multinomial logit model (MNL) is one of the most widely used discrete choice models in terms of implementing the assumptions of RUT. The model is derived under the premise that the error term is identical and independently distributed. This results in the probably of an alternative being selected outlined in the equation below. *Pi* is the probability that the individual will choose alternative *i, Vi* is the deterministic element of utility for alternative *i* and *J* is the number of alternatives in the choice set.

$$P_i = \frac{e^{V_i}}{\sum_{j=1}^{J} e^{V_j}}$$

Equation 5

5. Incorporation of Latent Variables

Many of the factors that influence individuals' are dependent on the attributes of the modes on offer or the socioeconomic characteristics that we as analysts can observe. Rather these factors are a product of individuals' internal attitudes and perceptions. Known as "latent variables" these unobservable factors could include (but are not limited to):

- Attitude towards the environment
- Perceived level of personal responsibility
- Belief regarding climate change
- Perceived access to sustainable alternatives
- Attitudes towards public transport
- Perceived safety of urban cycling

These factors cannot be assessed by viewing the actions and choices of individuals, rather other techniques such as pre-trip surveys have to be undertaken with field trail participants.

The incorporation of these variables in modelling is still a very immature area of discrete choice modelling and a universally accepted method has not yet emerged.

The use of this approach may be applicable to the second field trial but will not be suitable for the first Vienna trial.

6. Required Model Inputs

The behavioural model is designed to output the relative influence of a number of mode attributes in the user's mode choice. It will identify the relative significance of the each of the attributes examined and determine how a change in the level of these attributes would impact upon the decision making process.

The successful implementation of the model is contingent on accurate historic information that provides data on

- The routes and modes suggested to the user by the PEACOX Application in terms of
  - Route distance
  - Estimated travel time
  - Estimated emissions produced by each mode
  - Estimated exposure from undertaking each mode
- Other desirable information that could significantly increase the accuracy of the model includes
  - Weather conditions at the time of mode choice
  - Trip Purpose

- The socio economic characteristics of the decision maker such as
  - Age
  - Gender
  - Education
  - Income
  - Whether or not they have children
  - Employment Status
  - Occupation
- The following transport related variables are also very important
  - Access to cars
  - Access to bicycle

- Access to public transport links
- Ownership of weekly/monthly/annual public transport ticket or bicycle scheme card
- Location of user's home and place of work

7. Initial PEACOX Model

The initial base model for the PEACOX behavioural analysis is outlined below. This format accounts for the information provided to the user by the PEACOX application and does not include any other variables. The observable component of utility is assumed to be composed solely of the attributes of travel time and estimated emissions.

$$Vi = \beta_3 + \beta_1 X_1 + \beta_2 X_2$$

Equation 6

Where:

Vi = *The level of deterministic utility that the user assigns to alternative i*
β_3 = *The alternative specific constant*
β_1 = *The co − effiecnt for estimated travel time for alternative i*
X_1 = *The estimated travel time supplied by PEACOX for alterantive i*
β_2 = *The co − effiecnt for emissions estimate produced by alternative i*
X_1 = *The emissions estimate supplied by PEACOX for alterantive i*

8. Expected Results

Assuming that the users behave in a manner consistent with the transport literature, we can expect the following to occur

- As the time predicted for a given mode or route increases, the associated co-efficient will decrease. This will result in the overall utility of the mode/route decreases and in turn the probability of it being chosen by the user. Literature suggests that it is very likely that trip time will be a strong predictor of mode/route choice.

- As the emissions predicted by PEACOX increases for a given mode or route increases, we expect the same response to occur as seen with the time variable i.e. Reduction in probability of choosing this alternative. This does, however, depend on the users considering emissions when choosing their mode. Emission co-efficients may indicate a desire to select sustainable routes but may also be statistically insignificant results in a very low probability that they were considered by the decision maker.

9. Inclusion of other variables

Once the results of the field trial are collected and successfully formatted, the appropriateness of the purposed model, in terms of representing the user's decision making processes, can be tested. The inclusion of other variables such as those outlined in section 5 will be undertaken and their influence upon the goodness of fit of the model assessed. It is often the case that a given variable may play a statistically significant role in the assessment of one alternative put does come into the user's consideration when assessing another alternative.

In many ways the process of including more variables is one of trial and error as the model format does not allow for the inclusion of limitless attributes. Commonly used modelling approaches that may be applicable to the PEACOX data set include:

- Model Segmentation based upon some either previous known characteristic or a commonality identified within the data set. For example the data set could be split by gender, trip purpose or home/work location
- Lexicographic Analysis
- Nesting Models to reflect a decision maker's categorisation of modes (e.g. a decision maker may always choose public transport and only then uses PEACOX to choose the fastest or most sustainable of these)

N.B It is important to note that the predictive performance of the model and the manner in which variables can be incorporated is heavily dependent on the quality of the choice observations recorded for the user. The more information that is known about the conditions that were present when the user accessed the PEACOX application, the more likely the model is to correctly identify the mode attributes that where significant.

10. Conclusion

The purpose of this deliverable was to identify the best method of modelling the behaviour of PEACOX users. An examination of the literature has revealed that the use of discrete choice modelling methods based upon random utility theory is the most appropriate approach. This modelling technique is well established within transport academia and has repeatedly proven itself to be an efficient modelling technique of transport choices. This method assumes that the user will drive some level of utility from each of the attributes associated with the trip. Uniquely, PEACOX will highly the emissions associated with the available options and introduce emissions as a factor in the users' mode choices. The theoretical multinomial logit model presented in this deliverable has the ability to isolate the impact of emissions information. While trip time and emissions will form the basis of the model, MNL modelling also has the advantage of being able to incorporate additional variables, such as the socioeconomic characteristics of the user and their habitual transport behaviour, to increase model fit.

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