# Valuation of Travel Time Savings – Market Research

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Booz•Allen & Hamilton

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# EXECUTIVE SUMMARY

## 1. Project Background and Objective

Transport project evaluation in New Zealand is based on the Project Evaluation Manual (PEM) of Tranfund New Zealand. For typical road improvement projects, the value of time savings to motorists is the largest component of total benefits. The current unit values of time savings included in PEM have been derived from international market research studies and evaluation practices.

This research project aimed to overcome this deficiency and to develop unit time values based on New Zealand evidence. It is the first project involving market research in New Zealand, to establish unit time values for New Zealand motorists. It covers values for non-business travel, for a range of purposes and travel conditions. It was undertaken as part of Transfund New Zealand's Research Programme by a consultant team lead by Booz·Allen & Hamilton (New Zealand) Ltd.

The **overall objective** of the project was to undertake market research among motorists in New Zealand to establish unit values of travel time savings (VTTS) by:

- trip purpose (particularly commuter *v* other)
- degree of traffic congestion
- uncertainty of travel (arrival time).

## 2. Methodology – Market Research

Key features of the market research methodology were:

- Interviews with 450 residents in three metropolitan centres (Auckland, Wellington, Christchurch) and form smaller centres in New Zealand, undertaken in June/July 1999.
- Interviews undertaken at respondent's place of residence using the computer-assisted personal interview (CAPI) approach.
- Interviews covered a random sample of people who had made a trip (excluding business travel) as a car driver in one of the following categories:
  - local, commuter purpose } within previous 7 days
  - local, other purpose }
  - medium distance (up to 3 hours) } within previous 6 months
  - long distance (over 3 hours) }

*cont.*

- Interview covered:
  - person details
  - relevant trip details (eg. trip time, trip distance, number of people in car, proportion of trip time spent in free-flow conditions and various degrees of congestion)
  - preference between relevant trip and range of hypothetical trips with different characteristics.

- Each interview involved 16 'games' in which the respondent was asked to choose between their reference trip and two alternative trips, differing according to the following attributes:
  - total (expected) travel time
  - travel time spent in free-flow conditions, somewhat impeded conditions and highly congested conditions
  - additional time required to be reasonably confident of arriving at the destination by a particular time
  - running (fuel etc) costs paid and any toll charges paid.

## 3. Methodology – Analysis

A series of multinomial logit (MNL) models were estimated to identify the role of each attribute in the 'stated choice' experiment involving choice between the reference trip and the two alternative trips (sets of attribute levels) on offer.

The main models were limited to the above four main trip categories. Secondary analyses were undertaken with additional segmentation by centre (metropolitan *v* regional); i.e. Auckland *v* Wellington/Christchurch), income, vehicle occupancy, and whether or not the driver pays for the fuel.

Three alternative models were estimated:

- Model 1: simple trade-off between total (expected) travel time and total (running plus toll) costs.
- Model 2: trade-off between each of the three expected time components and the contingency time component, and the total costs.
- Model 3: trade-off between each of these four time components, and the two cost components separately.

Without exception, it was found that all choice models for all segments captured the choice process through the design attributes very well indeed. All attributes had the expected sign and were generally highly statistically significant: the only exceptions were in models for some sub-trip purposes, for the free-flow time and contingency time attributes (in cases where the sample sizes were relatively small).

## 4. Key Findings

The key findings relating to unit values of travel time savings for car drivers are summarised as follows:

**Values by trip purpose/length**

(i) A verage values for commuter travel appear to be significantly (c. 80%) greater than for other local trip purposes.

(ii) The evidence on variations in values by trip length is less conclusive: longer distance trips shown somewhat lower values than medium-distance (non-local) trips.

(iii) In round numbers, average values are about $11/hour for commuters, $6/hour for other local trips, $9/hour for medium-distance and $7/hour for long-distance trips.

**Values by traffic conditions**

(iv) In all cases, values increase substantially with the degree of congestion.

(v) For commuters, highly congested ('stop/start') time is valued at over twice 'free-flow' time. For other trip purposes, highly congested time is valued at around six times 'free-flow' time.

**'Contingency' time values**

(vi) 'Contingency' time is valued at around $4-$5/hour for all except long-distance trips, approaching $9/hour for long-distance trips.

(vii) These values imply total valuations for average trips of $0.60 - $0.70 for local trips, about $2 for medium-distance trips and $7 for long-distance trips. These values are significant relative to the other time components.

**Other bases of disaggregation**

(viii) Average values appear to increase quite significantly with income in the case of commuters, while results for other trip purposes were inconclusive.

(ix) Sample sizes generally were such that it was difficult to draw significant conclusions on differences between different centres. However there is strong evidence that highly congested time and 'contingency' time is valued more highly in Auckland than elsewhere.

(x) Attempts to derive significant differences according to other bases of disaggregation were largely inconclusive (in part because of sample size limitations):
- by car occupancy
- by responsibility for fuel costs.

## 5. Some Comparisons with Values Currently Used

For car drivers on non-business trip purposes, the current Project Evaluation Manual has a base value of time of $7.00/driver hour ($NZ 1998), with this value increasing up to $10.50/person hour in the most congested conditions.

Comparison of these values with those estimated in this research indicates that:

- On average, the research values are reasonably close to the PEM values.
- The research values indicate much greater differences between congested and uncongested conditions than the PEM values, particularly for non-commuter trips: the free-flow research values are much lower than those in PEM, while the congested values are much higher.
- When 'contingency' time is included, this increases the effective research values relative to the PEM values, particularly for congested conditions.

## 6. Implications and Further Research

This project provides a much-improved empirical basis for establishing separate values of time savings for car drivers in New Zealand by trip purpose (particularly commuter v other), traffic conditions (degree of congestion) and uncertainty of arrival time.

If the research results are to be used as the basis for adoption of revised values of travel time savings for project evaluation purposes, then further consideration is needed of several issues:

- contingency should be translated into a standard set of values for evaluation.
- Any adjustment of research (behavioural) values to give resource (evaluation) values.
- Case for extending the research to cover increased sample sizes, and thus provide revised values with greater How the research values relating to degree of congestion and uncertainty/ confidence and possibly greater disaggregation.
- Implications of the new car driver values for car passenger valuations (no market research was undertaken on car passengers).

Since this research project was commissioned, Transfund has determined to undertake a comprehensive market research programme in New Zealand, to derive improved unit benefit parameters for inclusion in its Project Evaluation Manual, and hence for application in evaluating transport investments throughout New Zealand. A major part of this research programme will be concerned with valuation of travel time savings and associated level of service aspects.

This project should serve as an invaluable pilot study for the research programme, in terms of survey design methodology, analysis methodology and the results obtained. The above implications should be taken into account in the further research.


## ABSTRACT

This project involved market research among motorists in New Zealand to establish unit behavioural values of travel time savings under a range of conditions, for application in the evaluation of transport projects.

Interviews involved a series of 'stated choice' games, in which respondents chose between a recent (reference) trip as car driver and two alternative trips, which differed in terms of various trip attributes (total travel time, degree of congestion, uncertainty of arrival time, fuel costs and toll charges). A series of multinomial logit models was estimated to identify the value of each trip attribute. Unit values of travel time savings for car drivers in a range of conditions were derived, in particular according to trip length and purpose, degree of congestion, and uncertainty of arrival time. The values derived were compared against those currently used for project evaluation purposes and recommendations were made.

# 1 INTRODUCTION

## 1.1 This Report

This report was prepared for Transfund by consultants Booz·Allen & Hamilton (New Zealand) Ltd, working in association with Professor David Hensher (Institute of Transport Studies, University of Sydney) and Colmar Brunton Research (market research consultants).

The project involved market research among motorists in New Zealand, to establish unit values of time savings (for non-business travel) in a variety of conditions – with a particular focus on differences in motorist valuations according to the degree of congestion and on valuations of uncertainty in travel time.

## 1.2 Project Background

### 1.1.1 VTTS in the Project Evaluation Manual

The present Transfund New Zealand Project Evaluation Manual (PEM) provides unit values of travel time saving (VTTS) disaggregated by:

- two trip purposes (work, i.e. in course of paid employment; all other purposes);
- vehicle/passenger type (car, light/medium/heavy commercial vehicles, bus passengers, pedestrians/cyclists); and
- drivers *v* passengers.

The history and rationale behind the derivation of the present values is somewhat involved. However, in regard to the base values key features are:

- VTTS for work time is estimated based on the gross hourly wage rate plus any employment-related on-costs borne by the employer (ie, the marginal productivity of labour approach). It might be noted that this approach takes no account of the traveller's willingness-to-pay (WTP) and hence of the conditions under which travel takes place (eg congested v uncongested).
- VTTS for non-work time for car drivers was set as 40% of the average full-time employed adult hourly income. This is said to be based on a car driver from an average income household travelling to full-time paid work in free-flowing traffic.

### 1.1.2 Recent New Zealand studies

In 1992, a substantial research study was undertaken for Transit New Zealand (Transit) by consultants Travers Morgan and Beca to "validate and/or refine the travel time values used in the Transit New Zealand Project Evaluation Manual 1991"

(Travers Morgan et al, 1992). This study did not undertake any original research, but focused on:

- reviewing recent international and New Zealand research on VTTS;
- identifying the principal areas of uncertainty and weakness in knowledge of VTTS and in the current PEM values; and
- setting out a research programme and priorities to address the areas of weakness where further research was likely to be most cost-effective.

Among the many points to emerge from the study, in the context of this project it was notable that:

- The PEM values make no distinction between different non-work purposes, eg commuting, social, holiday/recreational travel. Evidence from elsewhere is that values may differ substantially for such different purposes.
- The PEM values make no allowance for differences in travel conditions, eg according to comfort or travel time reliability (due to congestion).

A second Travers Morgan research project for Transit involved market research into road users' willingness-to-pay to travel on sealed rather than unsealed roads (Travers Morgan 1994). It resulted in modifications to the PEM procedures to include an additional user cost (per vehicle kilometre) for the disutility associated with travel on unsealed roads. This is currently the only situation where PEM adjusts 'base' travel time values to allow for the disutility associated with travel in adverse conditions.

A subsequent Transit research project, started in 1995, was designed to establish, through market research in New Zealand, valuations of savings in travel time and/or improvement in conditions of travel. These valuations were required to cover:

- The range of trip purposes, eg employer's business, commuting, personal business, social/recreational, 'pure' leisure trips.
- A range of travel 'comfort' conditions, particularly unsealed roads, congested conditions, roads with limited passing opportunities, roads with poor alignment, roads with high 'side friction'.

Stage 1 of this project developed a theoretical framework within which market research on VTTS in specific conditions could be carried out and applied. This framework distinguished between:

- the opportunity cost of time saved (dependent in part on trip purpose); and
- the 'discomfort' value of time saved.

Stage 1 also outlined the requirements for subsequent market research which would provide VTTS estimates within this framework (Booz·Allen & Hamilton, 1997).

Stage 2 of the project did not proceed as originally planned, as it was overtaken by other events (in particular the termination of the Transit research programme, the establishment of Transfund, and the major review initiated by Transfund into project evaluation procedures. However, this major review largely confirmed the desirability of proceeding with New Zealand-based market research along similar lines to that proposed in Stage 2 of the BAH project.

Subsequently this research project was commissioned by Transfund, and is largely consistent with the market research proposed within Stage 2 of the BAH project. It is the first substantial market research to estimate VTTS for New Zealand motorists, and covers a range of different trip conditions and trip purposes.

## 1.3 Project Objectives

The **overall objective** of the project was to undertake market research among motorists in New Zealand to establish unit values of travel time savings (VTTS) by:

- trip purpose (particularly commuter *v* other)
- degree of traffic congestion
- uncertainty of travel (arrival) time.

In the light of the market research results, the project was to make recommendations on changes to the VTTS figures used in PEM.

## 1.4 Report Structure

The remainder of this report is structured as follows:

Chapter 2 - describes the scope and design of the stated choice survey

Chapter 3 - provides summary survey statistics and outlines the basis of the multi-nominal models used in the stated choice analysis

Chapter 4 - sets out the main model results, in terms of values of travel time savings by various segmentation variables

Chapter 5 - provides a summary of supplementary analyses of survey results for urban commuting and medium-distance trips

Chapter 6 - summarises the study conclusions and outlines their implications in terms of VTTS application.

More details of the survey design, analysis methods and results are given in the appendices (*see* contents page).

# 2 Survey Design

## 2.1 Survey Population and Segmentation

Key features of the survey population and its segmentation were as follows:

(i) Personal interview approach (PC-assisted) at respondent's place of residence.

(ii) Households selected on a cluster sampling basis.

(iii) Interviews were with people in the selected households who had made a trip as **car driver** within the following categories:
- Local trips – within the last 7 days
- Medium/long trips – since Christmas 1998 (ie within a period of about 6 months).

Note: car passengers were **not** covered.

(iv) Relevant trip purposes were all **except employer business** trips.

(v) Trip purposes were first separated into:
- Commuter (work or education)
- All other.

(vi) Other (non-commuter) purpose trips were sub-divided into:
- Local (urban)
- Non-urban medium distance (up to 3 hours)
- Non-urban long distance (over 3 hours).

(vii) Other purpose trips were further sub-divided by trip purposes (but these were not subject to separate quotas):
- Social/recreational
- Visiting friends and relatives
- Shopping (not relevant to long distance segment).

(viii) The survey covered residents in three metropolitan centres and four smaller (regional) centres (with quotas for each):

**Metropolitan:**
Auckland
Wellington
Christchurch

**Regional Centres:**
Ashburton
Napier/Hastings
Palmerston North
Nelson.

(ix) Quotas for the number of drivers sampled were as shown in Table 2.1 (*next page*).

| TABLE 2.1 : QUOTAS FOR INTERVIEWS BY CENTRE AND TRIP TYPE | | | |
|---|---|---|---|
| **Trip Type** | **Metropolitan Centres(1)** | **Regional Centres(1)** | **Total** |
| Local – commuter | 75 | 75 | 150 |
| Local – other | 75 | 75 | 150 |
| Medium distance | 45 | 30 | 75 |
| Long distance | 45 | 30 | 75 |
| Total | 240 | 210 | 450 |

**Note:** (1) Quotas given divided evenly between the 3 metropolitan centres; and the 4 regional centres.

## 2.2 Scope of Survey Questionnaire

The questionnaire was PC (laptop)-based, with the interviewer generally undertaking data entry from the respondent's answers.

An extensive questionnaire development phase was involved prior to starting the survey proper, including:

- Development by ITS in conjunction with BAH
- Review by Colmar Brunton, followed by further modification
- Initial piloting (including with Transfund staff)
- Subsequent (second and third round) piloting, with further modifications.

Box 2.1 presents a summary of the questionnaire finally adopted: the full questionnaire is given in Appendix A. Essentially the same questionnaire was used for all trip types/ purposes, although with some minor differences (as shown) between commuter trips and other purpose trips: for commuter trips, details were collected for the 'typical' (1-way) trip; whereas for other purposes, details were collected for the most recent (or a recent) trip. These trips were treated as the 'reference' trips for stated choice 'games', as now described.

## 2.3 Design of the Stated Choice 'Games'

The central feature of the survey questionnaire is the stated choice (SC) experiment. Each respondent was required to complete 16 SC 'games'. In each of these he/she was required to choose between their reference trip (ie their typical or recent trip for which details were obtained) and two hypothetical alternative trips.
The reference trip and each alternative were defined by six attributes:

- Travel time – free flow
- Travel time – slowed down
- Travel time – stop/start or crawling
- 'Uncertainty' allowance (i.e. extra time required to be reasonably certain about arriving at the destination by a particular time)

*cont.*

- Running (fuel) costs
- Toll charges (payable by the driver, relating to road use).

For the alternative trips, the six attributes may take any of four levels. Except in the case of toll charges, these levels are defined as proportions of the levels associated with the defined reference trip.

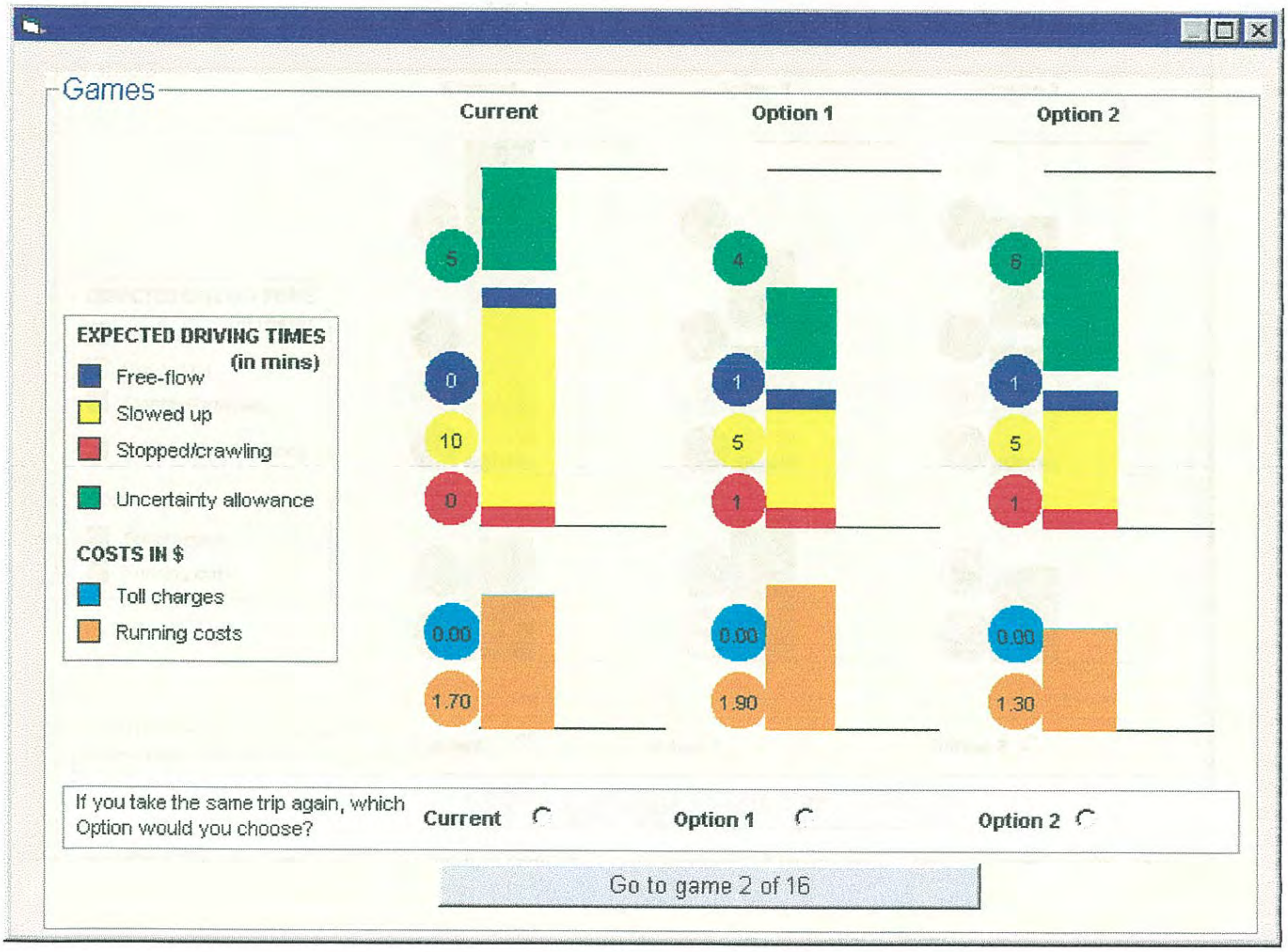
The design basis of the SC experiment is described in detail in Appendix B.

A typical SC screen is shown in Figure 2.1. The data on the reference trip were as identified from earlier questions; while the attribute levels for the alternatives (Options 1 and 2) are generated as defined by the SC experiment design.

## 2.4 Data Handling

The software (TIMEX99, developed by ITS) automates the complete data collection process; it accumulates respondent answers together with the design attribute levels into an MS-Access database, ready for choice model estimation.

### Figure 2.1: Typical Screen for Stated Choice Games



**BOX 2.1 : SUMMARY OF QUESTIONNAIRE[(1)]**

**Introduction**
A Interviewer ID
B Interview location (centre)
C Trip type
Introductory information to respondent (2 screens)

**Information on typical trip (commuter) or recent trip (other)**

| | |
|---|---|
| 1(O) | Trip purpose |
| 1(C) | Trip direction (to/from work) |
| 2(C) | Number of times trip undertaken within last 7 days |
| 2,3(O | Trip start and end (suburb or area) |
| ) | How many people in car (adults/children) |
| 3 | Total time of trip (excluding breaks) |
| 4 | Trip time by: |
| 5 | - free flow conditions |
| | - slowed down conditions |
| | - stop/start or crawling conditions |
| | Trip time if no congestion or other causes of delay |
| 6(C) | Extra time allowance to be reasonably certain about arriving at destination by a |
| 7 | particular time |
| | Estimated trip distance |
| 8 | Does driver pay for fuel |
| 9 | Ranking of importance of trip features: |
| 10 | - total driving time |
| | - time in congested conditions |
| | - certainty about arriving at a particular time |
| | - car running and other costs |
| | Summary of recent/typical trip (pictorial view of stated times and costs). |

**'Games'**
Introduction to Games
Practice Game
Games (1 to 16).

**Respondent information**
1. Age category
2. Employment category
3. Typical worked hour/week
4. Personal income category.

**Notes:** (1) (C) and (O) indicate questions applying to commuter trips (C) and other trip purposes (O).

# 3 SURVEY STATISTICS AND MODEL ESTIMATION

## 3.1 Number of Interviews

The main survey was executed in late June/early July 1999. A total of 451 interviews were successfully undertaken in the seven metropolitan and regional centres, within quotas set by individual centre and by the four trip type segments (Table 2.1).

Table 3.1 shows the numbers of completed interviews by centre and trip segment, with a further breakdown into the various non-commuter trip purposes (ie social/recreational, visiting friends and relations, shopping): no quotas were imposed on this latter breakdown.

## 3.2 Trip and Respondent Characteristics

Table 3.2 provides summary statistics from the survey on:

(i) Recent/typical trip details, including:
- purpose
- trip time
- trip distance
- occupancy
- whether driver paid for fuel.

(ii) Average trip details (averaged over the range of options presented), including:
- time components (free flow, slowed down, stop/start)
- contingency time
- running (fuel) costs
- toll charges.

(iii) Driver characteristics:
- age
- personal income
- work status.

The most interesting evidence for the recent/typical trip relates to the composition of travel time. The ratio of actual total travel time to estimated time in uncongested conditions is 1.46 for local commuters, 1.31 for local other, 1.18 for medium distance and 1.12 for long distance travel.

For the average trip (including the hypothetical options), notable points include:

- Free flow as a proportion of total time is 54% for local commuter trips, 66% for other local trips and 77% for medium/long distance trips.
- Contingency time as a proportion of total (expected) time is 40% for local commuter trips and 42% for other local trips, falling to 21% for medium distance and 16% for long distance trips.

## 3.3 Model Estimation

A series of multinomial logit (MNL) models were estimated to identify the role of each attribute in the SC experiment of choice between the recent/typical trip and the two other alternative trips (sets of attribute levels) on offer.

The main models were limited to the four main trip segments (not differentiated by centre), but stratified where possible by the various non-commuter trip purposes. Secondary analyses were undertaken with additional segmentation by centre (metropolitan v regional; Auckland v Wellington/Christchurch), income, vehicle occupancy, and whether or not the driver pays for the fuel.

Three alternative models were estimated:

- Model 1: simple trade-off between total (expected) travel time and total (running plus toll) costs.
- Model 2: trade-off between each of the three expected time components and the contingency time component, and the total costs.
- Model 3; trade-off between each of these four time components, and the two cost components separately.

Without exception, it was found that all choice models for all segments captured the choice process through the design attributes very well indeed. All attributes had the expected sign and were generally highly statistically significant: the only exceptions were in models for some of the sub-trip purposes, for the free-flow time and contingency time attributes (in cases where the sample sizes were relatively small).

Appendix D provides further details of the process for the choice model estimation and presents details of final model forms.

TABLE 3.1 : SUMMARY OF NUMBER OF SURVEYED TRIPS

| Centre | Local Commuter | Local non-commuter | | | | | Medium Distance | | | | | Long Distance | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Social/ Rec | VFR | Shop | Other | Total | Social/ Rec | VFR | Shop | Other | Total | Social/ Rec | VFR | Shop | Other | Total |
| **Metropolitan:** | | | | | | | | | | | | | | | | |
| Auckland | 26 | 8 | 6 | 5 | 5 | 24 | 6 | 4 | 0 | 4 | 14 | 4 | 11 | 0 | 1 | 16 |
| Wellington | 25 | 8 | 5 | 8 | 3 | 24 | 3 | 11 | 1 | 0 | 15 | 5 | 7 | 0 | 2 | 14 |
| Christchurch | 27 | 6 | 7 | 10 | 3 | 26 | 7 | 7 | 3 | 0 | 17 | 5 | 8 | 0 | 2 | 15 |
| Sub Total | 78 | 22 | 18 | 23 | 11 | 74 | 16 | 22 | 4 | 4 | 46 | 14 | 26 | 0 | 5 | 45 |
| **Regional:** | | | | | | | | | | | | | | | | |
| Ashburton | 22 | 3 | 11 | 5 | 0 | 19 | 0 | 3 | 1 | 2 | 6 | 4 | 3 | 1 | 0 | 8 |
| Napier/Hastings | 17 | 6 | 2 | 7 | 5 | 20 | 4 | 2 | 0 | 0 | 6 | 1 | 5 | 0 | 1 | 7 |
| Palmerston North | 19 | 4 | 3 | 8 | 4 | 19 | 5 | 0 | 1 | 0 | 6 | 3 | 3 | 0 | 2 | 8 |
| Nelson | 18 | 7 | 3 | 8 | 2 | 20 | 3 | 4 | 0 | 0 | 7 | 3 | 1 | 0 | 2 | 6 |
| Sub Total | 76 | 20 | 19 | 28 | 11 | 78 | 12 | 9 | 2 | 2 | 25 | 11 | 12 | 1 | 5 | 29 |
| **Grand Total** | **154** | **42** | **37** | **51** | **22** | **152** | **28** | **31** | **6** | **6** | **71** | **25** | **38** | **1** | **10** | **74** |

| TABLE 3.2 : SAMPLE SUMMARY STATISTICS[1] | | | | |
|---|---|---|---|---|
| Attribute | Local Commuter | Local Other | Medium Distance (<3 hours) | Long Distance (>3 hours) |
| Sample Cases[2] | 2427 | 2432 | 1069 | 1104 |
| **Last trip purpose** (cases): | | | | |
| Commuter | 2427 | - | - | - |
| Social/recreational | - | 672 | 384 | 368 |
| Visiting friends/relatives | - | 560 | 480 | 544 |
| Shopping | - | 816 | 96 | - |
| Other | | 384 | 109 | 192 |
| **Last trip details** (averages): | | | | |
| Total time (mins) | 20.8 | 20.9 | 106.9 | 291 |
| Time if no congestion (mins) | 14.2 | 15.9 | 90.7 | 259 |
| Ratio total time : uncongested time | 1.46 | 1.31 | 1.18 | 1.12 |
| Trip length (kms) | 16.2 | 16.6 | 131 | 426 |
| **Average trip details (averages):** | | | | |
| Free-flow time (mins) | 11.2 | 14.6 | 86.5 | 231 |
| Slowed down time (mins) | 5.4 | 4.9 | 15.5 | 44 |
| Stop start time (mins) | 4.0 | 2.6 | 10.7 | 23 |
| Contingency time (mins) | 8.2 | 9.3 | 23.5 | 49 |
| Running cost ($) | 1.50 | 1.70 | 13.30 | 41.67 |
| Toll charges ($) | 2.00 | 2.00 | 4.40 | 10.00 |
| **Other trip characteristics** (averages): | | | | |
| Occupancy – adults (no) | 1.4 | 1.9 | 2.0 | 1.9 |
| Occupancy – children (no) | 0.1 | 0.6 | 0.5 | 0.5 |
| Fuel paid by driver (%) | 92 | 89 | 88 | 96 |
| **Driver characteristics** (averages): | | | | |
| Driver age (years) | 40 | 47 | 47 | 41 |
| Personal income ($000pa) | 31.8 | 24.1 | 28.7 | 32.0 |
| Work status (%) : (3) | | | | |
| Full time | 61 | 25 | 46 | 48 |
| Part time | 25 | 17 | 17 | 20 |
| Casual | 9 | 9 | 8 | 4 |

**Notes:** (1) All figures are mean values for the sample.

(2) 16 cases for each survey respondent (but eliminating any cases with missing/ problematic data).

(3) Question not answered for a small proportion of cases.

# 4 Main VTTS Results and Commentary

## 4.1 Introduction

This chapter presents our commentary on the main VTTS results derived from the MNL choice models just described.

As noted, three different analysis models were used:

- Model 1 : simple trade-off between total (expected) travel time and total (running plus toll) cost.
- Model 2 : trade-off between individual time components and total costs.
- Model 3 : trade-offs between individual time components and running cost (Model 3A) or toll cost (Model 3B).

Full analytical results are given in Appendix E, including:

- Values by sub-segment (trip purpose) within the four primary segments
- Stratification of segment values by car occupancy, driver income, residential centre (metro *v* non-metro, Auckland *v* Wellington/Christchurch), and whether the driver pays for the fuel.

Summary results are given here by the four primary segments used (i.e. local commuter, local non-commuter, medium distance, long distance):

- Table 4.1: Summary results by primary segment (all models).
- Table 4.2: VTTS ratios for different time categories (ie ratio of values for 'slowed down', 'stop/start' and 'contingency' time relative to 'free-flow' time).

All VTTS values presented here relate to drivers only, and are expressed in $/person hour (NZ99$).

The following commentary highlights some of the key results.

## 4.2 Aggregate VTTS Results

Key findings and comments are as follows:

- For local (urban) trips, average values are $10.96 for commuters and $5.99 for other trip purposes. This relativity (factor 1.83) is broadly consistent with that found in other studies internationally.
- For non-urban trips, values are $9.12 for medium distance (up to 3 hours), $6.97 for long distance. This suggests that values decrease as total travel time increases: this trend is evident also for the separate sub-segments (social/recreational, visiting friends and relatives – refer Table E.2).

- As a percentage of average wage rates of those surveyed, the average values vary from 44% (long distance) to 69% (local commuter). These are very plausible, broadly consistent with other studies internationally.

## 4.3 Values Relative to Running Costs and Toll Charges

Model 3A expresses disaggregate values relative to running costs, Model 3B relative to toll charges. It is evident (Table 4.1) that, for local trips, values are systematically greater (by around 20% for commuter trips, 60% for other trips) relative to the toll than relative to the running costs; while for medium/long distance trips they are greater (by up to 60%) relative to the running costs. These relativities might be explained in terms of the toll being a higher proportion of costs on local trips, the running costs a higher proportion for the longer trips.

When the ratios of each time attribute to free-flow time values are taken, the results (Table 4.2) are identical whether running costs or toll charges is taken as the base.

## 4.4 Disaggregate VTTS Results by Traffic Conditions

Key findings and comments are as follows:

- For all segments, values for 'slowed-down' time are substantially higher than for 'free-flow' time, while values for 'stop/start' time are substantially higher again than for 'slowed down' time. This confirms prior expectations. Both Model 2 and 3 give similar relativities.
- For local commuters, slowed-down time is valued only slightly (c.10%) higher than free-flow time. Stop/start time is valued at over twice free-flow time.
- For the other (non-commuter) segments, free-flow time is valued at relatively low rates ($2.75 - $3.98), less than half that for commuters. Slowed-down time and stop/start time are valued at rates somewhat lower than for commuters for the other local segment; but higher than for commuters for medium/long distance travel.
- One result of these relativities is higher ratios for the different conditions for non-commuter than for commuter segments: for non-commuter segments, slowed-down time is valued at between 2.6 and 3.6 times free-flow time; while stop/start time is valued at between 4.4 and 7.2 times free-flow time.
- These results would be consistent with a hypothesis that commuters tend to value time savings more highly than the other segments; but place lower values on avoiding congested conditions (they probably have learnt to expect such conditions). On the other hand, other local and longer-distance travellers tend to have a lower intrinsic (opportunity cost) value of time savings, and may enjoy open-road driving, but place a high value (utility) on avoiding the frustration of travel in congested conditions.

## 4.5 Valuation of 'Contingency' Time

'Contingency' time was defined as the extra time (over the 'expected' travel time) one needs to allow for a trip in order to be reasonably confident about arriving at the destination by a particular time.

Contingency time values (Model 2) vary by segment between $3.70 and $8.76 per hour. These values reflect both the inconvenience of being late and the probability of this occurring.

Given the contingency time components of the average trip (Table 3.2), this implies total values for contingency time of approximately $0.70 for commuter trips, $0.60 for other local trips, $1.90 for medium distance trips and $7.20 for long distance trips. [Review this: better to use contingency time allowance relating to recent/typical trips.]

## 4.6 Disaggregation by Car Occupancy

It was determined early in the project to survey drivers only, and not to attempt to derive VTTS for passengers separately. The values presented in this chapter therefore relate to the driver only (unless the driver is effectively also building in passenger preferences to his/her response). It is not clear, a priori, whether drivers would tend to have higher VTTS values in cases of higher car occupancy, or lower.

The results are inconclusive (refer Table E.3):

- For two segments (Model 1), VTTS values with one passenger are higher than for solo driver, for the other two segments lower.
- For three segments, values with two passengers are higher than with one or no passengers, but lower for the other segment.

## 4.7 Disaggregation by Metropolitan *v* Regional Centres

Results for each segment have been disaggregated between the metropolitan centres and the regional centres, with the metropolitan centres split between Auckland and Wellington/Christchurch. These are shown in Table 4.3.

The main findings are:

- For commuter travel, there is little difference in metro and non-metro values.
- For other (local and longer distance) travel, metro values are higher than non-metro values – by between 6% and 31%.
- Comparing the metropolitan areas, for the two segments for which there is sufficient data (which include commuter trips), Auckland values are substantially (in the order of 50%) higher than Wellington/Christchurch values. However, for the other two segments, the data indicates lower Auckland values.

## 4.8 Disaggregation by Income Level

Results for each segment have been disaggregated by three broad income groups. For commuters, the results are given in Table 4.4:

- On model 1 (total time/total cost), values increase significantly with income: the value for the highest income group ($13.90) is some 55% higher than for the lowest income group ($8.99).
- Model 2 generally gives results consistent with Model 1, for each individual time component.

The results for the non-commuter segments are much less clear-cut, and appear to show no significant trends with income (Table E.3).

## 4.9 Disaggregation by Fuel Cost Responsibility

In approximately 90% of cases fuel costs were paid by the driver. Disaggregation of results according to whether or not the driver paid for the fuel was inconclusive (refer Table E.3), in part due to the small samples where the driver was not responsible.

**TABLE 4.1 : VTTS SUMMARY BY SEGMENT All figures in NZ$/person hour**

| Item | Local Commuter | Local Other | Medium Distance (<3 hours) | Long Distance (>3 hours) |
|---|---|---|---|---|
| **Model 1 (Total time/total cost)**(1) | | | | |
| All time | **10.96** | **5.99** | **9.12** | **6.97** |
| As % ave wage rate(2) | 69 | 50 | 65 | 44 |
| **Model 2 (Total cost)**(3) | | | | |
| Free flow time | **7.92** | **2.75** | **3.98** | **3.84** |
| Slowed down time | **8.86** | **7.46** | **13.90** | **10.09** |
| Stop/start time | **17.75** | **12.07** | **28.49** | **25.95** |
| Contingency time | **4.92** | **3.70** | **4.97** | **8.76** |
| **Model 3A (Running cost) and 3B (Toll charge)**(4) | | | | |
| Free flow time | 6.55/7.99 | 1.69/2.78 | 6.18/3.78 | 5.44/3.43 |
| Slowed down time | 7.17/8.75 | 4.69/7.71 | 22.31/13.68 | 15.16/9.57 |
| Stop/start time | 14.60/17.90 | 7.95/13.07 | 41.86/25.64 | 33.40/21.09 |
| Contingency time | 4.06/4.96 | 2.29/3.77 | 7.69/4.70 | 12.59/7.94 |

**Notes:** (1) Simple trade-off between total (expected) time and total cost.
(2) Based on annual gross personal income divided by 2000.
(3) Trade-off with total cost (running cost + toll charges).
(4) Separate trade-offs with running costs/toll charges.

| TABLE 4.2 : VTTS RATIOS BY SEGMENT<br>All figures are ratios of VTTS segment values divided by free-flow values | | | | |
|---|---|---|---|---|
| Item | Local Commuter | Local Other | Medium Distance (<3 hours) | Long Distance (>3 hours) |
| **Model 2** (Total cost) | | | | |
| Free-flow time | 1.00 | 1.00 | 1.00 | 1.00 |
| Slowed-down time | 1.12 | 2.71 | 3.49 | 2.62 |
| Stop/start time | 2.24 | 4.39 | 7.16 | 6.75 |
| Contingency time | 0.62 | 1.34 | 1.25 | 2.28 |
| **Model 3** (Running cost/toll charges) (1) | | | | |
| Free- flow time | 1.00 | 1.00 | 1.00 | 1.00 |
| Slowed-down time | 1.09 | 2.78 | 3.60 | 2.78 |
| Stop/start time | 2.23 | 4.70 | 6.70 | 6.14 |
| Contingency time | 0.62 | 1.35 | 1.24 | 2.31 |

**Notes** : (1) All figures are same for Model 3A and 3B.

| TABLE 4.3 : VTTS VALUES BY AREA OF RESIDENCE(1) All figures in NZ$/person hour | | | | |
|---|---|---|---|---|
| Area | Local Commuter | Local other | Medium Distance (< 3 hours) | Long Distance (> 3 hours) |
| Metro: | | | | |
| Auckland | 14.02 | ns | 12.22 | ns |
| WGN/CHC | 9.93 | 7.78 | 7.96 | 11.60 |
| Total | 11.03 | 6.38 | 9.11 | 7.27 |
| Non-Metro | 11.43 | 4.87 | 7.65 | 6.83 |
| Overall | 10.96 | 5.99 | 9.12 | 6.97 |

**Notes:** (1) All figures based on Model 1 results (ns denotes not significant).

| TABLE 4.4 : VTTS VALUES BY INCOME LEVEL – COMMUTER TRAVEL<br>All figures in NZ$/person hour | | | |
|---|---|---|---|
| **Item** | **Personal Income Group** | | |
| | **< $30,000** | **$30,000 - $50,000** | **> $50,000** |
| **Model 1:** | | | |
| Total time | 8.99 | 11.59 | 13.90 |
| **Model 2:** | | | |
| Free flow time | 5.75 | 9.58 | 7.96 |
| Slowed down time | 7.89 | 9.24 | 11.30 |
| Stop/start time | 17.13 | 17.47 | 20.26 |
| Contingency time | 3.35 | 5.91 | 7.15 |

# 5 Supplementary VTTS Analyses

## 5.1 Introduction

The empirical estimates of VTTS, reported in the previous chapter, were derived as the ratio of parameter estimates in a discrete choice model, using a multinomial logit (MNL) model formulation. While the MNL formulation is most commonly used for such analyses, it is quite restrictive. Model estimates are sensitive to design of the SP experiment, especially in terms of: the number of alternatives in a choice set, the number of choice sets evaluated, and the range and levels of time and cost attributes being traded. The limited literature on the topic indicates that the MNL model tends to under-estimate the mean VTTS.

Hence supplementary analyses have been undertaken (by Prof. Hensher) to examine the implications of analysing the survey responses using less restrictive models. These analyses have been confined to two of the four trip segments – local commuter and medium distance travel (up to 3 hours).

The analyses and results are reported in full in Appendix F. This chapter provides an overview of the supplementary analyses and describes the key results, in particular the variations from the MNL results given in the previous chapter.

## 5.2 Supplementary Analyses Undertaken

The supplementary analyses replaced the MNL model by a mixed logit (ML) model formulation (otherwise known as a random parameter logit (RPL) model).

The **urban commuter** analyses involved 144 respondents, providing 2304 cases (choice sets). Three ML model variants were tested, varying according to whether the choice sets were treated as independent or correlated, and whether the alternatives were independent or correlated. For each model variant, eight VTTS estimates were derived – four for the four time components relative to running costs, four relative toll to charges.

The **medium distance** (up to 3 hours) analyses involved 198 respondents, providing 3168 choice sets. Again three ML model variants were tested, varying according to their restrictions on correlation of choice sets and alternatives. VTTS estimates equivalent to those for the urban commuter analyses were derived.

## 5.3 Summary of Findings

These supplementary analyses have confirmed the importance of SP experimental design and data quality, and the need to specify choice models that capture the sources of behavioural variability. The findings overall suggest caution in adopting mean estimates of behavioural VTTS derived from the somewhat restrictive MNL model formulation.

The main finding of the supplementary analyses in relation to VTTS estimates are as follows:

### ML model compared to MNL model

- Compared to the MNL model, less restrictive model specifications tend to produce higher mean VTTS estimates for both urban commuter and medium distance travel. This finding is consistent with evidence from other studies.
- For urban commuting, the MNL model appears to under-estimate the mean VTTS by between 1% and 24%, with the under-estimation increasing from free flow time through to stop-start time: the degree of under-estimation is related to the degree of heterogeneity of travel time.
- For medium-distance travel, the MNL model appears to under-estimate the mean VTTS by between 8% and 30%, with (in this case) the under-estimation being greatest for free flow time.
- An important general conclusion is that the mean and variance have been confounded in previous studies which focus on the mean. Separating out mean and variance tends to increase the mean estimate, a very important finding. Since the variance (or standard deviation) varies according to the circumstances under which a minute of travel time is consumed, this indicates a strong case for establishing a series of VTTS for a specific type of time that is defined by measurable correlates of the unobserved sources of heterogeneity (eg age, income).

### Analyses by urban centre

- Further analyses of urban commuter travel, comparing Auckland with other centres, indicates that VTTS for stop-start time and particularly for uncertainty of arrival time are substantially higher in Auckland than elsewhere. This most likely reflects the higher congestion levels in Auckland.

### Alternative cost measures

- As indicated earlier (Section 4.3), for local trips VTTS estimates are greater relative to the toll charge than relative to the running cost; while the opposite applies for medium/long distance trips. It was hypothesised that this result arises as the toll is higher than the running costs for local trips, lower for longer trips. This hypothesis is strengthened by the supplementary analyses. They provide strong evidence that the range of an attribute has a significant influence on VTTS estimates. It seems likely, that if the same level and range were selected for both toll charge and running cost, then the mean VTTS estimates relative to the two measures would be much closer.

# 6 Conclusions Implications and Application

## 6.1 Overview of Conclusions – VTTS Estimates

The main conclusions relating to VTTS for car drivers from the results presented in Chapters 4 and 5 may be summarised as follows:

### Values by trip purpose/length

(i) Average values for commuter travel appear to be significantly (c.80%) greater than for other local trip purposes.

(ii) The evidence on variations in values by trip length is less conclusive: longer distance trips shown somewhat lower values than medium–distance (non-local) trips.

(iii) In round numbers, average values (using the MNL model) are about $11/hour for commuters, $6/hour for other local trips, $9/hour for medium-distance and $7/hour for long-distance trips.

### Values by traffic conditions

(iv) For all cases, values increase substantially with the degree of congestion (reflected in 'stop/start' and 'slowed down' time values relative to 'free-flow' time values).

(v) For commuters, 'slowed-down' time is valued only slightly higher than 'free-flow' time; whereas 'stop/start' time is valued at over twice 'free-flow' time.

(vi) For other trip purposes, 'slowed-down' time is valued at around three times 'free-flow time'; and 'stop/start' time at around six times 'free-flow' time.

### 'Contingency' time values

(vii) 'Contingency' time is valued at around $4-$5/hour for all except long-distance trips, approaching $9/hour for long-distance trips.

(viii) These values imply total valuations for average trips of $0.60 - $0.70 for local trips, about $2 for medium-distance trips and $7 for long-distance trips. These values are quite significant relative to the other time components.

### Other bases of disaggregation

(ix) Average values appear to increase quite significantly with income in the case of commuters: results for other trip purposes are inconclusive.

(x) Sample sizes generally were such that it was difficult to draw significant conclusions on differences between different centres. However there is strong evidence that 'stop/start' time and 'contingency' time is valued more highly in Auckland than elsewhere.

(xi) Attempts to derive significant differences according to other bases of disaggregation were largely inconclusive (in part because of sample size limitations):

- by car occupancy
- by responsibility for fuel costs.

## 6.2 Some VTTS Comparisons with Current PEM Values

The current Transfund Project Evaluation Manual (PEM) values for car drivers on non-work trip purposes are (July 1998):

- Base value $7.00/person hour
- Increment for congestion (up to) $3.50/person hour

The maximum value, in congested conditions, is thus $10.50/person hour.

On **average**, the values derived from this research are reasonably close to the PEM values:

- For commuters, the average value found (excluding contingency time) of $10.96/hour is somewhat higher than the range of PEM values typical of urban peak period conditions (ie range $7.00 - $10.50/hour)
- For other trip purposes, the 'other local' value ($5.99) is somewhat lower than the base PEM value; the long-distance value ($6.97) is comparable and the medium-distance value ($9.12) is somewhat higher.

However, the study values indicate **much greater differences between congested and uncongested conditions** than indicated by PEM, particularly for non-commuter purposes: the study free-flow values for non-commuter travel are much lower than those in PEM, while the congested values are much higher.

This appraisal also excludes the values placed on **contingency time**. If this is included, it increases the effective values found in the research relative to the PEM values, and this will be particularly so for congested conditions (which will be a major cause of travel time uncertainty).

## 6.3 Other Conclusions

Conclusions on two other important aspects were as follows:

### Modelling methods adopted

The use of the multinomial logit (MNL) model formulation for analysis tends to under-estimate VTTS estimates relative to alternative, less restrictive, model formulations. The extent of under-estimation varies with different elements of travel time, but overall may be in the order of 20%. This finding is consistent with that from other research on the issue. It suggests caution in adopting MNL results and indicates the need to consider use of alternative model formulations (such as mixed logit).

### Alternative cost measures: fuel *v* toll charges

The results indicate that VTTS estimates for local trips are higher relative to toll charges than relative to fuel costs, while the opposite applies for medium/long distance trips. It is hypothesised that this result reflects the choices offered, with toll charges being higher than running costs for short trips, but lower for longer trips. This highlights that results may be sensitive to the range of choices offered: this issue needs to be carefully considered in design of both the experiment and the analysis methods.

## 6.4 Implications and Applications

The research summarised here provides an improved empirical basis for establishing separate VTTS values for car drivers in New Zealand by:

- Trip purpose (particularly commuter *v* other)
- Traffic conditions (degree of congestion)
- Uncertainty of arrival time.

Further consideration will be needed as to how the study values relating to degree of congestion and uncertainty/contingency should be translated into a standard set of values for evaluation.

There is also need to assess the case for extending the original survey, to cover increased sample sizes (in some or all segments), and thus to provide new values with greater confidence and perhaps greater disaggregation in some dimensions (eg metropolitan v regional centres).

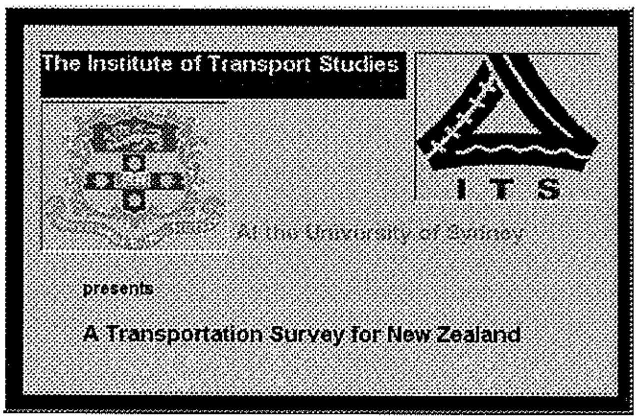
It should also be noted that the research to date has not covered car passengers. The appropriate relativity between passenger and driver time values is unclear (and has been little researched internationally): it might be expected (but is not proved) that passenger values would vary much less with the degree of congestion than driver values.

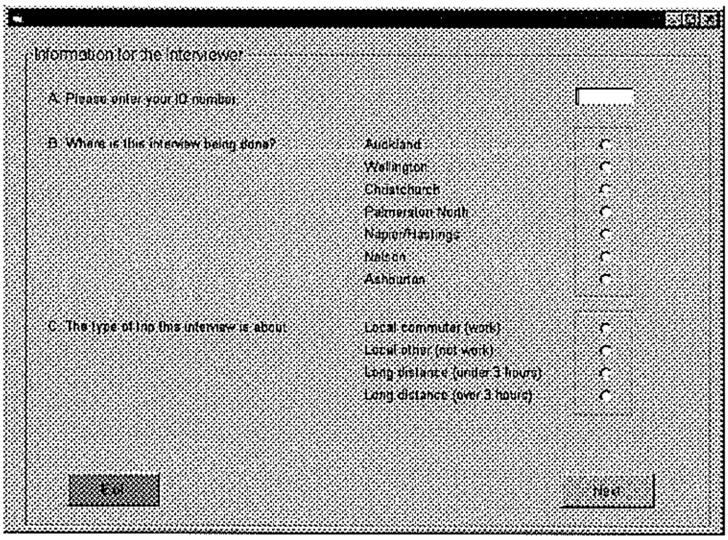
## 6.5 Further Market Research

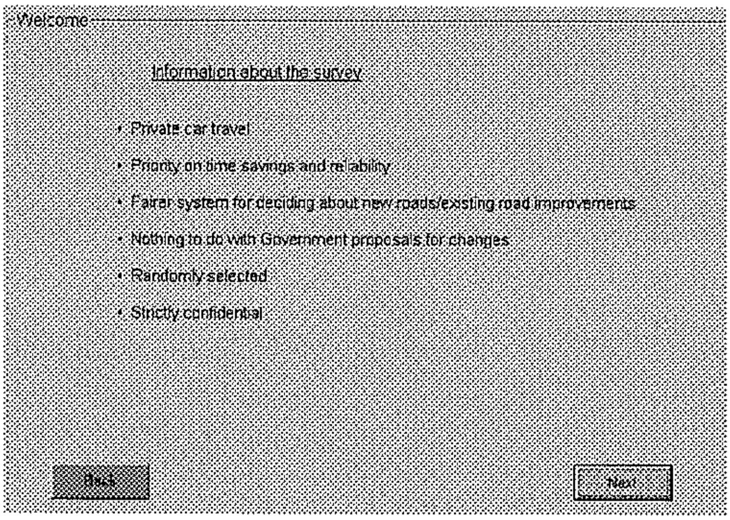
Since this study was commissioned, Transfund has determined to undertake a comprehensive market research programme in New Zealand, to derive improved unit benefit parameters for inclusion in its Project Evaluation Manual, and hence for application in evaluating transport investments throughout New Zealand. A major part of this research programme will be concerned with valuation of travel time savings and associated level of service aspects.

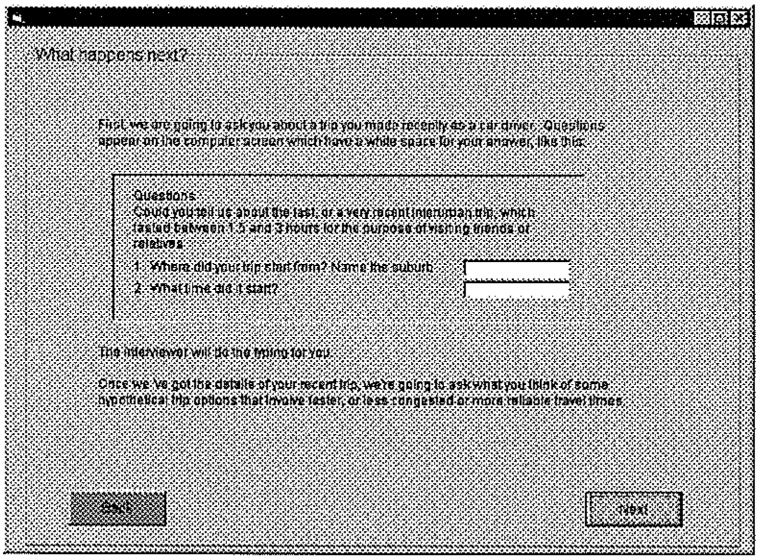
This study should serve as in invaluable pilot study for the research programme, in terms of survey design methodology, analysis methodology and the results obtained. The above implications should be taken account of in the further research.

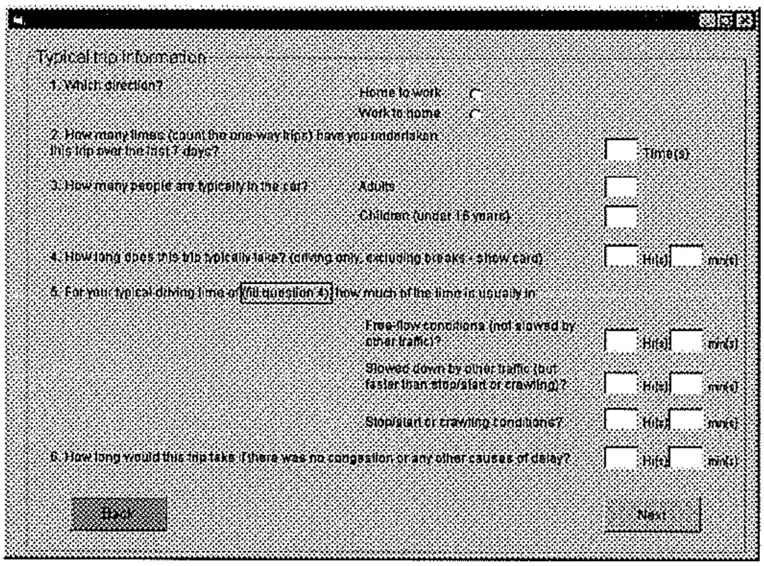
# APPENDIX A
# THE SURVEY QUESTIONNAIRE

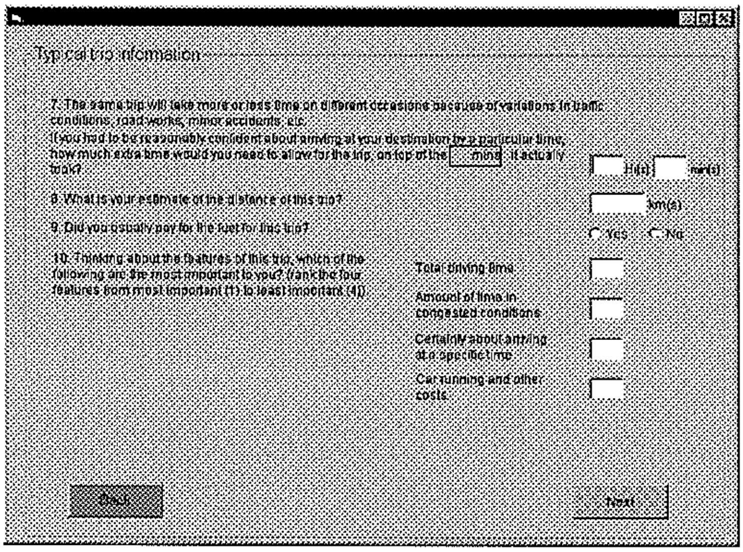


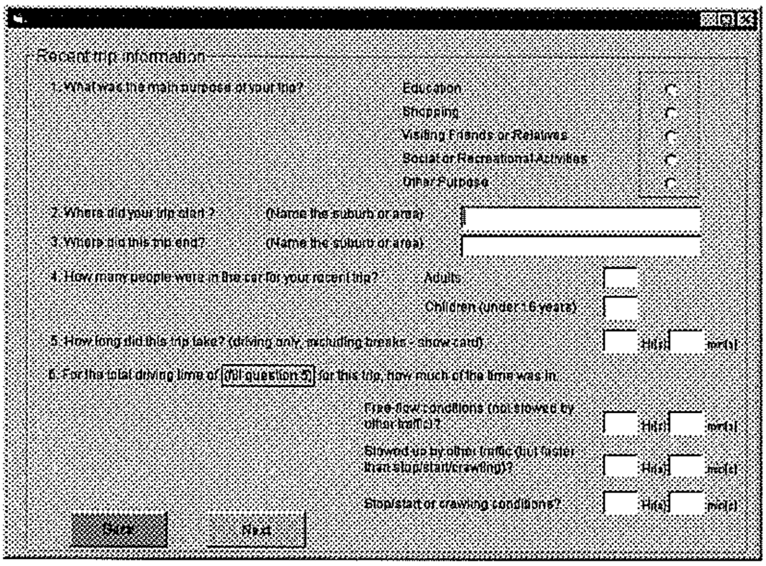



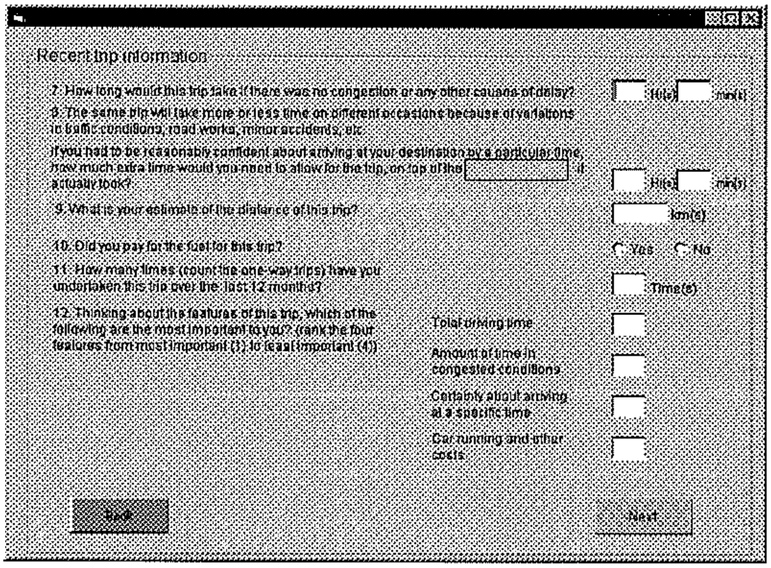



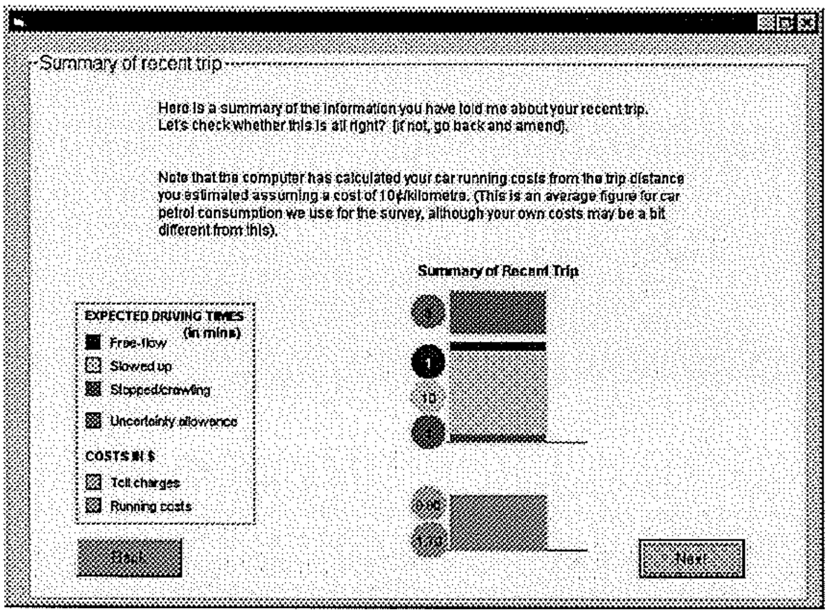

What happens next?
First we are going to ask you about a trip you made recently as a car driver. Questions appear on the computer screen which have a white space for your answer, like this:
Questions
Could you tell us about the last, or a very recent interurban trip, which lasted between 1.5 and 3 hours for the purpose of visiting friends or relatives
1. Where did your trip start from? Name the suburb
2. What time did it start?
The interviewer will do the typing for you.
Once we've got the details of your recent trip, we're going to ask what you think of some hypothetical trip options that involve faster, or less congested or more reliable travel times.
Next

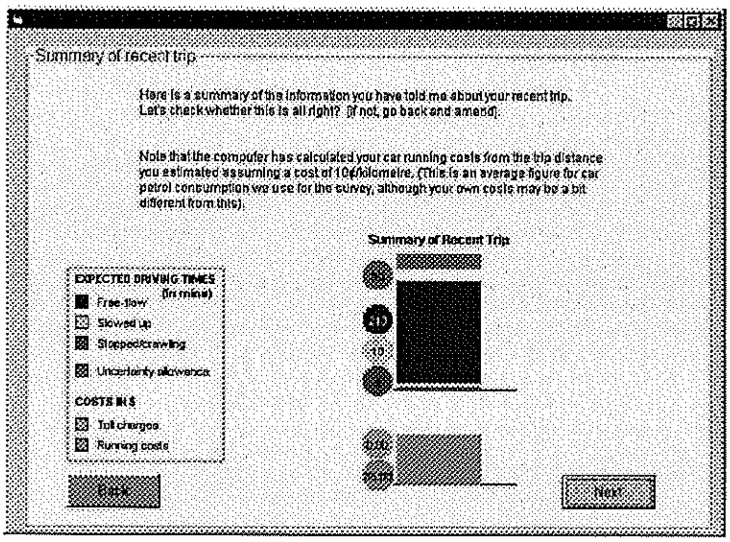

Typical trip information
1. Which direction?
Home to work
Work to home
2. How many times (count the one-way trips) have you undertaken this trip over the last 7 days?
Time(s)
3. How many people are typically in the car?
Adults
Children (under 16 years)
4. How long does this trip typically take? (driving only, excluding breaks - show card)
H(s)
min(s)
5. For your typical driving time of (fill question 4) how much of the time is usually in
Free-flow conditions (not slowed by other traffic)?
Slowed down by other traffic (but faster than stop/start or crawling)?
Stop/start or crawling conditions?
6. How long would this trip take if there was no congestion or any other causes of delay?
Back
Next

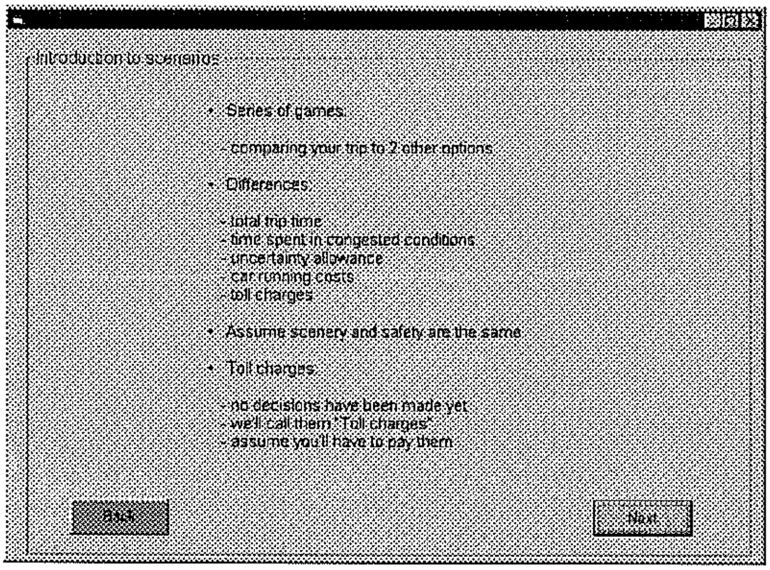

Typical trip information
7. The same trip will take more or less time on different occasions because of variations in traffic conditions, road works, minor accidents, etc.
If you had to be reasonably confident about arriving at your destination by a particular time, how much extra time would you need to allow for the trip, on top of the mins it actually took?
H(s)
min(s)
8. What is your estimate of the distance of this trip?
km(s)
9. Did you usually pay for the fuel for this trip?
Yes
No
10. Thinking about the features of this trip, which of the following are the most important to you? (rank the four features from most important (1) to least important (4))
Total driving time
Amount of time in congested conditions
Certainty about arriving at a specific time
Car running and other costs
Back
Next

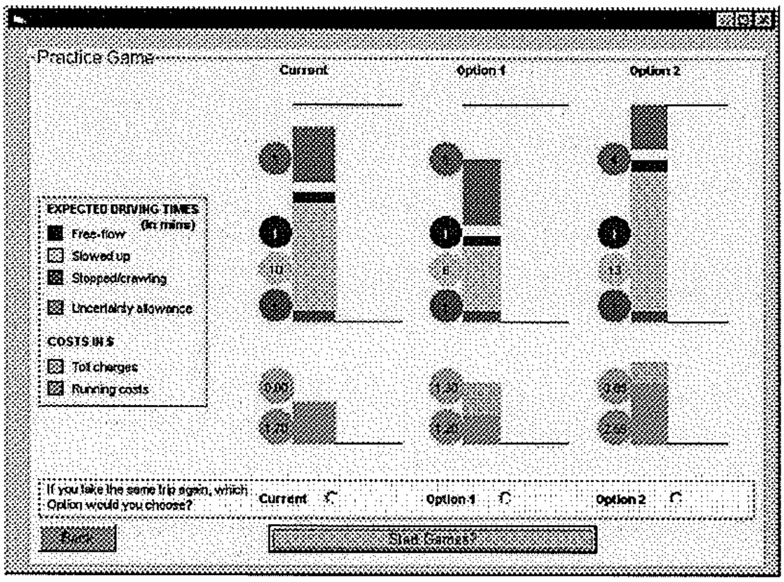

Recent trip information
1. What was the main purpose of your trip?
Education
Shopping
Visiting Friends or Relatives
Social or Recreational Activities
Other Purpose
2. Where did your trip start?
(Name the suburb or area)
3. Where did this trip end?
(Name the suburb or area)
4. How many people were in the car for your recent trip?
Adults
Children (under 16 years)
5. How long did this trip take? (driving only, including breaks - show card)
6. For the total driving time of [fill question 5] for this trip, how much of the time was in:
Free-flow conditions (not slowed by other traffic)?
Slowed up by other traffic (but faster than stop/start/crawling)?
Stop/start or crawling conditions?
Next

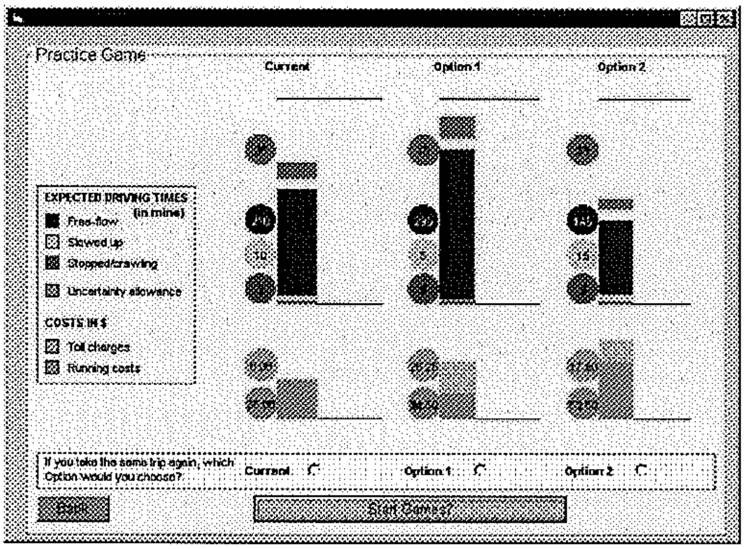

Recent trip information
7. How long would this trip take if there was no congestion or any other causes of delay?
8. The same trip will take more or less time on different occasions because of variations in traffic conditions, road works, minor accidents, etc.
If you had to be reasonably confident about arriving at your destination by a particular time, how much extra time would you need to allow for the trip, on top of the
actually took?
9. What is your estimate of the distance of this trip?
km(s)
10. Did you pay for the fuel for this trip?
Yes
No
11. How many times (count the one-way trips) have you undertaken this trip over the last 12 months?
Time(s)
12. Thinking about the features of this trip, which of the following are the most important to you? (rank the four features from most important (1) to least important (4))
Total driving time
Amount of time in congested conditions
Certainty about arriving at a specific time
Car running and other costs
Back
Next

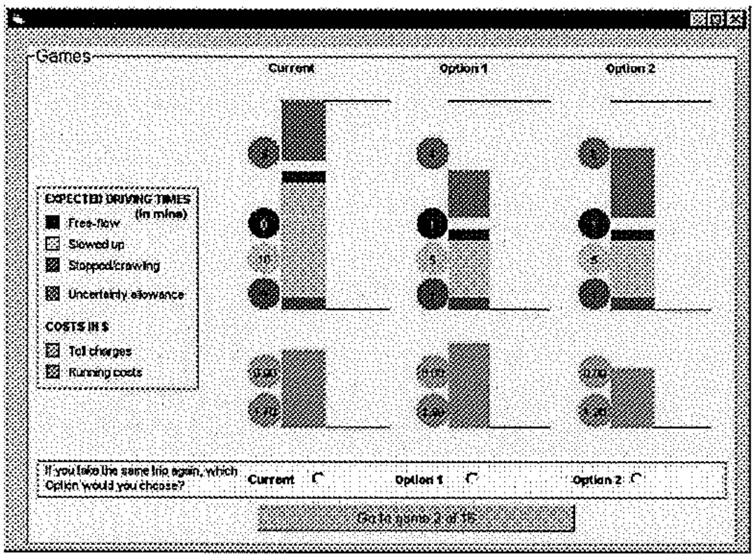

Summary of recent trip
Here is a summary of the information you have told me about your recent trip.
Let's check whether this is all right? (if not, go back and amend).
Note that the computer has calculated your car running costs from the trip distance you estimated assuming a cost of 10¢/kilometre. (This is an average figure for car petrol consumption we use for the survey, although your own costs may be a bit different from this).
Summary of Recent Trip
EXPECTED DRIVING TIMES (in mins)
Free-flow
Slowed up
Stopped/crawling
Uncertainty allowance
COSTS IN $
Toll charges
Running costs
1
10
Back
Next

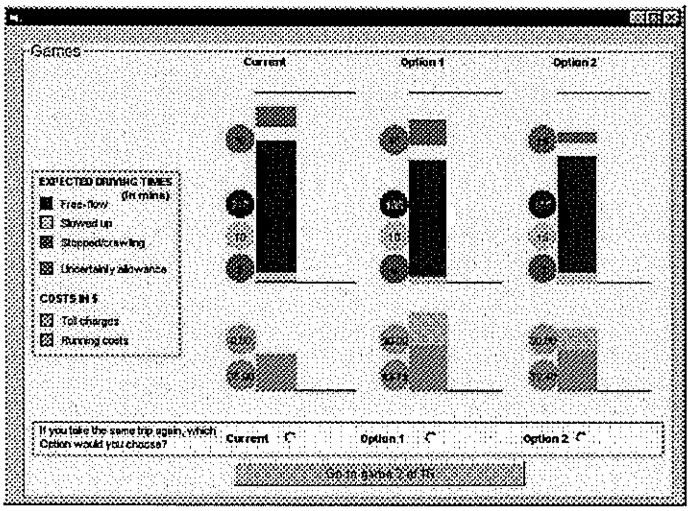

Summary of recent trip
Here is a summary of the information you have told me about your recent trip.
Let's check whether this is all right? (If not, go back and amend).
Note that the computer has calculated your car running costs from the trip distance you estimated assuming a cost of 10¢/kilometre. (This is an average figure for car petrol consumption we use for the survey, although your own costs may be a bit different from this).
Summary of Recent Trip
EXPECTED DRIVING TIMES (in mins)
Free-flow
Slowed up
Stopped/crawling
Uncertainty allowance
COSTS IN $
Toll charges
Running costs
Back
Next

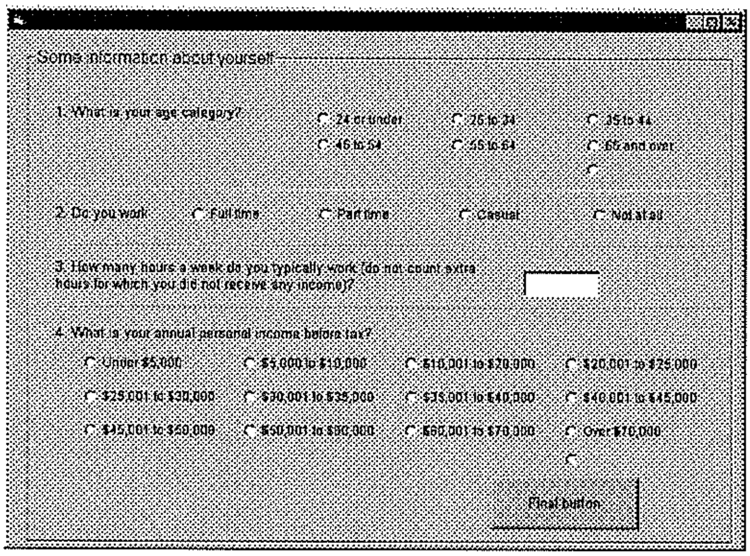

Introduction to scenarios
• Series of games
- comparing your trip to 2 other options
• Differences:
- total trip time
- time spent in congested conditions
- uncertainty allowance
- car running costs
- toll charges
• Assume scenery and safety are the same
• Toll charges
- no decisions have been made yet
- we'll call them "Toll charges"
- assume you'll have to pay them
Back
Next


Practice Game
Current
Option 1
Option 2
EXPECTED DRIVING TIMES (in mins)
Free-flow
Slowed up
Stopped/crawling
Uncertainty allowance
COSTS IN $
Toll charges
Running costs
If you take the same trip again, which Option would you choose?
Current
Option 1
Option 2
Back
Start Games?


Practice Game
Current
Option 1
Option 2
EXPECTED DRIVING TIMES (in mins)
Free-flow
Slowed up
Stopped/crawling
Uncertainty allowance
COSTS IN $
Toll charges
Running costs
If you take the same trip again, which Option would you choose?
Current
Option 1
Option 2
Back
Start Games


Games
Current
Option 1
Option 2
EXPECTED DRIVING TIMES (in mins)
Free-flow
Slowed up
Stopped/crawling
Uncertainty allowance
COSTS IN $
Toll charges
Running costs
If you take the same trip again, which Option would you choose?
Current
Option 1
Option 2


Games
Current
Option 1
Option 2
EXPECTED DRIVING TIMES (in mins)
Free-flow
Slowed up
Stopped/crawling
Uncertainty allowance
COSTS IN $
Toll charges
Running costs
If you take the same trip again, which Option would you choose?
Current
Option 1
Option 2


Some information about yourself
1. What is your age category?
24 or under
25 to 34
35 to 44
45 to 54
55 to 64
65 and over
2. Do you work
Full time
Part time
Casual
Not at all
3. How many hours a week do you typically work (do not count extra hours for which you did not receive any income)?
4. What is your annual personal income before tax?
Under $5,000
$5,000 to $10,000
$10,001 to $20,000
$20,001 to $25,000
$25,001 to $30,000
$30,001 to $35,000
$35,001 to $40,000
$40,001 to $45,000
$45,001 to $50,000
$50,001 to $60,000
$60,001 to $70,000
Over $70,000
Final button


Thank you very much for your cooperation!

# APPENDIX B
# DESIGN OF THE STATED CHOICE EXPERIMENT

This Appendix provides details of the design basis for the stated choice (SC) experiment, in which respondents make trade-offs between their reference trip and two hypothetical alternatives.

The design is based on two alternatives each defined by six attributes each of four levels (ie $4^{12}$): free flow travel time, slowed down travel time, stop/start travel time, uncertainty of travel time, fuel cost and toll charges. Except for toll charges, the levels are proportions relative to those associated with a current trip identified prior to the application of the SC experiment:

Free flow travel time: - 0.25, -0.125, 0.125, 0.25
Slowed down travel time: - 0.5, -0.25, 0.25, 0.5
Stop/Start travel time: - 0.5, -0.25, 0.25, 0.5
Uncertainty of travel time: - 0.5, -0.25, 0.25, 0.5
Car running cost: - 0.25, -0.125, 0.125, 0.25
Toll charges ($): varies depending on trip segment (up to $30 for long trip)

Including the current (i.e. revealed preference (RP)) alternative described by the exact same six attributes as the two SC alternatives, the design starts with six columns of zeros for the last trip attributes followed by six attributes for alternative A and then six attributes for alternative B. For example: 0, 0, 0, 0, 0, 0 -0.125, -0.5, 0.25, -0.25, 0.25, 1 0.125, 0.25, -0.25, 0.5, -0.25, 1.

The six attributes for alternative A are orthogonal to the six columns for alternative B, allowing for the estimation of models with complex structures for the random components of the utility expression associated with each of the alternatives (Louviere, Hensher and Swait, in press). The levels of the attributes for both SC alternatives were rotated to ensure that neither A nor B would dominate the RP trip, and to ensure that A and B would not dominate each other. For example, if free flow travel time for A was better than free flow travel time for the RP trip, then we structured the design so that at least one among the five remaining attributes would be worse for A relative to the RP trip; and likewise for the other potential situations of domination.

The fractional factorial design has 64 rows, as shown in Table B1. We allocated four blocks of 16 "randomly" to each respondent, defining block 1 as the first 16 rows of the design, block 2 the second set of 16 etc. Formally, we draw block b from blocks 1, 2 ,3 and 4 and assign block b to respondent 1, block [((b-1) mod 4) +1] to respondent 2, block [(b mod 4) +1]to respondent 3, block [ ((b+1) mod 4) +1] to respondent 4. We then go to block 1 for the next set of four respondents. For example, if the first respondent faces block 3 of the design, the next three respondents will receive blocks 4, 1 and 2 in that order.

Once the whole design has been allocated we again draw a number from 1 to 4 and repeat the block sequence. The advantage is that if the number of respondents interviewed by each interviewer is a multiple of four then we will have exactly the same number of respondents in each block. If not, we do not expect to be far from symmetrical representation of each block, a condition for complete orthogonality in model estimation.

The assignment of levels to each SC attribute conditional on the RP levels is straightforward. However, if the RP trip had a zero level for an attribute (which is possible for one or more components of travel time), we introduced rules of variation. The rules are as follows:

Free Flow for alternatives A and B = free flow for RP trip × (1+level); But if "Free Flow" for RP trip is zero then free flow for alternatives A and B = 0.1 × (Total time for RP trip) × (1+level), slowed down for alternatives A and B = 0.9×(Slowed for RP trip) × (1+level), and stop/start for alternatives A and B = 0.9×(Stop/Start for RP trip) × (1+level). Otherwise, Slowed Down for alternatives A and B = Slowed down for RP trip × (1+level) and Stop/Start for alternatives A and B= Stop/Start for RP trip × (1+level).

If "Slowed Down" for RP trip is zero then Slowed Down for alternatives A and B = 0.1 × (Free Flow of RP trip) × (1+level). If "Stop/Start" for last trip is zero then Stop/Start for alternatives A and B = 0.1 × (Free Flow for RP trip) × (1+level).

Uncertainty for alternatives A and B = uncertainty for RP trip (1+level). If uncertainty for RP trip is zero then uncertainty for alternatives A and B= 0.1 × (Total time for RP trip) × (1+level). Running Cost for the RP trip is taken as 10 cents per kilometre, and running cost for alternatives A and B = running cost for RP trip × (1+level). Finally, the toll charges are defined as follows:

- for urban trips levels are: $0, $2, $4, $6 or toll = level
- for interurban trips lasting up to 90mins: $0, $3, $6, $9 or toll = 1.5×level
- for interurban trips lasting between 90 and 180 mins: $0, $5, $10, $15 or toll = 2.5×level
- for interurban trips lasting more than 180 mins: $0, $10, $20, $30 or toll = 5×level

**TABLE B1 : ATTRIBUTE LEVELS FOR STATED CHOICE DESIGN** (Note: Toll charges shown are for urban trips)

| Free Flow A | Free Flow B | Slowed Down A | Slowed Down B | Stop/Start A | Stop/Start B | Uncertainty A | Uncertainty B | Cost A | Cost B | Toll Charges A | Toll Charges B |
|---|---|---|---|---|---|---|---|---|---|---|---|
| -0.25 | 0.25 | 0.25 | 0.5 | 0.25 | 0.5 | 0.5 | -0.5 | 0.125 | -0.25 | 4 | 0 |
| 0.125 | -0.125 | 0.5 | 0.25 | 0.25 | -0.5 | -0.5 | 0.5 | -0.125 | 0.25 | 4 | 4 |
| -0.25 | -0.125 | -0.25 | -0.5 | 0.5 | 0.5 | 0.5 | 0.25 | -0.25 | 0.25 | 6 | 2 |
| 0.125 | 0.125 | 0.25 | 0.5 | -0.25 | -0.5 | -0.5 | 0.25 | 0.125 | 0.125 | 2 | 2 |
| 0.25 | -0.125 | 0.25 | 0.5 | -0.5 | -0.25 | 0.25 | -0.25 | 0.125 | 0.25 | 0 | 6 |
| 0.125 | -0.25 | -0.25 | -0.5 | -0.5 | -0.5 | -0.5 | -0.5 | -0.25 | -0.125 | 0 | 0 |
| 0.25 | 0.125 | 0.5 | 0.25 | 0.5 | -0.25 | 0.25 | -0.5 | -0.125 | 0.125 | 6 | 0 |
| -0.125 | -0.125 | -0.5 | -0.25 | -0.25 | 0.25 | -0.25 | -0.5 | 0.25 | 0.25 | 2 | 0 |
| -0.125 | -0.25 | 0.25 | 0.5 | 0.5 | 0.25 | -0.25 | 0.5 | 0.125 | -0.125 | 6 | 4 |
| -0.125 | 0.125 | -0.25 | -0.5 | 0.25 | 0.25 | -0.25 | -0.25 | -0.25 | 0.125 | 4 | 6 |
| -0.25 | 0.125 | -0.5 | -0.25 | -0.5 | 0.5 | 0.5 | 0.5 | 0.25 | 0.125 | 0 | 4 |
| 0.125 | 0.25 | -0.5 | -0.25 | 0.5 | -0.5 | -0.5 | -0.25 | 0.25 | -0.25 | 6 | 6 |
| 0.25 | 0.25 | -0.25 | -0.5 | -0.25 | -0.25 | 0.25 | 0.5 | -0.25 | -0.25 | 2 | 4 |
| 0.25 | -0.25 | -0.5 | -0.25 | 0.25 | -0.25 | 0.25 | 0.25 | 0.25 | -0.125 | 4 | 2 |
| -0.125 | 0.25 | 0.5 | 0.25 | -0.5 | 0.25 | -0.25 | 0.25 | -0.125 | -0.25 | 0 | 2 |
| -0.25 | -0.25 | 0.5 | 0.25 | -0.25 | 0.5 | 0.5 | -0.25 | -0.125 | -0.125 | 2 | 6 |
| -0.125 | -0.125 | -0.25 | 0.5 | -0.5 | -0.5 | 0.25 | -0.5 | 0.25 | 0.125 | 6 | 4 |
| 0.125 | -0.25 | -0.5 | 0.25 | -0.25 | 0.25 | 0.5 | -0.5 | -0.25 | -0.25 | 4 | 4 |
| 0.125 | -0.125 | 0.25 | -0.5 | 0.5 | 0.25 | 0.5 | 0.5 | -0.125 | 0.125 | 0 | 0 |
| 0.25 | -0.25 | -0.25 | 0.5 | 0.5 | 0.5 | -0.25 | 0.25 | 0.25 | -0.25 | 0 | 6 |
| -0.25 | 0.25 | 0.5 | -0.25 | 0.5 | -0.25 | -0.5 | -0.5 | 0.125 | -0.125 | 0 | 4 |
| -0.125 | 0.125 | -0.5 | 0.25 | 0.5 | -0.5 | 0.25 | -0.25 | -0.25 | 0.25 | 0 | 2 |
| -0.25 | -0.25 | 0.25 | -0.5 | -0.5 | -0.25 | -0.5 | -0.25 | -0.125 | -0.25 | 6 | 2 |
| -0.125 | -0.25 | 0.5 | -0.25 | 0.25 | -0.5 | 0.25 | 0.5 | 0.125 | -0.25 | 2 | 0 |
| 0.125 | 0.125 | 0.5 | -0.25 | -0.5 | 0.25 | 0.5 | 0.25 | 0.125 | 0.25 | 6 | 6 |
| -0.25 | -0.125 | -0.5 | 0.25 | 0.25 | -0.25 | -0.5 | 0.25 | -0.25 | 0.125 | 2 | 6 |
| 0.125 | 0.25 | -0.25 | 0.5 | 0.25 | 0.25 | 0.5 | -0.25 | 0.25 | -0.125 | 2 | 2 |
| -0.25 | 0.125 | -0.25 | 0.5 | -0.25 | -0.25 | -0.5 | 0.5 | 0.25 | 0.25 | 4 | 0 |
| -0.125 | 0.25 | 0.25 | -0.5 | -0.25 | -0.5 | 0.25 | 0.25 | -0.125 | -0.125 | 4 | 6 |
| 0.25 | -0.125 | 0.5 | -0.25 | -0.25 | 0.5 | -0.25 | -0.25 | 0.125 | 0.125 | 4 | 2 |
| 0.25 | 0.25 | -0.5 | 0.25 | -0.5 | 0.5 | -0.25 | 0.5 | -0.25 | -0.125 | 6 | 0 |
| 0.25 | 0.125 | 0.25 | -0.5 | 0.25 | 0.5 | -0.25 | -0.5 | -0.125 | 0.25 | 2 | 4 |
| 0.125 | 0.125 | -0.5 | -0.5 | 0.25 | -0.25 | -0.25 | 0.25 | 0.125 | -0.25 | 0 | 0 |
| -0.25 | 0.125 | 0.25 | 0.25 | 0.5 | 0.25 | 0.25 | 0.5 | 0.25 | -0.25 | 2 | 6 |

*Cont.*

**TABLE B1 : ATTRIBUTE LEVELS FOR STATED CHOICE DESIGN** (Note: Toll charges shown are for urban trips)

| Free Flow A | Free Flow B | Slowed Down A | Slowed Down B | Stop/Start A | Stop/Start B | Uncertainty A | Uncertainty B | Cost A | Cost B | Toll Charges A | Toll Charges B |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.125 | -0.25 | 0.5 | 0.5 | 0.5 | -0.25 | -0.25 | -0.5 | -0.25 | 0.25 | 2 | 2 |
| 0.125 | -0.125 | -0.25 | -0.25 | -0.25 | -0.25 | -0.25 | 0.5 | -0.125 | -0.125 | 6 | 6 |
| 0.125 | 0.25 | 0.25 | 0.25 | -0.5 | -0.25 | -0.25 | -0.25 | 0.25 | 0.125 | 4 | 4 |
| -0.25 | -0.25 | -0.25 | -0.25 | 0.25 | 0.25 | 0.25 | -0.25 | -0.125 | 0.25 | 0 | 4 |
| -0.125 | -0.125 | 0.25 | 0.25 | 0.25 | 0.5 | -0.5 | -0.5 | 0.25 | -0.125 | 0 | 2 |
| 0.25 | -0.25 | 0.25 | 0.25 | -0.25 | -0.5 | 0.5 | 0.25 | 0.25 | 0.25 | 6 | 0 |
| -0.25 | -0.125 | 0.5 | 0.5 | -0.5 | 0.25 | 0.25 | 0.25 | -0.25 | -0.125 | 4 | 0 |
| 0.25 | -0.125 | -0.5 | -0.5 | 0.5 | -0.5 | 0.5 | -0.25 | 0.125 | -0.125 | 2 | 4 |
| 0.25 | 0.125 | -0.25 | -0.25 | -0.5 | -0.5 | 0.5 | -0.5 | -0.125 | -0.25 | 4 | 2 |
| -0.125 | -0.25 | -0.5 | -0.5 | -0.5 | 0.5 | -0.5 | 0.5 | 0.125 | 0.25 | 4 | 6 |
| -0.125 | 0.25 | -0.25 | -0.25 | 0.5 | 0.5 | -0.5 | 0.25 | -0.125 | 0.125 | 2 | 0 |
| 0.25 | 0.25 | 0.5 | 0.5 | 0.25 | -0.5 | 0.5 | 0.5 | -0.25 | 0.125 | 0 | 6 |
| -0.25 | 0.25 | -0.5 | -0.5 | -0.25 | 0.25 | 0.25 | -0.5 | 0.125 | 0.125 | 6 | 2 |
| -0.125 | 0.125 | 0.5 | 0.5 | -0.25 | 0.5 | -0.5 | -0.25 | -0.25 | -0.25 | 6 | 4 |
| 0.125 | 0.25 | 0.5 | -0.5 | -0.25 | 0.5 | 0.25 | -0.25 | 0.25 | 0.25 | 0 | 0 |
| -0.125 | 0.125 | 0.25 | -0.25 | -0.5 | -0.25 | 0.5 | -0.25 | -0.25 | -0.125 | 2 | 0 |
| -0.125 | 0.25 | -0.5 | 0.5 | 0.25 | -0.25 | 0.5 | 0.25 | -0.125 | 0.25 | 6 | 4 |
| -0.125 | -0.25 | -0.25 | 0.25 | -0.25 | -0.25 | 0.5 | 0.5 | 0.125 | 0.125 | 0 | 2 |
| 0.25 | -0.125 | -0.25 | 0.25 | 0.25 | 0.25 | -0.5 | -0.25 | 0.125 | -0.25 | 6 | 0 |
| 0.25 | 0.25 | 0.25 | -0.25 | 0.5 | 0.25 | -0.5 | 0.5 | -0.25 | 0.25 | 4 | 2 |
| 0.125 | -0.25 | 0.25 | -0.25 | 0.25 | 0.5 | 0.25 | -0.5 | -0.25 | 0.125 | 6 | 6 |
| 0.25 | 0.125 | -0.5 | 0.5 | -0.25 | 0.25 | -0.5 | -0.5 | -0.125 | -0.125 | 0 | 6 |
| -0.125 | -0.125 | 0.5 | -0.5 | 0.5 | -0.25 | 0.5 | -0.5 | 0.25 | -0.25 | 4 | 6 |
| -0.25 | -0.25 | -0.5 | 0.5 | 0.5 | -0.5 | -0.25 | -0.25 | -0.125 | 0.125 | 4 | 0 |
| 0.125 | 0.125 | -0.25 | 0.25 | 0.5 | 0.5 | 0.25 | 0.25 | 0.125 | -0.125 | 4 | 4 |
| -0.25 | 0.125 | 0.5 | -0.5 | 0.25 | -0.5 | -0.25 | 0.5 | 0.25 | -0.125 | 6 | 2 |
| 0.125 | -0.125 | -0.5 | 0.5 | -0.5 | 0.5 | 0.25 | 0.5 | -0.125 | -0.25 | 2 | 2 |
| -0.25 | 0.25 | -0.25 | 0.25 | -0.5 | -0.5 | -0.25 | -0.5 | 0.125 | 0.25 | 2 | 6 |
| 0.25 | -0.25 | 0.5 | -0.5 | -0.5 | 0.25 | -0.5 | 0.25 | 0.25 | 0.125 | 2 | 4 |
| -0.25 | -0.125 | 0.25 | -0.25 | -0.25 | -0.5 | -0.25 | 0.25 | -0.25 | -0.25 | 0 | 4 |

# APPENDIX C
# DATA SPECIFICATIONS FOR MODELLING

The following listing provides a specification of the variables for the database used in the SC modelling: it covers all the data from each respondent, on their existing trip, the 'games' presented and their choice between them.

*38 variables (or 36 when ignore suburb begin and end), 3 alternatives per treatment, 16 treatments per respondent*

| **Data Item** | **Description** |
|---|---|
| Intid | Interviewer id |
| Obsno | Respondent id |
| Profile | Profile 0,…, 63 |
| Fflow | Free flow time (mins) |
| Slowt | Slowed up time (mins) |
| Ststop | Stopped/crawling time (mins) |
| Uncert | Contingency time (mins) |
| Cost | Running costs (dollars) |
| Toll | Toll cost (dollars) |
| **Choice** | **Choice (0,1)** |
| Alt | Alternative (1,2,3) |
| Segid | Segment id<br>1=local commuter<br>2=other local (non commuter)<br>3=long distance (< 3 hrs)<br>4=long distance (> 3 hrs) |
| Intidd | Interviewer id (same as intid) |
| Locn | Survey location:<br>1-Auckland<br>2=Wellington,<br>3=Christchurch<br>4=Palmerston North<br>5=Napier/Hastings<br>6=Nelson<br>7=Ashburton |
| Idobss | Respondent id (same as obsno) |
| Idsegg | Id segment (same as segid) |
| Idvers | Id version (1,,2,3,4) of profile set start? |
| Mpurp | Trip purpose:<br>1=vfr<br>2=social & Rec activities<br>3=shopping<br>4=commuting<br>5=other purpose<br>6=education |
| Nbadult | Number of adults |
| Nbchild | Number of children |
| *Subbegin* | *Suburb began trip in (not in modelling data and not for commuters)* |
| *Subend* | *Suburb ended trip (not in modelling data and not for commuters)* |
| Timelast | Time of last trip (minutes) |
| *continued next page* | |

| **Data Item** | **Description** |
|---|---|
| Nocongt | Time of last trip if no congestion or other causes of delay (mins) |
| Vkm | Trip Length (kms) |
| Payfuel | Who paid for fuel (1=yes, 0=no) |
| tripfreq | Frequency of such trip over last 7 days (commuters), last month (local) or last 12 months (interurban) |
| Rtime | Rank of driving time (1-4) |
| Rcong | Rank of time in congested conditions (1-4) |
| Rconf | Rank of confidence about arriving at a certain time (1-4) |
| Rcost | Rank of car running and other costs (1-4) |
| Age | Age of driver (years):<br>1 = 24 or under<br>2 = 25-34<br>3 = 35-44<br>4 = 45-54<br>5 = 55-64<br>6 = 65 and over<br>-999=missing (Refuse to respond) |
| Income | Personal income of driver (category)<br>1 = under 5,000<br>2 = 5,000-10,000<br>3 = 10,001-20,000<br>4 = 20,001-25,000<br>5 = 25,001-30,000<br>6 = 30,001-35,000<br>7 = 35,001-40,000<br>8 = 40,001-45,000<br>9 = 45,001-50,000<br>10 = 0,001-60,000<br>11 = 60,001-70,000<br>12 = >70,000<br>-999=missing (refuse to respond) |
| Employ | Employment status:<br>1=Full time<br>2=Part time<br>3=Casual<br>4=Do not work |
| Hrswrk | Hours worked per week |
| Choice11 | No. times choice 1 (current) chosen out of 16 |
| Choice11 | No. times choice 2 chosen out of 16 |
| Choice12 | No. times choice 3 chosen out of 16 |

# APPENDIX D
# ESTIMATION OF CHOICE MODELS

A series of multinomial logit models were estimated to identify the role of each attribute in the SC experiment on choice between the current car trip and two other attribute levels on offer. We have limited the models to the four main segments, stratified where possible by trip purpose. All models are unordered and unranked in respect of the utility expressions defining the current trip (CURR) and the two experimental design alternatives (ALTA and ALTB). An unranked model specification treats the options as alternative descriptors of a bundle of attribute levels with no labelling of the specific alternatives. That is, the notion of a labelled route called ALTA or ALTB or even CURR is uninformative in estimation since what defines the trading between the options is the set of attributes in the design. All attributes are route abstract and as such are treated as generic attributes in model estimation. We specifically structured the survey to avoid a requirement for route switch. The objective was to evaluate alternative attribute bundles for travelling between predetermined locations by the existing route and time of day.

To confirm that this is exactly how individuals evaluated the attributes in arriving at a choice from the three options, we ran a series of nested logit models to see if the (variance) structure of the random components were systematically different. If they were, we would conclude that there are other attributes, not in the choice experiment, that are differentially impacting on the choice made. In all model tests we found that the variance parameter in the nested logit models (or the scale parameter) was not significantly different between the set of tree branches investigated (eg current vs options 1 and 2). This is comforting and is justification for maintaining the multinomial logit form in all model estimation.

The final set of models for each segment are summarised in Tables D1 and D2. We estimated three models; a simple model with total travel time and total travel cost; a more complex model in which travel time is disaggregated into its design components (ie free flow time, slowed up time, stop/start time and contingency (or uncertainty or arrival) time). Travel cost remained as one attribute. The final model included the fully disaggregated time as well as the two cost components – running costs and tolls.

In preparation for estimating the models we undertook an assessment of the quality of the data and edited a few observations where specific attribute levels were outliers in the complete distribution across the sub-sample. For example, for long distance trips (over three hours) we found contingency times as high as 1350 minutes, in contrast to a range up to 200 minutes for the bulk of the sample. We eliminated such outliers after testing their impact on the estimated parameters. In general, we eliminated five observations for long distance, eight observations for medium distance, two observations for each of local commuting and local non-commuting.

| TABLE D1: Final Urban Models Used to Obtain Empirical Estimates of Values of Travel Time Savings (All travel times are in minutes and costs are in dollars) | | | | | |
|---|---|---|---|---|---|
| Attributes | Local Commuter | Local Non Commuter | LNC Social-Recreation | LN: Visiting Friends & Relatives | LNC: Shopping |
| Model 1: | | | | | |
| Total time | -.1306 (13.2) | -.0686 (-7.6) | -.0757 (-4.6) | -.1056 (-5.1) | -.0561 (-3.4) |
| Total cost | -.7157 (-30.7) | -.6872 (-30.5) | -.6974 (-16.0) | .9578 (-13.5) | -.6373 (-17.7) |
| Pseudo-$r^2$ | .434 | .413 | .420 | .538 | .378 |
| Log-likelihood | -1508.6 | -1571.0 | -427.4 | -283.7 | -556.5 |
| | | | | | |
| Model 2: | | | | | |
| Free flow time | -.09597 (-5.3) | -.03113 (-2.3) | -.0524 (-2.0) | -.0399 (-1.4) ns | -.0221 (-.9) ns |
| Slowed down time | -.10754 (-7.3) | -.08446 (-5.4) | -.0679 (-2.5) | -.1624 (-3.7) | -.0648 (-2.3) |
| Stop/start time | -.21538 (-10.7) | -.13667 (-5.7) | -.1508 (-3.6) | -.2284 (-4.2) | -.1375 (-2.9) |
| Uncertainty | -.05972 (-5.2) | -.04199 (-4.0) | -.0732 (-3.3) | -.0194 (-.8) ns | -.0359 (-2.2) |
| Total cost | -.72787 (-30.5) | -.67917 (-29.8) | -.6959 (-15.7) | -.9256 (-13.0) | -.6309 (-17.4) |
| Pseudo-$r^2$ | .443 | .419 | .429 | .548 | .382 |
| Log-likelihood | -1483.3 | -1554.4 | -420.2 | -276.9 | -551.5 |
| | | | | | |
| Model 3: | | | | | |
| Free flow time | -.09677 (-5.4) | -.03134 (-2.3) | -.0522 (-2.0) | -.0445 (-1.6) | -.0194 (-.8) ns |
| Slowed down time | -.10598 (-7.2) | -.08674 (-5.4) | -.0658 (-2.4) | .1683 (-3.8) | -.0627 (-2.2) |
| Stop/start time | -.21671 (-10.7) | -.14701 (-6.1) | -.1583 (-3.7) | .2407 (-4.3) | -.1615 (-3.3) |
| Uncertainty | -.06003 (-5.2) | -.04242 (-4.1) | -.0738 (-3.3) | -.0200 (-.84) ns | -.0370 (-2.3) |
| Running cost | -.88648 (-7.3) | -1.1101 (-10.0) | -1.012 (-5.0) | -1.338 (-5.7) | -1.543 (-6.3) |
| Tolls | -.72621 (-30.4) | -.67487 (-29.8) | -.6911 (-15.7) | -.9126 (-13.0) | -.6308 (-17.3) |
| Pseudo-$r^2$ | .443 | .422 | .430 | .550 | .391 |
| Log-likelihood | -1482.4 | -1546.2 | -418.9 | -275.1 | -544.1 |
| | | | | | |
| Sample size | 2427 | 2437 | 672 | 560 | 816 |

We have limited the models to attributes in the design. Socioeconomic variables in a generic unranked model are problematic and should only be handled via either segmentation or by a more advanced discrete choice specification (such as mixed logit, covariance heterogeneity or random parameter logit – see Louviere et al. in press). Given that the current models are rich in attribute data from an orthogonal design and the diversity of segments selected to represent trip location context and purpose, we have the basis for a very rich distribution of values of travel time savings. Indeed, we have estimated models for 12 segments, each providing values for five classes of travel time (i.e. total time and its four constituent components), distinguished where appropriate by the nature of the costs (i.e. running costs *v* tolls *v* total cost).

Without exception, all choice models in all segments have captured the choice process through the design attributes very well indeed. Overall goodness-of-fit (pseudo $r^2$) varies over the range of .289 to .550. All attributes have the expected negative sign and are highly statistically significant with few exceptions. The exceptions are in models where we have segmented by trip purpose within a core segment (e.g. visiting friends and relatives in local non-commuting). The only two attributes that are occasionally not statistically significant are free flow time and contingency time (i.e. uncertainty of arrival time).

TABLE D2: Final Long Distance Models Used to Obtain Empirical Estimates of Values of Travel Time Savings (All travel times in minutes, costs in dollars)

| Attributes | Long Distance <3 hrs | LD<3h Visiting Friends & Relatives | LD<3h: Social-Recreation | LD<3h: Shopping | Long Distance >3 hrs | LD>3h Visiting Friends & Relatives | LD>3h: Social-Recreation |
|---|---|---|---|---|---|---|---|
| Model 1: | | | | | | | |
| Total time | -.0393 (-11.5) | -.0324 (-6.5) | -.03875 (-7.2) | -.0583 (-3.5) | -.0115 (-10.2) | -.00882 (-6.0) | -.0110 (-5.2) |
| Total cost | -.2590 (-19.6) | -.2671 (-13.2) | .24467 (-11.9) | -.4019 (-6.2) | -.0990 (-20.3) | -.08433 (-13.8) | -.131 (-12.1) |
| Pseudo-$r^2$ | .404 | .396 | .401 | .444 | .351 | .289 | .446 |
| Log-likelihood | -699.8 | -317.9 | -251.9 | -57.99 | -786.6 | -424.0 | -223.5 |
| | | | | | | | |
| Model 2: | | | | | | | |
| Free flow time | -.01639 (-3.8) | -.00139 (.21) ns | -.0227 (-3.4) | -.0547 (-2.3) | -.00589 (-4.2) | -.00595 (-3.3) | -.0029 (-1.1) ns |
| Slowed down time | -.05729 (-7.2) | -.05732 (-4.4) | -.0438 (-3.9) | -.1136 (-2.8) | -.01549 (-5.4) | -.01257 (-3.7) | -.0123 (-1.8) |
| Stop/start time | -.11742 (-12.2) | -.12629 (-8.9) | -.1089 (-7.3) | -.1304 (-1.9) | -.03984 (-10.8) | -.02108 (-4.6) | -.07979(-8.5) |
| Uncertainty | -.02080 (-3.5) | -.00418 (-.5) ns | -.0352 (-3.1) | -.0580 (-3.2) | -.01345 (-4.4) | -.01324 (-3.4) | -.0155 (-2.3) |
| Total cost | -.24725 (-17.8) | -.25683 (-11.9) | -.2307 (-10.7) | -.4354 (-6.1) | -.09210 (-18.3) | -.08154 (-13.0) | -.1170 (-9.9) |
| Pseudo-$r^2$ | .466 | .478 | .453 | .509 | .397 | .308 | .557 |
| Log-likelihood | -625.9 | -273.8 | -229.1 | -50.5 | -729.6 | -422.7 | -177.7 |
| | | | | | | | |
| Model 3: | | | | | | | |
| Free flow time | -.01643 (-3.7) | -.00166 (-.24) ns | -.0225 (-3.3) | -.0544 (-2.3) | -.00578 (-4.1) | -.00586 (-3.3) | -.0029 (-1.1) ns |
| Slowed down time | -.05927 (-7.3) | -.06019 (-4.6) | -.0454 (-4.0) | -.1123 (-2.8) | -.01612 (-5.6) | -.01319 (-3.8) | -.0126 (-1.8) |
| Stop/start time | -.1112 (-11.4) | -.12095 (-8.5) | -.1039 (-6.9) | -.1304 (-1.9) | -.03551 (-9.4) | -.01747 (-3.7) | -.0778 (-7.8) |
| Uncertainty | -.0205 (-3.4) | -.00376 (-.4) ns | -.0339 (-2.9) | -.0581 (-3.2) | -.01338 (-4.3) | -.01335 (-3.4) | -.0156 (-2.4) |
| Running cost | -.1594 (-5.7) | -.15932 (-3.6) | -.1611 (-3.7) | -.4091 (-2.8) | -.06376 (-7.7) | -.05833 (-5.8) | -.1089 (-5.8) |
| Tolls | -.2603 (-17.7) | -.27107 (-11.7) | -.2415 (-10.6) | -.4371 (-6.0) | -.10102 (-17.9) | -.08955 (-12.7) | -.1194 (-9.3) |
| Pseudo-$r^2$ | .471 | .483 | .456 | .506 | .404 | .314 | .557 |
| Log-likelihood | -619.9 | -270.8 | -227.5 | -50.4 | -720.8 | -407.5 | -177.6 |
| | | | | | | | |
| Sample size | 1069 | 480 | 384 | 96 | 1104 | 544 | 368 |

# APPENDIX E
# DETAILED VTTS RESULTS BY SEGMENT

This appendix provides the detailed VTTS results obtained, to supplement the more summarised results given in chapter 4:

- Tables E1, E2: values by four main segments and by sub-segments (trip purpose) for each model.
- Table E3: supplementary analyses to give values disaggregated by:
  - car occupancy
  - personal income
  - whether driver pays for fuel
  - residential location.

TABLE E1 Values of Travel Time Savings for each Segment ($ per person hour, NZ$99)
awr = average wage rate

| Attributes | Local Commuter | Local Non Commuter | LNC: Social-Recreation | LN: Visiting Friends & Relatives | LNC: Shopping |
|---|---|---|---|---|---|
| Model 1: | | | | | |
| Total time | 10.96 | 5.99 | 6.52 | 6.62 | 5.28 |
| As % awr | 68.9 | 49.6 | 48.5 | 57.5 | 41.1 |
| Model 2: | | | | | |
| Free flow time | 7.92 | 2.75 | 4.52 | 2.59 | 2.10 ns |
| Slowed down time | 8.86 | 7.46 | 5.86 | 10.52 | 6.17 |
| Stop/start time | 17.75 | 12.07 | 13.00 | 14.77 | 13.08 |
| Uncertainty | 4.92 | 3.70 | 6.31 | 1.28 ns | 3.41 |
| Model 3 for running cost: | | | | | |
| Free flow time | 6.55 | 1.69 | 3.09 | 2.00 | 0.75 ns |
| Slowed down time | 7.17 | 4.69 | 3.90 | 7.54 | 2.44 |
| Stop/start time | 14.60 | 7.95 | 9.39 | 10.80 | 6.27 |
| Uncertainty | 4.06 | 2.29 | 4.38 | 0.90 ns | 1.44 |
| Model 3 tolls: | | | | | |
| Free flow time | 7.99 | 2.78 | 4.53 | 2.93 | 1.84 ns |
| Slowed down time | 8.75 | 7.71 | 5.71 | 11.10 | 5.97 |
| Stop/start time | 17.90 | 13.07 | 13.74 | 15.80 | 15.30 |
| Uncertainty | 4.96 | 3.77 | 6.41 | 1.30 ns | 3.52 |

| TABLE E 2: Values of Travel Time Savings for each Segment ($ per person hour, NZ$99) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Attributes | Long Distance <3 hrs | LD<3h Visiting Friends & Relatives | LD<3h: Social-Recreation | LD<3h: Shopping | Long Distance >3 hrs | LD>3h Visiting Friends & Relatives | LD>3h: Social-Recreation |
| Model 1: | | | | | | | |
| Total time | 9.12 | 7.28 | 9.50 | 8.69 | 6.97 | 6.27 | 5.06 |
| As % awr | 63.6 | 52.9 | 59.2 | 69.5 | 43.5 | 37.9 | 32.8 |
| Model 2: | | | | | | | |
| Free flow time | 3.98 | 0.32 ns | 5.88 | 7.54 | 3.84 | 4.38 | 1.52 ns |
| Slowed down time | 13.9 | 13.39 | 11.4 | 15.65 | 10.09 | 9.25 | 6.33 |
| Stop/start time | 28.49 | 29.44 | 28.33 | 17.97 | 25.95 | 15.51 | 40.9 |
| Uncertainty | 4.97 | 0.98 ns | 9.16 | 7.99 | 8.76 | 9.74 | 7.98 |
| Model 3 for running cost: | | | | | | | |
| Free flow time | 6.18 | 0.62 ns | 8.38 | 7.98 | 5.44 | 6.03 | 1.65 ns |
| Slowed down time | 22.31 | 22.7 | 16.90 | 16.47 | 15.16 | 13.57 | 6.95 |
| Stop/start time | 41.86 | 45.6 | 38.70 | 19.14 | 33.4 | 17.97 | 43.2 |
| Uncertainty | 7.69 | 1.42 ns | 12.64 | 8.52 | 12.59 | 13.73 | 8.64 |
| Model 3 tolls: | | | | | | | |
| Free flow time | 3.78 | 0.36 ns | 5.59 | 7.47 | 3.43 | 3.93 | 1.51 ns |
| Slowed down time | 13.68 | 13.37 | 11.27 | 15.42 | 9.57 | 8.84 | 6.35 |
| Stop/start time | 25.64 | 26.77 | 25.82 | 17.91 | 21.09 | 11.71 | 39.13 |
| Uncertainty | 4.70 | 0.83 ns | 8.42 | 7.97 | 7.94 | 8.94 | 7.87 |

TABLE E3 : Distribution of VTTS by Income, Vehicle Occupancy, Residential location and Fuel Cost Commitment

| Local Commuting | Car occupancy | | | Personal Income | | | Who pays for fuel | | Residential Location | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Single occupant | Driver plus 1 passenger | Driver and 2 or more passengers | <$30,000 | $30000-49999 | $50000 and over | driver | Other party (eg company car) | Metro: Auckland Wellington Christchurch | Non-metro | Auckland | Wellington Christchurch |
| Sample Size | 1792 | 416 | 128 | 1005 | 944 | 432 | 2192 | 189 | 1184 | 1197 | 384 | 800 |
| Model 1: | | | | | | | | | | | | |
| Total time | 12.69 | 6.08 | 7.31 | 8.99 | 11.59 | 13.90 | 10.97 | 13.6 | 11.03 | 11.43 | 14.02 | 9.93 |
| Model 2: | | | | | | | | | | | | |
| Free flow time | 7.71 | 8.81 | 7.36 | 5.75 | 9.58 | 7.96 | 7.91 | 14.48 | 11.7 | 5.58 | 8.61 | 12.79 |
| Slowed down time | 2.69 | 5.64 | ns | 7.89 | 9.24 | 11.3 | 9.14 | 7.83 | 7.17 | 13.84 | 9.94 | 6.30 |
| Stop/start time | 19.89 | 5.98 | 10.1 | 17.13 | 17.47 | 20.26 | 17.09 | 48.77 | 17.89 | 18.95 | 25.3 | 15.95 |
| Uncertainty | 4.98 | 4.55 | 5.82 | 3.35 | 5.91 | 7.15 | 4.93 | 2.50 | 6.22 | 3.45 | 9.41 | 3.64 |
| Model 3 for running cost: | | | | | | | | | | | | |
| Free flow time | 6.09 | 5.37 | 11.7 | 2.72 | 9.62 | 5.49 | 6.81 | 3.76 | 10.29 | 4.22 | 14.65× | 7.81 |
| Slowed down time | 8.64 | 3.09 | ns | 3.20 | 9.30 | 12.23 | 7.72 | 2.06 | 6.19 | 10.48 | 18.19× | 3.53 |
| Stop/start time | 15.60 | 3.49 | ns | 8.20 | 17.55 | 21.9 | 14.66 | 15.85 | 15.7 | 14.69 | 44.9× | 9.20 |
| Uncertainty | 3.92 | 2.66 | 9.19 | 1.57 | 5.94 | 7.74 | 4.22 | 0.89 | 5.47 | 2.65 | 16.6× | 2.26 |
| Model 3 tolls: | | | | | | | | | | | | |
| Free flow time | 7.81 | 9.26 | 6.97 | 5.93 | 9.58 | 7.95 | 7.99 | 12.04 | 11.75 | 5.58 | 8.11 | 12.92 |
| Slowed down time | 2.58 | 5.34 | ns | 6.97 | 9.25 | 11.3 | 9.06 | 6.6 | 7.08 | 13.85 | 10.07 | 2.71 |
| Stop/start time | 18.65 | 6.02 | ns | 17.9 | 17.47 | 20.21 | 17.2 | 50.3 | 17.95 | 19.42 | 24.89 | 16.52 |
| Uncertainty | 5.03 | 4.57 | ns | 3.42 | 5.91 | 7.13 | 4.96 | 2.85 | 6.25 | 3.17 | 9.21 | 3.74 |

*× = running cost t-value = 1.40,*

| Local Non-Commuting | Car occupancy | | | Personal Income | | | Who pays for fue | | Residential Location | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Single occupant | Driver plus 1 passenger | Driver and 2 or more passengers | <$30,000 | $30000-49999 | $50000 and over | driver | Other party (eg company car) | Metro: Auckland Wellington Christchurch | Non-metro | Auckland | Wellington Christchurch |
| Sample Size | 784 | 832 | 784 | 1676 | 496 | Too small | 2160 | Too small | 1168 | 1260 | Too small | 800 |
| Model 1: | | | | | | | | | | | | |
| Total time | 6.74 | 3.71 | 9.60 | 7.06 | 6.58 | | 6.33 | | 6.38 | 4.87 | | 7.78 |
| Model 2: | | | | | | | | | | | | |
| Free flow time | ns | ns | 6.03 | 2.47× | ns | | 3.29 | | 2.43 | 2.46+ | | 3.03 |
| Slowed down time | 6.95 | 5.70 | 11.94 | 11.2 | 5.78# | | 7.29 | | 5.13 | 11.92 | | 9.84 |
| Stop/start time | 15.67 | 9.90 | 16.98 | 12.78 | 18.56 | | 12.50 | | 17.95 | ns | | 16.9 |
| Uncertainty | 5.34 | 1.75 | 4.35 | 4.25 | ns | | 3.24 | | 3.98 | 3.48 | | 6.5 |
| Model 3 for running cost: | | | | | | | | | | | | |
| Free flow time | ns | ns | 3.37 | 1.62× | ns | | 1.99 | | 1.94+ | 1.12+ | | 2.76 |
| Slowed down time | 3.46 | 3.49 | 6.85 | 6.79 | 2.60# | | 4.27 | | 4.07 | 5.54 | | 8.96 |
| Stop/start time | 8.78 | 6.76 | 10.40 | 8.35 | 8.57 | | 7.99 | | 14.64 | 1.78+ | | 15.5 |
| Uncertainty | 6.76 | ns | 2.45 | 2.61 | ns | | 1.94 | | 3.22 | 1.60 | | 6.06 |
| Model 3 tolls: | | | | | | | | | | | | |
| Free flow time | ns | ns | 6.18 | 2.67× | ns | | 3.38 | | 2.45+ | 2.61+ | | 3.02 |
| Slowed down time | 6.46 | 5.73 | 12.2 | 11.2 | 6.37 | | 7.25 | | 5.09 | 12.4 | | 6.70 |
| Stop/start time | 16.4 | 11.08 | 18.57 | 13.8 | 20.96 | | 13.6 | | 18.3 | 3.94+ | | 17.0 |
| Uncertainty | 5.5 | ns | 4.37 | 4.31 | 2.77& | | 3.29 | | 4.03 | 3.50 | | 6.58 |

*× free flow t-value 1.67 for model 2 and 1.78 for model 3, # = slowed down time t-value 1.45 for model 2 and 1.56 for model 3, + = free flow time t value 1.5*

| Long Distance (up to 3 hours) | Car occupancy | | | Personal Income | | | Who pays for fuel | | Residential Location | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Single occupant | Driver plus 1 passenger | Driver and 2 or more passengers | <$30,000 | $30000-49999 | $50000 and over | Driver | Other party (eg company car) | Metro: Auckland Wellington Christchurch | Non-metro | Auckland | Wellington Christchurch |
| Sample Size | 272 | 416 | 368 | 528 | 384 | 144 | 944 | 112 | 720 | 336 | 208 | 512 |
| Model 1: | | | | | | | | | | | | |
| Total time | 4.02 | 7.17 | 8.55 | 10.1 | 7.47 | 8.99 | 9.24 | 5.28 | 9.11 | 7.65 | 12.22 | 7.96 |
| Model 2: | | | | | | | | | | | | |
| Free flow time | 8.45 | ns | ns | 7.03 | ns | ns | 4.31 | ns | 3.48 | 4.32 | 7.36 | ns |
| Slowed down time | 20.5 | 8.45 | 15.57 | 11.87 | 14.23 | 16.65 | 14.23 | ns | 15.11 | 6.54 | 13.83 | 14.78 |
| Stop/start time | 29.2 | 26.8 | 28.5 | 20.29 | 38.16 | 33.8 | 25.9 | 51.25 | 28.5 | 27.6 | 38.32 | 26.24 |
| Uncertainty | ns | 10.47 | ns | 5.11 | ns | 7.61 | 4.48 | ns | 6.4 | ns | 10.6 | 4.92 |
| Model 3 for running cost: | | | | | | | | | | | | |
| Free flow time | 10.53 | ns | ns | 9.96 | ns | ns | 6.93 | ns | 5.25 | 6.47 | 11.77 | ns |
| Slowed down time | 25.38 | 15.95 | 14.29 | 16.95 | 19.7 | ns | 3.77 | ns | 23.27 | 10.93 | 23.46 | 19.4 |
| Stop/start time | 34.8 | 44.0 | 35.63 | 27.4 | 49.7 | ns | 38.4 | ns | 41.23 | 38.2 | 57.39 | 33.79 |
| Uncertainty | ns | 18.7 | ns | 7.09 | ns | ns | 6.94 | ns | 9.52 | ns | ns | 6.43 |
| Model 3 tolls: | | | | | | | | | | | | |
| Free flow time | 8.24 | ns | ns | 6.57 | ns | ns | 4.13 | ns | 3.31 | 4.03 | 6.75 | ns |
| Slowed down time | 20.2 | 8.12 | 15.53 | 11.2 | 14.1 | 17.82 | 13.88 | ns | 14.68 | 6,82 | 13.46 | 14.40 |
| Stop/start time | 34.5 | 22.42 | 26.97 | 18.08 | 35.62 | 22.48 | 22.92 | 49.5 | 26.0 | 23.80 | 32.93 | 25.09 |
| Uncertainty | ns | 9.52 | ns | 4.68 | ns | 7.28 | 4.14 | 8.70 | 6.0 | ns | ns | 4.78 |

| Long Distance (over 3 hours) | Car occupancy | | | Personal Income | | | Who pays for fuel | | Residential Location | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Single occupant | Driver plus 1 passenger | Driver and 2 or more passengers | <$30,000 | $30000-49999 | $50000 and over | Driver | Other party (eg company car) | Metro: Auckland Wellington Christchurch | Non-metro | Auckland | Wellington Christchurch |
| Sample Size | 176 | 512 | 352 | 512 | 352 | 224 | 1040 | 48 | 704 | 384 | 240 | 464 |
| Model 1: | | | | | | | | | | | | |
| Total time | 4.18 | 8.95 | 5.82 | 7.49 | 6.40 | 6.73 | 6.98 | 10.7 | 7.27 | 6.83 | ns | 11.6 |
| Model 2: | | | | | | | | | | | | |
| Free flow time | ns | 4.33 | 4.16 | 3.46 | 3.67 | 5.82 | 3.89 | 14.8 | 3.71 | 5.07 | ns | 9.28 |
| Slowed down time | ns | 17.5 | ns | 16.0 | 7.35 | ns | 10.2 | ns | 13.9 | 5.97 | 11.6 | 16.2 |
| Stop/start time | 20.9 | 38.6 | 17.5 | 33.8 | 25.63 | 23.4 | 25.6 | ns | 24.2 | 27.1 | 12.1 | 31.1 |
| Uncertainty | ns | 11.5 | ns | 5.49 | 8.47 | 17.5 | 8.5 | ns | 9.3 | 7.75 | 10.7 | 8.9 |
| Model 3 for running cost: | | | | | | | | | | | | |
| Free flow time | ns | 7.16 | 5.07 | 4.57 | 4.18 | 11.76 | 5.3 | 14.7 | 4.79 | 7.55 | ns | 13.1 |
| Slowed down time | ns | 30.4 | ns | 24.4 | 8.46 | ns | 14.9 | ns | 19.3 | 9.68 | 15.4 | 23.7 |
| Stop/start time | 24.9 | 57.3 | 19.9 | 44.0 | 28.2 | 38.8 | 32.0 | ns | 29.5 | 34.8 | 12.1 | 41.6 |
| Uncertainty | ns | 19.5 | ns | 8.47 | 9.88 | 33.0 | 11.9 | ns | 12.3 | 12.0 | 14.4 | 12.4 |
| Model 3 tolls: | | | | | | | | | | | | |
| Free flow time | ns | 4.01 | 3.71 | 2.85 | 3.50 | 5.3 | 3.47 | 14.8 | 3.29 | 4.64 | ns | 8.6 |
| Slowed down time | ns | 17.0 | ns | 15.2 | 7.09 | ns | 9.7 | ns | 13.2 | 5.94 | 10.1 | 15.5 |
| Stop/start time | 11.2 | 32.1 | 14.6 | 27.5 | 23.6 | 17.5 | 20.8 | ns | 20.2 | 21.4 | 7.91 | 25.7 |
| Uncertainty | ns | 10.8 | ns | 5.28 | 7.85 | 14.9 | 7.7 | ns | 8.4 | 7.38 | 9.37 | 8.1 |

# APPENDIX F
# FURTHER ANALYSIS FOR URBAN COMMUTER AND MEDIUM-DISTANCE TRIPS

**Note:** This appendix was provided by Professor Hensher, based on a separate paper prepared by him. Its main findings are summarised in chapter 5.


## Summary

The empirical valuation of travel time savings is a derivative of the ratio of parameter estimates in a discrete choice model. The most common formulation (multinomial logit) imposes strong restrictions on the profile of the unobserved influences on choice as represented by the random component of a preference function. As we progress our ability to relax the restrictions we open up opportunities to benchmark the values derived from simple (albeit relatively restrictive) models.

A small but growing literature is sending signals that the MNL model tends to under-estimate the (mean) VTTS. A re-analysis of the 1999 New Zealand VTTS study data (reported herein) and other studies (e.g. Bhat 1995) have found systematically higher mean VTTS for less restrictive discrete choice specifications such as the heteroskedastic extreme value model (HEV), the covariance heterogeneity logit model (CovHet), mixed (or random parameter) logit (ML/RPL) and multinomial probit (MNP). If this directional tendency persists, it raises questions about the implied loss of user benefit from the application of MNL-based VTTS in project appraisal.

This Chapter presents new empirical evidence for long distance and urban commuter settings in New Zealand. For urban travel, we contrast the values of travel time savings derived from multinomial logit and alternative specifications of mixed (or random parameter) logit models. The evidence supports the growing position that less restrictive choice model specifications tend to produce higher mean estimates of values of time savings compared to the multinomial logit model; however the degree of under-estimation of multinomial logit remains quite variable, depending on the context.


## 1. Introduction

Three facets of valuation have emerged as potentially major influences on the valuation of travel time savings (VTTS):

- the heterogeneity of travel time
- the design strategy for stated preference experiments, a popular data tool for valuation and
- the exploration of alternative error covariance structures of discrete choice models.

In deriving estimates of VTTS, the New Zealand study has moved beyond a focus on the heterogeneity of travel time that distinguishes between invehicle and out of vehicle time to a focus on the composition of invehicle time for car travel, distinguishing between free flow time, slowed down time and stop/start time. The value of congestion time savings, a topic of growing interest (e.g. Calfee and Winston 1998) is a mixture of the last two dimensions of travel time. In addition we accounted for the contingency time that a traveller includes in the face of uncertainty in respect of arrival time at a destination. Trip cost is also disaggregated into two components, running costs and tolls, to recognise the broadening range of monetary costs that impact directly on a trip.

With a richer disaggregation of travel time, revealed preference data (RP) is usually inappropriate (at least as the only source of attribute-trading). There is too much confoundment in RP data, best described as 'dirty' from the point of view of statistical estimation of the individual influences on choice. Predictor variables (attributes of alternatives, contextual effects) may exhibit high or extreme levels of multicollinearity consequent on market forces, technology and sampling considerations. Furthermore some attributes such as a toll often do not exist or are of limited variability so we are unable to establish their influence.

An alternative is a stated choice experiment in which we systematically vary combinations of levels of each attribute to reveal new opportunities relative to the existing circumstance of time-cost on offer. This literature is extensive (see Hensher 1994, Louviere et al. 2000). Through the experimental design paradigm we observe a sample of travellers making choices between the current trip attribute level bundle and other attribute level bundles. This approach is the preferred method of separating out the independent contributions of each time and cost component and hence is the preferred approach capable of providing disaggregated time values (Gunn 2000).

However, SP experiments have many features that can influence the resulting VTTS. In particular it is thought that the estimates are sensitive to the design of the SP experiment, especially 1) the number of alternatives in a choice set, 2) the number of choice sets (or treatments) evaluated and 3) the range and levels of the time and cost attributes being traded.

It is recognised that the structure of the unobserved effects conditions the form of a discrete choice model, and hence there exists the possibility of mis-inference from the simpler MNL specification[1]. The interesting question is the implication for VTTS of covariance amongst alternatives, the presence of individual specific (random) effects or heterogeneity, and differential variance of the unobserved effects. We expect to find that a more comprehensive definition of time heterogeneity, a carefully structured SP design to accommodate more complexity in attributes, and less restrictive error covariance structures will result in VTTS that are different from estimates used in the

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[1] *VTTS is likely to be under-estimated in multinomial logit (MNL) models because an element of the unobserved influences on travel choices is 'forced' into the parameter estimates of the observed effects when the strict independently and identically distributed (IID) condition is imposed on the utility functions. Theory suggests that this impacts on the time attributes more than the cost attributes because many of the unobserved attributes are more correlated with travel time than travel cost (Jara-Diaz 1998, 2000). From an econometric perspective, the mean of a random parameter is likely to be larger than for MNL because the random parameter (or mixed) logit model decomposes the unobserved component of utility and normalises (through the scale parameter) the parameter estimates on the basis of part of the unobserved component.*

economic evaluation of transport projects, currently derived from simple SP designs and MNL models with limited time heterogeneity. Since time savings are the greatest single user benefit the findings will be critical in either reinforcing or questioning current practice.

However, what is of particular interest is the interface between the SP design strategy and the error covariance structure (Bates 1988), since it is increasingly argued (see Louviere, Hensher and Swait 2000 for details) that the role of the properties of the error covariance matrix (especially the scale parameter) is very sensitive to the quality of the data. Louviere and Hensher (2000) suggest that:

> "Accumulating evidence from various literatures, especially in marketing, psychology and transportation, provides support for the desirability of combining sources of preference data as a way of transferring increasing power of understanding of travel behaviour from the econometrics of a model to the underlying data inputs".

In much of the theoretical and empirical work undertaken in the random utility theory paradigm the ε's are a unidimensional component associated with each choice option. This view of the ε's has obfuscated the fact that these random components of utility are multidimensional. That is, the ε's are better thought of as variance components that include variation within-subjects, between-subjects and variation due to the measurement instrument. In any given empirical study, unless the study is designed to separate these components, the data and model outcomes is likely to be confounded with the variability and cannot be separately identified. Of these components, there has been recognition of between-subjects variation especially in the form of preference parameter heterogeneity (Louviere and Hensher 2000), but there has been little recognition that there also can be between-subjects variation in model forms (Kamakura et al. 1996).

The statistical efficiency of choice experiments is as much a behavioural as a statistical issue. In particular, unlike the objects of analysis in many classical statistical experiments and indeed in the mathematical and statistical theory that underlies design optimisation, humans *interact* with choice experiments in ways not previously considered by transport analysts. In the following sections, we set out the more general error covariance model to be used in developing VTTS to contrast with the MNL model.

The paper is organised as follows. The following section sets out the arguments for considering less restrictive choice models. This is followed by a presentation of the preferred choice model specification - mixed (or random parameter) logit. The remaining substantive sections present the new empirical analysis for urban commuting and long-distance (up to 3 hours) travel with a focus on values of travel time savings, followed by a conclusion.

## 2. The Basis for Considering Less Restrictive Choice Models

There are many influences to take into account when studying and explaining the preferences and hence choice behaviour of individuals. Some of these influences are measured with great accuracy, some are measured with error and some are excluded. The set of unobserved influences to be accommodated in the estimation of the choice model might be correlated across the alternatives in the choice set (ie non-zero covariance). Furthermore when these potential sources of variability in preferences are taken into account, there may still remain additional sources of influence that are unique to each individual. Allowing for these idiosyncracies of individuals is known as accounting for unobserved heterogeneity.

The importance of a proper account of the treatment of the unobserved effects can be illustrated by the following example. Consider a simple random utility model, in which there are heterogeneous preferences for observed and unobserved attributes of offered alternatives:

$$U_{qjt} = \alpha_{qj} + p_{qjt}\gamma_q + x_{qjt}\beta_q + \varepsilon_{qjt} \qquad (1)$$

$U_{qjt}$ is the utility that individual $q$ receives given a choice of alternative $j$ on occasion $t$. In an SC experiment, $t$ would index choice tasks. $p_{qjt}$ denotes price, and $x_{qjt}$ denotes another observed attribute of $j$ (which for complete generality varies across individuals and choice tasks). $\alpha_{qj}$ denotes the individual specific intercept for alternative $j$, arising from q's preferences for unobserved attributes of $j$. $\gamma_q$ and $\beta_q$ are individual specific utility parameters that are intrinsic to the individual and hence invariant over choice tasks. The $\varepsilon_{qjt}$ can be interpreted as task-specific shocks to q's tastes, which for convenience are assumed to be independent over choice tasks, alternatives and individuals.

Suppose we estimate an MNL model, incorrectly assuming that the intercept and slope parameters are homogeneous in the population. The random component in this model will be

$$w_{qjt} = \hat{\alpha}_q + p_{qjt}\hat{\gamma}_q + x_{qjt}\hat{\beta}_q + \varepsilon_{qjt} \qquad (2)$$

where ^ denotes the individual specific deviation from the population mean. Observe that (from the analyst's perspective) the variance of this error term for individual $q$ on choice task $t$ is

$$\mathrm{var}(w_{qjt}) = \sigma_\alpha^2 + p_{qjt}^2\,\sigma_\gamma^2 + x_{qjt}^2\,\sigma_\beta^2 + \sigma_\varepsilon^2 \qquad (3)$$

and the covariance between choice tasks $t$ and $t$–1 is

$$\mathrm{cov}(w_{qjt}, w_{qj,t-1}) = \sigma_\alpha^2 + p_{qjt}\, p_{qj,t-1}\ \sigma_\gamma^2 + x_{qjt}\, x_{qj,t-1}\sigma_\beta^2 \qquad (4)$$

Equations (3) and (4) reveal two interesting consequences of ignoring heterogeneity in preferences. First, the error variance will differ across choice tasks as the price $p$ and attribute $x$ are varied. If one estimates an MNL model with a constant error variance, this will show up as variation in the intercept and slope parameters across choice tasks. In an SC experiment context, this could lead to a false conclusion that there are order effects in the process generating responses.

Second, equation (4) shows how preference heterogeneity leads to serially correlated errors. That heterogeneity is a special type of serial correlation is not well understood in the transportation literature. To obtain efficient estimates of choice model parameters one should include a specification of the heterogeneity structure in the model. One such way is to specify the parameters associated with each attribute (including price) as random[2]. But more importantly, if preference heterogeneity is present it is not merely a statistical nuisance requiring correction. Rather, one should model the heterogeneity in order to obtain accurate choice model predictions, because the presence of heterogeneity will impact on the marginal rates of substitution between attributes, and lead to IIA violations.

This discussion suggests the importance of paying attention to the behavioural source of the error terms in a choice model that may lead to new insights into how the model should be estimated, interpreted and applied. We have selected the mixed (or random parameter) logit model to contrast with MNL. Mixed logit is currently regarded as the most flexible and computationally practical discrete choice specification, providing a convenient approximation to multinomial probit (McFadden and Train 1997).

## 3. Mixed Logit

The utility expression for mixed logit (ML) is the same as that for a standard MNL model except that the analyst may nominate one or more taste weights (including alternative-specific constants) to be treated as random parameters[3] with the variance estimated together with the mean. The selected random parameters can take a number of predefined functional forms, such as normal, lognormal or triangular. The selection of the distribution assumption for each random parameter (with alternative distributions permitted across the attribute set) is a major ongoing research area, since no one distribution has all of the desirable behavioural properties. For example, the normal produces both positive and negative values across the parameter distribution and the lognormal contains the distribution to one sign but typically produces a very thick tail that is behaviourally implausible for valuation (Hensher 2000c). The

2 *Some empirical evidence (eg Daniels and Hensher 2000) suggests that once unobserved heterogeneity is taken into account via a random effects specification such as ML or RPL, serial correlation may be negligible or absent. That is, serial correlation may be spurious due to the failure to account for unobserved heterogeneity.*

3 *We focus on the random parameter specification that is equivalent to the error components form.*

triangular distribution, used herein for urban commuting has a density function that looks like a tent: a peak in the centre and dropping off linearly on both sides of the centre[4].

The ML form has important behavioural implications. The attributes with random parameters induce a distribution around the mean that provides a mechanism for revealing preference heterogeneity. This heterogeneity takes the form of a random effects version of unobserved heterogeneity that may be refined by making it a function of observed variables such as income and age. This is a way of revealing the specific sources of variation in unobserved heterogeneity across a sampled population. We can also account for correlation between random parameter attributes. The presence of additional terms as a representation of random tastes of each individual invariant across the choice set can induce a correlation among the utility of different alternatives (Bhat 1998, McFadden and Train 1997). It is the mixture of an extreme value type 1 (EV1) distribution for the overall utility expression and embedded distribution of the taste weights across a sample which has led to the phrase 'mixed logit' (Train 1997, 1999). Specifically, by treating the deviation around a mean taste weight as a component of the random component the model has been interpreted as an error-components model, where one component can take on any distributional assumption and the other component is assumed to be EV1. One can also choose to treat the random effects as different across the alternatives but independent (ie different standard deviations); or as different across alternatives and inter-alternative correlated.

The correlated structure of data on choice sets that is drawn from the same individual (as in stated choice tasks) can be handled within this framework. Serially correlated error terms and serially correlated random coefficients for the alternative specific constants are exactly the same thing and in that sense, random coefficients and serial correlation are exactly the same thing. Usually, however random coefficients are given to more attributes than the alternative specific constants, and random coefficients are not typically given an AR1 specification (though they could be given that). So in practice, there is often a difference[5].

This model engenders a relatively free utility structure such that IIA is relaxed despite the presence of the IID assumption for the random components of the alternatives. That is, the ML model disentangles IIA from IID and enables the analyst to estimate models that account for cross-correlation among the alternatives. When the random taste weights are all zero, the exact MNL model is produced. Applications of the mixed logit model are given in Bhat (1997), Revelt and Train (1996), Brownstone and Train (1999), McFadden and Train (1997) and Hensher (2000b, 2000c).

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[4] *Let c be the centre and s the "spread". The density starts at c-s, rises linearly to c, and then drops linearly to c+s. It is zero below c-s and above c+s. The mean and mode are c. The standard deviation is s/sqr(6). The height of the tent at c is 1/s (such that each side of the tent has area s*(1/s)*(1/2)=1/2, and both sides have area 1/2+1/2=1, as required for a density.) The slope is $1/s^2$. This specification converges much faster than the lognormal.*

[5] *The difference is in tradition and practice, rather than in the capabilities of the models per se. Discussions with Ken Train, Bill Greene and Chandra Bhat on this issue are greatly appreciated.*

From an econometric perspective, the mean of a random parameter is likely to be larger than for MNL because the mixed logit model decomposes the unobserved component of utility and normalises (through the scale parameter) the parameter estimates on the basis of part of the unobserved component. The interesting issue is the extent to which these mean estimates are relatively higher for time than for cost, which determines the direction of change in VTTS relative to MNL.

The mixed logit models are estimated by simulated maximum likelihood (SML) estimation using the Halton draws method (Bhat 1999), an alternative to the random draws approach. Numerous procedures have been proposed for taking *intelligent* draws from a distribution rather than random ones (e.g., Sloan and Wozniakowski, 1998) Rather than using psuedo-random sequences for the discrete points in a distribution, a quasi-Monte Carlo approach uses non-random and more uniformly distributed sequences within the domain of integration (Bhat 1999, 3). Thus the coverage of the random utility space is more representative.

The procedure offers the potential to reduce the number of draws that are needed for estimation of ML model, thereby reducing run times, and/or to reduce the simulation error that is associated with a given number of draws. Bhat (1999)[6] and Train (1999) have investigated Halton sequences for mixed logit estimation and found their use to be vastly superior to random draws. In particular, they found that the simulation error in the estimated parameters was lower using 100 Halton numbers than 1000 random numbers. In fact, with 125 Halton draws, they both found the simulation error to be half as large as with 1000 random draws and smaller than with 2000 random draws. The estimation procedure is much faster (often 10 time faster). We have investigated Halton sequences involving draws of 10, 25, 50, 100, 150 and 200 and compared the findings with random draws. In all models of the RPL investigated we conclude that a small number of draws (as low as 50) produces model fits and values of travel time savings that are almost indistinguishable (and at worse very similar – see footnote 15). This is a phenomenal development in the estimation of complex choice models.

## 4. Empirical Analysis: Urban Travel

The survey was undertaken in late June and early July 1999, sampling residents of seven cities/regional centres in New Zealand: Auckland, Wellington, Christchurch, Palmerston North, Napier/Hastings, Nelson and Ashburton on both the North and South Islands. The main survey was executed as a laptop-based face to face interview in which each respondent was asked to complete the survey in the presence of an interviewer. Each sampled respondent evaluated 16 choice profiles, choosing amongst two SC alternatives and the current RP alternative[7]. The main questions leading up to the SC screens are given in Appendix A. A total of 439 interviews were undertaken in the seven cities/regional centres, spread amongst four segments (local commuter, local non-commuter, long distance < 3 hours and long distance > 3 hours). The 439

[6] *Bhat (in press) also uses Halton draws in mixed logit estimation but does not describe his tests against random draws.*

[7] *The development of the survey instrument occurred over the period December 1998 to June 1999. Many variations of the instrument were developed and evaluated through a series of skirmishes, pre-pilots and pilot tests.*

interviews represents 7,373 cases for model estimation (ie 439×16 treatments). We limit the current paper to the urban commuter sample of 144 respondents or 2,304 cases. The long-distance models (< 3 hours) are presented in Hensher (2000)[8].

Descriptive statistics for each urban segment are presented in Table F1. The mean for each design attribute is based on the current trip levels and the variations around this level as produced by the experiment design. The most interesting evidence relates to the composition of travel time, especially the proportion of the trip time that is free flow in contrast to the current time which includes all sources of delay. The italicised columns in Table F1 provide evidence on the contribution of delays to travel time. Commuters incur a 31.7 percentage delay time or an average delay of 6.6 minutes. The average trip length is 16.2 minutes with a trip length distribution standard deviation of 22.2 minutes.

**Table F1**: Summary Descriptive Statistics (mean with standard deviation in brackets)

| Attributes | Mean and Standard Deviation (or percentage) |
|---|---|
| Free flow time (mins) | 11.2 (6.9) |
| Slowed down time (mins) | 5.4 (5.8) |
| Stop/start time (mins) | 4.0 (4.7) |
| Uncertainty (mins) | 8.2 (6.8) |
| Running cost ($) | 1.5 (1.4) |
| Toll Charges ($) | 2.0 (2.3) |
| No adults | 1.4 (2.4) |
| No children | .09 (.34) |
| Time last trip (mins) | 20.8 (16.6) |
| Time last trip if no congestion (mins) | 14.2 (14.6) |
| Percent of trip time that is delayed time (%) | 31.7 |
| Current trip length (kms) | 16.2 (22.2) |
| Fuel paid by driver (%) | 91.6 |
| Age of driver (years) | 39.6 (14.1) |
| Personal income ($pa) | 31798 (20619) |
| Full time work (%) | 60.9 |
| Part time work (%) | 25.2 |
| Casual work (%) | 8.6 |
| Sample Size | 2427 |

## 4.1 The Choice Models

A series of models were estimated to identify the role of each trip attribute in the SC experiment for the choice between the current car trip attributes and two other trip attribute scenarios on offer. All attributes are route abstract and are treated as generic attributes in model estimation. We specifically structured the survey to avoid a requirement for route switching. The objective was to evaluate alternative attribute

[8] *MNL models for all segments are available in Hensher, Louviere and Wallis (1999).*

bundles for travelling between predetermined locations by the existing route and time of day.

The final commuter models are summarised in Table F2. In the current paper we concentrate on those aspects of the models that are especially relevant in the derivation of the values of travel time savings. We have estimated three model forms for the fully disaggregated set of travel times and costs. Model 1 assumes that the attributes with random parameters are not correlated (hence the alternatives are independent) and the 16 choice sets are uncorrelated. Model 2 allows for correlation amongst the alternatives while preserving independence of choice sets. Model 3 permits correlation amongst alternatives and choice sets. Eight VTTS are derived, four for the time components based on the marginal utility of running cost and four based on the marginal utility of toll charge.

Although economic theory prescribes one marginal utility for cost regardless of the level and units (no money illusion), the implicit assumption is that units of cost are free from lumpiness or indivisibility constraints. Individuals however do impose non-linearity on the preference function for dollar commitments that is in large measure a function of the mechanism through which costs are expended. Running costs described in the stated choice experiment as fuel are a financial commitment at the time of refuelling which has high perceptual discounting in terms of its influence at the time of car use. In contrast a toll is an outlay that is normally 'physically' transferred at the point of car use from the driver to the toll booth attendant[9]. We hypothesise that VTTS will be higher for the cost attribute that is greatest in magnitude, which in the current application is the toll. This is confirmed by the evidence below.

All parameter estimates for the MNL model are statistically significant (t-values greater than 5.0) facilitating robust mean VTTS for each time component. It should be noted however that t-statistics are upwardly biased because MNL assumes independent choice sets across the 16 SP treatments[10]. The directional relativities between free flow time, slowed down time and stop/start time are as expected, with the marginal disutility increasing for the less attractive time component (ie stop/start). The ratio of slowed down to free flow time is 1.08; the ratio of stop/start time to free flow time is 2.14. The directional relativity between the VTTS components is preserved across all specifications of mixed logit although the ratios increase as we move from model 1 through to Model 3. The highest ratio for slowed down time to free flow time is 1.44 in Model 3b for non-Auckland; the highest ratio for stop/start to free flow time is 2.8 for Model 3a. The VTTS associated with stop/start time appears to be the appropriate value to use in the evaluation of congestion-reduction and incident management schemes. This suggests that in general the savings in travel time associated with noticeable traffic congestion is approximately 2.5 times the value for free flow travel and double that for slow traffic situations.

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9 *There are no tollroads in New Zealand and it is unclear whether electronic tolling will be the norm when introduced. This makes payment seamless although one still has to 'observe' the payment as one passes the toll capture location.*

10 *Practical experience suggest that despite the independence of choice set assumption that the t-statistics in this application will still be greater than the 95% confidence level. Mean estimates may also be biased which is more of a concern.*

A potentially important finding is the increasing deviation between the mean VTTS for each time component as we relax restrictions on the relationship between the alternatives and the choice sets. For example, the MNL model has a difference of $7.9/person hour whereas Model 3 has a difference of $11.3-$12.4 per person hour. The less restrictive model appears on the basis of the evidence herein to produce a greater separation of the mean VTTS across the time components. It must be recognised however that Models 2 and 3 that permit correlation across alternatives (Models 2 and 3) and correlation across choice sets (Model 3) provide Standard Deviation VTTS that provide overlap at the tails of the VTTS distribution. It is noteworthy that the standard deviation VTTS is very small for free flow time (in contrast to the more heterogeneous components of travel time) supporting a view that the mean VTTS for free flow is a more representative estimate across the entire sample than is the mean for the other time components.

**Table F2**: Final Commuter Models Used to Obtain Empirical Estimates of Values of Travel Time Savings. All travel times are in minutes and costs are in dollars

| Attributes | | RPL/ML | | | |
|---|---|---|---|---|---|
| | MNL | Independent Choice Sets | | Correlated Choice Sets | |
| | | Uncorrelated Alternatives | Correlated Alternatives | Correlated Alternatives | |
| | | Model 1 | Model 2 | Model 3a | Model 3b |
| Free flow time | -.1005(-5.5) | -.1019 (-5.5) | -.1044 (-5.0) | -.1109 (-5.5) | -.1128 (-5.8) |
| Slowed down time | -.1088 (-7.2) | -.1158 (-5.9) | -.1296 (-6.5) | -.1476 (-6.4) | -.1627 (-5.8) |
| Stop/start time | -.2151 (-10.5) | -.2208 (-.9.6) | -.2362 (-9.5) | -.3121 (-5.9) | -.2899 (-5.7) |
| Uncertainty | -.06134 (-5.3) | -.06208 (-5.2) | -.0636 (-4.8) | -.0746 (-2.9) | -.0615 (-2.5) |
| Running cost | -.8743(-7.2) | -.8979 (-6.9) | -.9160 (-7.1) | -.9564 (-8.7) | -.9372 (8.0) |
| Tolls | -.7141(-29.7) | -.7205 (-5.2) | -.7315 (-31.0) | -.7558 (-49.7) | -.7488 (-56.1) |
| Heterogeneity in mean (only significant betas) | | | | | |
| Uncert: Auckland Resident | | | | | -.1270 (-2.3) |
| Std Dev. of beta distn | | | | | |
| Free flow time | | .0011 (.008) | .06731 (.29) | .1334 (1.3) | .0421 (.40) |
| Slow down time | | .2136 (1.1) | .3347 (2.8) | .2111 (1.1) | .2331 (2.8) |
| Stop/start time | | .0172 (.095) | .1648 (.44) | .9479 (3.2) | .8559 (9.6) |
| Uncertainty | | .-107 (.13) | .0459 (.12) | .3831 (1.7) | .2977 (2.9) |
| Cholesky Matrix: | | | | | |
| FreeFlow:Slow | | | -.301 (-.58) | .139 (.90) | .221 (1.7) |
| FreeFlow:StopStart | | | -.148 (-.23) | .5964 (3.0) | .665 (2.5) |
| SlowDown:StopStart | | | -.064 (-.05) | -.5877 (-2.4) | .267 (.67) |
| FreeFlow:Uncertainty | | | .031 (.09) | -.1076 (-.7) | .055 (.28) |
| SlowDown:Uncertainty | | | .029 (.04) | -.1343 (-.62) | -.00001 (.00) |
| StopStart:Uncertainty | | | .016 (.02) | .2991 (2.3) | .051 (.21) |
| Pseudo-$r^2$ adjusted | .4393 | .4394 | .4394 | .451 | .451 |
| Log-likelihood | -1417.3 | -1417.3 | -1415.6 | -1386.9 | -1386.3 |

**Table F3**: Values of Travel Time Savings for Commuters ($ per person hour, NZ$99) average wage = $16.13/hour VTTS Standard Deviation in parenthesis[11]

| Attributes | | RPL/ML | | | | |
|---|---|---|---|---|---|---|
| | MNL | Independent Choice Sets | | Correlated Choice Sets | | |
| | | Uncorrelated Alternatives | Correlated Alternatives | Correlated Alternatives | | |
| Running cost: | | Model 1 | Model 2 | Model 3a | Model 3b Auckland | Other |
| Free flow time | 6.89 | 6.82 | 6.86 (1.8) | 6.95 (3.4) | 8.26 (1.1) | 7.21(1.1) |
| Slowed down time | 7.48 | 7.74 | 8.49 (8.9) | 9.26 (5.3) | 7.54(6.1) | 10.0(6.1) |
| Stop/start time | 14.8 | 14.77 | 15.47 (4.4) | 19.6 (24.2) | 20.7(22) | 18.5(22) |
| Uncertainty | 4.21 | 4.15 | 4.16 (1.23) | 4.68 (9.7) | 12.07(7.8) | 3.9(7.8) |
| Tolls: | | | | | | |
| Free flow time | 8.45 | 8.49 | 8.57 (2.3) | 8.8 (4.3) | 10.3(1.4) | 9.0(1.4) |
| Slowed down time | 9.15 | 9.63 | 10.64 (11.2) | 11.7 (6.8) | 9.5(7.6) | 13.0(7.6) |
| Stop/start time | 18.08 | 18.39 | 19.39 (5.5) | 24.7 (10) | 25.9(32) | 23.3(32) |
| Uncertainty | 5.15 | 5.17 | 5.21 (1.5) | 5.92 (12.4) | 15.1(9.8) | 4.9(9.8) |

The VTTS based on the toll in contrast to running cost is systematically higher (by 24.6 percent). The reasoning is linked to the higher toll in the SP alternatives, with a mean of $3 in contrast to $1.558 for running cost; and a higher standard deviation ($2.24) in contrast to $1.42 for running cost[12].

To gain further insight into the heterogeneity around the mean of the random parameters of travel time we evaluated its decomposition by all the socioeconomic and contextual characteristics in the data set. We investigated personal income (as a single variable and a number of segments), age, hours worked, and resident city. The only covariate having a statistically significant decomposition effect was the Auckland city dummy variable (1,0). Auckland is regarded by New Zealanders as the only city with noticeable congestion and so this finding is intuitively plausible. The most influential impact is on the uncertainty of time (defined by the extra amount of time one builds in to ensure arrival at work at the planned time). The mean VTTS for uncertainty for Auckland commuters is substantially higher than for commuters in other cities (Model 3b), almost four times higher. It is worth noting also that the stop/start mean VTTS is higher in Auckland, in contrast the slowed down mean VTTS is higher elsewhere, suggesting that Auckland commuters tend to experience much more stop/start traffic compared to non-Auckland commuters who experience mainly slow (but continuing) traffic.

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11 *Mean VTTS in the presence of heterogeneity in the mean as explained in part by an observed effect such as the Auckland dummy variable in trip uncertainty in arrival time is calculated by adjusting the mean parameter of the attribute. Thus VTTS (based on running cost) for uncertainty for Auckland commuters = (.0615-.1270*1.0)/.8743; for non-Auckland commuters the dummy variable is set to zero. Please also note that VTTS for Model 3b for the other three time components have been corrected for the Auckland effect although the Auckland heterogeneity effect was not statistically significant.*

12 *Juan de Dios Ortuzar has suggested (in a personal communication, June 2000) that the cost of a given trip is much more clearly associated with a toll than to running cost such as fuel which applies to more trips. For this reason there is a preference to calculate VTTS only on the basis of tolls or other direct out of pocket cost, and that good practice should encourage this emphasis.*

Model 3 is the preferred model since it allows for correlated choice sets, an issue of considerable interest to SC researchers (e.g. Morikawa 1994, Kim 1998). Does failure to account for serial correlation affect the VTTS? We contrast Models 2 and 3, and undertake a two-tailed z-test on the differences in means. The null hypothesis is that there are no statistically significant differences between Model 2 and Model 3. For a two-tailed test the results are significant at 0.05 if z lies outside the range ± 1.96. For each of the time components (free flow, slowed down stop/start, uncertainty), the respective z values are -3.71, -6.37, -36.61 and -4.47. Hence we can reject the null hypothesis of no significant differences for all time components. Indeed the null is rejected for the 0.01 level. Thus failure to account for choice set correlation has a statistically significant (downward biased) effect on the mean VTTS.

## 4.2 Conclusion

This urban commuter analysis has focused on the impact of alternative assumptions on the random components of the underlying utility expressions representing the preferences of commuter car drivers for alternative bundles of trip attributes[13]. We have distinguished free flow time, slowed down time and stop/start time. In addition we have accounted for the contingency time that a traveller includes in the face of uncertainty in respect of arrival time at a destination. Trip cost is disaggregated into running costs and toll charges to recognise the broadening range of monetary costs that impact directly on a trip.

| Halton draws: | 10 | 25 | 50 | 100 | 150 | 200 |
|---|---|---|---|---|---|---|
| *Running cost:* | | | | | | |
| Free flow time | 7.21 | 7.11 | 7.22 | 7.13 | 7.15 | 7.18 |
| Slowed down time | 7.45 | 7.31 | 7.37 | 7.32 | 7.32 | 7.33 |
| Stop/start time | 15.77 | 15.81 | 15.86 | 15.81 | 15.79 | 15.79 |
| uncertainty | 3.97 | 3.99 | 3.96 | 3.97 | 3.98 | 3.96 |
| *Toll cost:* | | | | | | |
| Free flow time | 8.56 | 8.54 | 8.65 | 8.58 | 8.59 | 8.64 |
| Slowed down time | 8.85 | 8.79 | 8.83 | 8.81 | 9.24 | 8.82 |
| Stop/start time | 18.73 | 19.00 | 19.00 | 19.02 | 18.98 | 19.07 |
| uncertainty | 4.71 | 4.80 | 4.75 | 4.78 | 4.79 | 4.76 |
| Log-likelihood | -1494.053 | -1492.123 | -1490.48 | -1490.829 | -1492.17 | -1491.216 |

13 *We estimated models for Halton draws of 10, 25, 50, 100, 150 and 200 and found very close equivalence as summarised in the Table below. All VTTS are in $NZ per person hour. We have used 50 draws in the models reported in the text.*

We have also taken into account the influence of correlation across alternatives and across choice sets. The evidence herein for urban commuter travel supports the intercity findings in other recent studies that less restrictive choice model specifications tend to produce higher mean estimates of values of time savings compared to the MNL model. The degree of under-estimation of MNL appears to be due mainly to travel time beyond free flow; however, statistical tests for the impact of ignoring serial correlation find strong evidence of underestimation even for the mixed logit model with uncorrelated choice sets. We also find that the greater the heterogeneity of travel time, the greater the deviation between the MNL and mixed logit results.

If the case for upwardly revised estimates of mean VTTS continues to be supported in further studies, we are defacto recognising the loss of user benefits in previous road projects due to an under valuation of time savings (subject to how behavioural VTTS are translated into resource values in benefit-cost analysis).

## 5. Empirical Analysis: Medium Distance Travel

We focus on the medium distance trips up to three hours, a sample of 198 individuals and 3,168 trip choice sets. The final MNL and RPL models are summarised in Table F4 including the preference variance-covariance matrix for the (statistically significant) correlated random parameters. Three models of varying degrees of disaggregation of time and cost have been estimated for each of MNL and RPL, with two distributions for the random parameters - normal and lognormal[14]. We have allowed for random parameter estimates for travel time as well as correlation amongst these random parameters (ie across the three alternatives). All mean parameter estimates are statistically significant, as are the parameters for the standard deviation except for trip time uncertainty.

There is clear evidence of preference heterogeneity (or traveller-specific taste parameters). As long as we accept that the taste parameter variability is (in our case) normally or lognormally distributed we can use the mean and standard deviation of each random parameter to produce a distribution of attribute marginal (dis)utilities across the sampled population segment.

The cost attributes have been assigned fixed parameters. Ruud (1996) has pointed out that mixed logit models have a tendency to be unstable when all parameters are allowed to vary. Fixing the cost parameter resolves this instability. If the cost parameter is allowed to vary, the distribution of VTTS is the ratio of two distributions, a Cauchy distribution, which has no finite moments (Brownstone 2000). With a fixed cost parameter, VTTS is distributed the same as the parameter of travel

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[14] *We also estimated all models using a uniform and a triangular distribution which are both bounded below and above making it easy to check the behavioural plausibility of the bounds. In contrast the lognormal has an unbounded upper tail which can be quite fat and hence behaviourally questionable for valuation. In the current study we found that the mean estimates for the uniform and triangular distributions lay either very close to the RPL (normal) or between the MNL and the RPL (normal), suggesting that the thick tail at the upper bound of the RPL (lognormal) is most likely an influence on the relatively higher VTTS under a lognormal distribution. This is a topic for important ongoing research.*

time. Furthermore the choice of distribution to use for a cost or travel time parameter is problematic (Revelt and Train 1996). These parameters are necessarily negative, such that a normal distribution is inappropriate. With a lognormal distribution (which assures that the price parameter is always negative), parameter values very close to zero are possible, giving very high (implausibly high) values of travel time savings. Likewise, with a lognormal distribution for travel time, parameter values very close to zero give VTTS close to zero (implausibly low values). Thus whichever parameter is set fixed with the other one random, the issue of plausibility remains. We present both the lognormal and normal estimates for comparison and suggest that this is an area for further research, given its importance.

We limit the discussion of mean values for the RPL model to the lognormal model. The mean VTTS based on time homogeneity (Model 1) is higher (by 8.4%) for the RPL than MNL specification. The higher mean values for RPL carries over to time decomposition for free flow time, with percentage increases of about 40% for Models 3 and 2. The mean estimates of VTTS are in contrast much more similar (up to a maximum of 8% difference) between the MNL and RPL models for stop/start time and slowed down time. This suggest that after accounting for any differences due to preference heterogeneity that the MNL model's underestimation of the mean overall VTTS is attributable to the differences in the free flow value. Indeed if we assume that we assign the appropriate VTTS to the circumstance on offer after someone has switched to an improved route (eg a toll road with a higher amount of free flow travel time), as is the correct procedure for determining a user time benefit (in contrast to the route they switched from - see Abelson and Hensher 2000) then the MNL model would underestimate the time benefits between 8% and 30%. The higher mean VTTS for mixed logit than MNL confirms accumulating evidence that the more restrictive MNL specification undervalues the mean VTTS (Hensher 2000a,b).

The median VTTS for the normal distribution equals the mean but is different for a lognormal distribution. Table F5 shows a median VTTS for total time of $7.77 compared to the mean of $9.42 per person hour. The standard deviation of $6.44 for total time suggests substantial heterogeneity and throws caution to using a single mean estimate. The median is considerably lower than the mean of the lognormal distribution suggesting a definite skewness to the left of the mean. When travel time is decomposed we find that the mean and median tend to fluctuate in relative magnitudes in both models 2 and 3. For example, the median VTTS is higher than the mean for slow down, lower for stop/start and very similar for uncertainty of time of arrival. The standard deviations of VTTS vary substantially across the components of time as well as alternative cost dimensions. Stop/start has the largest standard deviation supporting a view that this is the most heterogeneous element of travel time. Interestingly the standard deviation of VTTS increases as we move from free flow to slowed down to stop/start. Thus there are two effects operating on VTTS when we depart from the MNL model: a significantly higher mean VTTS for free flow and a widening standard deviation as time becomes more onerous. The other area of noticeable difference is in the use of alternative cost dimensions, to which we now turn.

An interesting and controversial aspect of Model 3 is the establishment of separate parameter estimates for the two cost components – fuel and toll. Beesley (1974) recognised the challenge in defining car costs as early as 1960 (a reason for him specialising his empirical work to public transport options). This concern continues for revealed preference data where an individual is either asked to indicate the cost of car travel (a reported perceived cost) or the analyst imposes a constant cost per kilometre and converts it to trip cost given knowledge of the distance travelled. Beesley (1973, 178-179) states that "...each of the [RP] studies involving car chose an average car 'cost' necessarily rather arbitrary" and then suggests "...one might be inclined to opt for the higher values [of time savings] as more representative of 'opportunity cost' of time, because they avoided the difficulties[15]". The use of SP methods largely overcomes these valid concerns by offering *pre-designed* levels of cost with sufficient variation to produce more robust estimates of the role of cost per se. The popularity of evaluating toll roads and alternative toll collection methods (ie electronic, automatic and cash at a booth) has produced a debate on the extent to which one associates a unit of fuel cost and a toll as sharing a common parameter estimate. It is reasonable to assume that as the outlay mechanism converges to a common base (as is the situation for electronic tolling using offsite collection), the differences in marginal utility will narrow if not disappear.

In model 3, the relativity of the VTTS for fuel and toll-based cost is linked to the levels of cost on each component. As reported above, the urban models produced higher mean VTTS for toll-based cost than fuel-based cost, the opposite to the evidence herein for long distance travel where there is a systematically *lower* VTTS associated with the toll-based calculation. The reason is linked to the relative magnitudes of fuel and toll cost offered in the SP exercise. For long distance travel up to 3 hours, the average fuel cost is $13.80 (sd=6.6) compared to the average toll cost of $6.57 (sd=5.2). In contrast, for urban travel, the average fuel cost was $2 compared to $3 for toll cost. There is a very important message here, supporting the contention that the range and levels of attributes in an SP design has a noticeable influence on the resulting VTTS (see new evidence in the next section). For long trips the fuel cost starts to build up and the perception of the difference in cost starts to favour the toll. This clarifies a generally held (and incorrect) view that individuals are necessarily more sensitive to a toll than to fuel cost and hence would be expected to have higher VTTS in a time-toll cost trade than a time-fuel cost trade. This only holds if the toll is greater than the fuel cost *as perceived* by the traveller. In a very real sense the SP method eliminates the lumpiness argument unless it is shown that reference to the mechanism for extracting a toll has a statistically significant influence on the marginal utility of a toll compared to the fuel cost. In the absence of such a 'collection' attribute, it is reasonable to assume that the differences in marginal utility are due to the magnitude of the outlay.

[15] *These difficulties refer to the measurement of car operating costs (and hence his preference to compare forms of public transport). The fact that he refers to higher values of time savings is purely coincidental with the tendency for the MNL model to underestimate values relative to less restrictive choice models.*

**Table F4**: Random Parameter (Mixed) Logit Models for Long Distance Travel in New Zealand up to 3 hours. All travel times are in minutes and costs are in NZ dollars

| Attributes | MNL Base | RPL Model (Normal) | RPL Model (Lognormal) × |
|---|---|---|---|
| Model 1: | | | |
| Total time | -.0382(-11.1) | -.0433 (-7.8) | -3.3325 (-25.4) |
| Total cost | -.2638 (-19.5) | -.2771 (-15.4) | -.2756 (-18.1) |
| Std Dev of Parameter Distribution | | | |
| Total time | | .02747 (2.2) | .6197 (2.27) |
| Pseudo-$r^2$ | .405 | .407 | .408 |
| Log-likelihood | -689.5 | -689.4 | -688.63 |
| | | | |
| Model 2: | | | |
| Free flow time | -.01507 (-3.4) | -.0242 (-3.4) | -3.663 (-9.6) |
| Slowed down time | -.05429 (-6.7) | -.0653 (-5.3) | -2.664 (-6.4) |
| Stop/start time | -.1168 (-12.1) | -.1524 (-8.1) | -2.131 (-13.1) |
| Uncertainty | -.0209 (-3.5) | -.02456 (-2.8) | -3.743 (-6.5) |
| Fuel plus toll cost | -.2520 (-17.7) | -.3129 | -.3126 (-11.6) |
| Std Dev of Parameter Distribution | | | |
| Free flow time | | .0419 (2.8) | .1587 (2.4)) |
| Slowed down time | | .0962 (3.3) | .7945(3.0) |
| Stop/start time | | .0964 (2.6) | .8128 (3.1) |
| Uncertainty | | .01352 (.18) | .3100 (.14) |
| Preference Var-Covar Matrix: Significant effects only | | | |
| Slow:stop/start | | .0918 (2.5) | -.7468 (-2.3) |
| Pseudo-$r^2$ | .467 | .473 | .472 |
| Log-likelihood | -616.9 | -608.1 | -607.9 |
| | | | |
| Model 3: | | | |
| Free flow time | -.0151 (-3.4) | -.0246 (-3.4) | -4.0524 (-12.5) |
| Slowed down time | -.0557 (-6.8) | -.0680 (-5.4) | -2.7421 (-5.1) |
| Stop/start time | -.1104 (-11.3) | -.1431 (-7.9) | -2.2548 (-14.4) |
| Uncertainty | -.0207 (-3.4) | -.0238 (-2.7) | -3.762 (-7.6) |
| Fuel cost | -.1647 (-5.7) | -.2143 (-5.4) | -.2006 (-5.9) |
| Toll Cost | -.2649 (-17.5) | -.3212 (-11.9) | -.3010 (-14.6) |
| Std Dev of Parameter Distribution | | | |
| Free flow time | | .04118 (2.7) | .1532 (.21) |
| Slowed down time | | .09459 (3.1) | .4037(0.78) |
| Stop/start time | | .08449 (2.1) | .7175 (0.4) |
| Uncertainty | | .01387 (0.2) | .2206 (.09) |
| Preference Var-Covar Matrix: Significant effects only | | | |
| Slow:stop/start | | .07572 (1.92) | ns |
| Pseudo-$r^2$ | .471 | .476 | .475 |
| Log-likelihood | -611.2 | -603.6 | -604.5 |

**Notes:** The parameters associated with a lognormal RPL are ln(beta).

**Table F5**: Values of Travel Time Savings ($NZ per person hour)

| Attributes | MNL Base | RPL Model (Normal) | RPL Model (Lognormal) × |
|---|---|---|---|
| ***Model 1:*** | | | |
| *Value travel time savings* | | | |
| Total time (mean) | 8.69 | 9.38 | 9.42 |
| Total time (standard deviation) | - | 5.34 | 6.44 |
| Total time (median) | - | 9.38 | 7.77 |
| ***Model 2:*** | | | |
| *Mean value of travel time savings* | | | |
| Free flow time | 3.58 | 4.66 | 4.98 |
| Slowed down time | 12.93 | 12.56 | 18.33 |
| Stop/start time | 27.8 | 29.2 | 31.68 |
| Uncertainty | 4.99 | 4.72 | 4.79 |
| *Median value of travel time savings* | | | |
| Free flow time | - | 4.66 | 4.93 |
| Slowed down time | - | 12.56 | 13.37 |
| Stop/start time | - | 29.2 | 22.79 |
| Uncertainty | - | 4.72 | 6.46 |
| *StdDev value of travel time savings* | | | |
| Free flow time | - | 8.03 | 0.79 |
| Slowed down time | - | 18.45 | 16.19 |
| Stop/start time | - | 18.49 | 30.6 |
| Uncertainty | - | 2.59 | 0.48 |
| ***Model 3:*** | | | |
| *Mean value of travel time savings: toll cost* | | | |
| Free flow time | 3.41 | 4.61 | 4.78 |
| Slowed down time | 12.62 | 12.7 | 13.93 |
| Stop/start time | 24.99 | 26.7 | 27.05 |
| Uncertainty | 4.67 | 4.46 | 4.74 |
| *Median value of travel time savings: toll cost* | | | |
| Free flow time | - | 4.61 | 4.22 |
| Slowed down time | - | 12.7 | 16.45 |
| Stop/start time | - | 26.7 | 20.9 |
| Uncertainty | - | 4.46 | 4.63 |
| *Std Dev value of travel time savings: toll cost* | | | |
| Free flow time | - | 7.69 | 0.74 |
| Slowed down time | - | 17.65 | 5.91 |
| Stop/start time | - | 15.78 | 22.2 |
| Uncertainty | - | 2.59 | 1.06 |
| *Mean value of travel time savings: fuel cost* | | | |
| Free flow time | 5.48 | 6.90 | 7.17 |
| Slowed down time | 20.29 | 19.06 | 20.90 |
| Stop/start time | 40.21 | 40.12 | 40.6 |
| Uncertainty | 7.51 | 6.68 | 7.12 |
| *Median value of travel time savings: fuel cost* | | | |
| Free flow time | - | 6.90 | 7.09 |
| Slowed down time | - | 19.06 | 30.04 |
| Stop/start time | - | 40.12 | 31.3 |
| Uncertainty | - | 6.68 | 6.95 |
| *Std Dev value of travel time savings: fuel cost* | | | |
| Free flow time | - | 11.53 | 1.1 |
| Slowed down time | - | 26.48 | 8.79 |
| Stop/start time | - | 23.65 | 33.3 |
| Uncertainty | - | 3.88 | 1.59 |

**Notes:** To derive the VTTS for a lognormal travel time, the numerator is equal to $\exp[\ln(\beta) + (\text{sd of } \beta)^2/2]$. For example, VTTS for model 1 = $60\times\{\exp[-3.3325 + (.6197)^2/2]\}/-0.2756\}$. Standard deviation of VTTS = $60\times\{\text{mean time parameter} \times (\exp(\text{sd of } \beta)^2 - 1)^{0.5}\}/-0.2756$ = $0.04326\times[\exp(0.6197)^2-1]^{0.5}/0.2756$ = $6.44. Note that the standard deviation of VTTS is based on the mean of the cost parameter. The median VTTS is $60\times\{\exp(-3.3325)/-.2756\}$ = $7.77.

# 6. An Important Diversion: The Influence of the Number of Choice Set Treatments

There remains a degree of scepticism in the transport planning community (often unwritten) about the ability of respondents to comprehend and respond to choice designs that involve many alternatives, many attributes and many treatments (ie choice sets evaluated). Typically, a design with more than two alternatives, three attributes per alternative and four treatments is often perceived as being "too complex" for a respondent. Analysts frequently ponder on the implications of simplified SP experiments in contrast to statistically more rigorous designs in respect of the goodness-of-fit and the values of travel time savings.

A review of the literature suggests that very little is really known about the basis for rejecting complex designs or accepting simple designs (See Johnson and Orme 1996, Stopher and Hensher 2000). Although it is appreciated that more complex designs provide the analyst with increasing degrees of freedom in the estimation of models, facilitating non-linearity in main effects and independent two-way interactions, it is by no means clear what the overall behavioural gains are to increasing the number of treatments. The question that we focus on is: are there any statistical and behaviourally substantive differences between the VTTS results from a stated preference model as we vary the number of treatments that are included in model estimation? Holding the set of attributes and choice set size constant, we investigate the implications on mean VTTS of 4, 8, 12 treatments in addition to the 16 treatments reported above.

The findings (for the MNL specification) are summarised in Table F6. We distinguish between an accumulating block strategy[16] (ie estimation using treatments 1-4, 1-8, 1-12 and all 16) and a non-accumulating block strategy (ie treatments 1-4, 5-8, 9-12 and 13-16)[17]. The numbering refers to the ordering in which the choice sets were presented. For example, 1-4 is the first four choice sets evaluated by each respondent.

A review of Table F6 suggests the general absence of any obvious relationship between the mean VTTS and the number of treatments in each block strategy. To establish sources of systematic variation in VTTS across the 91 observations in Table 6 (noting that column 1-4 is the same for both block strategies), we investigated the following potential influences: the number of treatments in a block, the accumulating/non-accumulating distinction, the range of the relevant travel time (from both SP and current RP levels), the standard deviation of the travel time attribute, the cost source used in valuation (ie fuel, toll or total) and the t-value of the estimated parameter of each travel time component.

16 *A block strategy refers to a set of choice sets.*

17 *Although the block strategies are based on a single design of 64 rows with four blocks of 16 allocated randomly to each respondent, in contrast to the design of experiments unique to each block strategy, it is unlikely that the loss of orthogonality in all but the 1-16 accumulating block strategy would be a significant contributor to differences in mean VTTS in Table 4. A check of partial correlations showed very little movement in the correlations, supporting empirically that any loss of orthogonality is negligible.*

A series of linear regression models were estimated in which mean VTTS (from Table 6) was the dependent variable. The empirical results (see Table F7) find no evidence of any systematic relationship between mean VTTS and the number of treatments in either the accumulating or non-accumulating block strategies (model sets 1-3).

**Table F6**: Variations in Mean VTTS under Alternative Blocking Strategies

| Attribute | Accumulating Block Strategy | | | | Non-Accumulating Block Strategy | | | |
|---|---|---|---|---|---|---|---|---|
| | 1-4 | 1-8 | 1-12 | 1-16 | 1-4 | 5-8 | 9-12 | 13-16 |
| Model 1 | | | | | | | | |
| Total time | 9.07 | 9.92 | 9.71 | 8.70 | 9.07 | 10.66 | 8.76 | 4.34 |
| Model 2: | | | | | | | | |
| Free flow | 4.95 | 5.85 | 5.19 | 3.59 | 4.95 | 6.88 | 3.04ns | 0.10ns |
| Slow down | 13.74 | 11.63 | 12.91 | 12.93 | 13.74 | 9.82 | 18.5 | 13.3 |
| Stop/start | 30.93 | 23.53 | 25.96 | 27.80 | 30.93 | 26.1 | 30.7 | 31.7 |
| Uncertainty | 2.61 | 5.03 | 4.61 | 4.98 | 2.61 | 7.19 | 4.02ns | 4.4ns |
| Model 3: fuel cost | | | | | | | | |
| Free flow | 7.66 | 8.96 | 7.63 | 5.48 | 7.66 | 10.79 | 3.84 ns | 0.36 ns |
| Slow down | 27.63 | 18.70 | 20.0 | 20.3 | 27.63 | 13.2 | 25.62 | 18.3 |
| Stop/start | 30.78 | 35.45 | 38.2 | 40.2 | 30.78 | 39.0 | 40.6 | 38.6 |
| Uncertainty | 6.67 | 7.79 | 6.96 | 7.51 | 6.67 | 9.66 | 5.30ns | 5.8ns |
| Model 3: toll | | | | | | | | |
| Free flow | 4.26 | 5.38 | 4.71 | 3.41 | 4.26 | 6.38 | 2.7ns | 2.72ns |
| Slow down | 15.36 | 11.20 | 12.34 | 12.62 | 15.36 | 7.81 | 17.7 | 13.7 |
| Stop/start | 17.11 | 21.3 | 23.62 | 25.01 | 17.11 | 23.1 | 28.6 | 28.9 |
| Uncertainty | 3.71 | 4.66 | 4.31 | 4.66 | 3.71 | 5.70 | 3.78ns | 4.3ns |

**Note:** column 1-4 is the same for both blocking strategies. The VTTS's for the RPL model produce similar relative results as those herein.

There is however, very strong evidence that the range of the time attribute (after controlling for time and cost heterogeneity by a series of time and cost-specific dummy variables) has a statistically significant influence on mean VTTS, increasing as the range narrows (model set 4). If we impose a range restriction varying from 10% to 100% of the existing range (i.e. a mean from 14.9 to 298.68 minutes) the mean VTTS across the 91 observations varies from $20.41 to $6.92. This is in accordance with a broader finding on the influence of attribute range by Louviere and Hensher (2000).

Although there appears to be no 'magic' formula to establish a behaviourally optimal attribute range, Louviere and Hensher (2000) suggest that the wider the range of levels, the more likely it will be that more subjects agree that some levels are "high" whereas others are "low." Thus, the more easily subjects can identify extreme levels, the more likely they are to respond to them more consistently (ie unambiguosly), which reduces within-subject variability (ie greater homogeneity across the treatments for each sampled respondent). Similarly, if more subjects agree that extreme levels are extremes, between-subject variability should decrease (ie there is increased homogeneity within the sample). However, the latter two variance outcomes also can be offset since more extreme levels may induce subjects to behave more extremely, thereby accentuating between-subject differences. The key message is that response

**Table F7**: Influences on Variability in Mean VTTS (91 observations)

| *Model Set 1* | Estimated parameter | t-value |
|---|---|---|
| Accumulating 1-4 | -.2085 | -.051 |
| Accumulating 1-8 | -.6000 | -.153 |
| Accumulating 1-12 | -.0800 | -.019 |
| Constant | 13.63 | 4.5 |
| Adjusted r-squared | -.062 | |
| *Model Set 2* | Estimated parameter | t-value |
| Non-Accumulating 1-4 | 0.612 | 0.139 |
| Non-Accumulating 5-8 | 0.752 | 0.174 |
| Non-Accumulating 9-12 | 2.05 | 0.421 |
| Constant | 12.81 | 3.73 |
| Adjusted r-squared | -.058 | |
| *Model Set 3* | Estimated parameter | t-value |
| Set 1-4 (accum & non-accum) | 0.612 | 0.139 |
| Accumulating 1-8 | 0.221 | 0.052 |
| Accumulating 1-12 | 0.741 | 0.167 |
| Accumulating 1-16 | 0.821 | 0.179 |
| Non-Accumulating 5-8 | 0.752 | 0.174 |
| Non-Accumulating 9-12 | 2.05 | 0.421 |
| Constant | 12.81 | 3.73 |
| Adjusted r-squared | -.068 | |
| *Model Set 4* | Estimated parameter | t-value |
| **Range of time attribute (minutes)**[18] | **-.05105** | **-2.99** |
| Fuel cost dummy | 6.498 | 6.56 |
| Total cost dummy | 1.408 | 1.90 |
| Free flow time dummy | -6.938 | -7.03 |
| Slow down time dummy | -.8776 | -.48 |
| Stop-start time dummy | 12.11 | 7.1 |
| Uncertainty dummy | -6.473 | -7.5 |
| Constant | 19.2058 | 5.33 |
| Adjusted r-squared | 0.901 | |

Note: except for range of attribute, all other variables are 1,0 dummy variables

variability is a behavioural phenomenon, and is an outcome of a choice experiment as much as observed choices and/or model preference parameters or specifications[19].

[18] *This explanatory variable is defined as the numerical ranges of a specific travel time attribute. Throughout the data set of 91 observations in Table F6 that were the data subject to regression analysis we have a number of travel time attributes- free flow, slow down etc. We derived the maximum and minimum levels for each attribute for each of the 91 data points and defined the range as the difference between the minimum and maximum.*

# 7. Overall Conclusions

There is an increasing recognition of the importance of the quality of the data as much as there is a major commitment to specifications of choice models that capture the richer sources of behavioural variability (Louviere and Hensher 2000). The extensions in this chapter that investigate these issues has revealed some important findings that in aggregate suggest caution in adopting mean estimates of the behavioural valuation of travel time savings derived from the somewhat restrictive multinomial logit model.

The most important policy-related findings are summarised below.

- The evidence for urban commuting supports the intercity findings in other recent studies and the current study that less restrictive choice model specifications tend to produce higher estimates of mean values of time savings compared to the MNL model.
- For urban travel, the relativity between the time components is preserved across all specifications of the unobserved effects, although absolute magnitudes differ.
- Overall for urban commuting, we find a strong locational effect associated with Auckland vs other locations as an explanation of the heterogeneity in the mean of the randomly distributed attribute parameters. This is especially strong for the trip contingency to allow for uncertainty of arrival time at the destination.
- For long-distance travel, after accounting for any differences due to preference heterogeneity, the MNL model's underestimation of the mean overall VTTS is primarily attributable to the differences in the free flow value.
- For long distance travel, the MNL model appears to underestimate the mean VTTS by between 8% and 30% with the underestimation increasing as we progress from stop/start to slowed down to free flow travel time.
- There appear to be two effects operating on VTTS when we depart from the MNL model: a significantly higher mean VTTS for free flow and a widening standard deviation as time becomes more onerous.
- An important message overall is that the mean and variance have been confounded in previous studies which focus on the mean. Separating out

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19 *Failure to recognise that experiments can produce different impacts on the behaviour of random components may lead to misinference, incorrect interpretations and/or possibly even biased results. Hence, it is not possible to optimise choice experiments a priori without also taking the behaviour of the random component into account as an outcome of the design and experiment.*

mean and variance tends to increase the mean estimate, a very important finding. Since the variance (or standard deviation) varies according to the circumstances under which a minute of travel time is consumed, there is a very good argument for establishing a series of VTTS for a specific type of time that is defined by measurable correlates of the unobserved sources of heterogeneity (e.g. age, income).

- The other area of noticeable difference is in the use of alternative cost dimensions. This appears to be more a function of the magnitudes of cost than the actual cost class (i.e. running vs toll costs). There is very strong and new evidence that the range of an attribute (both from revealed and stated preference data) has a significant influence on VTTS. If we were to have the same level and range for running cost and toll, we believe that the mean VTTS would be almost indistinguishable.

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