Developing a successful stated preference methodology for determining destination choice coefficients and using it to investigate its empirical structural relationship with toll route choice

Peter Davidson\textsuperscript{a,*}, Collins Teye\textsuperscript{a,b}, Rob Culley\textsuperscript{a}

\textsuperscript{a}Peter Davidson Consultancy, England, \textsuperscript{b}Now at University of Sydney, Business School

Abstract

Applying stated preference to destination choice has been little researched, partly because of the need for many more alternatives than could be available with stated preference. However during the course of several successive stated and revealed preference surveys, we have developed a successful experimental design and survey instrument so as to measure destination choice coefficients. We have taken this further so as to deal with the combined choice of destination and toll route. We have used this stated preference and revealed preference experimental design to investigate whether destination choice is above toll route choice or vice versa. This paper traces the different approaches adopted in a series of stated and revealed preference exercises in Nigeria in an attempt to understand this structural relationship between destination and toll route choice and reports on the final successful approach. It presents the detailed estimation results from the successful survey together with the estimated structural parameters using simultaneously estimated nested logit model estimation.

1. Introduction

Understanding how drivers value the different aspects of travel, and how changes in the transport level of service attributes might affect what they do is vital to both transport planners and transport providers. The structural relationship between mode and destination choice models' sensitivity to changes in these attributes of travel has

* Corresponding author. Tel.: +44 1442891665.
E-mail address: mail@peter-davidson.com
been extensively investigated by researchers and practitioners. For example, in the US, destination choice is considered to be less sensitive than mode choice whilst in the UK it is reversed. However, very little work has been published on the structural relationship between destination choice and toll route choice and the magnitude of the structural parameters - especially in the developing world. This is important because it could have a profound effect on the model's traffic forecasts and (in the toll road context) the revenue forecasts.

One of the two main approaches used to quantify the importance of the attributes of travel is Stated Preference (SP) which is based on what people say they would do in a hypothetical situation. In a typical SP experiment respondents are presented with hypothetical choice situations which are described with a set of well defined attributes (e.g., travel time, cost, etc) where each attribute has two or more levels (or fixed values) from given choice sets (Train 2003, 2009).

As noted in Teye et al. (2012), these hypothetical situations are generated through experimental design, (Kessels et al., 2006; Sándor and Wedel 2001, 2002, 2005). Traditionally, these designs are generated using a full or fractional factorial design approach. The key attractiveness of these methods is the fact that they generate designs which are orthogonal (where all levels of each attribute vary independently of one another). The assumption is that orthogonality guarantees that we can always estimate the effect of one attribute or interaction clear of any influence due to any other attribute or interaction. However, as argued in (Rose and Bliemer, 2006) that this orthogonality property may not be very useful when applying discrete choice models. They noted that in discrete choice, it is the correlations of the differences in the attributes which should be of interest rather than the correlation structure between the attributes. Furthermore these design types can only be available for a relatively small number of very specific problems as the number of choice situations generally increases exponentially with increasing number of attributes and/or attribute levels. Also the number of choice situations cannot be freely chosen by the Analyst (Bliemer and Rose, 2007; Kuzmanovia and Vukmirovic, 2005) and not available when the number of attribute levels is different for most of the attributes and when some combinations of attribute levels are unfeasible (Kuzmanovia and Vukmirovic, 2005).

In the last several years both researchers and practitioners have adopted a new design principle based on design ‘efficiency’ rather than the traditional principle of orthogonality (e.g., Huber and Zwerina 1996; Kessels et al. 2006; Sándor and Wedel 2001, 2002, 2005). This relatively new design approach produces stable and reliable parameter estimates in a fractional design setting by minimising at least one property of the information matrix (e.g., the determinant or trace) of the log-likelihood function of the chosen logit model (Huber and Zwerina, 1996).

In this paper we have successfully used both these design principles to determine the structural relationship between destination and toll choice. This is a non-trivial task as very little work exists on the structural relationship between destination choice and toll route choice and the magnitude of the structural parameters. This is important because it could have a profound effect on the model's traffic forecasts and (in the toll road context) the revenue forecasts.

Reliable revealed data on toll roads or a combination of toll and destination are almost non-existent especially in the study environment. On the other hand, it has hitherto been difficult to apply stated preference to destination choice alone because the destination choice experiment could need as many alternatives as destinations and stated preference is limited by its ability to deal with more than a few alternatives. However during the course of several successive stated and revealed preference surveys, we have developed a successful experimental design and survey instrument so as to measure destination choice coefficients. We have taken this further so as to deal with the combined choice of destination and toll route choice where one alternative is generally a high quality toll road and the other is the untolled alternative. We have used this stated preference and revealed preference experimental design to investigate whether destination choice is above toll route choice or vice versa.

The literature on the analysis of such revealed preference data is sparse and inconclusive. On the other hand, it has hitherto not been possible to apply stated preference to destination choice for practical reasons such as for example that destination choice would need as many alternatives as destinations and stated preference is limited by its ability to deal with more than a few alternatives. Ortuzar et al (2000) applied sp techniques to determine household choice of new residential locations and the measurement of accessibility. The attributes considered in the sp experiments were time (3 levels), distance (3 levels) and house rental (3 levels) with an orthogonal fractional factorial design. Moore (1989) modelled shopping destination choice using stated preference where respondents...
were asked to rank 9 alternatives in order of preference for a major grocery shopping trip and used exploded logit to estimate the model coefficients.

Hensher et al (1988) investigated toll route choice behaviour of urban car commuters. The attributes they considered in their sp experiment included the toll cost, free flow time, delay time, with an orthogonal fractional factorial design where each variable had 3 levels. In Wardman et al (2008) they used sp to determine the impact of different tolling scenarios on the demand for toll roads and the surrounding network including the willingness for motorists to switch to a toll route or change departure time in response to different tolling scenarios. Fox et al (2011) investigated toll route choice as a sub-model within the assignment process where each origin-destination pair was split between two routes (toll and non-toll) using a binary logit model. Li and Hensher (2012) highlighted the drivers attitude to risk and the importance of non-linear utility functions in estimating the value of travel time savings in the context of toll roads.

This paper traces the different approaches adopted in a series of stated and revealed preference exercises in Nigeria in an attempt to understand this structural relationship between destination and toll route choice and reports on the final successful approach. It presents the detailed estimation results from the successful survey together with the estimated structural parameters using simultaneously estimated nested logit model estimation.

2. Case Studies

2.1. Introduction

Under this section we give a brief description of the two main studies we undertook to investigate the structural relationship between destination and toll route choice. The overall approach in both studies comes from part of the survey data collected to measure the value of time during a toll road project in Nigeria in 2011. The overall approach involves a personal face-to-face interview of drivers at a roadside interview site who were using the main long distance spine route across Nigeria, some 1000 km long, which connected up major cities which were at least an hour apart. Trips were normally long distance with an average duration of several hours. The roadside interview survey had questions about the trip they were currently making, their household and personal characteristics which was followed by the stated preference game.

2.2. Treatment of the alternative destinations

The issue of narrowing the large number of alternative destinations into a number tractable by stated preference, was addressed by asking respondents what their alternative destinations were. These were listed out and the interviewer selected one at random for the sp game. Thus there was an element of self selection between all the destinations. This had to be taken into account when applying the parameters estimated from the stated preference game, in the traffic and revenue forecasting model.

This raised the key issue of how to treat the transferability of the activity at the current destination to the new destination. This is critical in practice because sometimes these activities are not transferrable at all, sometimes they can be transferred in the long term and sometimes they can be transferred immediately. If the activity was not transferrable the new destination will be most unattractive while if it were immediately transferrable the new destination could be quite attractive. For example consider the case of a driver going shopping for some common items. If his current destination was not available he could select another destination to effect the purchase making it easy for him to switch destination. By contrast consider the driver going to work in a highly specialised job which does not exist anywhere else or going to visit his mother. Such an activity would not be transferrable to the new destination and he would be most reluctant to switch destinations. The transferability of the activity to a new destination can be considered as falling between two extremes as follows:

1. in many cases drivers can only undertake their activity at their current destination because that is where they work, their relative lives etc. This mitigates for fixing the destination activity in the sp game to the current destination so that they may have to do something else at their destination. In this case they would be most reluctant to switch destination.
2. However in the long term, they may find a suitable job at another destination if for example they can get there much quicker via a new fast high quality tolled road. This mitigates for allowing the respondent to undertake the activity at other destinations too. In this case they would be much more likely to switch to the new destination.

The problem then arises of what situation, between these two extremes pertains to real life in the context of forecasting traffic and revenue for a new toll road. We adopted a pragmatic approach - we undertook two studies each of which explored one of the above two extremes. We considered that we should explore these two extremes before venturing to find the activity transferability balance:

1. For the first study (Study I) respondents were told that they could undertake the destination activity at both the current and the new destination. So for example they had the same job at the new destination as the one at their current destination. This corresponds to extreme 2 above.

2. For the second study (Study II), the respondent’s situation determined whether the activity at the destination could be undertaken at the new destination. So for example if the driver was going to work at his current destination, his work was not at his new destination. If he could change jobs easily then his work was at the new destination. If he was going shopping then there would be shops at both destinations. This corresponds to extreme 1 above.

In both studies there was a selection of respondents to remove those who had no destination choice. To do this the questionnaire asked various questions to probe the respondent’s choice of destination which culminated in the following question with five possible responses:

*If you could not go to your current destination for 2 years and you knew about it 6 months ago what would you have done?*

1. Cancel the trip
2. Find a job elsewhere (Please list the possible destinations)
3. Go to a different destination (Please list the possible destinations)
4. Make the trip in 2 years time
5. Other

Only respondents who chose 2 or 3 of the above responses were allowed to play the sp game. Thus the respondents selected for the game were those who had a choice of destination. Respondents listed out their main alternative destinations and the interviewer randomly selected one destination as the New Destination for the stated preference game.

The sp game used their current journey by the existing (non-tolled) road to their current destination as their reference trip. Respondents were asked to choose between their existing road and a toll road alternative and between their current destination and their new destination (as defined above) with various levels of travel time and cost. The toll road was a new high quality dual carriageway highway while the existing road was generally a poor quality congested single carriageway road so we expected the toll ASC to be positive (once the effect of the actual cost had been taken out).

The games were designed initially with prior knowledge about the values of time and were refined during the piloting stage. The first pilot was used to test the game context, attributes and their levels and also to train the interviewers. The second pilot was used to further refine the questionnaire, sp games and show card materials and also to ensure that the interview was completed within a reasonable amount of time. The results of the sp games were analysed to ascertain whether the games were functioning correctly and producing reasonable coefficients. The final stage of the pilot studies resulted in the final questionnaires, sp games and show cards for the main studies.

285 car drivers were sampled and interviewed in study I and each provided seven pseudo-observations resulting in a total 1995 observations. These observations were then used in estimating the parameters of the models. In study II, a total of 92 car drivers were intercepted and interviewed. However only 64 of them were qualified to play the sp game and each produced 12 pseudo-observations resulting in a total of 768 observations for estimating the model parameters.
Due to the small sample sizes in both studies and for comparison purposes the analysis was done over all car trip purposes.

2.3. Study I: Orthogonal Fractional Factorial Design

An orthogonal fractional factorial design was used to construct 8 different choice situations or scenarios of the experiment. In this type of design the selection of the number of attributes and their constituent levels governed the number of choice situations generated by the experimental design. Our experimental design had two continuous variables (‘travel time’ and travel cost) which varied across two levels and two categorical variables also defined at two levels each. The categorical variables were firstly the choice of toll versus the existing untolled road and secondly the choice of their Current Destination versus their New Destination. Due to the orthogonal property of this design, at least the main effects can be estimated independently assuming negligible two-way or higher- interactions between attributes. Main effects generally explain between 70 and 90 percent of the variance in response data (Louviere, Hensher and Swait 2000).

As part of the screening questions to sample respondents to play the sp games, we asked the respondent to assume that they can carry out their current activities at the ‘New destination’. Thus those who played the sp game may be willing to trade their current destination for improved travel time and/or travel cost as they can still carry out their intended activities in the new destination. In the 8 game scenarios, 4 of them (pseudo-alternatives) describe the toll alternative and the other 4 describe the non-toll alternative as shown in Fig. 1. Due to the expensive nature of the survey exercise, information on the most preferred option is not enough to get the required sample size to be able to estimate the model parameters. So we asked the respondents to rank the 8 scenarios instead of selecting the most preferred one. Using this approach resulted in each respondent providing seven observations instead of one for the estimation process.

An observed ranking for a respondent implies a complete ordering of the underlying utilities, with the first ranked option having the highest utility. For example if the respondent raked 8 options as (3, 2, 5, 4, 6, 8, 7 and 1) then it implied that:

\[ U_3 \geq U_2 \geq U_5 \geq U_4 \geq U_6 \geq U_8 \geq U_7 \geq U_1 \]

The ranking approach we adopted was in a form of a game. In the game respondents are asked to make a series of pair-wise choices for say a particular travel decision, where two options out of the 8 set are presented. Each option is compared with the others in a logical way whereby the choices led to a ranking of the options from most preferred to the least preferred.

The game was played in such a way that the respondent is first presented with two alternatives at a time (e.g., the alternative which was closest to their current trip which used the existing road versus the worse alternative using the existing road and current destination), and asked to state which alternative they would choose, and then, after they have made this choice, the winner (the chosen alternative) is placed in the top position and the loser (the non-chosen option) is placed below it. It is made to compete with any of the remaining alternatives for the second position. The winner for the second position then competes with the alternative at the first position else remains at the second position provided none of the remaining alternatives outperformed it. This is a process of successive pair wise comparisons. The process continues until the game is over, where the most preferred alternative is ranked first (ie at the top), followed by the second preferred alternative, and the least preferred ranked last (at the bottom). The resulting data constitute a ranking of the 8 alternatives that reflects the perceived utility that the respondent obtains from each alternative, with the alternative having the highest utility in the first position followed by the second best and so on. The ranking of the alternatives provided seven pseudo-observations for each respondent (see Train, 2009) where each alternative in turn is considered as a multinomial choice with all the alternatives below it as being the non-chosen alternatives. This game experiment ensures the option at the first position is indeed perceived by the respondent to have the highest utility whilst the option at the last position has the least utility.
### Study II: Efficient Design

In this study we used efficient design techniques to generate the game scenarios. Specifically we used the PDC algorithm (Teye et al, 2013) to generate the designs. This algorithm is shown to produce balanced designs (a very important property of efficient designs, Barone and Lombardo, 2005a) for any given number of attributes and their levels. Under this design approach the user has the freedom of selecting the required number of choice scenarios to present to each respondent and can include many more attributes and levels than the fractional factorial design. In this study each respondent was presented with 12 choice scenarios and each scenario consisted of a binary choice between non-toll and toll routes. In creating the designs, three continuous variables (Travel time, Travel cost, and Departure time) were varied across three levels. And one categorical variable, which was defined at two levels (Current Destination/ New Destination). The choice of three levels for each of the continuous variables allowed us to account for non-linearity in attribute levels.

The construction of efficient designs requires *a priori* knowledge of the weights associated with the attributes. As such, the parameter values play a key role in determining the level of efficiency of a design. Unfortunately, the exact parameter values are unknown at the design construction phase. However, several techniques exist for generating approximate values (termed priors) for generating the designs. We adopted the Bayesian approach to the design generation process. In this approach rather than assume a single fixed prior for each attribute, the efficiency of the design is now determined over a number of draws taken from prior parameter probability distributions. A total of 281 drivers were intercepted and interviewed and 129 of them successfully completed the survey.

#### Fig. 1: Example of an sp game

<table>
<thead>
<tr>
<th>Game</th>
<th>Cost PA</th>
<th>SP Spend</th>
<th>Destination</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td></td>
<td></td>
<td>Current_destination</td>
</tr>
<tr>
<td>H</td>
<td>850</td>
<td>40</td>
<td>New_destination</td>
</tr>
<tr>
<td>I</td>
<td></td>
<td></td>
<td>Current_destination</td>
</tr>
<tr>
<td>V</td>
<td>1000</td>
<td>40</td>
<td>Current_destination</td>
</tr>
<tr>
<td>W</td>
<td></td>
<td>50</td>
<td>New_destination</td>
</tr>
</tbody>
</table>
3. Methodology

This section is mainly devoted to the presentation and discussion of the models developed from the two studies. For the purpose of this study, the multinomial logit (MNL) and Nested logit (NL) were employed for a comparative assessment of the two studies (see McFadden 1974; Ben-Akiva and Lerman 1985; and Louviere, Hensher and Swait 2000; Train 2009; Davidson et al, 2012; Teye et al, 2013) for detail discussion of these models.

3.1. The Multinomial Logit (MNL) Model

MNL model is obtained by assuming that each error term is independently, identically distributed extreme value (McFadden, 1974). These assumptions imply that the choice probability \( P \) of the individual choosing an alternative is expressed as (McFadden, 1974; Train, 2009):

\[
P_i = \frac{\exp(U_i)}{\sum_{j=1}^{J} \exp(U_j)}
\]  

The number of alternatives available under study I is 8, obtained through the combinations of 2 destination alternatives (Current vs New destination) and 4 routes (2 toll and 2 non-tolled). For study II, the number of available alternatives is 4, made up through the combinations of 2 destination alternatives (Current vs New destination) and 2 routes (toll vs non-tolled).

3.2. The Nested Logit (NL) Model

The goal of applying this model type is to establish the structural relationship between destination choice and toll route choice. A nesting structure with destination above toll route makes the choice of toll routes more sensitive to changes in level of service variables and vice versa. It is therefore very important to get this relationship right, especially in the context of road pricing. The wrong structure could produce a wrong traffic and revenue forecast. In the nested logit model, the unconditional probability of an alternative is:
\[ P_i = P_m \times P_{i|m} \] (3)

where \( P_{i|m} \) is the conditional probability of choosing alternative \( i (i = 1, 2, ..J) \) given that it is in nest \( m (m=1, 2,..M) \) (Daly and Zachary, 1978):

\[ P_{i|m} = \frac{\delta_{im}\exp(U_i)}{\sum_{j=1}^{J}\delta_{jm}\exp(U_j)} \] (4)

The *logsum* for nest \( m \) is expressed as:

\[ L_m = \log \sum_{j=1}^{J}\delta_{jm}\exp(V_j) \] (5)

Where \( P_m \) is the conditional probability of choosing nest \( m (m=1, 2,.., M) \), and is expressed as:

\[ P_m = \frac{\exp(\mu L_m)}{\sum_{l=1}^{M} \exp(\mu L_l)} \] (6)

Where \( \delta_{im} \) is an indicator variable that equals 1 if alternative \( i \) is assigned to nest \( m \) and 0 otherwise and \( \mu \) is the structural parameter which should lie between 0 and 1 (Train, 2003; Ortuzer, 1983; Daly and Zachary, 1978; Ben-Akiva and Lerman, 1985). Under this model type two possible structures were considered; destination choice above toll route choice (Fig. 3a); Toll route choice above destination choice (Fig. 3b). The screening questions may be crucial to establish the right model structure. The estimation of these models was done in the estimation software Visual Choice. It allows for the estimation of Nested Logit models with normalisation from below or above. It can also be used to estimate more advanced models such as Mixed GEV and Latent GEV models.

**Fig. 3:** different nested Logit structures

**a) Destination above toll (DT)**

- Current Destination
  - Non toll
  - Toll

- New Destination
  - Non toll
  - Toll

**b) Toll above destination (TD)**

- Current Destination
  - Non toll
  - Toll

- New Destination
  - Non toll
  - Toll

**or**

- Destination Choice
  - Toll Route Choice
  - Current Destination
  - New Destination

- Toll
  - Non toll
  - Toll
4. Model Results

4.1. Study I

4.1.1. The Utility Equation

The observed utility of using a toll or a non-toll road to travel to a destination:

\[ U_{N_{toll}} = \beta_1^* T_{N_{toll}} + \beta_2^* T_{C_{N_{toll}}} \] (7)

\[ U_{toll} = \beta_{toll}^* + \beta_1^* T_{toll} + \beta_2^* T_{C_{toll}} \] (8)

where:

- \( U_{N_{toll}} \) is the observed utility of using a non-toll road to access a destination
- \( U_{toll} \) is the observed utility of using a toll road to access a destination
- \( TT \) and \( TC \) are the travel time and travel cost respectively
- \( \beta_{toll} \) is the toll constant
- \( \beta_1 \) and \( \beta_2 \) are the weights or importance attached to travel time, and cost respectively (expected to be negative).

4.1.2. The Multinomial Logit (MNL) Model Results

For comparison, a simple MNL model was first fitted to the data. The estimation results for this model are reported in the first part of Table 1. As expected, the results showed negative marginal utilities for increases in travel time or travel cost. The estimated parameters are 95% significant. In terms of the implied willingness to pay for travel-time reductions, the results showed a value of time (VOT) of about 4.2 pence per minute for the MNL model. The toll perception was valued at about 23 minutes of travel time.

<table>
<thead>
<tr>
<th>Table 1: Estimated results for Study I</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Variables</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>IVT (Min)</td>
</tr>
<tr>
<td>t-stats</td>
</tr>
<tr>
<td>Value of time (Pence/Min)</td>
</tr>
<tr>
<td>Cost (Pence)</td>
</tr>
<tr>
<td>t-stats</td>
</tr>
<tr>
<td>Toll Constant</td>
</tr>
<tr>
<td>t-stats</td>
</tr>
<tr>
<td>Relative to IVT</td>
</tr>
<tr>
<td>Structural Parameter</td>
</tr>
<tr>
<td>t-stats</td>
</tr>
<tr>
<td>No of Estimated Parameters</td>
</tr>
<tr>
<td>No of observations</td>
</tr>
<tr>
<td>Null log likelihood</td>
</tr>
<tr>
<td>Model log likelihood</td>
</tr>
<tr>
<td>Rho bar squared</td>
</tr>
<tr>
<td>BIC Statistic</td>
</tr>
</tbody>
</table>
4.1.3. The Nested Logit (NL) Model Results

To establish the structural relationship between destination choice and toll route choice, we developed two model structures. For the ‘destination above toll route’ (DT) structure, we grouped the road alternatives with current destination as the chosen destination into a nest called current destination, and the rest into another nest called new destination. For the ‘toll road above destination’ (TD) structure, we grouped destinations accessed by the toll road into a nest called toll nest, and the rest into another nest called the non-toll nest. The estimation results for the DT structure are shown in part 2 of table 1, whilst those of the TD structure are shown in part 3 of table 1.

Looking at the estimation of results of the DT model structure (part 2 of table 1) it is clear it is not different from that of the MNL model (part 1) with a structure parameter of 1. However, the results for the TD model structure (in part 3 of table 1) are significantly different from the MNL with the structural parameter of 0.81 which is significant at 95% level of confidence. The implied values of time (vot) of all the three models are similar at about 4 pence per minute. Comparing the NL TD model structure with the MNL model, in terms of model fit, the results showed a significant increase in Log-Likelihood (LL) by 7 units, with 1 additional parameter. This leads to a likelihood-ratio test value of 14, which has an associated chi-square p-value close to 0.00 which is less than the 0.05 level of significance. Also the structural parameter is within the expected range of 0 and 1. Clearly, the NL model with TD structure is best, with a structural parameter of 0.81 based on this study I data.

4.2. Study II

4.2.1. The Utility Equation

The observed utility of using a toll or a non-toll road to travel to a destination:

\[
U_{\text{Ntoll}} = \beta_3 \cdot EDT_{\text{Ntoll}} + \beta_4 \cdot LDT_{\text{Ntoll}} + \beta_1 \cdot TT_{\text{Ntoll}} + \beta_2 \cdot TC_{\text{Ntoll}}
\]

\[
U_{\text{toll}} = \beta_3 \cdot EDT_{\text{toll}} + \beta_4 \cdot LDT_{\text{toll}} + \beta_1 \cdot TT_{\text{toll}} + \beta_2 \cdot TC_{\text{toll}}
\]

where

*EDT* is the Early Departure Time relative to current departure time;
*LDT* is the Late departure time relative to current departure time;
*β*₃ and *β*₄ are the relative attractiveness of early and late departures with respect to current departure times.

4.2.2. The Multinomial Logit (MNL) Model Results

The MNL model results from this data set are shown in the first part of table 2. As expected, the results showed negative marginal utilities for increases in travel time, travel cost and late departure penalty. The earlier departure time coefficient is positive, which suggest that on average the respondents prefer to depart earlier than their current departure time. Note that the coefficients for the early and late departures were estimated relative to the current departure times and for long distance trips it makes sense for the early departure coefficient to be positive. In terms of the implied willingness to pay for travel-time reductions, the results showed a value of time (VOT) of about 6.2 pence per minute for the MNL model. The toll perception was valued at about 23 minutes of travel time.

4.2.3. The Nested Logit (NL) Model Results

The MNL model results from this data set are shown in the first part of table 2. As expected, the results showed negative marginal utilities for increases in travel time, travel cost and late departure penalty. The earlier departure time coefficient is positive, which suggest that on average the respondents prefer to depart earlier than their current departure time. Note that the coefficients for the early and late departures were estimated relative to the current departure times and for long distance trips it makes sense for the early departure coefficient to be positive. In terms of the implied willingness to pay for travel-time reductions, the results showed a value of time (VOT) of about 6.2 pence per minute for the MNL model. The toll perception was valued at about 23 minutes of travel time.
Table 2: Estimated results for Study II

<table>
<thead>
<tr>
<th>Variables</th>
<th>Multinomial (MNL)</th>
<th>Nested Logit (NL) DT</th>
<th>Nested Logit (NL) TD</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVT (Min)</td>
<td>-0.0245</td>
<td>-0.0298</td>
<td>-0.0245</td>
</tr>
<tr>
<td>t-stats</td>
<td>14</td>
<td>18</td>
<td>41</td>
</tr>
<tr>
<td>Value of time (Pence/Min)</td>
<td>6.2</td>
<td>6.3</td>
<td>6.2</td>
</tr>
<tr>
<td>Cost (Pence)</td>
<td>-0.0039</td>
<td>-0.0047</td>
<td>-0.0039</td>
</tr>
<tr>
<td>t-stats</td>
<td>12</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>Early Departure time (Min)</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>t-stats</td>
<td>12</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Relative to IVT</td>
<td>-1.1</td>
<td>-1.1</td>
<td>-1.1</td>
</tr>
<tr>
<td>Late Departure Time (Min)</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.02</td>
</tr>
<tr>
<td>t-stats</td>
<td>9</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Relative to IVT</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Structural Parameter</td>
<td>0.70</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>t-stats</td>
<td>92</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>No of Estimated Parameters</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>No of observations</td>
<td>768</td>
<td>768</td>
<td>768</td>
</tr>
<tr>
<td>Null log likelihood</td>
<td>-532</td>
<td>-532</td>
<td>-532</td>
</tr>
<tr>
<td>Model log likelihood</td>
<td>-407</td>
<td>-405</td>
<td>-407</td>
</tr>
<tr>
<td>Rho bar squared</td>
<td>23%</td>
<td>24%</td>
<td>23%</td>
</tr>
<tr>
<td>BIC Statistic</td>
<td>834</td>
<td>836</td>
<td>840</td>
</tr>
</tbody>
</table>

Here again, the marginal utilities with respect to the service variables reported by both NL models are similar to those of the MNL model. All the coefficients are significant at 95% level of confidence. As can be seen from the table 2, the values reported by the NL with TD structure is similar to those of the MNL suggesting that this structure is not appropriate to account for inter-alternative correlations between the alternatives. However, the results for the DT model structure (in part 3 of table 2) are significantly different from the MNL with the structural 0.70 and significant at 95% level of confidence. Also the structural parameter is within the expected range of 0 and 1 and is statistically very significant. Clearly, the NL model with DT structure is best with a structural parameter of 0.70 based on the study II data.

4.3. Accounting for the difference in model structure in the studies

The second study (study II) investigated respondents whose destination activity transferability was what it was for their actual trip and established that destination choice must be above toll choice (DT) with a structural parameter of 0.70. This makes toll choice more sensitive than destination choice which is the structure that many toll road studies adopt in practice, though in many cases these studies have not proven this empirically. The structural parameter of 0.70 was estimated on the basis that the respondents activity transferability was that which existed at the time of the interview whereas in practice over the long time horizon of model forecasts (eg 5 years to 30 years), it might be expected that the activity would be much more transferrable. This would tend to imply that for traffic forecasting a higher structural parameter would apply.

The more that the destination activity is transferrable, the higher the structural parameter. This could be increased until it got to unity. If the activity transferability increased further, then the choice nest order would have to change to be destination below toll choice. In this case if the activity transferability increased further the structural parameter would fall from unity towards zero. The lower it went the more transferrable the destination activity.
This is borne out by the study I results which investigated respondents whose destination activity could be undertaken at any destination (ie that the destination activity was fully transferrable) and established that toll route choice must be above destination choice (TD) with a structural parameter of 0.81. This therefore places a lower limit on the structural parameter of destination choice in the context of joint destination and toll route choice. The conclusion is that the destination/toll choice structure is bounded by:

1. Destination above toll with a structural parameter of 0.81, where the destination activity is not transferrable (above that normally occurring in our survey) to another destination and
2. Toll above destination with a structural parameter of 0.70, where the activity is easily transferrable to another destination.

5. Conclusion

This paper illustrates how these additional tools can better explain the value of time and substitution patterns thereby helping analysts improve their toll road forecasts. This paper traced two key approaches adopted in a series of stated and revealed preference exercises in Nigeria in an attempt to understand the structural relationship between destination and toll route choice. We presented detailed estimation results from the two successful surveys together with the estimated structural parameters using simultaneously estimated nested logit model.

The conclusion as to whether destination choice is above toll choice or vice-versa depends upon whether the activity undertaken at the destination of the trip is transferrable to other destinations or not. This study has measured these two extremes and found that the destination/toll choice structure is bounded by:

- Destination above toll with a structural parameter of 0.81, where the destination activity is not transferrable (above that normally occurring in our survey) to another destination and
- Toll above destination with a structural parameter of 0.70, where the activity is easily transferrable to another destination.

Further work is needed to find where within this range we should be modelling as it could have a potentially huge effect on the accuracy of our traffic and revenue forecasts for toll roads.

References

Davidson, P. W and Teye, Collins, Cully, R. Understanding the potential role of the latent mix model comprising a combination of latent class and mixed logit European Transport Conference, Glasgow, 2012.
Fownes and Wardman (1993): Non-orthogonal stated preference design, PTRC SAM


Teye C, Davidson P, Using Simulated Annealing algorithm to generate efficient stated preference designs, European Transport Conference, October, 2012, Glasgow

Toner, Clark, Grant-Muller, and Fowkes (1998): Anything you can do, we can do better. A provocative introduction to a new approach to stated preference design, CTR 8 at Anterp.


