LEABHARLANN CHOLÁISTE NA TRÍONÓIDE, BAILE ÁTHA CLIATH | TRINITY COLLEGE LIBRARY DUBLIN
Ollscoil Átha Cliath | The University of Dublin

Terms and Conditions of Use of Digitised Theses from Trinity College Library Dublin

Copyright statement

All material supplied by Trinity College Library is protected by copyright (under the Copyright and Related Rights Act, 2000 as amended) and other relevant Intellectual Property Rights. By accessing and using a Digitised Thesis from Trinity College Library you acknowledge that all Intellectual Property Rights in any Works supplied are the sole and exclusive property of the copyright and/or other IPR holder. Specific copyright holders may not be explicitly identified. Use of materials from other sources within a thesis should not be construed as a claim over them.

A non-exclusive, non-transferable licence is hereby granted to those using or reproducing, in whole or in part, the material for valid purposes, providing the copyright owners are acknowledged using the normal conventions. Where specific permission to use material is required, this is identified and such permission must be sought from the copyright holder or agency cited.

Liability statement

By using a Digitised Thesis, I accept that Trinity College Dublin bears no legal responsibility for the accuracy, legality or comprehensiveness of materials contained within the thesis, and that Trinity College Dublin accepts no liability for indirect, consequential, or incidental, damages or losses arising from use of the thesis for whatever reason. Information located in a thesis may be subject to specific use constraints, details of which may not be explicitly described. It is the responsibility of potential and actual users to be aware of such constraints and to abide by them. By making use of material from a digitised thesis, you accept these copyright and disclaimer provisions. Where it is brought to the attention of Trinity College Library that there may be a breach of copyright or other restraint, it is the policy to withdraw or take down access to a thesis while the issue is being resolved.

Access Agreement

By using a Digitised Thesis from Trinity College Library you are bound by the following Terms & Conditions. Please read them carefully.

I have read and I understand the following statement: All material supplied via a Digitised Thesis from Trinity College Library is protected by copyright and other intellectual property rights, and duplication or sale of all or part of any of a thesis is not permitted, except that material may be duplicated by you for your research use or for educational purposes in electronic or print form providing the copyright owners are acknowledged using the normal conventions. You must obtain permission for any other use. Electronic or print copies may not be offered, whether for sale or otherwise to anyone. This copy has been supplied on the understanding that it is copyright material and that no quotation from the thesis may be published without proper acknowledgement.

TRINITY COLLEGE
2 7 MAY 2008
LIBRARY DUBLIN
THOSIS
8450.

A STATED PREFERENCE ANALYSIS OF REAL TIME PUBLIC TRANSPORT INFORMATION

Brian Owen Caulfield

A dissertation submitted to the University of Dublin in the partial fulfilment of the requirements for the degree Doctor of Philosophy.

Department of Civil, Structural & Environmental Engineering
Trinity College Dublin

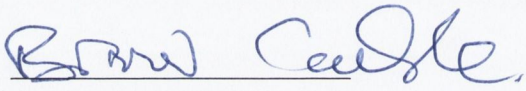
November 2007

DECLARATION

I declare that this thesis has not been submitted as an exercise for a degree at this or any other university. I further declare that, except where reference is given, it is entirely my own work.

The author confirms that the Library may lend or copy this thesis upon request, for academic purposes.

November 2007



Brian Owen Caulfield

Dedicated to the memory of my mother Annette and my brother Damien

ABSTRACT

This thesis reports the outcomes of a study conducted to ascertain the benefits derived from the use of real-time public transport information. The study focuses upon three areas of individuals preferences in relation to the use of real-time public transport information. The first area examined in the study asked respondents to choose between the following options for receiving real-time public transport information: the internet, via a mobile phone, a passenger information display and a call centre. The second aspect of the study investigated what type of information respondents required across three stages of a public transport trip, defined as: pre-trip planning from home to work, at-stop/station information and pre-trip planning from work returning home. The third area assessed how a series of explanatory and attitudinal variables impact upon the benefits derived from real-time public transport information.

A stated preference survey was completed to examine respondents' preferences for real-time public transport information. A sample of 495 office based workers in Dublin city centre was taken in May 2005. A multinomial logit model was used to model the survey responses. The models that this approach produced were found to produce significant coefficients and to have a good model performance based on the parameters defined in the literature.

Public transport users were found to derive the most benefit from the provision of real-time information. Of the public transport users examined, bus users were found to derive greater benefit compared to rail users. Public transport users who take more than one mode of transport to arrive at work, and those who have a longer wait-time at their stop where found to derive a greater benefit from real-time public transport information. While waiting at their stop/station, respondents that use a lower frequency service were found to derive a greater benefit from real-time information compared to those who live near a high frequency service. Younger respondents, those on a higher income, those on a pay monthly mobile phone contract and those with broadband available at home were found to derive a higher benefit from real-time public transport information.

Several attitudinal variables were examined to ascertain their impact upon the benefits derived from real-time public transport information. Those individuals who currently use transport information were found to derive a greater benefit from real-time information. Respondents were asked if missing services and not knowing if their service had passed or

when it was going to arrive caused frustration. The respondents that indicated these factors caused frustration were more likely to derive a benefit from real-time public transport information.

At the pre-trip planning stage from home to work respondents were found to derive the greatest benefit from using their mobile phone to receive real-time information via short message service (SMS), followed by the internet and a call centre. These preferences were also seen in the willingness to pay amounts of 28c for an SMS, 22c for the internet and 10c for a call centre. While waiting at their bus stop/train station respondents were willing to pay 22c per-trip to receive real-time information from a passenger information display, 20c to receive information from an SMS and 16c to from a call centre. These results demonstrate that individuals are likely to derive the greatest benefit from using a passenger information display at the second stage of their trip. At the pre-trip planning stage returning home from work, respondents were found to be willing to pay the most to receive real-time information from an SMS, 25c per message followed by 21c to use a call centre and 13c to use the internet. The results at this stage demonstrate that respondents derive the greatest benefit from using an SMS to obtain real-time public transport information.

The findings of this thesis demonstrate that individuals are willing to pay for real-time public transport information and have a preference for the most convenient and fastest methods of receiving this information. The results presented in this thesis contribute to the research previously conducted in this field by demonstrating individuals' preferences between methods of obtaining real-time information. The findings presented also have a specific policy focus as they detail the individuals most likely to derive a benefit from real-time information and the amount these individuals are willing to pay to receive this information.

ACKNOWLEDGMENTS

There are many people I would like to thank for their support and assistance in enabling me to complete this thesis.

Firstly, I would like to thank my supervisor Prof. Margaret O'Mahony for her constant support, encouragement and advice, while completing my thesis. I would especially like to thank Margaret for her support and understanding during a difficult period of my life in 2004.

Dr Séona Farrell, thank you so much for all your help with my stated choice modelling, and for all your advice and support. I am deeply grateful for all your help.

I would like to thank the following people for their advice in the early stages of my research, Prof. David Hensher, Dr Deborah Street and Dr John Rose.

Thanks to Clare and Markus it has been an interesting journey to get to this stage and I am deeply grateful for all your help and support.

I would also like to thank the Department of Transport for funding my research under the Pilot Programme for Transport Research.

A special thank you to all my friends for listening to me talk on and on about public transport information, and transport in general. I would like to especially thank Fay, for being such a fantastic flat mate during my PhD research, a source of constant amusement and a fantastic friend. I would like to thank the following friends who I roped into proof reading, Ailish, Cathy, Gillian and Linda. I would like to thank Sarah for all her help with the formatting for the final submission.

Finally to my family, my dad, my sister Aoife and my nephews, Séan, Dylan and Adam, thank you for all your love and support.

TABLE OF CONTENTS

ABSTRACT.....iv
ACKNOWLEDGEMENTS.....vi
TABLE OF CONTENTS.....vii
LIST OF TABLES.....x
LIST OF FIGURES.....xiv
LIST OF ABBREVIATIONS.....xvi

1. INTRODUCTION.....1

2. OPERATING AND EVALUATING REAL-TIME PUBLIC TRANSPORT INFORMATION.....7
2.1 INTRODUCTION.....7
2.2 PUBLIC TRANSPORT IN DUBLIN.....7
2.3 AUTOMATIC VEHICLE LOCATION METHODS.....9
2.4 AVL SYSTEMS IN DUBLIN.....14
2.5 REAL-TIME TRANSPORT INFORMATION IN DUBLIN.....16
2.6 OPERATION BENEFITS FROM AVL.....19
2.7 MEASURING THE BENEFITS OF PUBLIC AND PRIVATE TRANSPORT INFORMATION.....22
2.8 BEST PRACTICE EXAMPLE OF PROVIDING REAL-TIME PUBLIC TRANSPORT INFORMATION.....34
2.9 SUMMARY.....40

3. METHODOLOGY.....41
3.1 INTRODUCTION.....41
3.2 SURVEY DESIGN.....41
3.3 SURVEY LAYOUT.....48
3.4 SAMPLING METHOD.....49
3.5 DISCRETE CHOICE MODELLING.....55
3.6 MAXIMUM LIKELIHOOD ESTIMATION OF DISCRETE CHOICE MODELS.....60
3.7 DISCRETE CHOICE MODELLING APPROACH APPLIED.....62
3.8 MEASURING THE PERFORMANCE OF DISCRETE CHOICE MODELS.....65

3.9 Behavioural Outputs of Discrete Choice Models....70
3.10 Summary....71

4. UNDERSTANDING PERCEPTIONS OF REAL-TIME PUBLIC TRANSPORT INFORMATION....72
4.1 Introduction....72
4.2 At-Stop Survey....72
4.3 Exploratory Public Transport Information Study....77
4.4 Summary....89

5. SUMMARY OF QUESTIONNAIRE STATISTICS....91
5.1 Introduction....91
5.2 Travelling to Work....91
5.3 Working Patterns....98
5.4 Location Factors....99
5.5 Opinion of Public Transport Information....102
5.6 Access to Information Technology....111
5.7 Socio-Economic Results....112
5.8 Qualitative Comments to the Survey....113
5.9 Summary....116

6. MODEL ESTIMATION INCORPORATING EXPLANATORY VARIABLES..117
6.1 Introduction....117
6.2 Base Models....118
6.3 Analysis of Explanatory Variables....122
6.4 Estimation of Models with Current Mode of Transport Variables....123
6.5 Estimation of Models with Socio-Economic Variables....142
6.6 Estimation of Models Using Location Specific Variables....153
6.7 Estimation of Models Using Access to Technology Variables....162
6.8 Estimation of Models with Work Pattern Variables....168
6.9 Models Combining Explanatory Variables....173
6.10 Summary....177

7. MODELS INCORPORATING ATTITUDINAL RESPONSE VARIABLES....180

7.1 Introduction.....180
7.2 Incorporating Attitudinal Variables into the MNL Models.....181
7.3 Estimation of Models Including Frustration Variables.....184
7.4 Estimation of Models Including Convenience Variables.....192
7.5 Estimation of Models Including Perceived Quality of Public Transport Information Variables.....201
7.6 Estimation of Models Including Current Use of Transport Information Variables.....209
7.7 Estimation of Models Including Attitudinal and Explanatory Variables .213
7.8 Summary.....217

8. INTERPRETATION OF THE BEHAVIOURAL OUTPUTS FROM THE CHOICE MODELS.....219
8.1 Introduction.....219
8.2 Segmented MNL Models by Mode of Transport.....219
8.3 Estimated Direct Elasticises of Choice.....233
8.4 Willingness to Pay.....239
8.5 Tests of Independence from Irrelevant Alternatives (IIA) Assumption.....244
8.6 Nested MNL Models.....247
8.7 Summary.....253

9. CONCLUSIONS.....256
9.1 Introduction.....256
9.2 Respondents Requirements for Real-Time Public Transport Information...256
9.3 Respondents Characteristics that Impact Upon the Utility Derived from Real-Time Information.....257
9.4 Impact of the Research.....260
9.5 Critical Assessment.....261
9.6 Areas for Further Research.....262

REFERENCES.....263
APPENDIX I: MAIN SURVEY.....281
APPENDIX II: ALTERNATIVE MODEL SPECIFICATIONS.....294
APPENDIX III: PUBLISHED RESEARCH.....299

LIST OF TABLES

Table 3-1 International list of SMS charges 47
Table 3-2 International list of call centre charges 48
Table 3-3 List of willingness to pay amounts for at-stop real-time passenger information display 48
Table 3-4 Attribute levels - stage one 49
Table 3-5 Attribute levels - stage two 50
Table 3-6 Attribute levels - stage three 50
Table 3-7 Response rates to internet surveys 56
Table 3-8 Number of office based workers in Dublin 2 58
Table 4-1 Response rate from the at-stop survey 80
Table 4-2 At-stop survey - Respondent characteristics 81
Table 4-3 At-stop study - frequency of bus patronage 82
Table 4-4 At-stop study - preferences for additional transport information 83
Table 4-5 At-stop study - preferences for additional at-stop information 83
Table 4-6 At-stop study - use of extra time while waiting at the bus stop 84
Table 4-7 At-stop study - how respondents would use their time at the bus-stop. 85
Table 4-8 Exploratory study - respondent characteristics 87
Table 4-9 Exploratory study - respondents current sources of transport information 88
Table 4-10 Exploratory study - opinion of public transport information provision in Dublin 89
Table 4-11 Exploratory study - Preferences for information at each stage 96
Table 5-1 Mode of transport used to travel to work 100
Table 5-2 Respondents that use more than one mode of public transport to travel to work 100
Table 5-3 Combination of public transport modes used to get to work 100
Table 5-4 Time taken to walk from home to public transport 101
Table 5-5 Time spent waiting at the bus stop/train station 102
Table 5-6 Tine spent travelling to work on public transport 103
Table 5-7 Time taken to walk from bus stop/train station to work 104

Table 5-8 Time spent driving to work 106
Table 5-9 Time spent looking for parking 106
Table 5-10 Time spent walking from your car to your place of work 106
Table 5-11 Departure time of respondents 107
Table 5-12 Working patterns 108
Table 5-13 Location travelled from to get to work 110
Table 5-14 Within 15 min walk to a bus service using a priority corridor 110
Table 5-15 Within 15 min walk of a Green line Luas stop 111
Table 5-16 Within 15 min walk of a Red line Luas stop 111
Table 5-17 Within 15 min walk of a DART Stop 111
Table 5-18 Within 15 min walk of any other rail station 111
Table 5-19 Perceptions of the quality of transport information currently provided 113
Table 5-20 Convenience of using technology to access public transport information 117
Table 5-21 Frequency usage of public transport information 118
Table 5-22 Mobile phone ownership 121
Table 5-23 Mobile phone contract type 121
Table 5-24 Internet access 121
Table 5-25 Broadband available 121
Table 5-26 Gender of respondents 122
Table 5-27 Age of respondents 122
Table 5-28 Respondents income 123
Table 5-29 Number of cars per-household 123
Table 5-30 Selection of comments 126
Table 6-1 Base Model Estimates 133
Table 6-2 Description of Explanatory Variables 135
Table 6-3 MNL models incorporating mode specific variables - stage one 138
Table 6-4 MNL models incorporating mode specific variables - stage two 141
Table 6-5 MNL models incorporating mode specific variables - stage three 144
Table 6-6 MNL models incorporating multi-stage trip variables 146
Table 6-7 MNL models incorporating journey time variables 151
Table 6-8 MNL model combining mode of transport variables - stage one 153
Table 6-9 MNL model combining mode of transport variables - stage two 154
Table 6-10 MNL model combining mode of transport variables - stage three 155
Table 6-11 MNL models with gender variables 157

Table 6-12 MNL models including age variables 159
Table 6-13 MNL models including income variables 161
Table 6-14 MNL models including car available variables 163
Table 6-15 MNL model combining socio-economic variables - stage one 164
Table 6-16 MNL model combining socio-economic variables - stage two 165
Table 6-17 MNL model combining socio-economic variables - stage three 166
Table 6-18 MNL models with proximity to high quality public transport route variables 169
Table 6-19 MNL model with residential zone variables..... 173
Table 6-20 MNL model combining location variables - stage one 174
Table 6-21 MNL model combining location variables - stage two 175
Table 6-22 MNL models with access to technology variables..... 179
Table 6-23 MNL models combining access to technology variables - stage one 180
Table 6-24 MNL models combining access to technology variables - stage three ... 181
Table 6-25 MNL models with work pattern variables..... 185
Table 6-26 MNL model combining work pattern variable - stage one..... 187
Table 6-27 MNL model combining work pattern variable - stage two 188
Table 6-28 MNL model combining explanatory variables - stage one..... 189
Table 6-29 MNL model combining explanatory variables - stage two 191
Table 6-30 MNL model combining explanatory variables - stage three 192
Table7-1 Base models including explanatory variables..... 198
Table 7-2 Description of attitudinal variables 199
Table 7-3 MNL models including frustration variables - stage one 203
Table 7-4 MNL model including frustration variables-stage two 205
Table 7-5 MNL model including frustration variables - stage three 207
Table 7-6 MNL models including convenience variables - stage one..... 212
Table 7-7 MNL models including convenience variables - stage two..... 214
Table 7-8 MNL models incorporating convenience variables - stage three 215
Table 7-9 MNL models incorporating perceived quality of information variables -stage one 220
Table 7-10 MNL models including perception of the quality of information variables - stage two..... 222
Table 7-11 MNL models incorporating perception of quality of information variable-stage three..... 224

Table 7-12 MNL models incorporating current use of public transport information variables 227
Table 7-13 MNL model incorporating explanatory and attitudinal variables - stage one 229
Table 7-14 MNL model incorporating explanatory and attitudinal variables - stage two 230
Table 7-15 MNL models incorporating attitudinal and explanatory variables - stage three 232
Table 8-1 MNL models including segmented mode options - stage one.....241
Table 8-2 MNL models including segmented mode options-stage two..... 245
Table 8-3 MNL models including segmented mode options-stage three..... 248
Table 8-4 Elasticities of choice - stage one 251
Table 8-5 Elasticities of choice - stage two 254
Table 8-6 Elasticities of choice-stage three 256
Table 8-7 Willingness to pay - stage one 258
Table 8-8 Willingness to pay - stage two 259
Table 8-9 Willingness to pay - stage three 260
Table 8-10 The Small-Hsiao test of the IIA for Base Model 1..... 263
Table 8-11 The Small-Hsiao test of the IIA for Base Model 2..... 264
Table 8-12 The Small-Hsiao test of the IIA for base model 3..... 264
Table 8-13 Nested model results - stage one 267
Table 8-14 Nested model results - stage two..... 269
Table 8-15 Nested model results - stage three..... 271

LIST OF FIGURES

Figure 2-1 Quality Bus Corridor network - Dublin 9
Figure 2-2 Dublin Rail Network 10
Figure 2-3Signpost AVL 11
Figure 2-4 Differential GPS System 13
Figure 2-5 On-board components 15
Figure 2-6 Q-time display 19
Figure 2-7 Proposed model for dissemination of transport information in Dublin21
Figure 2-8 Web-based transport information in Gothenburg 41
Figure 2-9 4th Generation passenger information displays - Gothenburg 41
Figure 2-10 Passenger information kiosks - Gothenburg 42
Figure 2-11 5th Generation passer information displays - Gothenburg 43
Figure 2-12 On board passenger information displays - Gothenburg 43
Figure 3-1 Example of a nested logit approach 64
Figure 3-2 Structure of modelling approach 70
Figure 4-1 At - stop study - satisfaction with information provided 82
Figure 4-2 Exploratory study - importance ratings of characteristics of information provision via the internet 90
Figure 4-3 Exploratory study - importance ratings of characteristics of information provision via call centres 91
Figure 4-4 Exploratory study - importance ratings of characteristics of information provision via mobile phone 92
Figure 4-5 Exploratory study - importance ratings of characteristics of information provision via paper based options 93
Figure 4-6 Exploratory study - importance ratings of characteristics of information provision via passenger information displays 94
Figure 5-1 Time taken to walk to bus stop/train station 102
Figure 5-2 Wait time at stop/station 103
Figure 5-3 Travel time on public transport option 104
Figure 5-4 Walk time from stop/station to place of work 105

Figure 5-5 Postal Zones in Dublin 109
Figure 5-6 Quality of maps at stops/stations 113
Figure 5-7 Quality of time tables at bus stops/train stations 114
Figure 5-8 Quality of public transport web-sites 115
Figure 5-9 Availability of information on the cost of your trip 115
Figure 5-10 Availability of real-time information on your trip 116
Figure 5-11 Current use of transport information - stage one 119
Figure 5-12 Current use of transport information - stage two 119
Figure 5-13 Current use of transport information - stage three 120
Figure 5-14 Breakdown of qualitative responses 125
Figure 6-1 Location zones in the Dublin metropolitan area 170
Figure 6-2 Map of zone 5 171
Figure 7-1 Calculation of individuals frustration score 201
Figure 7-2 Calculation of the CONVN1 score 209
Figure 7-3 Calculation of the CONVN2 score 210
Figure 7-4 Calculation of the PERSEP score 218
Figure 8-1 Comparison of willingness to pay amounts across all stages 262
Figure 8-2 Nested model structures - stage one 265
Figure 8-3 Nested model structures - stage two 268
Figure 8-4 Nested model structures - stage three 270

LIST OF ABBREVIATIONS

APTS	Advanced Public Transport Systems
AVL	Automatic Vehicle Location
AVM	Automatic Vehicle Monitoring
BRT	Bus Rapid Transit
CBA	Cost Benefit Analysis
CIS	Customer Identification System
CO	Carbon Dioxide
CSO	Central Statistics Office
DART	Dublin Area Rapid Transit
DGPS	Differential Global Positioning System
DTO	Dublin Transportation Office
ED	Electoral District
GDA	Greater Dublin Area
GEV	Generalised Extreme Value
GoTiC	Gothenburg Traffic Information Centre
GPS	Global Positioning System
IIA	Independence from Irrelevant Alternatives
ITS	Intelligent Transportation Systems
LCD	Liquid Crystal Displays
LED	Light Emitting Diode
MNL	Multinomial Logit
NMNL	Nested Multinomial Logit
NOX	Nitrogen Oxide
PATH	Partners for Advanced Transit and Highways
PDA	Personal Digital Assistant
PID	Passenger Information Display
PTIO	Passenger Transport Information Office
QBC	Quality Bus Corridor
RP	Revealed Preference
RPA	Railway Procurement Agency

RTPI	Real Time Public Transport Information
SCOOT	Split Cycle Offset Optimisation Technique
SMS	Short Message Service
SP	Stated Preference
TCRP	Transit Cooperative Research Program
UK	United Kingdom
US	United States
USD	United States Dollars
VMS	Variable Message Sign
WTP	Willingness to Pay

1 INTRODUCTION

Since the introduction of intelligent transport systems (ITS) in the mid 1980s, much has been written about their potential to improve public and private transport. ITS applications have been used for both public and private transport options to improve their efficiency and to maximise the potentials of both modes of transport. This research focuses upon the use of ITS in providing real-time public transport information. Public transport planners in many cities have used ITS applications to provide real-time information to public transport users. This thesis investigates the introduction of an integrated system of public transport information by examining what type of real-time information individuals require at each stage of their public transport trip. This is achieved by using a stated preference study to determine what type of information individuals require across three stages of a public transport trip. These stages were defined as pre-trip planning from home to work, at-stop/station planning and pre-trip planning from work to home. At each of these three stages, different methods of accessing real-time information were examined to establish at each stage of a trip what method of accessing real-time information individuals are most likely to choose. The options for receiving real-time information examined in the stated choice scenarios were: passenger information displays, a call centre, the internet and via a short message service (SMS).

There are two approaches to measure the benefits of real-time public transport information, the revealed preference approach and the stated preference approach. In transport, evaluation revealed preference studies examine how individuals use a mode or service. This evaluation is based upon actual recorded behaviour, measuring how individuals interact with the mode of transport in question. As revealed preference studies examine observed behaviour, they are confined to studies which examine transport infrastructure or policies which are actually in place. As revealed preference studies measure what respondents have actually done as opposed to what they say they might do, whereas stated preference studies measure individuals stated intentions. Therefore proponents of this approach cite this as one of the main advantages of revealed preference studies compared to stated preference studies (Louviere, et al 2000).

The second approach to measuring the impacts of real-time public transport information is by conducting a stated preference study. The main advantage the stated preference approach has over the revealed preference approach is that it can be used to evaluate the impacts of the introduction of a transport policy or the construction of new transport infrastructure. As such, the stated preference approach may be used to evaluate the potential impacts of the proposed policy or infrastructure project. Stated preference studies have been used to evaluate a wide range of transportation policies varying from road pricing studies, the introduction of new public transport modes to measuring how to improve road safety. As the real-time public transport information options considered in this thesis are hypothetical and are not currently in place in Dublin, the stated preference approach was considered to be the most appropriate method of analysing individuals' preferences.

A number of stated preference studies in the literature have reported individuals' opinions and willingness to pay amounts for real-time public transport information. This research has focused upon the implementation of a single method of delivering this information. Molin and Timmermans (2006) examined the benefits of providing real-time transport information via the internet in the Netherlands, using the stated preference approach. The authors of this study found that respondents to the survey were found to be willing to pay 26c per minute to access real-time public transport information via the internet.

Wolinetz et al (2001) conducted a survey of residents in San Francisco, to identify their preferences for real-time transport information via a call centre. The authors found that respondents derived a benefit from the provision of real-time information and were willing to pay for information via a call centre. Molin and Chorus (2004) conducted a study to estimate willingness to pay amounts for real-time information via mobile phone SMS. The authors estimated an average willingness to pay per message of 12c and that those with a higher education, males and those on higher incomes were willing to pay more for an SMS.

The literature demonstrates that previous studies have been limited to examining preferences for a single method of obtaining real-time information, with the choice scenarios examining the choice between various options of the same method of obtaining real-time information. This thesis aims to add a contribution to knowledge by examining the choice between real-time information options at different stages of a public transport

trip. Some studies have looked at the provision of transport information across a number of stages of a transport journey such as that completed by Grotenhuis et al, (2007). These studies have concentrated upon what information individuals require such as departure times, the quality of maps and other requirements, as opposed to the method they used to acquire this information, via the internet, call centre or any other method of receiving such information. Polak and Jones, (1993) investigated how real-time information can change individuals' mode choice by providing them with estimated real-time journey times at different stages of their journey. A similar study was completed by Khattak et al (1993) to examine the impact of pre-trip traveller information on routeing decisions of car users. As with the previous studies, this study focused on the impact of traveller information as opposed to the methods by which individuals choose to obtain this information.

In the field of research conducted on the evaluation of real-time transport information, little research has been completed upon the impacts of access to information technology, the frustration and annoyance related to the use of public transport, the convenience associated with using real-time information. A further gap exists in the literature with the lack of research into the choice between real-time information options. Additional work is required in these areas: i) preferences between real-time public transport information options, ii) the type of information respondents require at each stage of their public transport trip, iii) the impact of explanatory and attitudinal variables upon the utility derived from real-time public transport information. This thesis attempts to address the lack of research conducted in these areas.

To achieve this, choice scenarios were created asking respondents to choose between different methods of receiving real-time information. At each of the three stages of a public transport trip examined, respondents were asked to indicate which option they would choose to obtain real-time information from. Therefore, this study provides insights as to the benefits individuals derive from the real-time information options examined.

Therefore, the objectives of this research are as follows:

1. To conduct a detailed literature review in the following areas: i) methods of providing real-time public transport information, ii) operator and passenger benefits from real-time information, iii) methods of accessing the impacts of real-time information, iv) willingness to pay evaluations of real-time information.

2. To create several stated preference scenarios, to examine respondents' preferences for real-time public transport information across three stages of a public transport trip.
3. To develop a stated preference survey using a fractional factorial design to measure respondents' preferences and attitudes towards the use of real-time public transport information.
4. To investigate and model the choices made by respondents in relation to the different methods of receiving real-time public transport information offered at each of the stages examined, using the multinomial logit approach.
5. To examine the impacts of explanatory variables such as socio-economic characteristics and attitudinal variables such as frustration with public transport, on the utility derived from real-time public transport.
6. Estimate willingness to pay amounts for real-time public transport information for each of the stages of a public transport trip examined.

The remainder of this thesis is structured as follows. The first step in investigating the benefits from the introduction of a system of real-time public transport information is to examine the literature on the benefits of providing this information. ***Chapter 2*** presents a discussion of the literature on the benefits of public transport information. This chapter also provides background on the public transport network in Dublin and the real-time public transport information available in the city.

Two preliminary studies were initially completed to frame the research question and to guide the further stages of the research. ***Chapter 3*** presents the methodologies used to undertake the research presented in this thesis. This chapter discusses the approaches used to collect and analyse the data. The modelling approaches used to analyse the data are detailed in this chapter with reference to where the tests are applied in the subsequent chapters.

Chapter 4 reports on the preliminary research that was conducted on real-time public transport information. This chapter details the findings of two studies. The first study examined the perceived benefits derived from using an at-bus stop system of real-time information system. The second study presents the results of an exploratory survey undertaken to test the various real-time information options which were being considered

for inclusion in the stated preference survey. This chapter concludes with a discussion on the implications of these studies and how the findings impacted upon the later stages of the research.

A summary of the results from the stated preference survey are presented in ***Chapter 5***. This chapter presents the results of the responses to the questions asked in the main survey. The chapter is divided into six sections detailing the responses on the mode of transport used to travel to work, the working patterns of respondents, location factors of individuals, opinions of public transport, access to information technology and socio-economic variables.

The first of the analysis chapters, ***Chapter 6***, presents the base model results. In this chapter a series of explanatory variables are incorporated into the multinomial logit models to ascertain what, if any, impact these variables have on the model results. The explanatory variables presented in this chapter vary from gender and age to mode of transport used. The modelling approach uses a building block approach, adding variables one-by-one to the base models to improve the model performance. The final section of the chapter combines several explanatory variables into one model for each of the stages examined. This produces a series of models with an improved model performance compared to the base models.

Chapter 7 presents the findings from the examination of several attitudinal variables. The attitudinal variables examined in this chapter measure frustration with public transport and opinions related to public transport information. The final models presented in the chapter combine the attitudinal variables with the explanatory variables in chapter 6, to produce a set of final models.

The behavioural outputs from the models are analysed and interpreted in ***Chapter 8***. In this chapter elasticities of choice, willingness to pay and utility coefficients are examined and interpreted to draw conclusions as to the motivation behind the choices made by the respondents. This chapter produces the main conclusions and findings of the thesis and sets out the main factors which impact upon individuals' choice between options of real-time public transport information.

The final chapter, ***Chapter 9***, concludes with a discussion of the main findings and the contribution to knowledge. This chapter summarises the main findings of the thesis, discusses the shortcomings of the research and possible areas for further research.

2 OPERATING AND EVALUATING REAL-TIME PUBLIC TRANSPORT INFORMATION

2.1 INTRODUCTION

This chapter introduces the concept of real-time public transport information, its purposes and the benefits that can be derived by the individual and the public transport operator. The first section of this chapter describes the public transport in Dublin at the time of this study and modal split amongst all modes available. The following section details the methods by which real-time public transport information can be obtained using ITS, and how it may then be relayed to the public transport user. As this study was conducted in Dublin, section 2.4 details the methods available at the time of the study to access real-time public transport information.

The benefits of providing real-time public transport information to the operator and to passengers are discussed in sections 2.6 and 2.7. Section 2.7 also examines the methods to evaluate the benefits of real-time public transport information. A detailed case study of the provision of real-time public transport information in Gothenburg, Sweden is presented section 2.8. Gothenburg is seen as on of the best practice examples of providing integrated real-time information and this case study details the development of the system and the analysis of the costs and benefits of the system. This chapter concludes with a summary section.

2.2 PUBLIC TRANSPORT IN DUBLIN

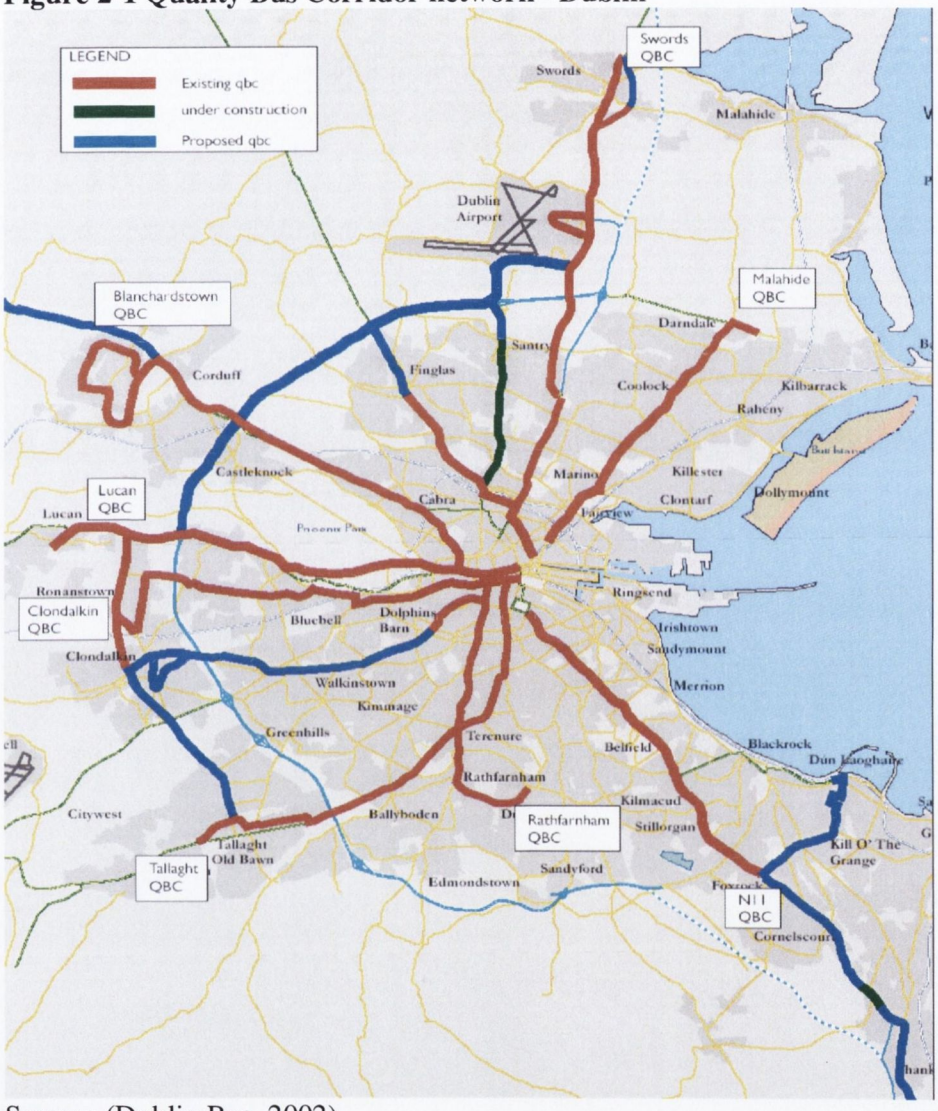
In Dublin 56% of all morning trips are made by public transport (Dublin Bus, 2006). Of this 56%, 70% of all public transport is made by bus and 30% by heavy rail or light rail. This demonstrates the importance of bus in the public transport network in Dublin.

2.2.1 Bus network in Dublin

Bus is the largest mode of transport in Dublin. The main operator of bus services in the city is Dublin Bus. Dublin bus has a fleet of 1,079 busses and operates over 170 routes, and in 2005 provided 146million passenger journeys (Dublin Bus, 2006). In 1996 the first Quality Bus Corridors (QBC) opened in Dublin (see Figure 2-1). The introduction of

QBC's in Dublin has been a huge success, with patronage increasing by as much as 232% on the Stilorgan QBC (Dublin Transportation Office, 2002). QBC's have been demonstrated to provide a high quality of service, and provide journey times shorter than that of the private car (Caulfield and O'Mahony, 2003).

Figure 2-1 Quality Bus Corridor network - Dublin



Source: (Dublin Bus, 2002)

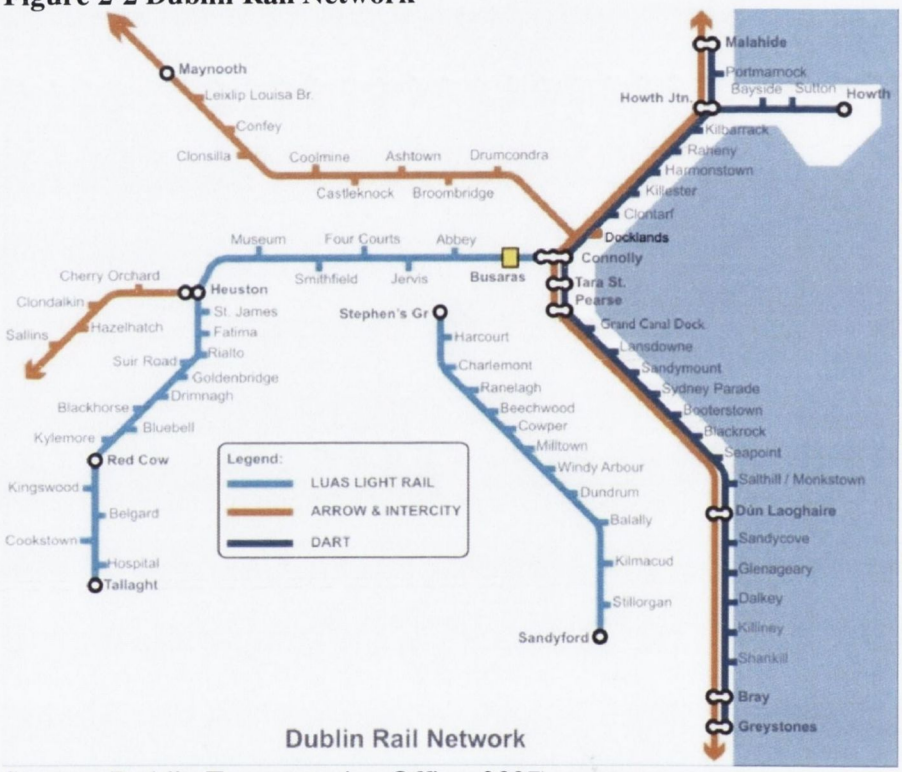
2.1.1 Rail network in Dublin

The Dublin urban rail network at the time of the survey in 2005 consisted of three rail options as shown in Figure 2-2. Transport planners in Dublin are currently developing a tram network called Luas. Currently this network consists of two segmented lines, the green line which connects St Stephens Green in the city centre with Sandyford in the south of the city, and the red line which connects Tallaght with the city centre, linking the two

main rail stations (Heuston and Connolly stations), see Figure 2-2. Luas in 2005 carried 22.2million passengers (Railway Procurement Agency, 2006).

Dublin Area Rapid Transit (DART) is a heavy rail service which connects Malahide in the north of the city with Greystones to the south of the city. The service follows the coast line, and links three of Dublin's main rail stations in the city centre, Connolly, Tara Street and Pearse Street, see Figure 2-2. Arrow services operate between Sallins to the city centre, and from Maynooth to the city centre. In 2005 DART and Arrow services provided 37.7million passenger journeys (Irish Rail, 2006).

Figure 2-2 Dublin Rail Network



Source: (Dublin Transportation Office, 2007)

2.2 AUTOMATIC VEHICLE LOCATION METHODS

Automatic Vehicle Location (AVL) and fleet management is a process whereby transport vehicles are tracked on-route, providing real-time information on the position of the vehicle for both passengers and operators. This is generally done via the measurement of the real-time location of the vehicle and relaying the position data to a central source. Generally the benefits of AVL monitoring of bus systems can be defined as follows:

- Automatic vehicle monitoring and control,

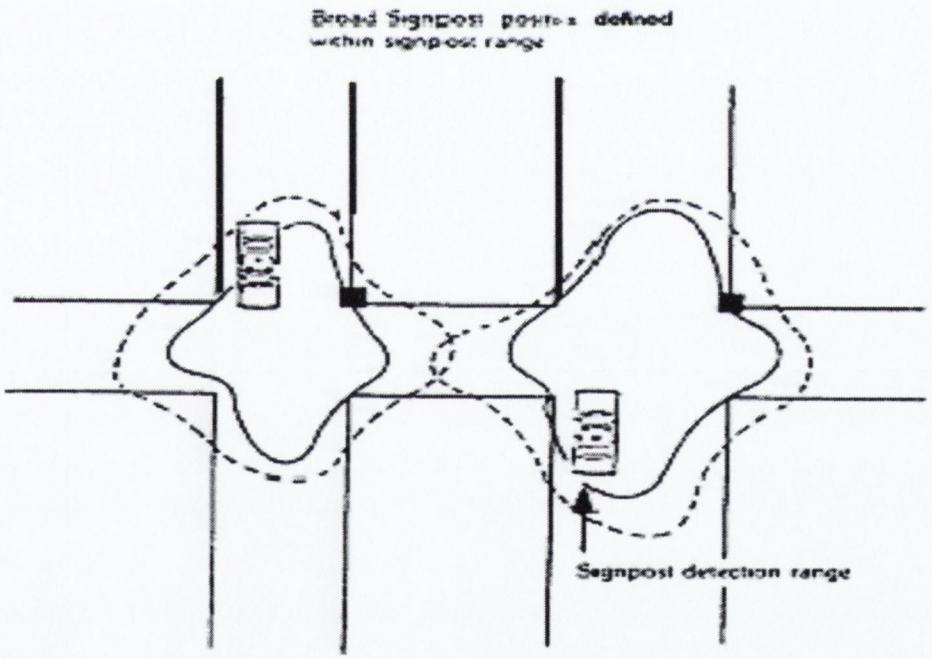
- Fleet management,
- Performance management, maintaining headway,
- Emergency location of vehicles, and
- Increased customer satisfaction, due to improved performance.

The methods by which the location of the vehicle can be determined can be defined by one of the following sections.

2.3.1 Signpost

The majority of the early AVL systems used signpost technology as the location sensor. Signpost systems consisted of a signpost (device that sends the signal) located above the height of the bus, to ensure a line of sight exposure to the onboard receiving antenna see Figure 2-3. This onboard antenna and transponder comprised the whole onboard system. These two systems worked together and determined the location of the bus at any part of its route.

Figure 2-3Signpost AVL



Source: TCRP 1997, AVL systems for Bus Transit, p 18

The accuracy of this system depends upon the density of the signposts along the route. Therefore in order for the system to be accurate it requires a well-equipped infrastructure.

One disadvantage of the system is that it's fixed to the route and therefore can only display information on buses following that route.

2.3.2 Ground-Based Radio Positioning

This system is based on measuring the time difference of signal reception against the known position of a stationary transmitter. Also called radio triangulation, where obtaining the bearing of the moving object with reference to two or more fixed points derives the location, that is a known distance apart.

A central control will contact the bus and communicate the location of the vehicle, calculating its location. The onboard component is a simulcast paging system that comprises of an antenna and a vehicle location unit. This is a method by which more than one signal is sent to the central control unit, in order to triangulate the position of the vehicle. The vehicle location unit acts as communications device, equipped with an identification device that responds to calls from central control.

This system has moderate accuracy of between 100ft – 150ft (Transit Cooperation Research Program, 1997). It has a low capital cost, however it may have a high monthly service cost due to the calls (this is dependent on usage). Signals may also be lost when travelling through tunnels or by surrounding high buildings.

2.3.3 Global Positioning Systems

Global Positioning Systems (GPS) were first introduced by the US Department of Defence in the 1970's as a means to track military vehicles to within 25 meters (Transit Cooperation Research Program, 1997). In 1995 full complements of 24 satellites was deemed fully operational, and orbit the earth in such a way as to ensure full visibility at all times. These satellites transmit estimated position and time every second. These signals are then transmitted to tracking stations on earth, which then responds to the position and model of each satellites exact location. This is then uploaded to the satellite and relayed to the GPS receivers.

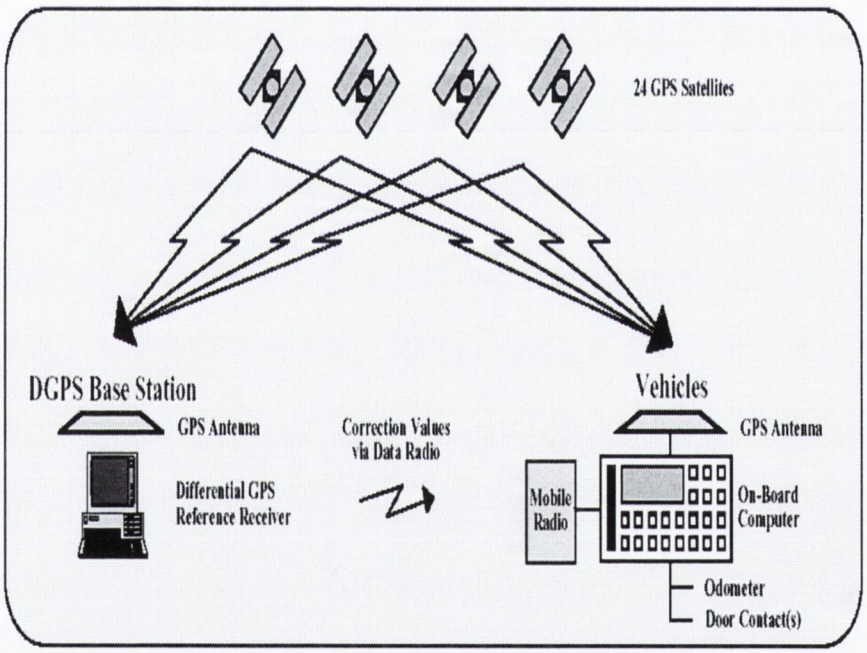
The GPS receivers convert the signal into position velocity and time estimates. In order for this to be achieved, GPS receivers must be in a line-of-sight of at least four satellites. The main advantages of this system are that it is moderately accurate to 100ft – 150ft (Transit Cooperation Research Program, 1997). It has global coverage and therefore not

subject to route restrictions ensuring maximum flexibility. However it too can have poor signal coverage due to tunnels and large buildings. One of the main drawbacks is that it may be subject to multi-path errors, degrading the accuracy of its location.

2.3.4 Differential GPS

GPS systems alone as seen above may be subject to multi-path errors. Differential Global Positioning System (DGPS) is a system whereby these errors are corrected. The theory behind this system is that the GPS receiver observes the bias of each satellite based upon its own position. Corrections are then made based upon differences between observed signals and predicted signals transmitted to the GPS receiver with a communications link within coverage. For the corrections to remove signal bias the differential corrections must be transmitted to the remote receiver at an update rate, as seen in Figure 2-4.

Figure 2-4 Differential GPS System

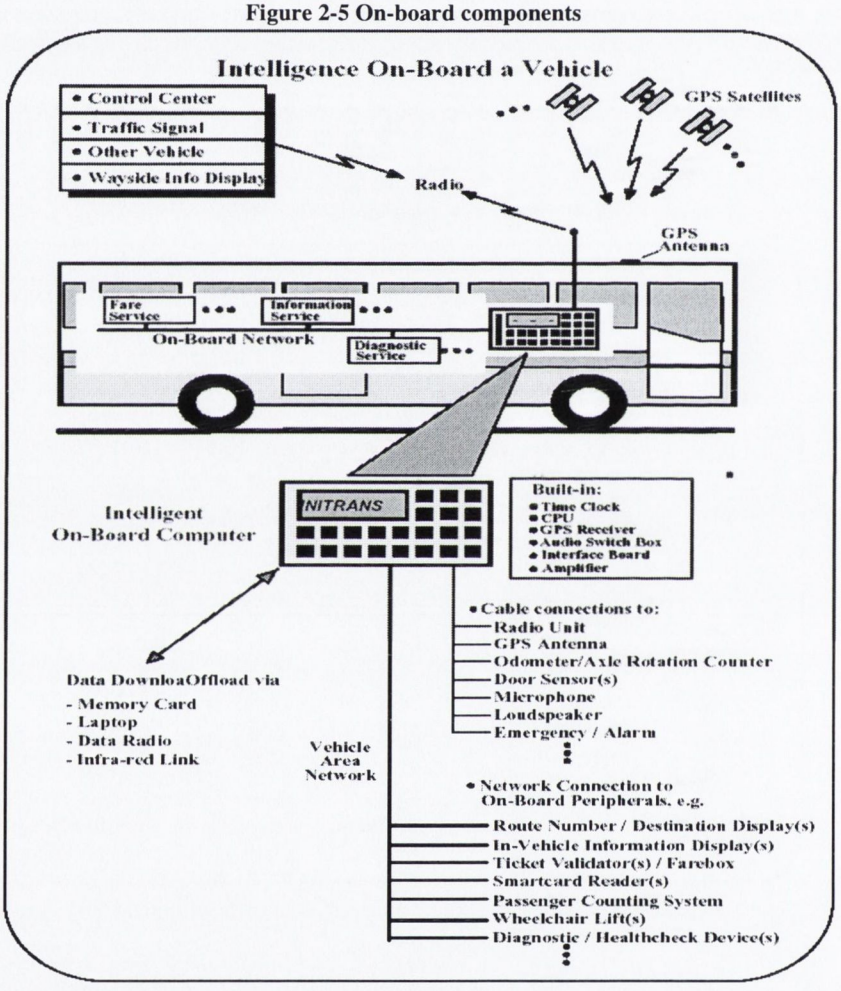


Source: CODE 2000: Guidelines for Implementing Real-Time Information Projects: p106

The onboard component of the system requires a GPS receiver, and a differential unit with a radio link that receives corrections from the differential reference station. The infrastructure required is a differential station that is in view of the orbiting satellites, and a communications link with the onboard differential receiver.

Figure 2-5 shows how the onboard computer component of the DGPS system can work. This system utilises a GPS receiver, an odometer and a door sensor to estimate the position of the vehicle and relay this to control station, which in turn relays the position to real-time passenger information, displays and any other forms of communication the operator desires.

Figure 2-5 On-board components



Source: CODE 2000: Guidelines for Implementing Real-Time Information Projects: p108

This system gives increased accuracy to within 10ft, with an operating cost of between $1,000 United States Dollars (USD) to $1,200 (USD) per year (TCRP, 1997). However it is subject to two sets of technology restrictions, in that the radio link to the differential unit must be within range of the signal (losing the ability of global coverage) and differential corrections must be updated frequently to ensure accuracy, which adds to the cost.

2.3.5 Dead reckoning

Dead reckoning systems are among the oldest navigational systems. They measure the distance and direction from a fixed point. One of the first applications to bus transit was via a wheel odometer, which was used as the primary navigational tool. The wheel odometer is used to count the number of wheel rotations between distances between known points to estimate the time of arrival.

Unlike the previous technologies dead reckoning is self-contained onboard and does not require any supporting infrastructure. It is still used on many buses today as an aiding sensor to signposts and GPS systems, and as explained above, it may be used in DGPS systems.

When the real-time position of the vehicle has been determined, the position is relayed back to a central point, and then this data can then be relayed to stops, vehicles and other forms of communication.

2.4 AVL Systems in Dublin

Currently several modes of public transport are utilising AVL in order to improve operator efficiency and maximise the quality of service provided to passengers. The main players in the market are Dublin Bus, Irish Rail, and Luas. The following is a description of the current methods of AVL in Dublin.

2.4.1 Dublin Bus – AVL system

In the 1970's Dublin Bus implemented a system of Automatic Vehicle Monitoring (AVM). This was a system based upon dead reckoning. The system was abandoned in the mid 1990's due to a lack of reliability of the data; this was largely due to the high degree of manual data imputing. Two agents imputed the data, the controller in the depot and the bus driver on route.

The controller at the start of the day inputted the work allocation across the fleet. This had to be updated throughout the day as buses were changed and substituted. Bus drivers had to input into an onboard AVM console and input a reference that indicated the start of each

journey. Then along the journey an odometer relays pulses signalling the location of the bus along the corridor, to a central computer system.

A display at the central computer displayed a fixed line display of the route, and the AVM gave controllers an indication of the location of the bus throughout its journey.

Due to the extent of the human interaction with the system, it left it open to human error, and as the number of errors increased it resulted in a lack confidence in the location of the bus along the route. This resulted in the depot controllers relying on audio verification through radio contact, undermining the whole AVM system.

In the mid 1990's this lack of confidence combined with the desire of Dublin Bus to introduce roadside supervision led to the abandonment of the system (CODE, 2000).

2.4.2 Irish Rail – AVL system

Currently the Suburban and outer suburban stations which consists of approximately 48 stations are commissioned with a passenger information display. The current system is networked and consists of mainly basic platform signs and booking office personal computers with additional monitors in public waiting areas displaying arrival/departure information.

Before each train starts its journey it is given a unique ID. This ID follows the train throughout its journey. As it passes over the track circuits its progress is monitored and thus its location. This information is fed into a dedicated Customer Information System (CIS) personal computer that compares the location of the train with the scheduled timetable that contains all the information of where the train is due to stop and the unique ID of the train for that service.

Not all track circuits are configuring as reporting locations to update the CIS and because of this the system is not truly Real Time. At each reporting track circuit the estimated travelling time to the next one is calculated and fed into the system, thus if the train stops unexpectedly between these two points the system does not know. At this stage it is up to the operator of this system to manually update the information for this train remotely.

2.4.3 Luas – AVL system

The Luas AVL system will provides the operator with information regarding the location of the tram at any point on the route; therefore monitor the quality of service provided by the operator.

The main component of the AVL system is an on-board computer that dynamically calculates the trams location from a variety of data sources generated during operation. Data is collected via induction loops in the track-bed and on-board tram odometer. The on-board computer compares the trams actual location with its scheduled timetable location and this comparison is the presented to the tram driver via an AVL console to assist the driver in monitoring the trams performance.

These data are forwarded to the signalling system so a priority message can be sent to traffic light signal junction controllers. The data is also sent to a central control system that monitors the performance. This control centre also relays information to passenger information displays indicates the approximate time of arrival of the next tram.

From this system operating staff are able to monitor the quality of service in two ways. Firstly during off-peak hours the location of the trams relative to their scheduled position. From the control centre the operator are able to ascertain if the tram is falling behind schedule and take appropriate actions to maintain headway. Secondly during peak times schedule adherence will be less important than maintaining headway. Therefore the control room will use the data to preserve this headway.

2.5 Real-Time Transport Information in Dublin

This section details the real-time public transport information services provided by the various public transport operators in Dublin.

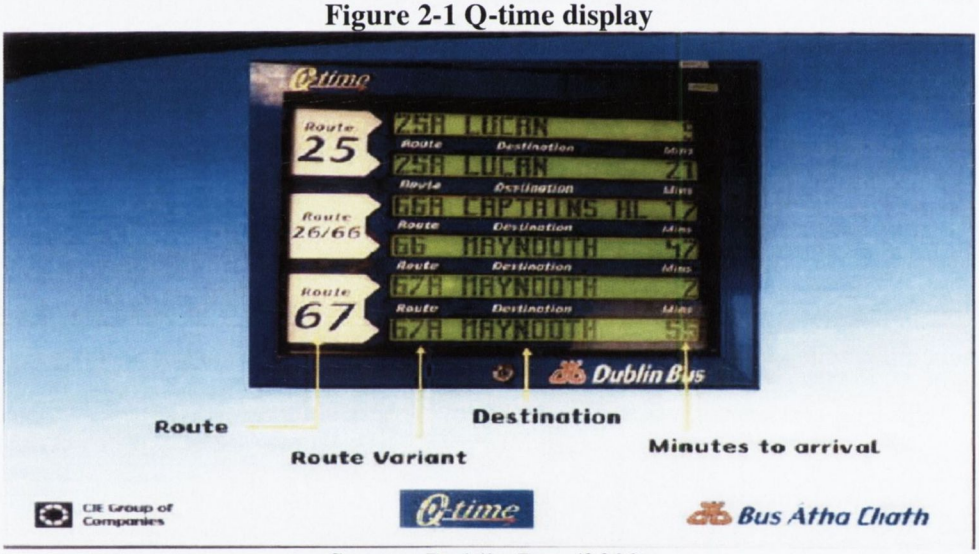
2.5.1 At-stop passenger information displays

Dublin bus in 2006 completed a three-year pilot programme to introduce at-stop real-time public transport information to the Dublin Bus network is called "Q-time". In this pilot programme all of the services that operate out of a bus depot in south west Dublin were

fitted with AVL systems and several stops along the route have been fitted with at-stop real-time information displays.

The AVL system is based upon a system of differential GPS that is complemented by a wheel odometer and a door sensor. These three sources namely the GPS co-ordinates, odometer and a door sensor signal feed into an onboard computer that relays to the real-time passenger information display. The GPS signal is updated every 20-30 (Dublin Bus, 2003) seconds and the real-time passenger information is updated with the same frequency. This information is then relayed to a control centre in Dublin Bus, and after differential corrections the information is sent to the real-time passenger information displays at the appropriate bus shelters. The displays provide information on the route a route variant, destination and the minutes to arrival as seen in Figure 2-1, it displays route, route variant destination and minutes left to arrival. The pilot scheme is to be extended across the whole network; this is expected to be in place by 2009.

Figure 2-1 Q-time display



Source: Dublin Bus (2003)

Both DART and Luas services provide real-time passenger information displays at all of the stops/stations. The displays provide passengers with information on the arrival time of the next two services to the stop/station in question.

2.5.2 Public transport web-sites

At the time of this study in Dublin, there was no one website which provided public transport information on all modes of transport. Each of the public transport operators

provides a website which contains timetables of all of the scheduled services and the routes provided. The only service which provides real-time information is the DART and suburban rail system. The system provides the real-time arrival times of the next three services to a DART station specified by the user.

2.5.3 SMS public transport information

Dublin Bus in 2004 introduced a system called 'BUSTXT'. This service provides users with the departure time from the terminus of the next three services in either direction, when the user sends a message requesting information on a specific bus route. This service is available at a charge of 30c per message (Dublin Bus, 2007). This information is static, and is taken from the scheduled timetable. The information is not real-time, and as the departure time is the scheduled departure time from the schedule, it does not provide any benefits over a printed timetable.

In the same year Irish Rail introduced a similar service for DART users called 'DARTXT'. The service works in a similar way to the Dublin Bus service; however the information provided is real time information indicating the expected arrival time of the train to the station specified by the user. The cost of the service is 30c per message (Irish Rail, 2007).

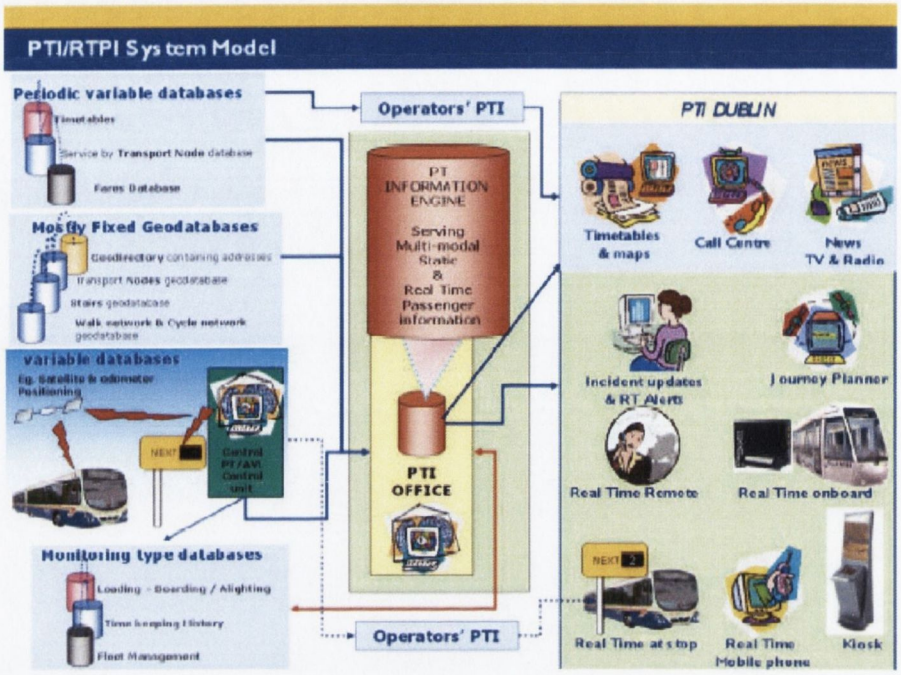
2.5.4 Plans for developing real-time information in Dublin

Public transport information services currently available in Dublin are disjointed and incoherent. This statement may be backed up by the fact that there is no one single source for public transport information covering all modes in the city. Each of the individual operators in the city provides their own information services. There is some level of integration with information on connecting services; however this does not take the form of a journey planner. This lack of integration is also found with the lack of information at transfer points. The absence of integrated transport information is also seen in the lack of integrated information via a call centre or SMS.

In 2004, the Dublin Transportation Office (DTO) published a report which examined the costs and benefits of implementing a city wide real-time public transport information network (Dublin Transportation Office, 2004). One of the main recommendations of this report was that a Public Transport Information Office (PTIO) be established which would integrate public transport information in the city. The report recommended that all public transport operators pool their real-time information, which is then transmitted to the PTIO

and subsequently relayed to passengers. The proposed model of providing real-time information is shown in Figure 2-2.

Figure 2-2 Proposed model for dissemination of transport information in Dublin



Source: Dublin Transportation Office, 2004, pp31

The DTO report also estimated the cost of introducing at stop real time information. The cost of introducing real-time information at bus stops in the city was estimated to be €21million (Dublin Transportation Office, 2004). The report also indicates that the introduction of an interactive on-line journey planner, a call centre and a system to relay real time information via SMS would cost €360,000 to set up, and would have an operating cost of €180,000 per annum.

The costs of implementing a system of real-time information as outlined in the DTO 2004 report, demonstrate the considerable cost involved in introducing a city wide real-time information system. Sections 2.6 and 2.7 below detail the benefits which could offset the investment in a real-time public transport information system.

2.6 Operation Benefits from AVL

Both passengers and operators benefit from the use of AVL systems in tracking public transport vehicles. This section examines the operator benefits under the headings of headway, scheduling and data collection and monitoring.

2.6.1 Headway

Headway in terms of bus operation is defined as the time between bus services arriving at a stop. Public transport planners and operators would aim to have headway uniformed to provide a service which does not have several buses arriving at once at a bus stop. Headways can be inherently unstable (Dessouky, et al, 2002) when a bus falls slightly behind schedule, it tends to pick up more passengers, causing it to slow further, until it eventually bunches with the trailing bus (Barnett, 1974; Newell, 1974; Turnquist, 1978). Services that run off schedule can cause a continual problem with regard to levels of frustration, greater waiting times, loss of transfers and an increase in the total origin to destination time (Hickman, 2003).

The introduction of an AVL to provide real-time public transport information would enable bus operators regulate the arrival times of buses at their stops, thereby reducing headway and providing a more uniformed service (Hickman, 2003).

2.6.2 Scheduling

Liping Fu, et al. (2003) present a new transit operating strategy in which service vehicles operate in pairs with the lead vehicle providing an all-stop local service and the following vehicle being allowed to skip services providing an express service. It is possible with AVL data to measure this cost effectively.

The design of services on a transport corridor on the one hand is expected to have a fixed schedule or service frequency to provide broad coverage, and on the other hand, variability of passenger boarding numbers along the route varying by population density. This variability cannot be efficiently serviced by transit with fixed routes and schedules. Therefore transport operators may employ various scheduling strategies to alleviate the problem. Scheduling strategies can be put into four categories (Lehtonen, et al, 2001):

1. Zone scheduling: this can be where inbound services make all the stops within a particular zone, and then run non-stop to the terminus. However this approach has two main disadvantages. Firstly it may lead to decreased frequency and increased waiting time, and secondly may require a cross-zone transfer.
2. Short turning: this consists of a system of short-run and full-length trips operating on the same route. Short run trips only cover times of high demand and they are complemented by full-length trips.

3. Deadheading: this is a system whereby buses run empty through a number of stops at the beginning or at the end of their route. This is done to save time and reduce the headways at later stations.
4. Dynamic stop skipping: this is an operating system with the use of AVL technologies. This strategy is to allow buses that are behind schedule to skip low demand stops in order to maintain headway and catch up with the schedule.

Liping Fu, et al, (2003) follows the idea of dynamic stop skipping. The study allowed every second bus to stop skip. This resulted in schedule headway at any stop to be no more than twice the dispatch headway. From the study, the following results were found; by implementing the skipping strategy the skipping bus had an average reduced weighted trip time of 6%, however the complementary bus had a decrease of 16%.

The main benefit of this control system is that minimum service frequency is ensured at all stops while both passengers and transit agencies enjoy reduced travel time and operating costs.

Bus Rapid Transit (BRT) system is the US equivalent to the Dublin's QBC, providing a lower-cost, high capacity mode of public transportation. Baltes (2003) conducted on-board surveys to measure what extent passenger's value the existence of the BRT service. The initial results recognise that passenger's value the 'frequency of service', 'comfort' and 'travel time' and 'reliability of service'.

2.6.3 Data collection and monitoring

Advanced Public Transport Systems (APTS) include a number of Intelligent Transport Systems such as AVL and APC data, real-time passenger information can help transit agencies increase safety and improve operational efficiency. For example, vehicles fitted with self-diagnostic tools can alert mechanics of any problems on route and dispatch a replacement vehicle.

Transit management systems have demonstrated that they are capable of reducing travel time both by improving the operation of the vehicles and the overall operation of the transportation network.

Systems with a combined AVL technology have been implemented in the US cities of Portland, Oregon, Kansas City, Missouri and Baltimore, (Mitretek Systems, 2001). Evaluations of these systems have shown increased on-time performance, reporting an average improvement of 15%. 'Transit Watch' a real-time public transport information system in Seattle has shown from customer satisfaction surveys that although it did not improve satisfaction of existing customers, new riders were impressed with the system and indicated that the system would help retain their new patronage.

A similar study in Denver Colorado (Mitretek Systems, 2001) showed the following results: early arrival decreased by 12%, late arrival decreased by 21%, and customer complaints decreased by 26%. Portland Oregon's Tri-Met system realised the following benefits: on-time performance increased by 9.4%, variability of headway's between services improved by 5%. No significant change in the average run-time of buses was observed. However the average coefficient of variability for bus run times did improve overall by 18%.

Research was conducted as part of University College Berkeley's PATH (Partners for Advanced Transit and Highways) programme and this model of adaptive priority was tested in real life on the El Camino corridor in San Francisco Bay. The model 'optimises the green time allocation under the real-time traffic flow conditions considering the bus priority requests' (Liu, et al, 2002).

The current system in Dublin does not have a system of public transport priority, however this type of system has been tested in London, Turin and Gothenburg, Sweden via an urban traffic control system namely Split Cycle Offset Optimisation Technique (SCOOT). The results in London show that bus delays per junction decreased by between 23-33%, with resulting journey times decreasing by 7-8% (Levinson, 2003). Gothenburg and Turin reported similar results; they also noted a drop in fuel consumption by an average of 5%.

2.7 Measuring the Benefits of Public and Private Transport Information

This section details the methods used to evaluate the benefits of real-time transport information and presents the main findings from several studies conducted to quantify the benefits of providing real-time information.

2.7.1 Analysing the impact of real-time information using modelling and simulation approaches

The literature presents several studies where network models have been used to ascertain the benefits of real-time information for both public transport and road users. Hickman and Wilson (1995) employ a path choice modelling technique to ascertain the benefits of real-time public transport information. Within a mode choice model, the authors incorporate a variable which represented the estimated time of arrival of a bus service into the model. The model was calibrated using data from a bus corridor in the Massachusetts Bay Transit Authority, and the authors found that the introduction of real-time information on this corridor could result in a 2-3% saving in total travel time. Hato et al (1999) also developed a route choice model to demonstrate how information acquisition impacts upon route choice. The authors examined how the introduction of traffic information impacted on the goodness-of-fit of a model which takes traffic information into account compared to one that does not. The model outcomes demonstrated that the models which took the impact of traffic information into account were found to produce the best model fit.

Al-Deek et al (1998) applied a composite traffic assignment model which combined a probabilistic traveller behaviour model of route diversion to evaluate the impacts of passengers using real-time traffic information. This study examines the impact of real-time traffic information on the choice of route. The models produced indicated that as use of real-time traffic information increases, so too does the potential time savings for drivers. The authors conclude that under incident conditions drivers who receive traffic information via their radio are most likely to avoid queuing. Lo and Szeto (2004) model the impact of real-time traffic information by looking at two classes of driver, those with advanced information and those without. The model used to examine this approach is a cell-based variational inequality model of the dynamic traffic assignment model. This model assumes the drivers who have prior information as to the traffic conditions have a lower perception of variation of travel time due to having real-time information. The authors conclude that in lower demand conditions the behaviours of both sets of drivers are similar, whereas under heavier traffic conditions, those with real-time information are most likely to vary their trip.

Chatterjee and McDonald (2004) reports the findings of study conducted in nine cities in Europe to ascertain the benefits of providing drivers with traffic information via a variable message sign. This study did examine the perceptions and the benefits derived from the

information provided to drivers and it also used models to simulate the overall reduction in travel time. The results of this simulation found that overall travel time reduced by 1-2%.

Another approach to analysing the uses and benefits derived from advanced traveller information systems is to analyse route choice behaviour when choosing between transport options generated by a computer simulator. Chorus et al (2007) employed the simulator approach to examine how respondents choose between four route options which consist of two car options and two rail options. The different route options were given real-time arrival times at the respective destinations, and varied by cost and travel times. The travel simulator was used in conjunction with a comprehensive transport survey to analyse the route choices made by respondents. The choices made in the simulator were compared against those found in the survey. The findings demonstrate respondents actual behaviour was found to closely resemble choices made in a hypothetical setting as generated by the travel simulator. Lotan (1997) analysed the impact of traffic information also using a computer based simulator. The sample of respondents the authors used was split between those familiar with the road network in question and those who were not. Both groups were unfamiliar with the transport information tool under consideration. The authors concluded that the group that was unfamiliar with the road network were more likely to switch routes than those who were familiar with the route as a result of en-route traffic information.

Geweke and Zumkeller (2006) also used the simulator to examine the impacts of using traffic information at pre-trip and on-route stages of a trip. The simulator used by the authors in this study was a computer based simulator designed to examine route switching based upon the provision of real-time information. The study found that 18% of respondents would change their route based upon real-time information on the traffic conditions. Bogers et al (2004) employed a similar computer based simulator to access the impact of variable message signs on three different transport routes in the Netherlands. Information was provided to the participants on the length of queue on the road and the expected delay. Participants were found to be very responsive to information on the length of queue, and were found to be more likely to divert routes if they perceived the length of wait to be unacceptable.

Both the modelling approach and the simulator approaches have several merits. The behaviour that is modelled in these approaches can be based upon observed actions.

Therefore the findings are subject to less variation than the findings of a stated preference study, which is based upon stated intentions. However, when evaluating real-time public transport information the approaches presented in this section can not examine aspects of interest such as attitudes, socioeconomic characteristics or daily routine.

2.7.2 Analysing the impact of real-time information using the stated preference and willingness to pay approaches

This section presents the findings of several stated preference studies which examine the benefits of providing real-time traffic and public transport information. Stated preference studies enable the researcher to examine several aspects of behaviour using controlled statistical experiments to ascertain preferences for changes in a good or a service. Hall et al (2000) conducted a willingness to pay study on the provision of a call centre service providing real-time traffic information. This study took a revealed preference approach and asked how much current users of the call centre would be willing to pay for the service. A sample of 1,100 individuals was taken in the state of Kentucky, USA. The average willingness to pay amount of the sample was $0.42 per call. When the authors examined how satisfied users were with the service, both land line users and mobile phone users were found to be equally satisfied with system. However, mobile phone users were found to derive a greater benefit from real-time information at this information was typically accessed on-route.

In a public transport network with a large number of passengers transferring between different modes, the requirements for accurate real-time information increases. In Hong Kong it is estimated that up to a fifth of passengers make a transfer during their daily commute (Tam and Lam 2005). Tam and Lam (2005) examined individuals' preferences for receiving real-time public transport information via a mobile phone or a Personal Digital Assistant (PDA). The authors found that as travel time and trip complexity increased, so too did the likelihood that an individual would choose to access real-time information using SMS or a PDA. The results also demonstrated that females, those on higher incomes and those on a monthly mobile phone contract were more likely to choose to obtain real-time information. The willingness to pay amounts from the study show that 53% of respondents were willing to pay $100 (USD) per month and 20% were willing to spend $200 (USD) per month to avail of real-time public transport information via SMS.

The benefits of providing real-time transport information via the internet in the Netherlands were examined by Molin and Timmermans (2006). The authors administered a stated preference survey to intercity rail passengers to ascertain their preferences for public transport information via the internet. In the survey respondents were asked to rank the importance of several attributes of a web-based public transport information system. The results found that the provision of real-time information was the most important aspect, followed by the availability of planning options and purchasing tickets. The respondents to the survey were found to be willing to pay 26c per minute to access real-time public transport information via the internet.

Wolinetz et al (2001) conducted a survey of residents in San Francisco, to identify their preferences for real-time transport information via a call centre. Initially, respondents were asked to identify their preference for paying for the service, 17% indicated they would pay on a monthly basis, 56% on a call by call basis and 22% said they would not use the service if they had to pay. 53% were found to be willing to pay up to $1 (USD) per call and 38% indicated they would pay up to $7 (USD) per month for this service.

Molin and Chorus (2004) present a study conducted to estimate willingness to pay amounts for real-time information via SMS. This study was conducted on bus users in the Netherlands using an on-line survey tool. The authors estimated an average willingness to pay per message of 12c. The study also concluded that those with a higher education, males and those on higher incomes were willing to pay more for an SMS.

Whelan et al (2002) conducted a stated preference study in the UK to ascertain how much users would be willing to pay for several bus infrastructure improvements, such as increased security at stops and on board buses, improved maps and the introduction of at-stop real-time information. The model results demonstrate the respondents would be willing to pay 37.1p per trip for real-time information and 38.2p for improved maps located at bus stops.

Zhang and Levinson (2006) used the multinomial logit approach to examine drivers' requirements for traffic information. The authors found that trip purpose had a strong role to play in the benefits derived from traffic information. The results found that respondents derived a greater benefit from traffic information while on a work trip as opposed to a shopping or recreational trip. In the study, 65% of respondents were not willing to pay for

traffic information, and of those who were willing to pay, the models estimated a willingness to pay amount of $1 per trip. Mahmassani et al (2001) also found that the purpose of the trip impacts upon the effectiveness of real-time public transport information. The authors concluded that individuals had different information requirements while conducting their shopping trips and leisure trips.

Molin and Timmermans (2002) conducted a stated preference study on the provision of real-time information via the internet to passengers of Dutch rail. The study examined what type of information respondents require from the internet. Respondents were found to have the highest preference for real-time information and were willing to pay 56c per-minute to receive this information. The provision of planning options was valued at 25c per-minute and the ability to purchase tickets on line, 22c per-minute. The findings of this study demonstrate the value individuals place on the provision of public transport information from the internet.

The empirical evidence demonstrates that individuals are very price sensitive when it comes to paying for real-time information. Polydoropoulou et al (1997) in an examination of the traffic information system SmarTraveler system in Boston found that respondents in the stated preference survey were very sensitive to an increase in price. Englisher et al (1997) conducted a study of the same system in Boston and also found respondents to be very price sensitive to an increase in the price of accessing traffic information. The authors found that when respondents were asked would they pay a fee to access real-time traffic information, the projected use of the system fell by 36%. In 2003, a similar study of the multimodal transport information system TavInfo system in San Francisco found that respondents to a stated preference study were found to be quite sensitive to an increase in price (Khattak et al 2003). Dedicated real-time public transport information systems have also been shown to be price sensitive. Molin et al (2007) in a study of providing real-time information at public transport interchange points found that the price of receiving this information to be one of the most important attributes, demonstrating that respondents were highly price sensitive.

The literature presented in this section demonstrates the versatility of the stated preference approach as it can be used to examine several aspects of individuals' behaviour. The approach allows for an in depth analysis of the factors which impact upon choice, enabling

the researcher to draw conclusions based upon characteristics of the individual such as gender, age and socioeconomic background.

2.7.3 Reductions in perceived wait time

Public transport users traditionally tend to overestimate their waiting time at public transport stops/stations (Nijkamp et al, 1996). Several studies have been conducted to ascertain if the provision of real-time information at bus stops reduces passengers' perceived wait-time. Kronborg et al, (2002) demonstrated that passengers with real-time information displays at their stop overestimated their wait time by 9-13% compared to 24-30% without real-time information. In London the provision of real-time information at stop was found to reduce perceived wait-time by 26% (Schweiger, 2003). Dziekan and Kottenhoff (2007), examined the introduction of passenger information display on a tram line in The Hague and found that the introduction of this service reduced perceived wait time by 20%.

Warman (2003) examined the perceived reduction in at-stop wait time for bus passengers after the introduction of real-time information for three bus routes in London. The findings show that on each of the three routes, respondents, in a face-to-face survey, said that 65%, 24% and 21% (at each of the routes) experienced a shorter wait time due to the provision of real-time information. The same study examined anxiety of waiting at a bus stop at night time, and found that 46% of respondents felt safer at their bus stop, as they knew when the bus was due to arrive.

2.7.4 Type of information required by respondents

Several studies have focused upon what type of information individuals require as opposed to how respondents access this information. Grotenhuis et al, (2007) examined passengers' preferences for real-time public transport information over three stages of a public transport trip. The authors examined a pre-trip planning stage from home, an at-stop stage and an on-board bus/train stage. At each of the stages examined, respondents were asked what information they require. This study was completed using an internet survey. At the pre-trip planning stage, respondents indicated that they required the greatest need for maps with interchange points, information on the total travel time and real-time delay information. At the at stop stage, respondents were found to have the highest preference for information on walking routes, real time delay information and route advice. At the final stage examined by the authors, the on-board vehicle component, respondents were

found to have the highest preference for real-time information on delays, information on interchanges and route advice.

While this research is similar to the study presented in this thesis, it differs on many levels. Firstly, the research conducted in this thesis discounted the on-board information stage due to the similarities found between the results and introduced a pre-trip planning stage from work returning home. Grotenhuis et al (2007) examined real-time information regardless of the method of acquiring this information, whereas this study examined the choices between information provision options at each stage.

Wall and McDonald (2007) examine the benefits bus users derive from real-time information. This study examines both regular bus users and non-regular bus users to ascertain which user group derives the greater benefit from the provision of real-time information. The authors found that more frequent bus users indicated that they derived a greater benefit from at-stop information compared to new users.

In a study conducted to ascertain the information needs of individuals using web-based journey planners, Molin and Timmermans (2006) found that the provision of real-time information to be the most important to respondents. The authors also found the provision of planning options, the option to purchase tickets on-line and information on walk routes and interchange points were also important to individuals using the internet to access public transport information.

A longitudinal study conducted by Goulias et al (2004) examines the use of several methods of accessing traffic information in the USA. This study examines the frequency of use of the following for accessing real-time traffic information: the internet, television, radio and telephone. The authors of this study indicate that frequency of use is highly dependent upon awareness of the different systems available. The study identifies that there is strong competition (substitution) between the internet and the television, whereas the radio and telephone services were found to have a complementary relationship. The frequency of use findings of this study demonstrate that individuals are most likely to use the television, followed by the radio and then the internet to access real-time traffic information.

Abdel-Aty (2001) conducted a stated preference survey of public transport users and non-public transport users in a survey in Northern California. The objective of this study was to ascertain what type of information individuals require on their daily commute. The findings show that information on frequency of service, number of transfers, seat availability, walking time to stop/station and fare information as the most important factors. In the non-public transport users group, those who currently carpooled were more likely to derive a benefit from transport information, and 38% indicated they would use public transport if the appropriate information were available.

2.7.5 The type of individual most likely to use real-time information

Knowing what type of person is likely to derive a benefit from real-time traffic or public transport information is as important as know what type of information they require. By identifying the type of person most likely to use real-time information systems transport planners may target these users to maximise the benefits of these systems. Yim et al (2003) examined what type of information respondents required from a multi-modal traveller information service. The findings of the study indicated that individuals derived the greatest benefit from frequently updated congestion information, followed by information on alternative routes around these congested zones. Automatic delivery of unexpected traffic congestion to individuals' mobile phones or pagers was found to be beneficial to the respondents examined in this study.

Kenyon and Lyons (2003) examined the value of integrated multimodal public transport information. The authors conducted several focus groups to ascertain what factors impact upon the use of real-time information. The results demonstrated that low awareness of information sources and the perception that accessing transport information is difficult and time consuming. The authors found that respondents do not just require information on their journey, but also information on convenience and comfort. Horst and Ettema (2004) examined the information requirements of visitors to a theme park in the Netherlands. The authors found that younger visitors and those visiting the park for the first time were more likely to seek travel information. Gender was not found be a significant variable when looking at what type of individual accessed transport information. However, family size was found to be a significant impact upon the type of information required, with those respondents with larger families less likely to examine the possibility of using a public transport option to arrive at the park.

Emmericnk et al (1996) examined the potential of variable message signs (VMS) and radio traffic information to change drivers' behaviour. The authors examined several characteristics to ascertain their impact on the likelihood of using real-time traffic information. Males and professionals were found to be more likely to change route, attaching a greater importance to making an accurate route choice. Flexibility of arrival time was found by the authors to influence the possibility of switching routes, with those individuals who have the possibility of arriving late at work not willing to use real-time information. Yim et al (2002) found in a study in San Francisco, respondents who could be termed early adaptors, in that they had access to various forms of information technology such as a mobile phone or the internet, and were more likely to access advanced transport information systems. This same study found that females and professionals were more likely to use real-time information systems.

Peirce and Lappin (2004) conducted a study in Seattle to ascertain why individuals do not use real-time information services, even though the information provided in the Seattle area is free of charge. This study was completed by including a series of questions in the State of Washington travel survey. Lack of awareness of how to use the technology and where to access real-time information from was found to have an impact upon the lack of individuals using these systems. The authors did find a strong correlation between the length of trip and the use of information services; however 70% of trips in the Seattle region were reported to take less than 20 minutes resulting in fewer trips requiring such information. The time of day was also found to impact upon when individuals were likely to demand real-time information, with the majority of respondents accessing real-time information during the morning peak (6-9am).

2.7.6 Examining individuals information needs at each stage of their trip

This section reports the literature which examines the information required by public transport users at each stage of their trip. The research to date in this field has tended to focus specific section rather than take an individual's whole trip into account. Polack and Jones (1993) examined the impact of at-home pre-trip information. The study was conducted on a sample of respondents in Athens and Birmingham. The aim of the study was to examine if respondents had accurate information with regard to the arrival time of a bus service which they could use, would they change transport modes from a car to a bus service. The findings of the study demonstrate that respondents in Athens were more likely to take advantage of the real-time information and switch modes, compared to the

respondents from Birmingham. Khattak et al (1996) examine the use of pre-trip traffic information, to ascertain how individuals travel decisions change as a result of real-time traffic information. The authors conducted a survey of car users crossing the Golden Gate Bridge in San Francisco, asking them their pre-trip and en-route responses to various different congestion scenarios. The authors concluded that providing the information given was accurate, individuals were willing to change routes and consider different modes of transport when severe congestion is reported on their normal route.

Peng and Jan (1999) analysed the different methods of accessing real-time public transport information across three stages of a transport trip. The stages examined were: pre-trip at home, at stop and on board vehicle information. The different methods of accessing real-time information were measured by examining the following criteria: accessibility, versatility, information carrying capacity, cost to install and to use and user friendliness. Each of these criteria was ranked using a set of performance measurements defined by the authors. At the pre-trip stage, the authors ranked the internet to be the most efficient method of getting information at this stage followed by information kiosks and mobile phones. Using variable message signs followed by kiosks and mobile phones were found to be most beneficial at the at-stop stage. Finally, at the on-board public transport stage using a variable message sign followed by audio announcement was found to be the most efficient methods of accessing real-time information.

The provision of real-time public transport information at the interchange stage between two modes of public transport is important in achieving seamless movement of passengers between modes of transport. Hine and Scott (2000) conducted extensive focus group research on the priorities for public transport interchange facilities in Scotland. The findings of the study demonstrated that individuals felt that the provision of accurate multi-modal public transport was essential in ensuring seamless movement of passengers. Molin et al (2007) adopt a stated preference approach to valuing the benefit individuals derive from the provision of public transport information at interchange points. The findings presented in this study demonstrate the certainty of arrival time plays a large role when transferring between modes of public transport. The model estimates demonstrate that when passengers are transferring to a lower frequency mode of transport, they are more likely to be willing to pay for real-time information compared to those transferring to a high frequency mode. Steer Davies Gleave (1996) undertook a study of bus passenger preferences for transport information. The study examined bus users' preferences for real-

time information at a pre-trip planning stage and at an at-stop stage. The study found that bus users were willing to pay the most for the provision of standard timetables (5.5p per trip), followed by maps (3.9p per trip). At the pre-trip stage using a call centre was found to have a lower willingness to pay amount of 2.8p per trip. At the at-stop stage, bus users were found to be willing to pay 10.0p per trip for customised information at the stop, and 9.0p for real-time information via a passenger information display. The results of this study show that bus users do not necessarily have a higher preference for real-time information as the static information sources were found to have higher willingness to pay amounts.

Wardman et al (2001) examined the perceptions of public transport interchange and how it deters people from public transport use in Scotland. The authors conducted a stated preference examination of the facilities required at public transport interchange points. The findings demonstrated that respondents require good shelters, real time information, printed information and good signage at interchange points. The willingness to pay amounts reflected these preferences with respondents willing to pay 1.7p per trip for improved shelters, 1.4p per trip for real-time information and 1.3p per trip for printed timetables. This finding demonstrates that there is very little difference in the willingness to pay amounts for real-time information compared to static information in this study.

Beirão and Sarsfield Cabral (2007) conducted a qualitative examination of what discourages individuals from using public transport in Porto in Portugal. A lack of information and poor communication between bus companies and poor timetable information at bus stops was found to discourage use of public transport. The authors cite one of the most appropriate methods of encouraging the use of public transport is to provide real-time information at-stops as it increases the individuals' perception of control.

2.7.7 The gap in the evaluation literature

The literature presented in this section demonstrates that considerable work has been conducted to evaluate the impacts of real-time public transport and traffic information. While there has been extensive research done on evaluating specific methods of accessing real-time information in isolation, there is no research conducted to date which examines individuals' choice between accessing real-time information from different alternatives. It is this gap in the literature that the research presented in this thesis seeks to address. Furthermore much of the empirical evidence to date has failed to address what real-time

public transport information individuals require at each stage of their public transport trip. The findings presented in this thesis will contribute to understanding what information is required and how it this impacts upon an individuals' utility.

2.8 BEST PRACTICE EXAMPLE OF PROVIDING REAL-TIME PUBLIC TRANSPORT INFORMATION

This section presents a case study of Gothenburg in Sweden. The city has a well established integrated real-time public transport information system and is seen as one of the best practice examples of real-time public transport information. This section details the results of an evaluation undertaken of the systems in place in Gothenburg, and how they have developed since the early 1990's.

2.8.1 Background information on Gothenburg

Gothenburg is Sweden's second city with a population of over 475,000 (Pattison et al, 2002). The public transport system includes buses, trams, ferries and commuter trains. In 2002 there was an average of 100 million public transport journeys in the Gothenburg region (GoTiC, 2002). The organisation of public transport in the Gothenburg region is the responsibility of the Traffic and Public Transport Authority in the City Council of Gothenburg. This authority works with Västtrafik, which is the public transport company for western Sweden. Västtrafik runs buses, trams, ferries and trains in the Gothenburg region, with over 100 million passenger journeys annually (Västtrafik, 2003).

Research into providing Gothenburg with a passenger information system began in 1994 when GoTiC (Gothenburg Traffic Information Centre) was established (GoTiC, 2002). Collaboration between Chalmers University of Technology, the Department of Human Centred Technology and the Department of Transportation and Logistics, produces research for GoTiC. The Swedish Transport and Communications Board centrally funds GoTiC research. Key to this research is a list of prerequisites that a city needs to have in order to provide accurate and efficient real-time passenger information, these are listed below.

- A road system that separates public transport and car traffic

- A system of traffic stoplight priority that allows public transport vehicles to pass and thus enables very accurate predictions of driving times
- Electricity at all stops in the system
- Internal marketing of the idea to ensure the wholehearted support of municipal decision makers
- A detailed study of travellers' needs and requirements
- Established cooperation between the different actors in the public transport system (authorities, traffic operators, suppliers of hardware and software)

2.8.2 Public transport information in Gothenburg

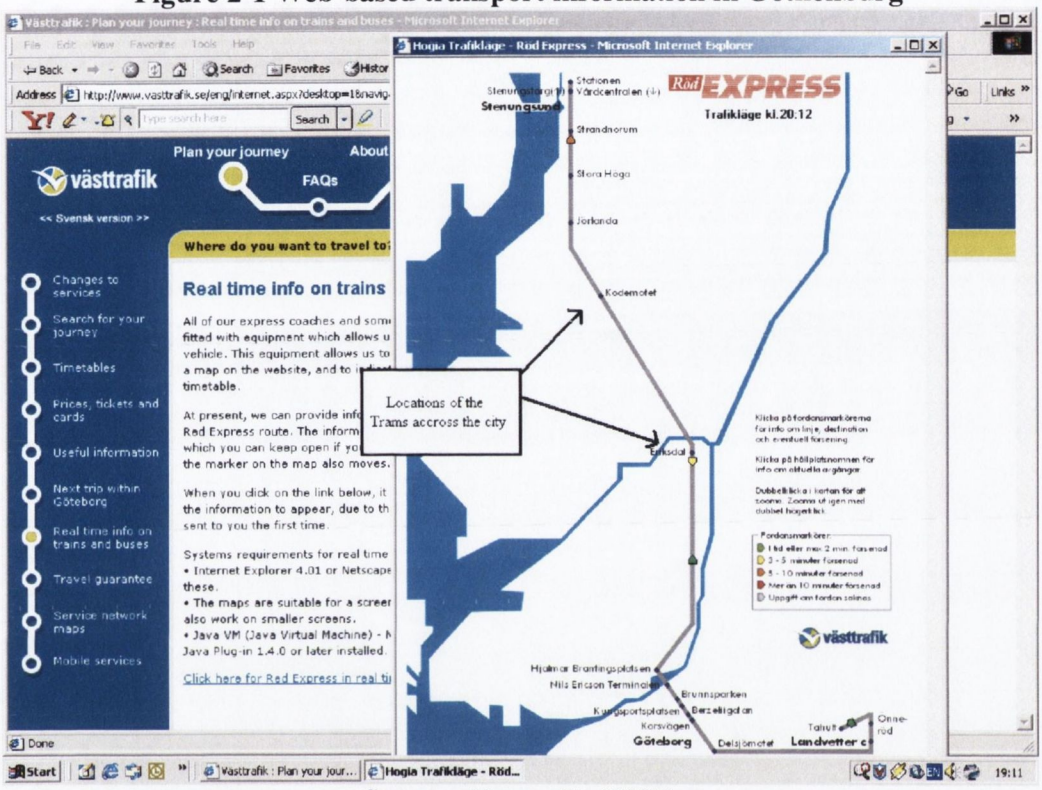
In 1984 the first trials began of real-time passenger information for the tram network. The first generation of the real-time passenger information system was basic and located on the tram platforms. In 1990 the second generation of real-time passenger information was introduced. This was a system of 13 signs that provided the same information as the first generation, but the signs were bigger and not just placed at the tram stops but near residential areas and commercial zones. These signs were colour coded for each of the tramlines.

The third generation of the real-time passenger information system was introduced in 1993. This was the first system to use a passenger information displays with Light Emitting Diodes (LED). The passenger information was displayed in a 3-row LED display and reported the time to the next service. In 1993, 30 of these passenger information displays were installed in Gothenburg on the No. 5 tram route. Before 1994 GoTiC had not done any extensive research into what passengers wanted from their real-time passenger information service.

In 1994 a joint venture with the Department of Consumer Technology and the Chalmers University of Technology undertook an extensive market consultation as to what passengers wanted. The study looked into the feasibility of installing real-time passenger information at every vantage point for the passenger. The study looked at shelters, stops, information kiosks, and where to locate these amenities. Different channels for the information were also examined; telephone, internet and mobile technology were all examined.

From this study various real-time passenger information applications have been introduced. A real-time passenger information system was launched on-line in 1995. The initial results of the on-line service have seen the annual visitors grow from 100,000 in 1995 to 1,200,000 in 2001 (GoTiC, 2002). The internet service gives real-time information on the location of the vehicle on the network as seen in Figure 2-1.

Figure 2-1 Web-based transport information in Gothenburg



Source: Vasttrafik (2007)

The fourth generation of signs introduced in 1996 were an improvement on their predecessors in that they were able to display several routes at the same time as seen in Figure 2-2. This fourth generation was also the first passenger information displays in Gothenburg to display information on disturbances along the route. This new sign also integrated a loud speaker into the system to provide audible information on the arrival of vehicles.

Figure 2-2 4th Generation passenger information displays – Gothenburg



Source: GoTiC (2002)

Before the current generation of real-time public transport information was introduced, a system of mobile phone travel information was introduced in 1998. This system used GRPS system to send passengers information on the arrival time of their vehicles. This service is provided free of charge. Another recommendation of the 1994 GoTiC study was introduced initially in 1996 and improved in 2000 was the introduction of information kiosks. These kiosks are located at points in the city with substantial foot traffic, providing passengers with route maps; real-time public transport information and timetable information (see Figure 2-3).

Figure 2-3 Passenger information kiosks – Gothenburg

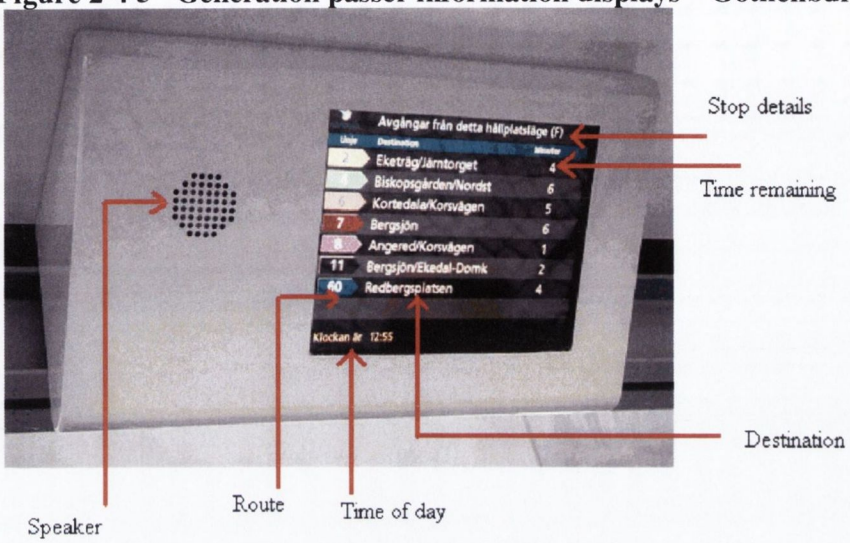


Source: GoTiC (2002)

In 2002 GoTiC introduced its latest and the fifth generation of real-time passenger information displays, which can be seen in Figure 2-4. This new generation Liquid Crystal Displays (LCD) has the benefit of having increased visibility with strong daylight. This fifth generation also includes an onboard real-time passenger information system as seen

below in Figure 2-5. This on-board passenger information displays provides the same information as the on-street passenger information displays but it also provides information on the next stops.

Figure 2-4 5th Generation passer information displays – Gothenburg



Source: GoTiC (2002)

Figure 2-5 On board passenger information displays – Gothenburg



Source: GoTiC (2002)

2.1.1 Reported benefits of passenger information in Gothenburg

The research undertaken by GoTiC with regard to the benefits that have accrued since the introduction of the real-time passenger information system categorises the benefits into four categories, economic benefits, social benefits, service benefits and travellers' attitudes and behaviour.

Economic Benefits:

Since 1994 there has been a €15million investment in the real-time passenger information system. Initially the main benefit was the monitoring of the public transport system that enabled Västtrafik to provide the same level of service but reduce its operating fleet by 10% (GoTiC, 2002). The savings were then used for the construction of the new tramline that opened in 2003.

Västtrafik has also realised an increase in patronage of 2% that equates to €2million annually. The overall benefits that Västtrafik are accruing from the system are €15million in annual profit (not taking passenger benefits into consideration) and therefore the system has paid for itself in 1.5 years (GoTiC, 2002).

Social Benefits:

GoTiC has not done any cost benefit analysis of the system. However GoTiC has estimated that there is on average a one-minute reduction in travel time on each trip. Assuming this occurs on 95million trips annually using €6 as the value of time per hour, there is an annual benefit of €9.5million (GoTiC, 2002). One would assume if a full cost-benefit analysis were completed the list of benefits would be substantially longer.

Service Benefits:

The benefits that have been derived from the system as detailed above have enabled the savings to be put back into the system. This has enabled €10million annually to be used for improvements to the system to attract more passengers.

Travellers Attitudes and Behaviour:

In order to ascertain the benefits the passengers derived from the system and identify system aspects utilised, a survey was conducted (GoTiC, 2002). The results showed that in pre-trip planning the majority of passengers used printed timetables or used the public transport call centre. Respondents indicated that they did not use the Internet or mobile phones extensively in trip planning.

Passengers responded positively to the introduction of at-stop and on-street real-time passenger information kiosks. The study noted it enabled passengers to have more control over their trip and at interchange points reduced the time spent changing from one mode to another.

2.9 SUMMARY

The literature review on the benefits of providing real-time public transport information looks at the benefits to the operator and to the passenger. The operator advantages centre on the improvement in performance of the transport network in relation to increased on-time performance and network reliability. The literature presented on the benefits which accrue to the passenger examines the methods by which these benefits are measured. This chapter concludes with a case study on Gothenburg. Gothenburg is seen internationally as a best practice example in the implementation of real-time public transport information. This study demonstrates how a fully integrated and multi-modal real-time public transport information system can benefit a city.

3 METHODOLOGY

3.1 INTRODUCTION

This chapter presents the methodologies followed to construct the stated preference survey and to analyse the subsequent data collected. The first section of this chapter describes the survey design process. This section details the stated preference scenarios examined, the attributes and attribute levels and the factorial design applied. The following section presents the steps completed to construct the survey including the layout of the survey and the motivation behind the questions asked. Section 3.4 discusses the sampling method used to obtain the respondents for this survey. Theories of discrete choice modelling are described in the fifth section, focusing upon the approaches utilised in this thesis. This is followed by a section detailing the estimation procedures used to produce the model coefficients presented in the analysis chapters.

The structure of the analysis completed is described in this thesis is detailed in section 3.7. The final section of this chapter details the behavioural outputs from discrete choice models and their interpretation. The chapter concludes with a summary section.

3.2 SURVEY DESIGN

This section details the design process undertaken to produce the survey. As this survey included a series of stated preference scenarios, it was important that the design of the survey provided sufficient information to respondents to enable them to make the appropriate choices. The scenarios presented to the respondents are described, along with the attributes and attribute levels, and the factorial design process.

3.2.1 Stated preference scenarios examined

In the survey respondents are asked to consider three scenarios. Each of the three scenarios examined is a stage of a public transport trip. The first stage examined is the pre-trip planning stage from home to the respondents' place of work. At this stage it is assumed that the information will be obtained before the individual leaves his/her home to arrive at their public transport stop/station. At this first stage respondents were offered the choice

between accessing information from a call centre, from a public transport web-site or via their mobile phone in the form of an SMS message.

The second scenario asked respondents if they were at their public transport stop/station, which of the following would they use to receive public transport information: at stop PID, from a call centre or via an SMS. The final scenario presented to respondents asked before leaving their place of work, which of the following they would choose to access public transport information from, a call centre, from a public transport web-site or via an SMS.

3.2.2 Attribute levels

In stated preference studies individuals are asked to choose between a number of alternatives which vary by their attribute levels. An alternative in this study refers to the real-time information options (SMS, PID, call centre and the internet). The attributes of these alternatives are the identifying factors which define these alternatives; in the case of this study, cost, wait time saved and the type of information.

In order for individuals to choose between the options presented in this study, it is necessary to place a monetary and a time saved value on the different methods of accessing transport information examined. As this is a stated preference study and the majority of the options presented are currently not available, it is therefore necessary to place a value on these options using similar options already available. This sub-section presents the methodologies used to obtain cost, wait time saved values and the type of information available for the information options examined in this thesis.

Type of information - attribute levels:

It was decided to present two levels of information type: real-time information and static (time-tabled) information. The purpose of these two levels is to ascertain how respondents value the real-time information relative to static information. The same information attribute levels are used for all the alternatives examined, internet, PID, SMS and call centre.

Cost of information – attribute levels:

For each of the options considered, the cost of information had three attribute levels.

Cost - SMS:

To examine what level of cost should be presented to respondents, an examination of international examples was conducted. Table 3-1 below details the cost of receiving real-time information from an SMS.

Table 3-1 International list of SMS charges

City	Real-time information	Cost (€)	Reference
Nottingham	Yes	37c	Nottingham County Council (2004)
London	Yes	Free	Transport for London (2004a)
Dublin	No	30c	Dublin Bus (2007)
Dublin	Yes	30c	Irish Rail (2007)
Adelaide	Yes	Free	Adelaide Metro (2004)
Auckland	Yes	16c	Rideline (2004)
Melbourne	Yes	32c	Metlink (2004)
Berlin	Yes	19c*	BVG (2004)
Munich	Yes	19c*	MVV (2004)

* Just operator charges

The examples above demonstrate that the range of costs vary between 0c and 37c. Using this as a scale for the cost of receiving public transport information via SMS, this study will use the following increments in the cost scale, 0c, 15c and 30c.

Cost - call centre:

As with the cost levels for SMS an examination of international examples was conducted to ascertain what level of cost to present to respondents. Table 3-2 details the cost of receiving real-time information via a call centre.

Table 3-2 International list of call centre charges

City	Real-time information	Cost (€) Per min	Reference
London	Yes	Free	Transport for London, (2007)
UK	Yes	7c-24c	Lancashire County Council (2004)
Helsinki	Yes	34c	YTV Helsinki (2004)
San Francisco	Yes	Free	Muni, San Francisco (2004)
Stockholm	Yes	22c	SL Transport, Stockholm (2004)
Frankfurt	Yes	12c	RMTV Frankfurt (2004)
Vienna	Yes	Free	VL, Vienna (2004)
Adelaide	Yes	Free	Adelaide Metro (2004)

The costs found for SMS similar to the costs of using a call centre range from 0c calls to 34c per call. As the range of costs of using call centre were found to be very similar to the range of costs of using SMS, it was decided to use the same cost structure of 0c, 15c and 30c for using a call centre to receive public transport information.

Cost - PID:

An examination of international examples found no examples where public transport operators charge extra for providing at-stop real-time PID's. Therefore it was necessary to examine literature for willingness to pay amounts for providing real-time transport information via a PID. Table 3-3 below details the cost of receiving real-time information via a passenger information display from several stated preference studies conducted in London.

Table 3-3 List of willingness to pay amounts for at-stop real-time passenger information display

City	Routes	Cost (€) Per trip	Reference
London	36	17c	Wardman. P. (1994)
London	18	38c	Accent Marketing (1995a)
London	18(follow up)	28c	Accent Marketing (1995b)
London	Uxbridge Road	6c	Accent Marketing (1996)
London	Nag's Head	7c	Whelan et al (2002)
London	Nags Head (follow up)	1c	Whelan et al (2002)

From the research available on providing PID displays, there is a range of values between 1c and 38c. As these values are similar to the values reported for SMS and call centre, it was decided to use the same levels once again for the cost of PID, 0c, 15c and 30c for competitive purposes.

Cost - internet:

An examination of the literature and real life examples failed to produce values for the cost of using the internet. One avenue that was explored for this option was to present the cost attribute as the time taken to access information from the web-site. If this approach had been applied, it would have rendered the results from the cost of internet non-comparable to the costs of the other options. Therefore, it was decided to use the same attribute levels as the other options, 0c, 15c and 30c. The cost was described in the survey as an annual subscription fee to a public transport information web-site and that the cost per trip would be one of the following 0c, 15c or 30c.

Time saved attributes:

A search of the literature found no studies for the approximate reduction in wait-time due to the introduction of a real-time information system. Therefore, it was decided to use percentage savings in wait-time. To ensure the potential savings in wait-time were not overestimated, low percentages were chosen of 0%, 10% and 20%. The same wait-time savings were applied to all options. Percentage reductions in wait-time was used to

measure a reduction in wait-time rather than a reduction in minutes as it is assumed that each individual would be familiar with his/her usual. Therefore each respondent can apportion a benefit to this reduction in wait-time.

The attributes and attribute levels used in the survey are presented in tables 3-4, 3-5 and 3-6.

Table 3-4 Attribute levels – stage one

	Attribute Levels		
Attributes	**Internet**	**Mobile Phone**	**Call Centre**
Reduced Waiting Time at stop/station	0%	0%	0%
	10%	10%	10%
	20%	20%	20%
Real-time information given	Yes	Yes	Yes
	No	No	No
Cost	No charge	Free Text	Free Call
	15c	15c	15c
	30c	30c	30c

Table 3-5 Attribute levels – stage two

	Attribute Levels		
Attributes	**PID**	**Mobile Phone**	**Call Centre**
Time Saved at stop/station	0%	0%	0%
	10%	10%	10%
	20%	20%	20%
Real-time information given	Yes	Yes	Yes
	No	No	No
Cost	0c	Free Text	Free Call
	15c	15c	15c
	30c	30c	30c

Table 3-6 Attribute levels – stage three

	Attribute Levels		
Attributes	**Internet**	**Mobile Phone**	**Call Centre**
Time Saved at stop/station	0%	0%	0%
	10%	10%	10%
	20%	20%	20%
Real-time information given	Yes	Yes	Yes
	No	No	No
Cost	No charge	Free Text	Free Call
	15c	15c	15c
	30c	30c	30c

3.2.3 Factorial design

Stated preference studies are concerned with the choice between different alternatives. These alternatives are characterised by attributes. In the case of the alternatives considered in this study, the attributes were; wait time saved, cost and type of information. These attributes and attribute levels are then varied over the three alternatives at each stage examined (SMS, call centre, passenger information display and the internet, depending on the stage). A single combination of these alternatives varied by their attributes and attribute levels is called a treatment. Therefore, a full factorial design is where all possible treatment combinations are enumerated (Hensher et al, 2005).

In the case of the attributes and attribute levels examined in this thesis, two of the attributes, cost and wait time saved have three levels, and type of information has two levels (see Table 3-4, Table 3-5 and Table 3-6). In this study there are three alternatives and 8 attribute levels (3 cost levels + 3 wait time saved levels + 2 type of information levels). Therefore, if a full factorial were to be used of 3^8 there would be 6,561 treatment combinations to be evaluated per scenario and as 3 scenarios (each of the three stages) were to be evaluated this would have meant 19,683 treatment combinations to be evaluated.

3.2.4 Fractional factorial design

It is only really feasible to use a full factorial design process for stated preference experiments with a small number of attributes or variables (Louviere et al, 2000). Fractional factorial design looks at a subset or a sample of complete factorials, to enable particular effects of interest to be estimated as efficiently as possible. This subset of factorials is not simply randomly selected from the full set of factorials; several statistical methods have been developed to produce fractional factorials, to get the best possible values for the estimated coefficients.

As the number of attributes and attribute levels increase, the possible combinations of these also increase exponentially (Bateman et al, 2002). This renders the possibility of using a full factorial impossible. Therefore it is necessary to use the fractional factorial approach. The fractional factorial design approach is an orthogonal main effects only design. This method assumes there is no interaction between each of the attributes, that is, that the effect of each attribute is independent of the value that any other attribute takes.

Louviere et al (2004), justifies examining only the main effects, as they typically account for 70 to 90% of explained variance, whereas the interaction effects typically only account for 5-15% of variance.

To produce a fractional factorial, a statistical package, *SPSS Conjoint*, was used. The method of producing a factorial using this software is described in Hensher et al (2005). An important property in any such design is the property of orthogonally, which means that each of the alternatives has zero correlation with any other attribute. In other words, the influence of changes in any of the attributes on the respondent's choices can be identified and measured. In this way, the impact of attributes on a respondent can be measured separately.

The fractional factorial produced required 36 treatment combinations to be examined in this study. As each of the stages examined has the same number of attributes and attribute levels, in order to evaluate all three stages, 108 (36*3) treatment combinations are to be examined.

3.2.5 Survey versions

Given the high number of treatment combinations required to be examined, it is necessary to split the number of treatments across a number of different versions of the same survey. The minimisation of respondent fatigue is an important consideration when designing the survey. It is important to present the appropriate number of treatment combinations to each respondent. Smith and Desvouges (1987) established that they achieved the most consistent results for ranking sets when respondents were given between 4 and 6 treatment combinations, and concluded that more than 8 combinations confused respondents. However, Johnson and Desvouges (1997) found that for paired ratings, respondents could evaluate up to 26 treatment combinations. Brazell & Louviere (1997) demonstrated that response rates and model parameters were much the same when comparing respondents that had been given 24, 48 and 96 treatment combination sets for a particular task. To conclude, a rule of thumb is that respondents can answer between 1 – 16 treatment combinations, with an average of 8 combinations (Carson et al, 1994).

Based upon the literature outlined above, it was decided to present respondents with 12 treatment combinations, 4 from each stage, with 9 versions of the survey created. As the survey was administered via an online survey it was possible to use a random number

generator to randomly choose one of the 9 versions of the survey as the respondent clicked on the link to the survey. This meant that each respondent had an equal probability of completing any of the 9 versions of the survey. The 108 treatment combinations were then randomly distributed to the 9 versions of the survey. This splitting of stated preference treatments is very common, especially when it is deemed that evaluating the whole model is too much for one respondent, as described in Louviere et al, (2000) and Ben-Akiva & Lerman (1985).

3.3 Survey Layout

This section details the layout of the survey used in this study, a copy of which may be found in Appendix A.

3.3.1 Introduction section

The first section of the survey consisted of a welcome note and some details with regard to the purposes of the survey. In the interests of attaining a higher response rate it was decided to offer respondents an incentive to complete the survey. Church (1993) found that by providing financial incentives, the response rate increased from 28% to 37%. James and Bolsten (1992) found that by offering a monetary incentive of $2 on the first mailing to complete a survey, they attained a 78% response rate. As a monetary benefit for each respondent was not feasible in this study due to the budgetary constraints, respondents were entered into a draw for a prize, as an incentive to complete the survey. The use of a prize draw was reported by Warriner et al, 1996, to result in a 76% response rate.

Following the survey introduction, the first section concentrated upon the details of the respondents' journey to and from work each day. It primarily focused upon which mode of transport they use most frequently and the time it takes to conduct the different stages of their journey. Questions on the characteristics of the respondents' residential location were asked, such as origin and the proximity of residential location to a bus corridors or a light/heavy rail line.

3.3.2 Perceptions of public transport information

The purpose of this section was to ascertain passengers' opinions of the current public transport information provision. Data was collected on what factors would persuade the

respondents to use public transport information. Finally, questions relating to respondents annoyance/frustration while waiting for public transport were asked in this section.

3.3.3 Scenario evaluation

The third section of the survey consisted of the stated preference scenarios. This section began with information on the options to be evaluated and the attributes of each of the methods of obtaining real-time public transport information.

3.3.4 Attitudes to technology

After evaluating the different stated preference scenarios, this section asked several questions on respondents' perceptions of public transport. This section also required respondents to rate the convenience of using the various technologies such as the internet, SMS and call centre to access public transport information.

3.3.5 Socio-economic characteristics

The final section of the survey asked respondents to fill in personal details with regard to age, gender, income, employment status etc. The survey concluded with a comment box for respondents to air any opinions with regard to the survey.

3.4 Sampling Method

This section describes the data collection techniques used in this thesis. The sampling frame and the use of the internet as a surveying tool are discussed. The data collection and the response rate are also reported in this section.

3.4.1 Defining the sample frame

Office based workers in Dublin city centre were the individuals chosen to complete this survey. This sample of individuals was chosen for a number of reasons. Individuals travel from all areas of the greater Dublin area to the city centre, and use all of the various modes of transport available in Dublin. Therefore a sample of individuals that travel to the city centre would provide a good cross section of respondents that would be exposed to all modes of transport in the city. A web-based surveying tool was chosen due to the speed and low cost associated with collecting responses from this method. The internet was also chosen in order to make the choice between alternatives realistic; individuals must have

access to the various methods of obtaining transport information. Therefore, office based workers were chosen as this group are most likely to have daily access to the internet.

3.4.2 The use of the internet as a survey tool

The use of web-based surveys has increased dramatically in recent years, which is mainly due to their ability to collect large amounts of data without the need to conduct interviews, to process results without data entry and the elimination of stationery and postage costs (Witt, K. 1998). However, one must take into account the biases that a web-based survey introduces, in that not all individuals have access to the internet. In Ireland the rates of internet usage is increasing; in 2004, 41.4% of households in Dublin had access to the internet (Central Statistics Office, 2007). Given the fact that it was decided that respondents to the survey should have exposure to the different methods of technology (mobile phone and the internet), the biases associated with using the internet as a data collection tool would not result in a biased sample. Ownership of a mobile phone was not controlled for because mobile phone ownership is currently at 106% (Commission for Communications Regulation, 2006). Indicating that in Ireland in some cases individuals own more than mobile phone.

However, even though the sample chosen was done in such a way as to try maximise the number of people that would have access to each of the technologies examined, it must be noted that some individuals may not have access to all technologies examined. Section 5.6 in chapter 5, details the access to information technology respondents indicated they had on a daily basis.

Web-based surveys have been increasingly adapted for transport studies, for example, in stated preference, travel diaries and travel behavioural studies (Fayish, and Jovanis (2004), Stinson and Bhat (2004), DeSalle and Tarko (2003), Marca (2003)). Table 3-7 details the response rates achieved in a number of studies that have used a web-based survey tool. The studies reported are confined to transport studies. The reported response rates vary from 12% to 50%. This compares to an average response rate of 61% from postal surveys, 70% from face-to-face surveys and 67% from telephone surveys (de Leeuw & Collins, 1997).

Table 3-7 Response rates to internet surveys

Authors	Year	Response Rate %
Farag et al	2002	13
Humpherys. I and Ison. S	2002	19
Raub. T	2002	30
Berfort et al	1996	34
Moiln. E and Chours. C.	2003	37
Cerero. R.	2002	38
Schafer. D.R and Dillman. D. A	1998	41
Hayslett. M.M and Wildermuth B. M	2004	44
Buntine. C.	2002	47
Wells, K. et al	2004	50
Kraan, M et al	1999	12
Watters, P. et al	2006	20

The use of internet surveys has been criticised due to the bias it can introduce as not all members of the population have internet access. Dillman (2000) discusses the disadvantages of this tool and demonstrates how it can introduce bias into estimates. The bias Dillman refers to is the bias towards responses from individuals who have access to the internet and the absence of those who do not.

Given the population of interest where individuals who have access to different forms of technology such as a mobile phone and the internet, it was deemed appropriate to use this tool for data collection. Fricker & Schonlau (2002), indicate that while the internet may not be a perfect approximation of the population, when the population of interest has access to the internet it may be appropriate to use this tool in a case like this.

Iragüen & Ortúzar (2004) indicate that the use of the internet as a survey tool is a potentially very interesting medium for conducting stated preference surveys. The authors discuss the ability of internet surveys to eliminate error in response coding, and the ability to tailor the survey to the individual as some of the other benefits of using the internet in stated preference studies. Stinson & Bhat (2005) found negligible bias when using the internet to administer a survey to measure preferences for bicycle lanes. The study concluded that, due to the fact that the population of interest had good access to the internet, it was the most appropriate method of collecting responses to this study.

Several studies examining real-time traffic information using stated preference techniques have utilised the internet as the main data collection tool. Hato et al (2000) used the internet to elicit responses for a route choice stated preference analysis of drivers responding to real-time traffic information. A similar study was conducted by Kraan et al

(2000), where the use of advanced transport information was examined for use in recreational and shopping trips. The authors administered their stated preference survey via the internet to examine respondents' departure times and their uses of real-time traffic information. Killi & Samstad (2003) used an internet survey to estimate willingness to pay for real-time traffic information. This study examined commuters' preferences and estimated willingness to pay amounts based upon data obtained from an internet survey.

Based upon the discussion above and the cost and time advantages of using the internet as a survey tool, it was deemed the most appropriate tool for collecting the survey responses required in this thesis.

3.4.3 Simple random sample

Random sampling is a process whereby every subject in the population of interest has an equal and independent chance of being selected (Dillman, 2000). The sampling procedure used to elicit survey respondents in this thesis uses a simple random sampling process to select the companies to target with the survey.

3.4.4 Sampling strategy used

The population defined for this study was office based workers in the Dublin 2 (post code) area (city centre). An on-line business search tool called KOMPASS was used to search for office based businesses in this area. At the time of the survey there were 1,718 office based companies in this area (KOMPASS, 2005).

Having defined the number of companies, it was necessary to get the number of employees to produce an estimate of the population of office workers in Dublin city centre. Using the Dublin 2 area as the search criteria in KOMPASS it was utilised to obtain the number of employees that work in the Dublin 2 area. Traditionally one would use government statistics to ascertain the number of individuals that work in a particular zone. At present, government agencies only collect employment data by electoral district (ED). These data only contain the number of people that live in that ED and are employed, and not the actual number of people that live elsewhere and work in that ED. Therefore, using any ED data was ruled out for the following reasons:

1. The data for EDs only contains the number of people employed in that ED

2. For comprehension purposes, when completing the survey it is likely that respondents' will have a better understanding of postal codes as opposed to ED
3. A comprehensive data set of people working in the Dublin 2 area was not available

KOMPASS categorises companies by the number of employees into eight classifications as seen in Table 3-8. Therefore in order to calculate a population the midpoints between the numbers of employees were taken and multiplied by the number of companies to provide a proxy of the total number of people working in the Dublin 2 area. By using the midpoint estimate, the population of employees working in Dublin 2 has been estimated at 60,428 as seen below.

Table 3-8 Number of office based workers in Dublin 2

Employee Ranges	Midpoint	No of Companies		No of Employees
		N	%	
1 – 10	5	962	56	4810
11 – 20	15	344	20	5160
21 – 50	35	240	14	8400
51 – 100	76	83	5	6308
101- 250	176	48	3	8448
251 – 500	376	14	1	5264
501 – 1,000	746	14	1	10444
1000 +	1000	14	1	14000
Total		**1725**	**100**	**62834**

3.4.5 Defining the Sample size

When defining the sample size the following considerations need to be taken into account:

- The amount of sampling error that can be tolerated
- The population size
- How varied the population is with regard to the characteristic of interest
- The confidence interval one wishes to estimate the population with

The sample size can be estimated by using Equation 3-1 (Dillman, 2000).

Equation 3-1

$$Ns = \frac{(Npp)(pp)(1-pp)}{(Npp-1)(B/C)^2 + (pp)(1-pp)}$$

Where: Ns = sample size required for the desired level of precision

Npp = Size of population

pp = Proportion of the population expected to choose one of the two response categories

B = Acceptable amount of sample error

C = Z statistic associated with the confidence level

The $(pp)(1\text{-}pp)$ expression in equation 3-1 is a measure of the expected variation in answers to a question of interest. For example in a question with two possible answers A and B, this expression measures how much the population of interest is varied in answering the question of interest. In order to allow for the maximum variation in the sample, a 50/50 split was chosen, resulting in a 50% chance an individual would choose an option, and 50% that they would not. For example, with a 5% sampling error allowed at a 95% confidence level and a population of 60,428, the following sample size was estimated.

$$N_s = \frac{(62834)(0.5)(0.5)}{(62834-1)(0.05/1.96)^2 + (0.5)(0.5)} = 382$$

As stated above, the sample size is dependent upon the amount of sampling error and the confidence interval chosen. If, at this stage, we decide upon a confidence interval of 95% and accept a sampling error of 5%, this results in a sample size of 382.

3.4.6 Data collection

The survey was conducted over a two-week period from the 18th April – 9th May 2005 using web-based methods. A controlled sample was taken of office workers in Dublin city centre. Companies were randomly drawn from the KOMPASS database of all companies operating in Dublin 2. The selected companies were contacted via their human resources department and the survey was then sent out centrally to all employees. A total of 1,500 surveys were distributed to the employees of the companies targeted. 495 fully completed surveys were returned, resulting in a response rate of 33%. The response rate of 495 is greater than the required sample size calculated above. Therefore, the results in this thesis can be said to be a good approximation of the population of office based workers in Dublin city centre, with internet access.

Stated preference studies use the concept of pseudo respondents when constructing a database for respondents. This concept essentially means that every choice made by a respondent in the stated preference scenarios is treated as an individual respondent. Each

respondent was required to evaluate 12 choice observations, which results in 5,940 pseudo respondents.

3.5 Discrete Choice Modelling

This section presents the main concepts of discrete choice modelling. The basic concepts of random utility theory, multinomial logit and nested logit models are presented. For more detail on these approaches see Ben-Akiva & Lerman, 1985, Louviere et al, 2000, Train, 2003 or Hensher et al, 2005.

3.5.1 The choice set

Discrete choice models describe decision makers' choices among a set of alternatives. In order for alternatives to be included in a choice set they must have the following traits. Firstly, they must be mutually exclusive, whereby choosing one alternative necessarily implies not choosing any of the other alternatives. The alternatives must be exhaustive where all possible alternatives are considered. Finally, the choice set must be finite, in that the alternatives have a maximum number (for more detail see Train, 2003).

3.5.2 Random utility theory

Discrete choice models are usually derived under the premise of a utility maximising consumer and therefore use random utility theory. This sub-section presents the main aspects of this theory.

In random utility theory it is assumed that an individual will derive utility from alternatives J. The utility that one derives from alternative j is $U_{nj}, j = 1,...,J$. Individuals will choose the alternative that he/she will derive the highest utility from. As stated in Equation 3-2, the individual will only choose alternative i, if and only if the utility he/she derives from this alternative is greater than all the other alternatives in the choice set.

Equation 3-2

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

In the case of this study, the respondent will only choose the real-time transport information option he/she derives the maximum utility from.

Utility is assumed to be composed of a deterministic component V_i and a random component ε_i. The deterministic component can be measured, as this component is related to the alternatives in the choice set. The random section can not be measured, and the most appropriate way to model this component is to assign a distribution to the random element and estimate the probabilities of choice. Therefore, in random utility models the utility expression is outlined in Equation 3-3.

Equation 3-3

$$U_i = V_i + \varepsilon_i$$

As the random component cannot be measured, it is assumed to be set to a probability distribution defined by the model used to analyse the data (Train, 2003). As the random component cannot be modelled, the probability that individual n will choose alternative i can be expressed as in Equation 3-4.

Equation 3-4

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

Therefore, the probability that the respondent will choose alternative i is the probability that the utility of that alternative is greater than any of the other alternatives in the choice set.

3.5.3 Multinomial Logit Model

The multinomial logit model (MNL) is one of the most widely used discrete choice models. This sub-section presents the main features of this model (see Louviere et al (2000) or Train, (2003) or Hensher et al (2005) for a more comprehensive review of this model).

The model is derived under the premise that the error term is identically and independently distributed or Gumbel distributed. This results in the probability of choosing an alternative as expressed in Equation 3-5.

Equation 3-5

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

P_i is the probability that the individual will choose alternative i, V_i is the deterministic element of utility for alternative i and J is the number of alternatives in the choice set.

One of the main assumptions in the use of the MNL model is that the ratio of probabilities of choosing any two alternatives is independent of the choice set (Ben-Akiva & Bierlaire, 1999). In the context of this study this means that within the choice set, PID, SMS and call centre, the ratio of probabilities of choosing either PID or SMS is the same, whether or not call centre is in the choice set. This is called the independence from irrelevant alternatives (IIA) property. The IIA for any two alternatives i and k, the ratio of the logit probabilities can be termed as in Equation 3-6.

Equation 3-6

$$\frac{P_{ni}}{P_{nk}} = \frac{e^{V_{ni}} / \sum_j e^{V_{ni}}}{e^{V_{nk}} / \sum_j e^{V_{nk}}}$$

Equation 3-6 states the ratio of probability of individual n choosing either alternative i or k, is related to the logit probability of an individual choosing such an option (as outlined in equation 3-5).

Hence, the ratio of choice does not depend upon any alternatives only i and k (Train, 2003). The IIA property brings a number of advantages to the estimation of MNL models. Hensher et al, (2005) demonstrate that one of the main advantages of the IIA property is the ability to deal with a large set of alternatives to estimate a model on a sub-set of these alternatives. Train, (2003) points to another advantage of the IIA property in that if one were only interested in a respondent's choice between two alternatives, even if the choice set contains multiple alternatives, providing the IIA property holds, the MNL can make estimates on this sub-set.

However, the IIA property of MNL models is the most criticised component of the model. The literature highlights several examples where the differences between the alternatives

are such that the IIA property becomes unrealistic. Ben-Akiva & Lerman, (1985), demonstrate this with the blue-bus, red-bus example. Therefore, when the difference between two choices is minimal, it may result in biased estimates and incorrect predictions, where the IIA property has been violated (Louviere et al, 2000).

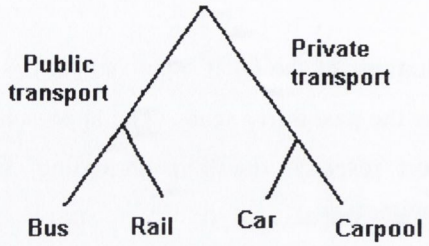
Notwithstanding the limitations of the MNL approach, it has been widely applied in the transport research field for the past thirty years. The approach has been used to evaluate a wide number of transport research questions including; mode choice, road pricing, evaluation of environmental impacts of transport and in many other fields such as marketing, medicine and environmental economics.
The majority of the discrete choice modelling conducted in this thesis uses the MNL approach; see section 3.6 for detail on the estimation techniques of the approach.

3.5.4 Nested logit models

Given the restrictive nature of the MNL model due to the IIA assumption, approaches such as the nested multinomial logit model have been developed. These models use generalised extreme value (GEV) models to model the unobserved proportion of the utility function. GEV models allow for correlations over alternatives. A nested logit model can be used when a set of alternatives faced by the decision maker can be partitioned into subsets or a nest, providing the IIA property holds (Ben-Akiva & Lerman, 1985). This sub-section provides an overview of the nested approach. Louviere et al (2000) or Train (2003) or Hensher et al (2005) or Ben-Akiva & Lerman, (1985) can be referred to for a more detailed overview of this model.

The following example describes the nested logit approach. Take the example of a mode choice situation, with a decision between bus, rail, car and carpool. A nested logit approach could nest this choice situation between public transport and private transport, as in Figure 3-1. In the terminology used in this approach, the public transport choice represents a branch and bus or rail a limb.

Figure 3-1 Example of a nested logit approach



The theory follows a similar approach to that of the MNL model, in that it is utility maximising. Therefore, let the set of choice alternatives j be partitioned into K non-overlapping subsets denoted by $B_1, B_2, ..., B_K$. These are called nests. Utility as in the MNL model has an observable proportion and an unobservable proportion. Nested logit models assume that unobserved utility is contained in a vector and has a cumulative distribution as in Equation 3-7. In equation 3-7, the parameter λ_k is a measure of the degree of independence in unobserved utility among the alternatives in nest k.

Equation 3-7

$$\exp\left(-\sum_{k=1}^{K}\left(\sum_{j\in Bk} e^{-\varepsilon_{nj}/\lambda k}\right)^{\lambda_k}\right)$$

The nested logit model approach assumes that the error term may be correlated among alternatives in each nest, but not between nests. The closer λ_k is to 1 the lower the correlation, and the closer to 0 the greater the correlation. The probability for alternative $i \in B_k$ is given in Equation 3-8. This is also known as the LOGSUM coefficient. Equation 3-8, demonstrates that the probability of individual n will choose option i, is

Equation 3-8

$$P_{ni} = \frac{e^{V_{ni}/\lambda_k}\left(\sum_{j\in Bk} e^{V_{nj}/\lambda_k}\right)^{\lambda_k - 1}}{\sum_{\ell=1}^{K}\left(\sum_{j\in B\ell} e^{V_{nj}/\lambda_\ell}\right)^{\lambda_\ell}}$$

The estimate of the probability of choosing alternative *i* is conditional on choosing the nest alternative of which *i* is a member. Therefore the probability of alternative *i* amongst the possible *J* alternatives belonging to nest *B* out of a total *N* nests, with a nested structure of one level (an example of which can be seen in Figure 3-1) is given by Equation 3-9.

Equation 3-9

$$P_i = P(B).P(i \mid B) = \frac{e^{\mu(V_m+L_m)}}{\sum_{n\in N} e^{\mu(V_m+L_m)}} \cdot \frac{e^{\mu(\beta_m V_i)}}{\sum_{j\in J} e^{\mu(\beta_m V_i)}}$$

The expected maximum utility of the j^{th} alternative in nest *B* is given in Equation 3-10.

Equation 3-10

$$L_n = \frac{1}{\beta_n}\left(In \sum_{j\in J} \exp(\beta_n V_i) \right)$$

The nested logit approach is applied in chapter 8 of this thesis to ascertain if this approach is an improvement upon the MNL approach which is used in the majority of this thesis.

3.6 Maximum Likelihood Estimation of Discrete Choice Models

This section details the estimation process used to estimate the utility coefficients in the discrete choice models used in this thesis. The maximum likelihood estimation approach assumes that a given sample could be generated by different populations, and it is more likely to come from one population rather than another. In other words, the maximum likelihood estimates are the set of population parameters that produce the observed sample most often. The remainder of this section details the theory behind maximum likelihood estimation and its application in the MNL model. The theory presented in this section is based upon the following texts Louviere et al, (2000), Mittlehammer et al, (2000) and Pudney, (1989).

The following example is presented to illustrate the principles of the maximum likelihood approach. Consider a random set of *n* observations of a random variable Z denoted by (z_1, z_2,…,z_n), which are drawn from a population characterised by parameter θ. The probability density function of Z given some value of θ, and if all the *n* values of Z in the

sample are independent, then the joint probability density function may be written as in Equation 3-11.

Equation 3-11

$$f(z_1, z_2, ..., z_n \mid \theta) = f(z_1 \mid \theta) f(z_2 \mid \theta), ..., f(z_n \mid \theta)$$

In the joint probability density function in Equation 3-11, the Zs are considered to be variable, and the θ fixed. Equation 3-11 may be transformed from a probability density function to a likelihood function if the Zs are assumed to be fixed and the θ is allowed to vary. Using this approach, it is then possible to make postulations on the population characterised by θ, based on some value of Z.

The above may be extended to situations where the population is defined by more than one variable θ. As the Zs follow a normal distribution, they will be characterised by a mean (μ) and a variance (σ^2). Defining θ as a 2-dimensional vector of elements (μ, σ^2), it allows the likelihood function detailed in Equation 3-11 to be maximised to a vector of θ.

The following derives how the maximum likelihood approach is used for MNL models. Suppose a random sample of Q individuals is examined, for each of the individuals we have an observed choice made by the individuals and we have the values of X_{jkq} (where X_{jkq} is the value of the choice set observed by individual q). If individual q is observed to choose i, the probability density function for that observed choice (or data point) is $f(\text{Data}_q|\beta)$. Data_q is the observed data for individual q, and β is the vector of utility parameters contained in the observable component of utility V_{jq} (for the set of alternatives J observed by individual q). Based upon these assumptions, if all of the observations are independent, the likelihood function can be rewritten replacing $f(\text{Data}_q|\beta)$ by the expression for the probability of the alternative actually chosen by the individual. Assuming the order of observations follow the following sequence, where n_1 individuals choose alternative 1, and n_2 individuals choose alternative 2 and so on, the likelihood function may be written as in Equation 3-12.

Equation 3-12

$$L = \prod_{q=1}^{n_1} P_{lq} \prod_{q=n_1+1}^{n_1+n_2} P_{2q}, ..., \prod_{q=Q-n_J+1}^{Q} P_{Jq}$$

Equation 3-12 can be simplified by introducing a dummy variable f_{jq}, which is equal to 1 if j is chosen and 0 otherwise. Resulting in the simplification of the previous equation to the expression found in Equation 3-13.

Equation 3-13

$$L = \prod_{q=1}^{Q} \prod_{j=1}^{J} P_{jq}^{f_{jq}}$$

Given the previous two expressions the log likelihood function may be written as in Equation 3-14.

Equation 3-14

$$L^* = \sum_{q=1}^{Q} \sum_{j=1}^{J} f_{jq} \ln P_{jq}$$

In the equation above, the L^* is maximised with respect to the βs contained in the utility expression producing utility estimates for the alternatives being examined. The estimation of the MNL and nested models presented in this thesis were completed using ALOGIT 4.2 (Hague consulting, 2004). This is popular discrete choice modelling software used extensively in the stated preference analysis field.

3.7 Discrete choice Modelling Approach Applied

This section presents the methods of discrete choice modelling applied in this thesis. The approach reported in this section was used in chapters 6, 7 and 8.

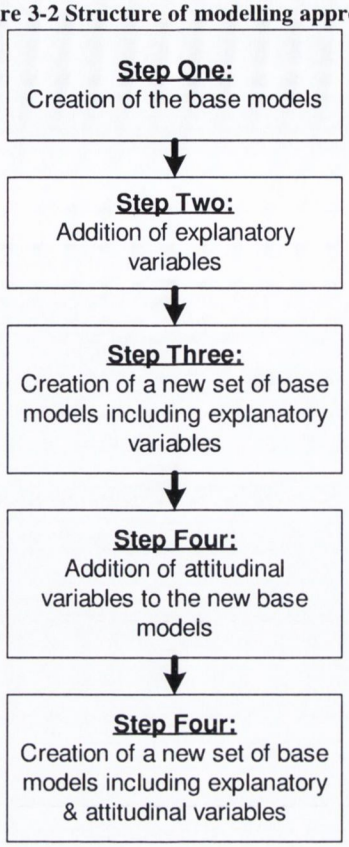
3.7.1 Structure of the analysis

This first sub-section details the steps taken to produce the final models in this thesis. The modelling approach applied took a step-by-step approach, adding variables to the base models to improve the model performance and increase the explanatory power of the models. Figure 3-2 details the steps taken to produce the final models, which are analysed in chapter 8. The objective of this approach is to test the variables to ascertain their impact upon the performance of the model, adding significant variables to improve the explanatory power of the models.

The first step taken was to produce base modes. These base models consist of estimates for the alternatives (PID, SMS, call centre and the internet) and the attribute levels (cost, wait time saved and information type). Chapter 6 presents the results of the second step, which added the explanatory variables such as, age, income, mode of transport used etc, to the base models. The third step added a group of explanatory variables to the base model to produce a new set of base models. These new base models were then used in chapter 7 to examine the impact of attitudinal variables. The new base models were used as opposed to the old ones, as these models were proven to have a higher explanatory power compared with the old base models.

The fourth step in the modelling approach is detailed in chapter 7, where a series of attitudinal variables are added to the new base models to test for significance. The final step in the modelling process was the creation of a set of new base models, which include attitudinal and explanatory variables. These final models are shown to have a higher explanatory power than the preceding models. These final base models are used in chapter 8 to produce willingness to pay and elasticity values.

Figure 3-2 Structure of modelling approach



3.7.2 Introducing explanatory and attitudinal variables

The addition of the explanatory variables into the utility equations for each of the options examined was completed using the following steps.

Taking the gender variable for example, the procedure followed would see this variable added to each of the utility equations to examine which equation produced the most significant result. The significance of the result was determined by the *t*-ratio value. The *t*-ratio with the most significant result was chosen and reported. For example, if the reported *t*-ratios for the inclusion of mode of transport were 1.9, 3.4 and 2.1, for SMS, PID and call centre, the PID value of 3.4 would be used and reported.

In discrete choice modelling, it is not possible to include the variable of interest with all of the utility equations, as it would result in the variable collapsing and becoming a constant in the model. This would render the coefficients produced relating to the variable in question becoming useless, as they would have no relation to the variable in question.

The other values would be tested, and where the inclusion of the mode of transport variable resulted in a different sign or an insignificant *t*-ratio, these differences were reported.

3.7.3 Summing variables

Summing of variables to create a single variable for analysis is conducted on variables relating to frustration and convenience in chapter 7. The approach uses a simple scoring approach where a number of single variables are summed to produce a single combined variable to represent a single factor. This process involves more than one variable which is given a score relative to the definition of that variable.

Consider a variable measuring comfort on public transport, with the following levels, comfortable, not comfortable and uncomfortable. This could be given a rating scale of 0, 1 and 2, the higher the number the greater the level of discomfort. A second variable measuring at-stop wait time, with the following levels, 0-5 minutes, 5-10 minutes and 10-20 minutes, these are given a rating scale of 0, 1 and 2 respectively. A variable is then created to measure overall satisfaction with public transport, assuming this variable is comprised of comfort and wait time. This variable is created by adding the score for comfort to the wait time score to produce a variable for overall satisfaction.

Stradling et al (2007) used a similar approach to measure satisfaction with travel modes. The authors combined several factors pertaining to travel mode and produced a factor termed 'disgruntlement' with mode of transport. Saleh & Farrell (2005) also employed this methodology to define flexibility of departure time in the context of a road pricing study.

3.8 Measuring the Performance of Discrete Choice Models

As with all modelling techniques, there are certain statistics and tests which need to be interpreted from the output of discrete choice models. This section examines statistics and tests which are used for the evaluation of the performance of MNL models. This section also explains how model performance was measured in this thesis, and how improvements in model performance were measured.

3.8.1 Sign of the coefficient

An important aspect to interpret in this thesis is the sign of the utility coefficients. These signs should make intuitive sense when interpreting them. For example, one would expect a cost coefficient to be negative because when cost rises individuals are less likely to demand the good in question.

3.8.2 Statistical significance of the coefficients

An important element in assessing the performance of an individual coefficient is that the estimated coefficient can be said to be statistically different from zero. Discrete choice models use the *t*-ratio to determine if the statistic produced is statistically different from zero. Standard *t*-tests provide a significance level of rejecting the null hypothesis. The null hypotheses being that coefficients estimated are statistically different from zero. The *t*-values are placed in brackets next to each estimated coefficient in this thesis. A *t*-value of < ±2.56 rejects the null hypothesis at the 99% confidence level and value of between ± 2.56 and 1.96 is significant at the 95% confidence level. Whilst values of between ± 1.96 and 1.50 are significant at the 85% confidence level, they are not considered in this thesis, and *t*-values below 1.9 are considered not to be significant. To accept a coefficient with a lower significance can be said to be stretching the usefulness of the estimate (Louviere *et al*, 2000).

3.8.3 *Rho*-squared values

This model estimate is similar to the R^2 in regression modelling, in that it is a measure of goodness of fit (Louviere et al, 2000). The statistic called the likelihood ratio index is used with discreet choice models to measure goodness of fit. This test measures how the estimated model performs against a model where all the parameters are set equal to 0. The statistic is called *rho*-squared (ρ^2) and it provides values between 0 and 1. Equation 3-15 details how to calculate *rho*-squared.

Equation 3-15

$$\rho^2 = 1 - \frac{LL(\hat{\beta})}{LL(0)}$$

In this case $LL(\widehat{\beta})$ is the value of the log likelihood function, and $LL(0)$ is the value of the parameters when they are set to equal to 0. Under this the likelihood ratio has a range of between 0 – 1, and the model with the higher ρ^2 it is fair to say fits the data better. Two

rho-squared values are reported in this thesis; the first is *rho*-squared with respect to zero ($\rho^2(0)$) as calculated in Equation 3-15. To calculate *rho*-squared with respect to constants $LL(0)$ is replaced with $LL(c)$ where $LL(c)$ is the log-likelihood of the model is estimated with respect to a constant. *Rho*-squared with respect to zero measures how much of an improvement the estimated model offers over a model that assumes all parameters are zero. R*ho*-squared with respect to constants measures how much of an improvement the estimated model offers over a model that assumes all parameters are zero, but also allows for a constant (Train, 2003). The literature on discrete choice models indicate that a good *rho*-squared should be between 0.2 and 0.4 (Louviere et al 2000).

3.8.4 Likelihood ratio test

The likelihood ratio test measures the performance of one model relative to another model. Typically in MNL modelling this test is used to compare models, one which may have additional variables included in the model, and the other without these variables. Thus the purpose of the test is to ascertain if the inclusion or omission of the said variables improves the model fit.

This statistic uses the measures of the difference between two models using the final likelihood statistics from both models and using the following formula:

Equation 3-16

$$L^* = -2[L(0) - L(\beta)]$$

Here L^* is the likelihood ratio and $L(0)$ is the final likelihood of the base model, and $L(\beta)$ is the final likelihood statistic from the model with different number of variables. A specified level of confidence is taken (0.1 or 0.5) with the given degrees of freedom from the chi-squared tables. If the estimated value of the chi-squared exceeds the critical value of the specified level of confidence, the null hypothesis is rejected. That is the $L(0)$ has a better model fit than $L(\beta)$.

3.8.5 Tests of the IIA property

As detailed in section 3.5.3 the IIA property is one of the most important assumptions of the MNL model. This sub-section details the Small & Hsiao (1985) test which was used to search for violations in the IIA property. The IIA property states that the probability of choosing one alternative from a choice set which contains three alternatives is the same

with or without the third alternative present. The Small & Hsiao test examines this property by splitting the choice set and examining the differences between the reported log-likelihood ratios.

The following procedure must be followed to conduct the Small & Hsiao test (see Small & Hsiao, 1985 for more detail on this test):

1. The dataset is split into two samples N^A, and N^B, model parameters are then obtained by running MNL models using both data sets, resulting in parameter estimates for both models (β^A and β^B)
2. A weighted average of these estimates is then calculated using Equation 3-17

Equation 3-17

$$\beta^{AB} = (1/\sqrt{2})\beta^A + (1-1/\sqrt{2})\beta^B$$

3. Omit one of the choice outcomes from N^B, therefore N^{B*}, is the reduced sample. For example in this study this would be the omission of either SMS, a call centre or the internet from the choice set.
4. Once again estimate two models, on with the full choice set N^A and one with the restricted choice set N^{B*}
5. One of the models should be constrained using the parameter vector β^{AB} as calculated in Equation 3-17.
6. The second model is estimated with the unconstrained parameter vector β^{B*}
7. The final likelihood estimates of the two models are compared by substituting them into

Equation 3-18

$$\chi^2 = -2[LL^{B*}(\beta^{AB}) - LL^{B*}(\beta^{B*})]$$

8. The critical value estimates from Equation 3-18, are compared to a chi-squared statistic calculated with the number of degrees of freedom equal to the number of parameters in β^{AB}
9. The null hypothesis, that there is a violation of the IIA property, will be accepted in the critical value estimated by Equation 3-18 is less than the chi-squared value, and vice versa.

3.8.6 Decision process for identifying an improvement in model performance

The modelling approach in this thesis starts with base models which have been estimated using just the coefficients estimated for the attributes and attribute levels (as seen in the utility expression below).

$$U_{SMS} = \alpha_1(COST) + \alpha_2(TIME_SAVED) + \alpha_3(TYPE_OF_INFO)$$

These initial base models have been enhanced with the inclusion of explanatory variables such as age, gender and frustration levels etc. These additional variables were included in the utility equation to ascertain their impact upon the utility derived from the specific option.

$$U_{SMS} = \alpha_1(COST) + \alpha_2(TIME_SAVED) + \alpha_3(TYPE_OF_INFO) + \alpha_4(age) + \alpha_5(income).....$$

The inclusion of additional variables can improve the performance of the model and this is seen by improvements in the *rho*-squared values. The following criteria have been used in this thesis to identify that a model with additional variables is an improvement on the base model.

1. The *t*-values which correspond to the coefficients in the model are significant at the 95% level that is greater than 1.96. This indicates that the coefficient is significant and has an impact upon utility.
2. There is an improvement in the *rho*-squared values.
3. Finally, that the likelihood ratio test rejects the null hypothesis, that is that this test demonstrates that the newly estimated model with the additional variables demonstrates an improvement in goodness of fit compared to the base model.

Providing the model passes these three criteria, it is then used to estimate further models. Chapter 6 adds explanatory variables to the models such as mode of transport, age, gender etc. The chapter tests the inclusion of various variables, and concludes with models which have demonstrated the best model fit, that is it passes all three criteria above. The chapter concludes with three models which were found to produce the best model fit. Chapter 7 introduces attitudinal variables such as frustration with public transport and perceptions of the quality of public transport information with the final models produced in chapter 6. These models include both explanatory variables and attitudinal variables. The final

models in chapter 7 are the final models produced in this thesis, and it is these models that are used to interpret the willingness to pay and elasticity values in chapter 8.

3.9 Behavioural Outputs of Discrete Choice Models

Discrete choice models are used to calculate several behavioural outputs. This section details the theory and the methods to calculate elasticity and willingness to pay estimates.

3.9.1 Segmented models

Segmented models split the data set by a specific characteristic. In the case of the segmented models used in this thesis, the data set has been segmented by mode of transport. The models are estimated in the same way as the other models, however, the coefficients estimated pertain to the specific characteristic of the segment, for example bus users. Therefore, coefficients produced may be interpreted as to be directly attributable to the user group, enabling elasticises and willingness to pay amounts to be estimated for specific user groups.

3.9.2 Direct point elasticity

Direct point elasticity measures the percentage change in the probability of choosing a particular alternative in the choice set with respect to a given percentage change in an attribute of that alternative (Louviere et al, 2000). To put it in the context of this study, direct point elasticity measures the percentage change in probability of choosing for example SMS, if there was a 1% increase in the cost of SMS.

Equation 3-19

$$E_{x_{ikq}}^{P_{iq}} = \frac{\partial P_{iq}}{\partial X_{ikq}} \cdot \frac{X_{ikq}}{P_{iq}}$$

The above equation details the probability of choosing alternative i for individual q with respect to a change in the kth variable which represents the utility of the ith alternative for individual q. Elasticises calculated in this study represent the impact of a 1% increase in the cost of information to the respondent.

3.9.3 Willingness to pay

Discrete choice models can be used to calculate the amount that a respondent would be willing to pay for a particular good. In linear models such as those presented in this study where each attribute in a utility expression is associated with a single taste weight, the ratio of these two utility parameters can be used to estimate willingness to pay (Hensher et al, 2005). Willingness to pay can also sometimes be termed the marginal rates of substitution. Equation 3-20 is used to calculate an individuals willingness to pay, where β_{ia} is a coefficient for attribute *a,* for example type of information, and β_{ib} is a coefficient for attribute *b,* for example cost of information. In this study willingness to pay amounts were calculated for type of information, thereby producing willingness to pay amounts for real-time information.

Equation 3-20

$$WTP = \frac{\beta_{ia}}{\beta_{ib}}$$

3.10 Summary

This chapter presents the processes used to produce the results presented in chapters 5, 6, 7 and 8. A discussion on the appropriateness of the approaches used is presented in the conclusions and discussion chapter. Several of the statistical tests described in this chapter are applied in the subsequent analysis chapters.

4 UNDERSTANDING PERCEPTIONS OF REAL-TIME PUBLIC TRANSPORT INFORMATION

4.1 INTRODUCTION

This chapter presents the results of two preliminarily studies undertaken before the main stated preference questionnaire was conducted. The purpose of these studies was to help frame the final questionnaire, by obtaining a better understanding as to the perceptions and opinions of real-time public transport information. The first study presented reports the findings of an at-stop survey conducted on the Lucan bus corridor. The purpose of this survey was to evaluate the introduction of real-time passenger information displays on this bus corridor. The survey asked respondents their opinions on the passenger information displays, and how they would use the information provided by the display.

The second study presented in this chapter focuses on public transport information. For this study a questionnaire was developed asking broad questions about public transport information. The purpose of this questionnaire was to test and develop scenarios for the final stated preference questionnaire. As there is a limit to what can be analysed in the final questionnaire, this study examined a variety of transport information options. This chapter concludes with a discussion of the two studies presented in this chapter, with specific reference to the decisions made based on the findings from these studies.

4.2 AT-STOP SURVEY

This section presents the results from an at-stop study conducted to evaluate a system of at-stop real-time transport information on the Lucan bus corridor. The details of this system of real-time information are presented in section 3.2. The results in this section are based largely on Caulfield and O'Mahony (2004).

4.2.1 Purpose of the research

The purpose of this survey was to understand how passengers who receive real-time public transport information use this information. A further aim of the survey was to ascertain if

passengers require any extra information to be displayed. One of the main benefits of real-time information is that passengers at the bus stop know that the bus is coming and the estimated time of arrival. This questionnaire attempted to ascertain what the passenger would do during this time, as they knew exactly how long they would be waiting; either continue to wait at the bus stop or leave and pursue some other activity. The second part of the questionnaire asked the passengers were they happy with the information provided. Passengers were also provided with a list of additional information that could be provided and asked which of the following information they would like to see displayed? They were also asked to 'rank these in order of importance 1-5, 1 being the highest and 5 the lowest'. The following attributes were presented to respondents, times of connecting buses, is the bus arriving full, the current time, traffic news, expected time of arrival at major bus stops on route e.g. City Centre, cost of the journey, if seating is available on the approaching service, and the location of local amenities.

4.2.2 At-stop study - methodology and data collection

The responses were collected over the same sample period 19th February to the 25th March 2003. Passengers waiting at the bus stop were asked several questions with regard to the information provided at the bus stop (see appendix B for a copy of the questionnaire). 71% of individuals approached responded to the survey (see Table 4-1).

Table 4-1 Response rate from the at-stop survey

	Responses	Non-responses
Number of Responses	257	102
Percentages of Responses (%)	71	29

4.2.3 At-stop study - results

The following section outlines different characteristics of the sample such as gender and age distribution.

The characteristics of the respondents are presented in Table 4-2. The results show that 52.6% of the respondents were male and 47.4% female. The distribution of age showed that 50.7% of respondents were in the 20-29 age group, 18.9% in the 30 – 39 age group and 14.6% under 20. The questionnaire asked respondents their occupation and 72.5% were found to be professionals, 19.9% students and 7.6% retired/pensioners.

Table 4-2 At-stop survey – Respondent characteristics

	Frequency	Percent (%)
Gender		
Male	135	52.6
Female	122	47.4
Total	257	100.0
Age Group		
Under 20	38	14.6
20 – 29	129	50.7
30 - 39	49	18.9
40 – 49	21	8.2
50 – 59	4	1.4
Over 60	16	6.2
Total	257	100.0
Occupation		
Professional	186	72.5
Student	51	19.9
Retired/pensioner	20	7.6
Total	257	100.0

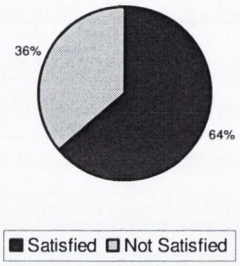
Table 4-3 details the distribution of frequency of bus patronage. 62.7% of respondents were found to use the bus 5 or more times per week and 23.4% use the bus 3 – 5 times a week.

Table 4-3 At-stop study – frequency of bus patronage

Frequencies	Frequency	Percent (%)
5 + times a week	160	62.7
3 – 5 times a week	60	23.4
1 – 2 times a week	23	8.9
1 – 3 times a week	14	5.0
Total	257	100.0

During the survey period passengers were asked if they were satisfied with the information provided and, if not, what extra information they required. The first question passengers were asked were they satisfied with the information displayed on the PID. Possible answers to the question were either yes or no. Figure 4-1 below shows the number of passengers that responded to the question and their answers. The results show that 64% of respondents were satisfied with the information provided, and 36% indicated that they were not satisfied.

Figure 4-1 At – stop study – satisfaction with information provided



(N=257)

Respondents were presented with a list of additional information attributes that could be added to the current real-time information display. Passengers were asked to list in order of preference from the list of attributes. The results have been outlined in Table 4-4. The first column details the attribute offered and the following columns the number of individuals in the sample selecting a particular level of preference (percentage of total is also presented). The numbers of individuals selecting each preference rating are then used to come up with a ranking of the options in terms of their popularity and this is presented in Table 4-5. The top three options were 'to show the current time', to show 'is seating available' and to show 'is the bus arriving full'.

Table 4-4 At-stop study – preferences for additional transport information

	First Preference (%)	Second Preference (%)	Third Preference (%)	Fourth Preference (%)	Fifth Preference (%)
Option					
Times of the connecting buses	-	5.2	16.7	8.8	6.1
Is the arriving bus full?	18.0	25.3	16.0	7.3	0.2
The current Time	31.0	14.4	16.7	13.7	11.6
Traffic News	13.0	5.8	9.1	7.8	5.5
Expected time at major stops i.e. city centre	8.0	7.4	10.1	14.7	10.2
Cost of the Journey	5.0	10.0	7.3	17.2	8.2
Is seating available	16.0	25.3	18.0	6.1	15.7
Location of the nearest shop	3.0	2.9	0.2	4.9	2.7
Location of the nearest Public Toilet	3.0	0.9	0.2	9.8	11.6
Location of the nearest ATM	-	1.9	2.7	4.4	17.8
Location of the nearest Public Telephone	-	-	2.4	2.9	5.0
Car parking Information	3.0	0.9	0.6	2.4	5.4
Total	100.0	100.0	100.0	100.0%	100.0

(N=257)

Table 4-5 At-stop study – preferences for additional at-stop information

Preference	Rating
The current Time	1
Is seating available	2
Is the arriving bus full?	3
Expected time at major stops i.e. city centre	4
Cost of the Journey	5
Traffic News	6
Times of the connecting buses	7
Location of the nearest ATM	8
Location of the nearest Public Toilet	9
Location of the nearest shop	10
Car parking Information	11
Location of the nearest Public Telephone	12

Passengers at the bus stop were asked hypothetically what they would do if they got to the bus stop and found out that they had a 15-minute wait time. The purpose of this question was to ascertain how passengers would use the time they had available before the bus arrived.

The activities offered were either to wait by the bus stop, walk to a nearby shop or any other activity. Table 4-6 displays how passengers responded to the question. The opportunities available at the bus stop e.g. shops etc. would have a bearing on the response. The results showed that passengers had a higher preference for waiting at the bus stop rather than engage in any other activity.

Table 4-6 At-stop study – use of extra time while waiting at the bus stop

Activity	Frequency	Percent (%)
Would continue to wait at the bus stop	150	58.3
Go to a nearby shop	99	38.6
Other	8	3.1
Total	257	100.0

The questionnaire asked how respondents would spend their time at the bus stop. The purpose of this question was to ascertain what passengers did with their time while they were at the bus stop on the day of the survey. Passengers were asked to select from a list of activities as detailed in Table 4-7. The table presents the findings with regard to the number of responses and this as a percentage of the total sample.

The missing values in the table of 104 represent people that did not fill out this section of the survey. The results also illustrate that 10.7% and 12.5% would organise something

work related and pursue a leisure activity respectively. From the respondents only 6.6% indicated that they would take an alternative mode of transport (see Table 4-7).

Table 4-7 At-stop study – how respondents would use their time at the bus-stop

	Frequency	Percent (%)
Contact place of employment	15	6.0
Read or organise something work related	28	10.7
Leisure activity i.e. read or organise something work related	32	12.5
Wait for the bus	61	23.6
Take an alternative mode of transport	17	6.6
Total	153	59.3
Missing	104	40.7
Total	257	100.0

4.2.4 Conclusions from the study

Overall passengers seem to be happy with the information provided by the displays, 63.7% of the 257 sample responding positively to the question asking if they were happy with the system.

From the preferences suggested to passengers relating to potential improvements in terms of additional information that might be provided at bus stops, passengers' information preferences were highest when asked if they would like the current time displayed. Information on the availability of seats and whether the bus would stop for pick-ups at the bus stop also ranked highly.

When passengers were asked what they would do if they knew they had an extra 15 minutes the majority (58.3%) of passengers decided that they would wait. 38.6% indicated that they would leave the bus stop to engage in a retail activity.

4.3 Exploratory Public Transport Information Study

This section presents the results from a survey conducted before the main stated preference questionnaire was designed. The purpose of this survey was to obtain information on the preferences for different types of real-time public transport information. The main objective of this study was to test various questions and scenarios to and to provide feedback for the development of the main survey. The results in this chapter are based largely on Caulfield and O'Mahony (2007a).

4.3.1 Exploratory study - purpose of the research

This study focuses on the provision of public transport information in Dublin. It examines both existing and potential methods of accessing information, with particular focus on the implementation of various real-time public transport information applications. One of the main objectives of this research is to examine the stages a passenger experiences when deciding to undertake a public transport trip and examining in what form they require information at each stage. This study defines these stages as 'pre-trip to destination', 'at-stop', 'on-board' and 'pre-trip to origin'. Each of these four stages is examined in this study. A web-based survey was used to collect data on passenger preferences and describes the methods of information delivery each passenger requires at each stage. The survey also details results of passengers' opinions of the different information provision formats such as call centres, mobile phones, the Internet and paper-based methods.

4.3.2 Exploratory study - methodology and data collection

The survey was conducted over a two-week period from the 23rd March – 6th April 2004 using web-based methods. The sampling method chosen was a form of non-probability convenience sampling called snowball sampling (Weisberg et.al 1996). This method of sampling elicits responses from people with a common attribute, in this case those who work in Dublin City Centre and have Internet access. The first group of respondents complete the survey and then pass the survey on to their network. The process repeats and gathers momentum as the number of responses increases and the snowball effect occurs. This effect was demonstrated in the results whereby the majority of the results from the survey were collected within the first three days of the survey being hosted. In the case of this study, the survey was initially sent to 40 individuals working in Dublin City Centre with computer access, the survey remained open for two weeks; enough for a snowball affect to occur, resulting in 248 responses when the survey closed.

4.3.3 Exploratory study – results

The survey results detail the three main purposes of the survey: [1] an individual's current attitudes to passenger information, [2] an importance ranking of the different attributes of

the information provision options and [3] the form in which information is required at each of the stages of a public transport trip.

The characteristics of the sample are outlined in Table 4-8. More females than males completed the survey (38% male, 62% female). The majority of respondents (78%) were aged 34 or under. The results for the current mode of transport used demonstrated that a high percentage of the group use public transport with 31% and 16% using bus and rail respectively. The results for other modes, namely walking (25%) and car (21%), constituted a sizeable proportion of respondents. Far less used the other modes offered, namely cycle (3%), motorbike (1%) and taxi (1%), (see Table 4-8).

Table 4-8 Exploratory study – respondent characteristics

	No. of observations	Percentage (%)
Gender		
Male	94	38
Female	154	62
Total	248	100
Age		
Under 24	82	33
25-34	112	45
35-44	27	11
45-54	22	9
55+	5	2
Total	248	100
Mode of transport		
Bus	77	31
Rail	40	16
Walk	62	25
Cycle	12	3
Car	52	21
Motorbike	2	1
Taxi	2	1
Total	248	100

Table 4-9 outlines the respondents' current sources of passenger information. The findings indicate that the 35% of passengers use their existing knowledge to obtain information, while 30% use the Internet. Paper timetables were placed third with 20% of respondents using this method. The other options of SMS, TV/radio and call centre were placed fourth, fifth and sixth respectively.

Table 4-9 Exploratory study – respondents current sources of transport information

Which of the following sources do currently you use to obtain public transport information?		
	No. of Responses	**Percentage (%)**
Existing Knowledge	87	35
Internet	74	30
Mobile Phone	12	5
Paper Time Tables	50	20
Call Centre	5	2
TV/Radio	12	5
None of these	7	3
Total	248	100

Passengers' opinions on the current passenger information provided in Dublin are displayed in Table 4-10. Passengers were first asked if they agreed that good information is provided and secondly they were asked if they would like to see more information provided. Respondents were divided on whether information provided was good: 42% either strongly agreed or agreed that it was good, 19% had no opinion and 39% either strongly disagreed or disagreed. Furthermore, although over 40% agreed that information provided was good, 73% of respondents either strongly agreed or agreed that more information should be provided. Only 8% strongly agreed/disagreed with this statement.

Respondents were also asked to rate the quality of passenger information currently provided at stops/stations. When asked about the quality of the timetables currently provided, 68% either strongly agreed or agreed that the quality was poor. Moreover, 73% either strongly agreed or agreed that the quality of maps provided was poor. Finally, respondents were asked if the lack of information deterred them from using public transport. The majority of respondents disagreed with this statement (59% strongly disagreed/disagreed). A further 21% of respondents either strongly agreed or agreed that the lack of information deterred them from using public transport information. This 21% is a sizeable proportion of respondents and demonstrates that improvements to the system may attract more passengers. The results show that passengers found the current provision of information inadequate; however, it was not a strong enough factor to deter them from using the services.

Table 4-10 Exploratory study – opinion of public transport information provision in Dublin

Opinion on public transport information provision in Dublin					
	Strongly Agree (%)	**Agree (%)**	**No Opinion (%)**	**Disagree (%)**	**Strongly Disagree (%)**
Good information is provided	2	40	19	32	7
I would like to see more information provided	31	42	19	6	2
The quality of bus/rail time tables at stops/stations provided is poor	33	35	11	19	2
The quality of bus/rail maps at stops/stations is poor	40	33	17	7	3
The lack of information deters me from using public transport	6	15	20	49	10

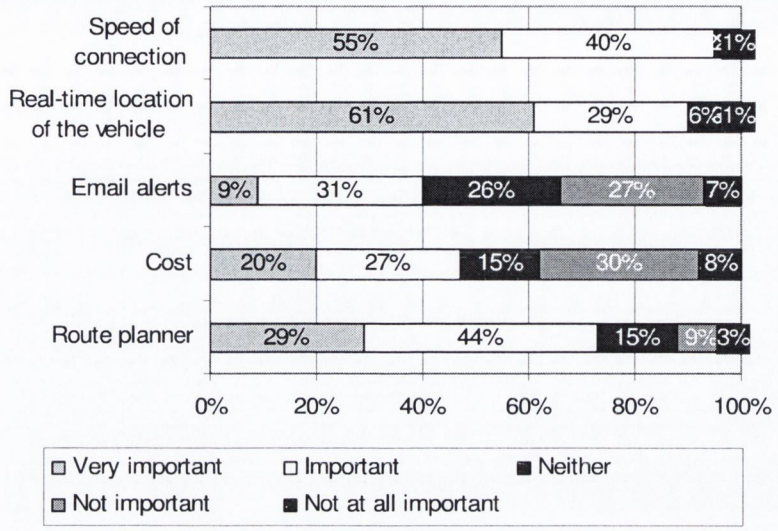
Respondents were asked to rate the different characteristics of each of the information provision options. The results for each option are presented below.

The Internet:

The survey elicited respondents' opinions on several characteristics of a public transport information website, the results of which are in Figure 4-2. Respondents indicated that the speed of connection was very important with an overwhelming 95% indicating it to be very important or important. The cost of connection was less influential than the speed of connection with 47% stating it to be very important/important. Interestingly, 38% indicated that cost was not at all important/not important.

The services provided by the website were also rated. Over 90% of respondents indicated that a map with the real-time location of the vehicle was either very important or important. Only 4% of respondents stated that this was either not at all important or not important. A route planner was found to be very important/important by 73% of respondents. Interestingly, only 40% of respondents stated that email alerts on public transport services were very important/important, while 34% stated that they were not at all important/not important.

Figure 4-2 Exploratory study – importance ratings of characteristics of information provision via the internet



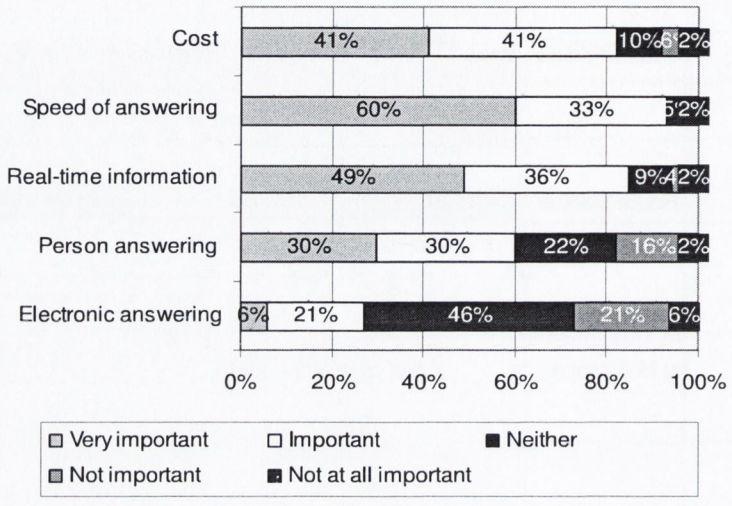
(N=248)

Call Centre:

The respondents' ratings of the characteristics of call centres are shown in Figure 4-3. As seen with the Internet, the speed of answering was shown to be more important than cost. 93% of respondents stated that the speed of answering was either very important or important, whereas 82% stated that the cost of the call was very important/important. The higher emphasis on the cost of contacting a call centre versus that of the internet demonstrates passengers may perceive the cost of phoning a call centre to be more significant than logging on to a website, thus preferring the internet over a call centre; this is also demonstrated later with mobile phone options.

The method of call answering was also evaluated based on two answering options: [1] electronic answering and [2] personal voice answering. The results reveal that personal answering is very important/important for 60% of respondents. However, 46% of respondents stated that electronic voice answering was neither important nor not important with a further 27% stating that it was not at all important/not important. The provision of real-time information was found to be one of the most important aspects of information provision via call centres, with 85% of respondents stating that it was very important/important.

Figure 4-3 Exploratory study – importance ratings of characteristics of information provision via call centres

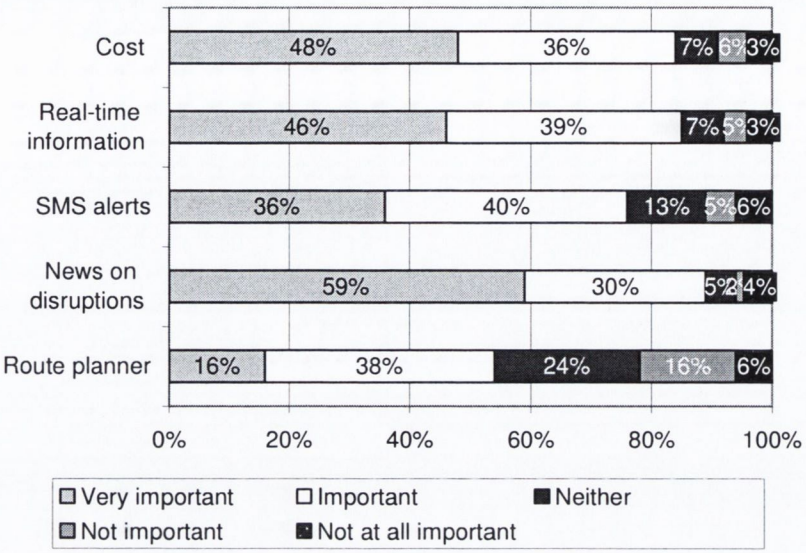


(N=248)

Mobile Phones:

Respondents were also asked about the provision of information via mobile phones. The results for this option are shown in Figure 4-4. News on public transport disruptions was rated as very important or important by 89% of respondents. This was followed closely by the provision of real-time information at 85%. The cost of information provided via mobile phones was also found to be important with 84% of respondents stating that this characteristic was either very important or important. This result is similar to that observed for call centres in that the cost of information access is a considerable factor.

Figure 4-4 Exploratory study – importance ratings of characteristics of information provision via mobile phone

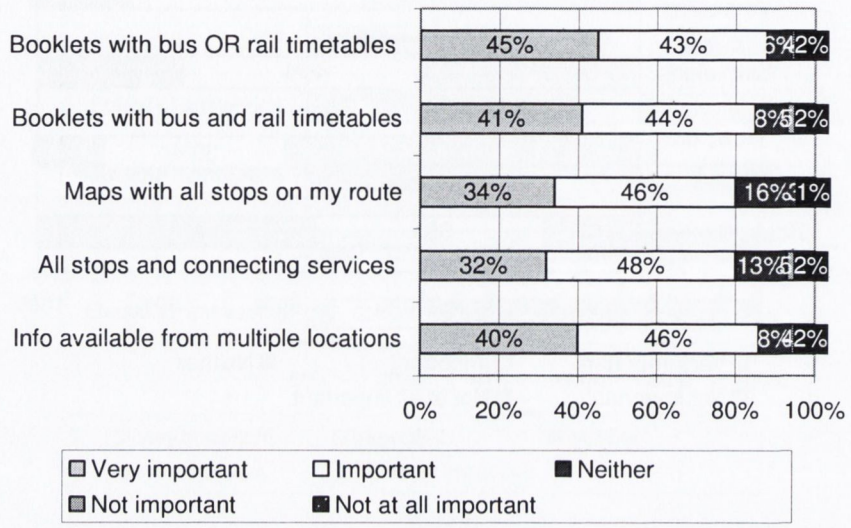


(N=248)

Paper-based Information:

In the previous section the results demonstrated that passengers were not happy with the quality of at-stop/station paper-based information. This is reiterated in this section as respondents reacted positively to the options offered, deeming them all to be very important as seen in Figure 4-5. The highest level of very important ranking was for the option of having booklets with bus or rail timetables, with 89% indicating it to be very important/important. The second highest level was for having combined booklets of bus and rail timetables with an 85% very important/important rating. The provision of maps with all stops/stations displayed had the third highest of 80% very important/important rating. Maps with details of connecting services had 80% of respondents indicate it to be either very important or important. Another issue covered in this section was the availability of this information, at not just the stop/station, but to be available at multiple locations around the city, with 86% indicating it was either very important or important.

Figure 4-5 Exploratory study – importance ratings of characteristics of information provision via paper based options

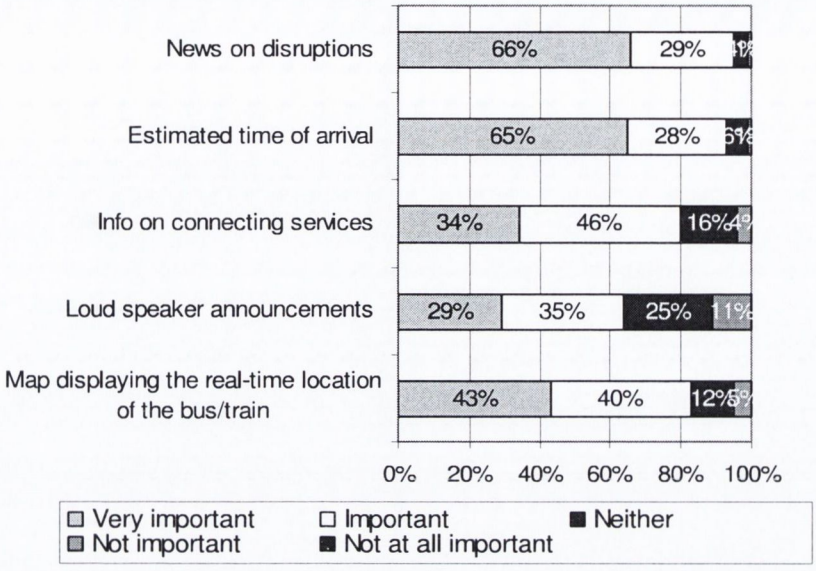


(N=248)

Real-time passenger information displays:

The levels of importance for each characterisers of a RTPI system are shown in Figure 4-6. The results show that the most important characteristic to respondents (very important/important) is news on disruptions (95%), followed directly by estimated time of arrival (93%). The majority of respondents rated all five characteristics as very important/important with the lowest level of importance being attributed to loudspeaker announcement. Nevertheless, 64% of respondents indicated that this characteristic was either very important or important.

Figure 4-6 Exploratory study – importance ratings of characteristics of information provision via passenger information displays



(N=248)

In the survey respondents were asked outline their preferences for the tools of information provision offered in the survey, at each stage of their trip.

Stage One: Pre-trip information from origin to destination:

The information options offered to respondents for the first stage of a trip were: [1] the Internet, [2] paper-based timetables, [3] call centres and [4] SMS. The results demonstrate that paper-based timetables are the most popular option with 48% of the first preference and 25% second preference responses (see Table 4-11). The Internet was ranked second with 30% and 27% of the first and second preferences respectively. The results show that mobile phone (17%) and call centres (5%) as the third and fourth preferred options, with relatively lower first and second preference responses. The lower rankings for SMS and call centres may be attributable to the cost associated with these forms of communication as highlighted earlier.

Stage Two: At-stop information:

The alternatives offered to respondents for this stage of a trip were: [1] information kiosks, [2] paper-based timetables, [3] call centres, [4] SMS and [5] RTPI displays. The results for this stage indicate that the majority of respondents have a preference for RTPI displays

with 74% of first preference responses as seen in Table 4-11. Paper-based methods had the next highest number of first preferences with 12% and 39% of second preferences. Call centres were ranked third with 5% of the first preferences and 36% of second. The remaining two options had similarly low first and second preferences with SMS indicated to be slightly preferred to the call centre option.

Stage Three: On-board vehicle information:

The alternatives presented to respondents at this stage were: [1] paper-based information placed on the inside of the vehicle, [2] call centres, [3] SMS, [4] onboard RTPI displays and [5] asking the driver. The results for this stage are quite similar to the results in the second stage, with the onboard RTPI system achieving the highest number of first preference responses at 68% (see Table 4-11). Similarly to the previous results, paper-based methods had the second highest preference with 12% of first and 57% of second preferences. The remaining options had lower levels of first and second preferences; asking the driver 12% and 13%, SMS 6% and 15% and call centres 3% and 3% of first and second preferences respectively.

Stage Four: Pre-trip information from destination to return to origin

The choices given to respondents at this stage were: [1] information kiosk, [2] paper-based timetables, [3] the Internet, [4] call centres and [5] mobile phones. The results show that the Internet is the favoured option at this stage with 64% of the first preference responses (see Table 4-11). Paper-based information again had the second highest number of first preferences with 26% and 31% of second preferences. A contributing factor to the Internet having the higher preference may be due to the sample taken, in that it was of office workers with access to the Internet. The next highest preference was for SMS with 7% of first and 19% of second preferences, followed by the Internet with 6% and 18% of first and second preferences. The fifth placed option is the information kiosks, with 3% and 15% of first and second preferences.

Table 4-11 Exploratory study – Preferences for information at each stage

	First Preference (%)	Second Preference (%)	Third Preference (%)	Fourth Preference (%)	Fifth Preference (%)	Mean Score
Stage One: Pre-trip information from origin						
Paper Based	48	25	15	11		1.36
Call Centre	5	24	37	36		2.19
SMS	17	24	34	25		1.87
Internet	30	27	14	28		1.7
Stage Two: At-stop information						
Call Centre	5	36	36	17	8	2.0
Paper-based	12	39	27	15	10	1.89
Information Kiosk	3	3	16	27	54	2.92
SMS	6	15	16	38	27	2.51
RTPI Display	74	9	5	3	1	0.98
Stage Three: On-board vehicle information						
Ask Driver	13	13	41	14	20	2.21
Paper Based	12	57	23	4	1	1.63
Call Centre	3	3	11	33	55	3.0
SMS	4	12	18	47	23	2.57
RTPI Display	68	2	7	2	1	1.03
Stage Four: Pre-trip information from destination						
Call centre	6	18	22	25	30	2.48
Paper-based	26	31	17	16	11	1.78
Information Kiosk	3	13	34	25	28	2.53
SMS	7	19	20	29	26	2.45
Internet	64	20	7	4	5	1.22

(N=248)

4.3.4 Exploratory study – conclusions

This piece of exploratory research demonstrates that passengers in Dublin would like to see improvements to their public transport information system and have, as demonstrated in the results, indicated preferences to different forms of information provision.

The conclusions of the study are as follows:

1. Currently the majority of passengers in Dublin use their own existing knowledge or paper-based timetables to acquire public transport information.
2. At present, according to respondents, the information provided by operators in Dublin is not of a high quality, with the majority agreeing that they would like to see a higher quality of information provided.
3. The cost of using data sources such as SMS, call centres and the Internet were illustrated to be very important to the respondents, if they were to use these

applications. This may have resulted in the lower preference scores of these options.

4. The provision of real-time information was shown to be the most important method of information provision. Improved paper-based information also received a high rating by the respondents.

4.4 SUMMARY

As previously stated one of the main reasons for conducting the two studies reported in this chapter was to provide gather information on opinions and perceptions of real-time public transport information. The findings from both studies have been used to develop the stated preference questionnaire.

The results from the first study show that bus passengers do derive a benefit from the provision of real-time transport information. As the majority of respondents indicated that they were satisfied with the information provided by the displays, a description of these displays was used in the main survey.

The second study was somewhat more influential on the design of the final questionnaire. The following decisions were made on the final questionnaire based on the results of this study.

The results in Table 4-11, demonstrate that the preferences for real-time information at the second and third stages to be quite similar. Due to this similarity, it was decided to drop the 'on-board vehicle information' stage. Therefore, from this point forward, only three stages of a public transport journey are considered; stage one: pre-trip planning from home to work, stage two: at-stop planning and finally stage three: pre-trip planning from place of work returning home.

It was decided to drop all information sources that could not provide real-time information. This meant the removal of the paper-based options from the study. Although paper-based information options did yield good preference results, the option of providing real-time information produced higher preference scores for all stages with the exception of the first

stage. Based upon these results it was decided to limit the study to real-time information options and to examine what format individuals would demand this information. Therefore, only real-time information options were considered.

Based upon the results in Table 4-11, at each of the stages the following methods obtaining real-time transport information were considered.

- Stage one: Call centre, the Internet and SMS
- Stage two: passenger information display, SMS and call centre
- Stage three: Call centre, the Internet and SMS

The option of providing information using an information kiosk was dropped, as the preference scores in Table 4-11 indicate that it scored the lowest of all of the real-time public transport information options.

5 SUMMARY OF QUESTIONNAIRE STATISTICS

5.1 INTRODUCTION

This chapter contains a summary of the data collected from the main questionnaire. The findings are split into seven sections which present results on the following; mode of transport used, work patterns, location specific information, opinion of public transport information, opinion of the use of technology to access public transport information, socio-economic details and qualitative responses. These sections mirror those used in the questionnaire, a copy of which may be found in Appendix A. The results in this chapter are based largely on Caulfield and O'Mahony (2007a).

5.2 TRAVELLING TO WORK

An important aspect in this study is to identify the current travel patterns of the respondents and to analyse how these factors may impact upon their choice of real-time public transport information options. This section presents the data collected on the modes of transport and the time taken to travel to work on a daily basis. This section refers to the public transport network in Dublin. A description of this network can be found in section 3.2.

5.2.1 Mode of transport

The survey was aimed at individuals who work in Dublin city centre and, as such, it was open to all individuals regardless of their mode of transport. The findings demonstrate that approximately a quarter of the respondents use a private car to get to work with 22.4% driving alone and 3.2% as passengers (See Table 5-1). The proportion of individuals that either cycle or walk to work was 14.2% and 7.9% respectively. The remaining respondents in the sample (52.3%) used public transport, with the majority of these individuals using the bus, (28.7%) and the remainder using one of the light/heavy rail options.

Table 5-1 Mode of transport used to travel to work

Mode of Transport	Number of respondents	Percentage (%)
Walk	70	14.2
Cycle	39	7.9
Car (Drive)	111	22.4
Car (Passenger)	16	3.2
Bus	142	28.7
Luas	33	6.6
DART	43	8.6
Arrow	29	5.8
Taxi	1	0.3
Another rail	11	2.3
Total	495	100.0

5.2.2 Combinations of public transport used

The survey asked those respondents who said they used public transport, did they use a combination of modes. The results show that 17.1% of public transport users used more than one mode to travel to work (see Table 5-2). The respondents that indicated that they took more than one mode of transport were asked what modes they transferred between. 56.4% of all those who transferred modes, transferred between bus services, followed by combinations of light and heavy rail with bus (see Table 5-3).

Table 5-2 Respondents that use more than one mode of public transport to travel to work

Answer	Number of respondents	Percentage (%)
Yes	85	17.1
No	410	82.9
Total	495	100.0

Table 5-3 Combination of public transport modes used to get to work

Modes Used	Number of respondents	Percentage (%)
Bus and bus	48	56.4
Bus and Luas	17	20.5
DART and bus	16	18.8
DART and Luas	4	4.3
Total	85	100.0

5.2.3 Time taken to travel by public transport

As the subsequent analysis in this thesis examines the stages of a public transport trip, data was collected on the time it takes an individual to use public transport, from their home to the office.

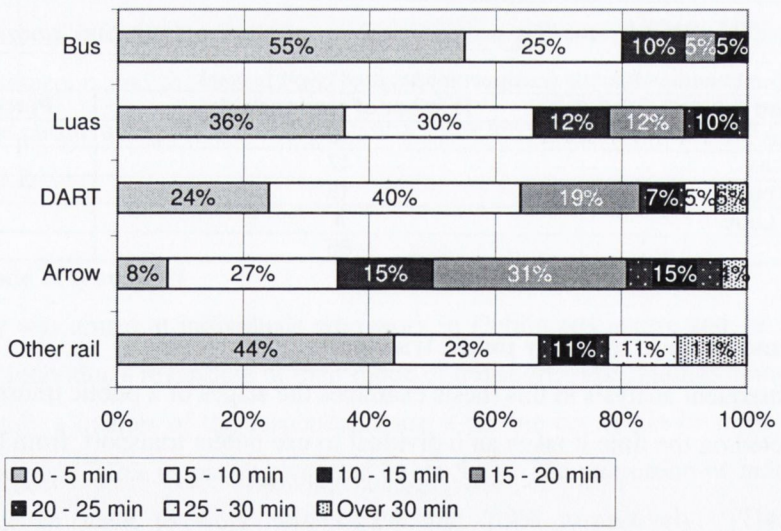
The reported walk times of the respondents from their home to the nearest public transport stop/station are contained in Table 5-4. 41.8% of respondents are less than a five minute walk and 28.2% between a five and ten minute walk from their stop/station.

Table 5-4 Time taken to walk from home to public transport

Time Taken	Number of respondents	Percentage (%)
0-5 min	108	41.8
5-10min	72	28.2
10-15min	33	12.6
15-20min	22	8.5
20-25min	10	3.9
25-30min	5	1.9
30-35min	1	0.2
Over 35min	7	2.9
Total	258	100.0

Figure 5-1 presents the results in table 4 segmented by the modes of transport used. The findings show that 55% of bus users, 44% of other rail users, 36% of Luas users, 24% of DART users and 8% of Arrow users were less than a 5 minute walk from their stop station. Bus users were found to have the shortest walk distance to their stop as 90% of bus users were less than a 15 minute walk away. The walk time for rail users was found to be greater, with Arrow and Luas users found to walk the largest distances to their services (see Figure 5-1).

Figure 5-1 Time taken to walk to bus stop/train station



(N=258)

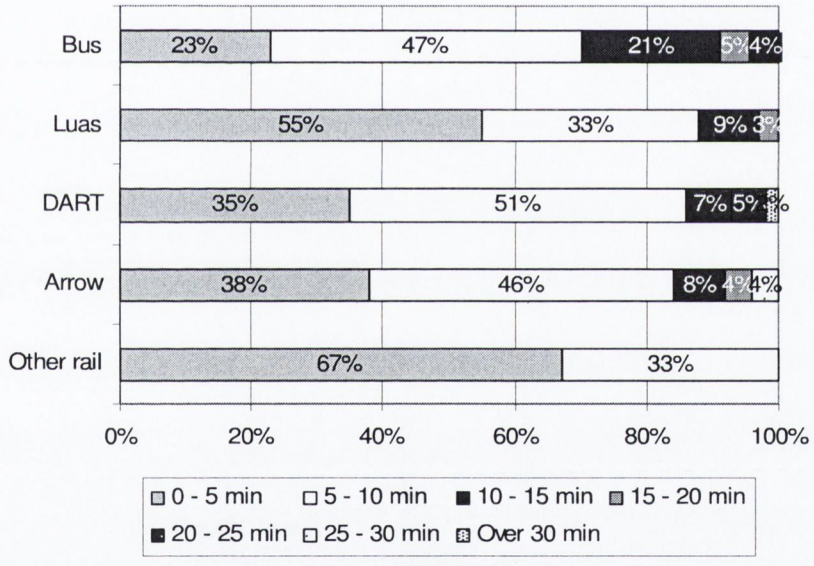
The reported wait-times at stop/station are presented in Table 5-5. As with the walk time to stop/station, the majority of respondents indicated that the wait time was less than ten minutes. 32.0% indicated that they had a less than five minute wait and 44.3% were found to have a wait time of between five and ten minutes (see Table 5-5).

Table 5-5 Time spent waiting at the bus stop/train station

Time Taken	Number of respondents	Percentage (%)
0-5 min	83	32.0
5-10min	114	44.3
10-15min	39	15.3
15-20min	13	5.0
20-25min	6	2.2
25-30min		-
30-35min	2	0.7
Over 35min	1	0.5
Total	258	100.0

The wait times in Table 5-5 are reported with the specific mode of transport used presented in Figure 5-2. The findings show that bus users had the longest wait time, with 23% found to have a wait time of less than 5 minutes compared to 55% of Luas users, 35% of DART users, 38% of Arrow users and 67% of other rail users. A further 26% of bus users were found to wait between 10 and 20 minutes.

Figure 5-2 Wait time at stop/station



(N=258)

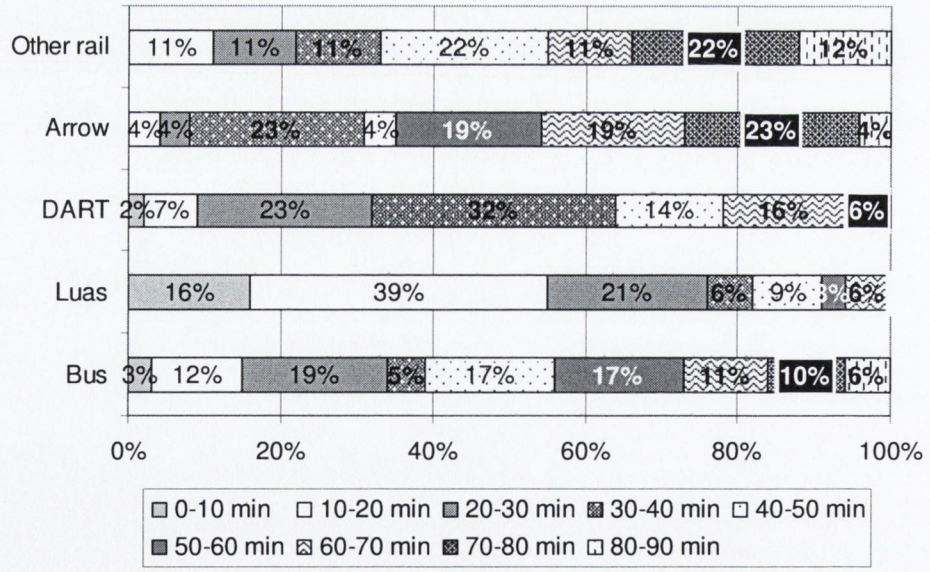
Table 5-6 reports the results for the journey time on public transport. The most common length of journey time was 20-25 minutes (17.1%) (see Table 5-6). Grouping the journey times together, the results demonstrate that 27.7% had a travel time of between 0 and 20 minutes, 35.7% reported a travel time of between 20 and 35 minutes. 15.6% indicated a travel time of between 35 and 40 minutes, and 21.0% had a travel time of between 40 minutes and 80 minutes (see Table 5-6).

Table 5-6 Tine spent travelling to work on public transport

Time Taken	Number of respondents	Percentage (%)
0-10 min	8	2.8
10-15min	27	10.5
15-20min	37	14.4
20-25min	44	17.1
25-30min	17	6.6
30-35min	31	12.0
35-40min	40	15.6
40-50min	30	11.7
50-1hour	14	5.4
1.10-1.20hours	10	3.9
Over 1.20 hours	-	-
Total	258	100.0xd

The results for the total time spent on-board public transport are segmented in to the mode of transport and are presented in Figure 5-3. The results show that bus users were found to have the longest travel times, with 27% of the respondents spending 60 to 80 minutes travelling by bus. Luas users were found to have the lowest travel times, followed by DART users.

Figure 5-3 Travel time on public transport option



(N=258)

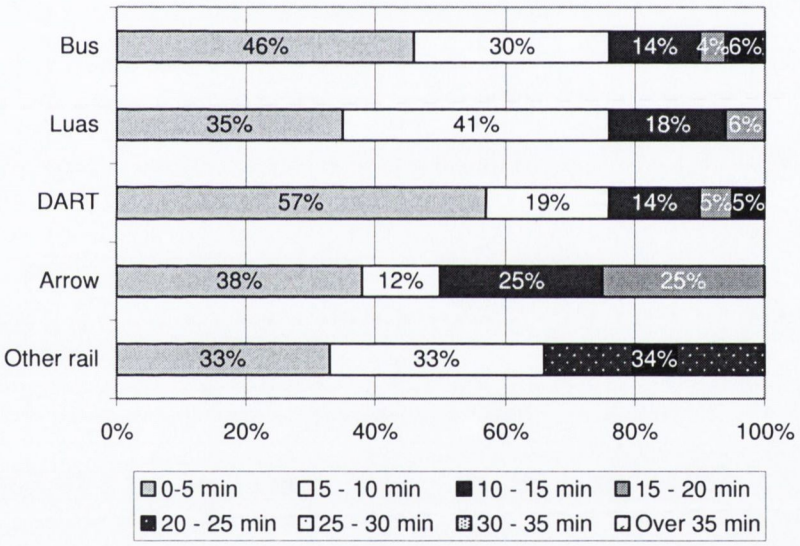
Table 5-7 presents the reported walk time from stop/station to place of work. The results, as with the walk to stop/station from home, demonstrate that the majority of respondents have less than 10 minute of a walk. 39.1% were found to have a less than 5 minute walk, and 33.6% to have a walk of between 5 and 10 minutes (see Table 5-7).

Table 5-7 Time taken to walk from bus stop/train station to work

Time Taken	Number of respondents	Percentage (%)
0-5 min	101	39.1
5-10min	87	33.6
10-15min	39	15.0
15-20min	14	5.6
20-25min	8	3.2
25-30min	5	1.9
30-35min	1	0.2
Over 35min	3	1.4
Total	258	100.0

The walk time from stop/station to place of work for each of the modes of public transport are presented in Figure 5-4. The results demonstrate that other rail users have on average the longest walk times to their place of work, followed by Luas, bus and DART users.

Figure 5-4 Walk time from stop/station to place of work



(N=258)

5.2.4 Time taken to drive to place of work

This section presents the travel time taken by those who drive to work on a daily basis. The reported drive times of the sample are presented in Table 5-8. As with the distribution of time spent travelling by public transport, the findings for the time taken to drive to work are quite dispersed. 18.8% of respondents who drove indicated it took them less than 20 minutes, 32.6% said it took them between 20 and 35 minutes. It was found that 41.0% of

respondents took between 35 and 50 minutes to drive, and 7.6% of those that drove to work took between 50 and 60 minutes.

Table 5-8 Time spent driving to work

Time Taken	Number of respondents	Percentage (%)
0-10min	8	6.8
10-15min	6	4.7
15-20min	9	7.3
20-25min	18	14.1
25-30min	10	8.2
30-35min	14	10.3
35-40min	20	16.0
40-45min	19	14.7
45-50min	13	10.3
50-60min	10	7.6
60-80min	-	-
90min+	-	-
Total	127	100.0

The time spent looking for parking was the second component of trip which was examined. The results show that 87.0% of respondents found parking when they arrived at their place of work in less than 5 minutes (see Table 5-9).

Table 5-9 Time spent looking for parking

Time Taken	Number of respondents	Percentage (%)
0-5 min	110	87.0
5-10min	11	8.6
10-15min	5	3.5
15-20min	1	0.9
20-25min	-	-
25-30min	-	-
30-35min	-	-
Over 35min	-	-
Total	127	100.0

The final component of a trip by car to be examined was the walk time between their car parking space and their place of work. As with the results for the time spent looking for parking, the majority (84.8%) indicated that it took them less than 5 minutes to walk from their car to their place of work (see Table 5-10).

Table 5-10 Time spent walking from your car to your place of work

Time Taken	Number of respondents	Percentage (%)
0-5 min	107	84.8
5-10min	11	9.2
10-15min	4	2.8
15-20min	2	1.4
20-25min	1	0.9
25-30min	1	0.3
30-35min	1	0.6
Over 35min	-	-
Total	127	100.0

5.3 WORKING PATTERNS

One of the main benefits of providing real-time public transport information is to provide commuters with reliable information on departure time, so they can make informed decisions on when to depart for their stop/station. It was therefore decided to collect data on the respondents work patterns to ascertain if this impacted upon the utility derived from real-time public transport information.

5.3.1 Work trip departure time

The work trip departure time of respondents is presented in this section. 34.1% of respondents were found to depart to work before 7:30 and 20.8% depart between 7:30 and 8:00 (see Table 5-11). 38.8% departed between 8:00 and 9:30, and 6.3% indicated that they departed after 9:30.

Table 5-11 Departure time of respondents

Start time	Number of respondents	Percentage (%)
Before 6:30	26	5.3
6:30-7:00	66	13.3
7:00-7:30	77	15.5
7:30-8:00	103	20.8
8:00-8:30	115	23.2
8:30-9:00	67	13.5
9:00-9:30	21	4.2
After 9:30	20	4.0
Total	495	100.0

5.3.2 Working patterns

In the questionnaire, respondents were asked to indicate their working patterns. 34.9% of respondents indicated that they worked with regular set hours and 52.0% said they worked on a flexible start-time basis (see Table 5-12). 10.8% of respondents in the sample indicated that they had no set working hours. The results show the proportion of the

sample that are required to arrive at work at a set time each day, and those that have a degree of flexibility to their work schedule.

Table 5-12 Working patterns

Start time	Number of respondents	Percentage (%)
Regular set hours	173	34.9
Flexible start time	257	52.0
Shift work	12	2.3
No set hours	53	10.8
Total	495	100.0

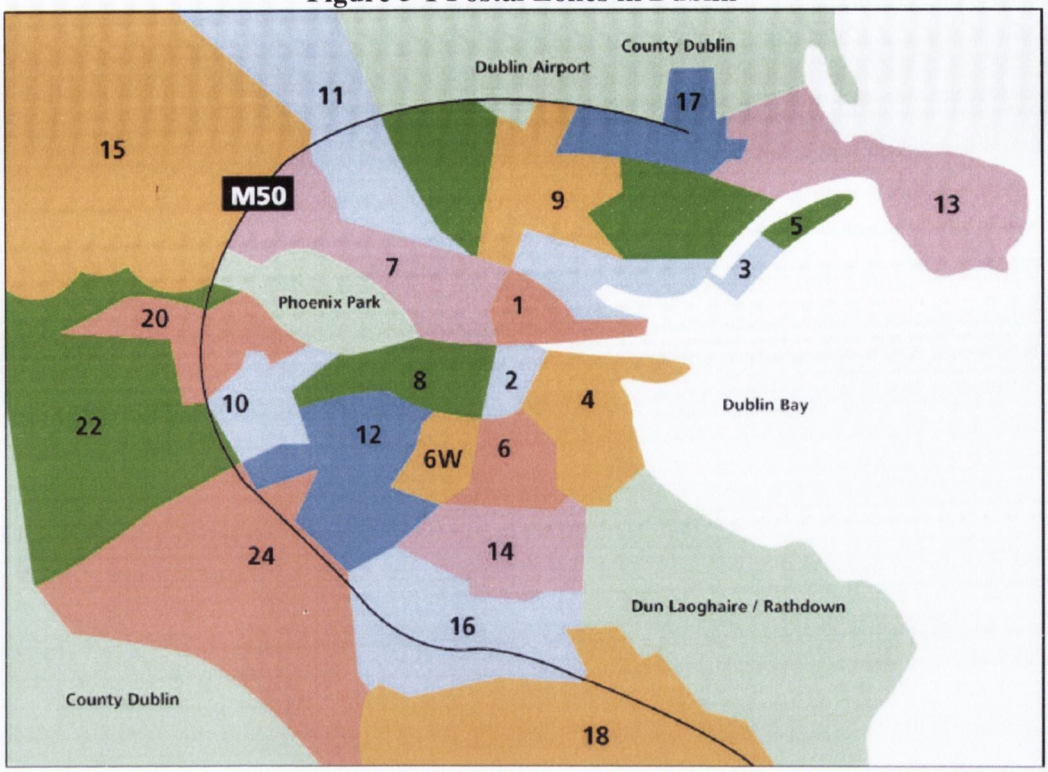
5.4 LOCATION FACTORS

This section presents the results pertaining to the location specific questions contained in the questionnaire. The purpose of eliciting responses with regard to the residential location of the respondent was to ascertain if location specific factors impact upon their choice of real-time transport information option.

5.4.1 Location travelled from to work

Ireland currently lacks a street level postal code system, similar to the post code systems in the United Kingdom. Dublin has a postal code system, which separates the city and county into 23, zones as seen in Figure 5-5. This postal code system was used in conjunction with the 5 neighbouring counties, to provide an indication of where respondents travel from to get to Dublin city centre, the work location of the participants.

Figure 5-1 Postal Zones in Dublin



The results from the survey demonstrate a spread of respondents from all of the Dublin postal zones (see Table 5-1).

Table 5-1 Location travelled from to get to work

Area	Number of respondents	Percentage (%)
Dublin 1	6	1.2
Dublin 2	10	2.0
Dublin 3	13	2.6
Dublin 4	17	3.4
Dublin 5	14	2.9
Dublin 6	20	4.1
Dublin 6w	16	3.2
Dublin 7	22	4.4
Dublin 8	20	4.1
Dublin 9	22	4.4
Dublin 10	3	0.6
Dublin 11	14	2.9
Dublin 12	22	4.5
Dublin 13	9	1.9
Dublin 14	25	5.0
Dublin 15	27	5.4
Dublin 16	26	5.1
Dublin 17	1	0.3
Dublin 18	10	2.0
Dublin 19	3	0.6
Dublin 20	5	1.0
Dublin 22	14	2.9
Dublin 24	86	17.4
Co. Dublin	27	5.4
Kildare	17	3.4
Meath	23	4.7
Wicklow	6	1.2
Louth	17	3.4
Total	495	100.0

5.1.1 Proximity to public transport modes

The questionnaire asked respondents did they live within close proximity (less than a 15 minute walk) to a high frequency/quality mode of public transport. For the purposes of this study a high frequency mode of public transport was defined as either a light rail or heavy rail service, or a bus service on a priority corridor.

52.8% of respondents indicated that they lived within a 15 minute walk to a bus service using a priority corridor (see Table 5-2).

Table 5-2 Within 15 min walk to a bus service using a priority corridor

Bus	Number of respondents	Percentage (%)
Yes	262	52.8
No	233	47.2
Total	495	100.0

Respondents were asked if they lived within a 15 minute walk to a tram (Luas) stop. At the time of the survey the tram network consisted of two separate lines (red and a green lines) so the questionnaire asked if they lived near either of these services. The results show that 22.2% and 23.5% live within a 15 minute walk to a stop on the green and red lines respectively (see Table 5-15 and Table 5-16).

Table 5-15 Within 15 min walk of a Green line Luas stop

Luas Green Line	Number of respondents	Percentage (%)
Yes	110	22.2
No	385	77.8
Total	495	100.0

Table 5-16 Within 15 min walk of a Red line Luas stop

Luas Red Line	Number of respondents	Percentage (%)
Yes	116	23.5
No	379	76.5
Total	495	100.0

27.0% of respondents were found to be within a 15 minute walk to a DART station (see Table 5-17). The final question in this section asked if the respondent did not live near a DART or a tram station, did they live near any other rail station. 21.6% indicated that they lived within a 15 min walk of a rail station (see Table 5-18).

Table 5-17 Within 15 min walk of a DART Stop

DART	Number of respondents	Percentage (%)
Yes	134	27.0
No	361	73.0
Total	495	100.0

Table 5-18 Within 15 min walk of any other rail station

Any other rail	Number of respondents	Percentage (%)
Yes	107	21.6
No	388	78.4
Total	495	100.0

5.5 Opinion of Public Transport Information

The questionnaire asked respondents their opinion of public transport information. Data was collected on perceptions of public transport information; the frequency at which respondents currently use public transport information, how convenient they perceive it to access information and the frequency at which they currently use transport information.

5.5.1 Opinion of public transport information

The questionnaire asked respondents how they perceived the quality of the public transport information currently available in Dublin. The quality of maps at stop/stations, timetables, websites, information on the cost of a trip and the availability of real-time information were examined. Respondents were asked to rate these information options as; very good, good, average, poor and very poor.

55.1% of respondents indicated that they found the quality of maps provided at bus stops/train stations to be poor or very poor (see Table 5-19). Few respondents (4.4%) found the quality of the maps provided to be very good and the quality of the timetables provided at stop/station were said to be poor or very poor by 41.0%. As with the quality of maps, 6.6% of respondents found the quality of timetables to be very poor.

42.3% of respondents indicated the quality of public transport web-sites to be good or very good, however, 26.3% of the sample said the quality was poor or very poor (see Table 5-19). The availability of information on the cost of public transport was found to be poor or very poor by 52.3% of respondents. 29.5% of respondents said that the availability of information on the cost of public transport was average, and 14.0% indicated the current provision of information was good. Finally, this section asked respondents to rate the availability of real-time information currently available on public transport. 64.9% indicating the availability of real-time information was poor or very poor, with only 3.5% indicated that the availability of real-time information was very good (see Table 5-19).

Table 5-19 Perceptions of the quality of transport information currently provided

Option	Very Good (%)	Good (%)	Average (%)	Poor (%)	Very Poor (%)
Maps provided at bus stops/train stations	4.4	13.5	27.0	28.8	26.3
Timetables provided at bus stops/train stations	6.6	21.8	30.7	22.4	18.5
Public transport websites	8.8	33.5	31.4	13.6	12.7
The availability of information on the cost of your trip	4.2	14.0	29.5	27.6	24.7
Availability of real-time information on your trip	3.5	11.1	20.5	29.2	35.7

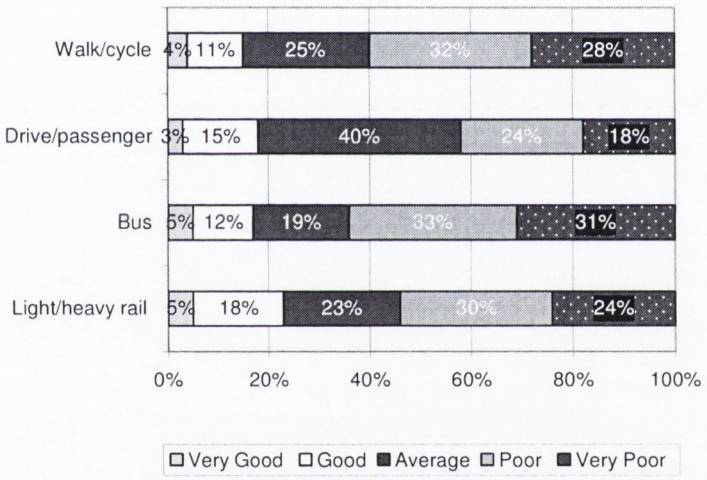
(N=495)

The results from Table 5-19 have been broken down by mode of transport most commonly used and presented in Figure 5-6 to Figure 5-10. The modes of transport used have been

combined, into the following four groups, light/heavy rail, bus, drive/passenger and walk/cycle.

31% of bus users deemed the quality of maps at bus stops to be very poor, and 33% indicated that they were poor (see Figure 5-7). 28% of those who walk and cycle perceived the quality of maps to be very poor, with only 4% indicating they were very good. Interestingly drivers/car passengers were found to have the lowest poor/very poor scores, as 40% indicated that the quality of maps was average. This suggests that they may not be familiar with public transport maps, as the user groups that regularly use public transport found the quality to be poor.

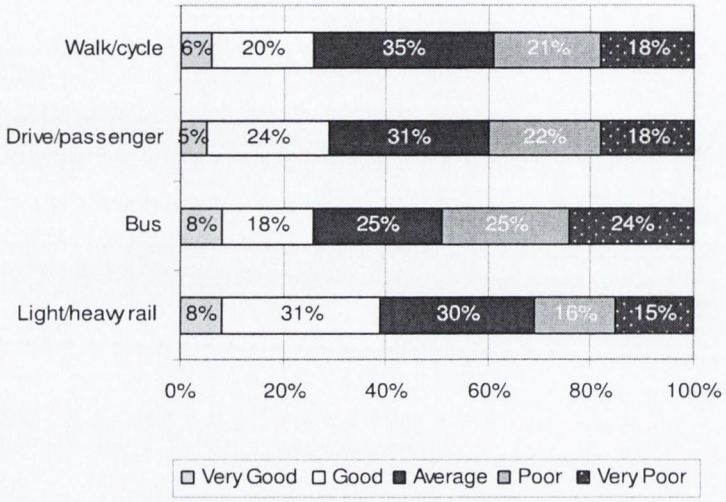
Figure 5-6 Quality of maps at stops/stations



(N=495)

Bus users were found to have the highest percentage of respondents indicating very poor quality (24%) of the current provision of timetables at stop. Compared to the other user groups a higher percentage of rail users perceived the quality of timetables to be very good or good, 8% and 31% respectively. 61% of the walk/cycle group and 60% of drivers/passengers were found to perceive the quality of timetables to be either very good/good/average (see Figure 5-7).

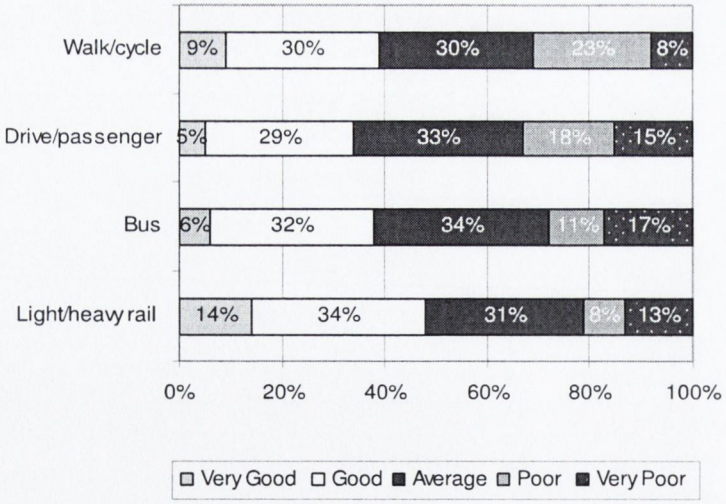
Figure 5-7 Quality of time tables at bus stops/train stations



(N=495)

48% of rail users indicated that they found public transport websites to be good or very good; this was the highest of all the user groups (see Figure 5-8). The walk/cycle group followed next with 39% indicating the quality to be very good/good followed by 38% of bus users. Of all the user groups drivers/passengers had the poorest perception of public transport websites, with 34% indicating them to be very good/good.

Figure 5-8 Quality of public transport web-sites

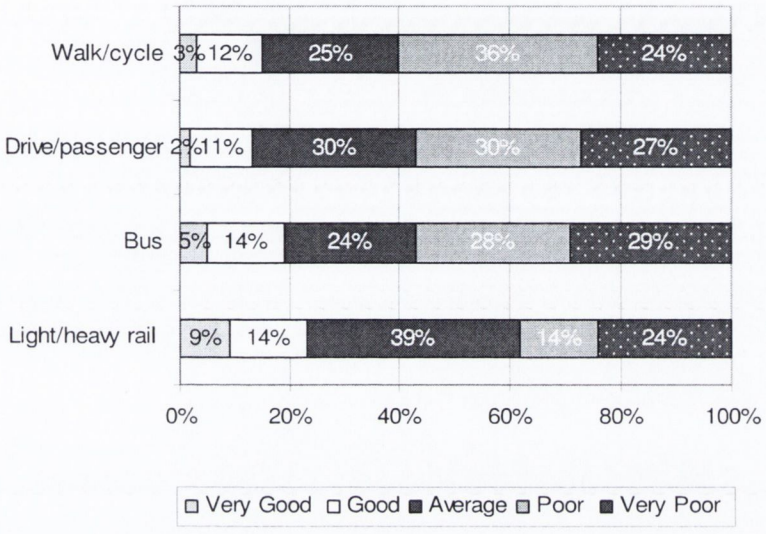


(N=495)

60% of the walk/cycle group indicated that they perceived the availability of information on the cost of public transport to be poor/very poor (see Figure 5-9). The bus users group

were found to have the second highest percentage of respondents indicating that the quality to be poor/very poor, followed by drive/passenger and light/heavy rail.

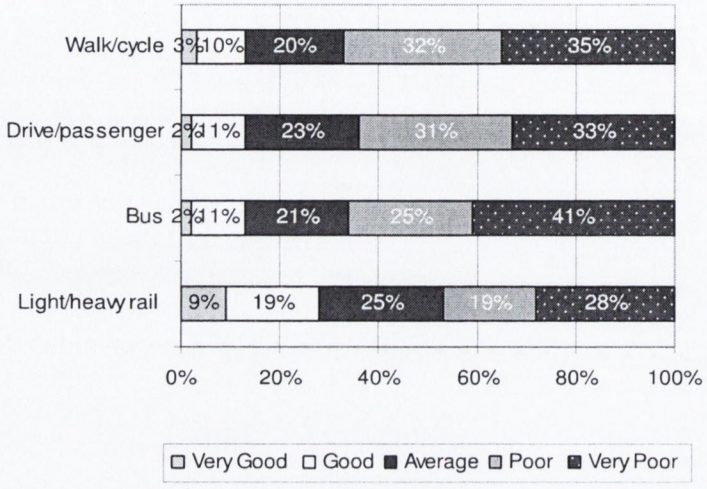
Figure 5-9 Availability of information on the cost of your trip



(N=495)

67% of the walk cycle group indicated that the availability of real-time transport information to be poor/very poor (see Figure 5-10). The light/heavy rail user group were found to have the lowest number of respondents indicating that the availability of real-time information was poor. This result may be attributable to the fact that the majority of rail services in Dublin have real-time passenger information available at each stop/station. 66% of bus users and 64% drive/passengers indicated that the availability of real-time information is poor/very poor.

Figure 5-10 Availability of real-time information on your trip



(N=495)

5.5.2 Convenience of using technology to obtain public transport information

The questionnaire asked how convenient respondents perceive access to public transport information using the internet, a mobile phone, a PID or using a call centre to be. Respondents were asked to rate these methods as either convenient, no opinion or inconvenient, the results of which are presented in this section.

The results demonstrate that 70.9% of respondents deem accessing public transport information using the internet to be convenient, with just 16.8% indicating it to be inconvenient (see Table 5-20). 68.1% indicated that using a mobile phone to access transport information to be convenient and 18.3% indicated that they had no opinion.

The findings for the convenience of accessing public transport information using a call centre were less conclusive compared to the other options. 39.6% indicated it to be convenient, 28.2% were found to have no opinion, and 32.2% said it was inconvenient. Compared to the other options, the inconvenience score for using a call centre was found to be highest of four options. The final method of accessing transport information using a PID was found to be convenient by 82.5% of respondents. The results found that just 5.8% of respondents indicate that using a PID to be inconvenient.

Table 5-20 Convenience of using technology to access public transport information

Option	Convenient (%)	No opinion (%)	Inconvenient (%)	Total (%)
Internet	70.9	12.3	16.8	100.0
Mobile Phone	68.1	18.3	13.6	100.0
Call Centre	39.6	28.2	32.2	100.0
Passenger Information Display	82.5	11.7	5.8	100.0

(N=495)

5.5.3 Frequency of current use of public transport information

The questionnaire asked respondents how often they currently access public transport information at each of the three stages of a public transport trip examined in this study. 14.5% of respondents were found to regularly access public transport information when planning their trip from home to work. However, 38.0% said they seldom and 30.7% said they never access transport information at this stage (see Table 5-21).

At the second stage, 33% of respondents said that they regularly access public transport information while waiting at their bus stop/train station (See Table 5-21). However, 23.5% indicated that they currently seldom and 24.9% said they never currently access transport information at this stage.

Finally, 26.9% said they never, and 28.9% indicated that they seldom access transport information when planning their public transport trip from work returning home. 20.0% of respondents at this stage said that the regularly access transport information at this stage.

Table 5-21 Frequency usage of public transport information

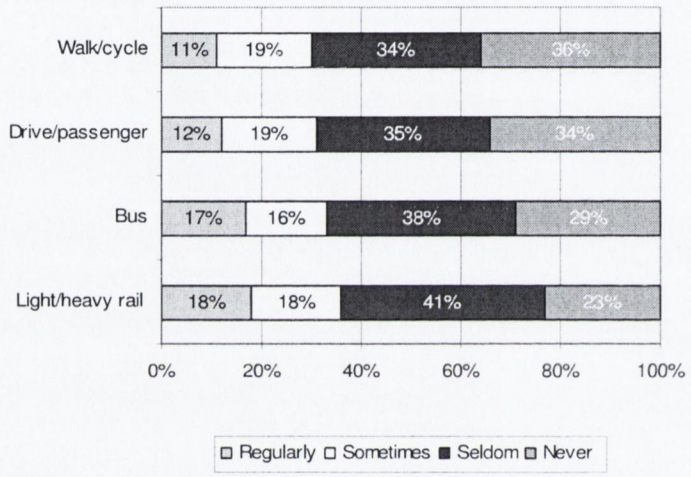
Option	Regularly (more than 3 times a week) (%)	Sometimes (1-3 times a week) (%)	Seldom (less than once a week) (%)	Never (%)	Total (%)
At home planning your trip to work	14.5	16.8	38.0	30.7	100.0
At your bus stop/train station	33.3	18.3	23.5	24.9	100.0
At work planning your trip home	20.0	24.2	28.9	26.9	100.0

(N=495)

The responses to the questions in table 5-21 were segmented by the mode of transport used, and presented in Figure 5-11 to Figure 5-13.

The results show that the light/heavy rail user group currently use transport information more often than the other user groups, at the first stage. 33% of bus users were found to regularly/sometimes access public transport information at stage one (see Figure 5-11). The drive/passenger and walk/cycle user groups were found to equally seldom/never access public transport information. The results show that 35% of drive/passengers and 34% of walk/cycle users seldom access public transport information.

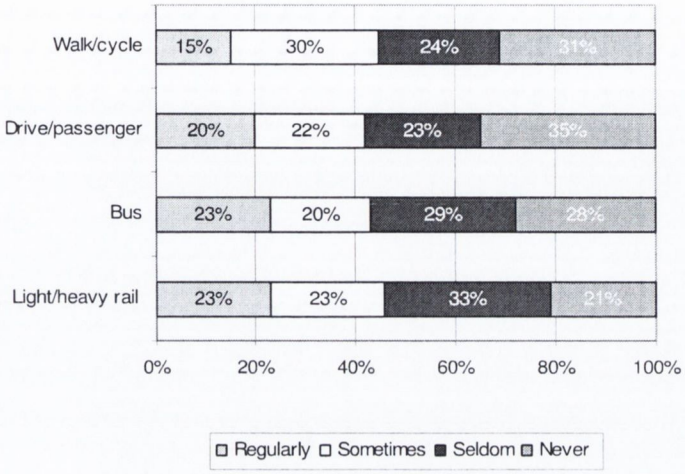
Figure 5-11 Current use of transport information - stage one



(N=495)

The results for the second stage shows that 35% of the drive/passenger user group never access transport information if travelling on public transport at the second stage (see Figure 5-12). 32% of the walk/cycle users indicated that they never access transport information at the second stage. 23% of both the bus and heavy/rail user groups were found to regularly access transport information at the second stage.

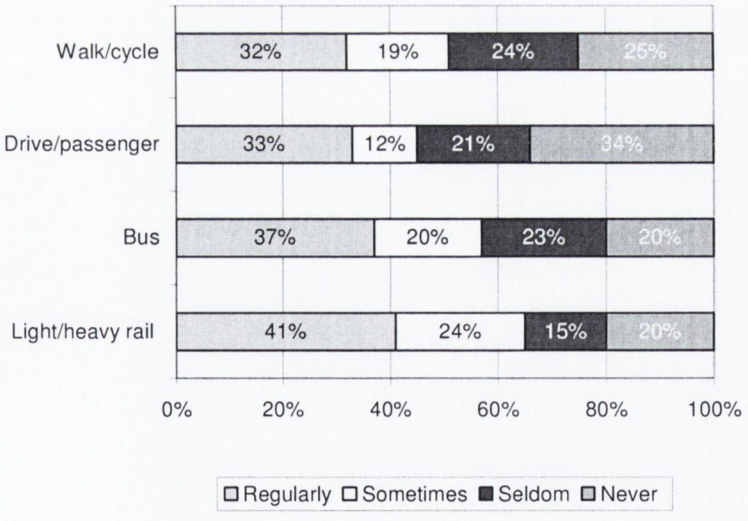
Figure 5-12 Current use of transport information - stage two



(N=495)

Light/heavy rail users were found to currently access transport information at the third stage more frequently than any of the other user groups at the third stage (see Figure 5-13). 57% of bus users were found to regularly/sometimes access transport information at the third stage.

Figure 5-13 Current use of transport information - stage three



(N=495)

5.6 ACCESS TO INFORMATION TECHNOLOGY

An important factor in determining the choices made by respondents among real-time transport information options is their access to information technology.

5.6.1 Mobile phone ownership

Rates of mobile phone ownership and contract type are presented in this section. 97.1% of respondents indicated that they had a mobile phone available (see Table 5-22). In Ireland there are two mobile phone contract types, pay-as-you-go and pay monthly. The first contract type is where users pay for their calls on a prepaid basis, and the second contract type is where users pay for their calls on a monthly basis. The results show that 48.2% of respondents had a pay monthly contract type, and 51.8% had a pay-as-you-go contract (see Table 5-23).

Table 5-22 Mobile phone ownership

Mobile phone ownership	No of respondents	Percentage (%)
Mobile phone available	481	97.1
No mobile phone	14	2.9
Total	495	100.0

Table 5-23 Mobile phone contract type

Mobile phone contract type	No of respondents	Percentage (%)
Pay monthly	239	48.2%
Pay-as-you-go	256	51.8%
Total	495	100.0%

5.6.2 Internet access

Access to the internet is examined in this section. Initially respondents were asked where they currently accessed the internet most often. The results show that 20.8% of respondents accessed the internet at home, and 79.2% accessed the internet at work (see Table 5-24).

Table 5-24 Internet access

Mobile phone contract type	No of respondents	Percentage (%)
Home	102	20.8
Work	393	79.2
Total	495	100.0

In the questionnaire respondents were asked if they had broadband internet access at home. The results demonstrate that 33.3% of individuals have broadband access at home (see Table 5-25).

Table 5-25 Broadband available

Broadband internet connection at home	No of respondents	Percentage (%)
Yes	165	33.3
No	330	66.7
Total	495	100.0

5.7 SOCIO-ECONOMIC RESULTS

The socio-economic characteristics of the respondents are presented in this section. This section presents results on, gender, age, income and the number of cars in the household.

5.7.1 Gender

The results show that 43.4% of the respondents were male, and 56.6% were females (see Table 5-26).

Table 5-26 Gender of respondents

Gender	Number of respondents	Percentage (%)
Male	215	43.4
Female	280	56.6
Total	495	100.0

5.7.2 Age of respondents

In the questionnaire, respondents were asked to indicate their age using one of the five age bands; under 24, 25 – 34, 35-44, 45-54 and over 55. 42.0% of respondents were found to aged 25-34, and 24.0% were aged 35-44 and 21.0% age 45-54 (see Table 5-27).

Table 5-27 Age of respondents

Age	Number of respondents	Percentage (%)
Under 24	35	7.0
25 – 34	208	42.0
35 – 44	119	24.0
45 – 54	104	21.0
Over 55	29	6.0
Total	495	100.0

5.7.3 Income

Table 5-28 presents the reported incomes of the respondents to the questionnaire. The results show a wide distribution of income. 36.3% of respondents were found to earn

between €20,000 and €49,999, and 40.9% earn between €50,000 and €99,999 (see Table 5-28).

Table 5-28 Respondents income

Income	No of respondents	Percentage (%)
Less than €9,999	9	1.8
€10,000 - €19,999	26	5.0
€20,000 - €29,999	69	13.7
€30,000 - €39,999	58	11.8
€40000 - €49,999	53	10.8
€50,000 - €59,999	61	12.3
€60,000 - €79,999	77	15.6
€80,000 - €99,999	64	13.0
€100,000 - €119,999	37	7.5
€120,000 - €139,999	18	3.7
More than €140,000	12	2.5
I do not wish to revel my income	11	2.3
Total	495	100.0

5.7.4 Number of cars per household

This section presents the result on the number of cars per household. 6.7% of respondents indicated that they have no car available and 16.5% have one car in their household (see Table 5-29). 41.4% of households were found to have two cars in their household, and 35.4% have three or more cars in their household.

Table 5-29 Number of cars per-household

Number of cars	No of respondents	Percentage (%)
No car	33	6.7
One car	82	16.5
Two cars	205	41.4
Three or more cars	175	35.4
Total	495	100.0

5.8 Qualitative Comments on the Survey

The final section of the survey asked respondents if they had any comments or suggestions on the survey or the theme of the research, to submit them in a text box at the end of the survey. 33% of all respondents placed a comment into the comment box.

5.8.1 Analysis of qualitative information

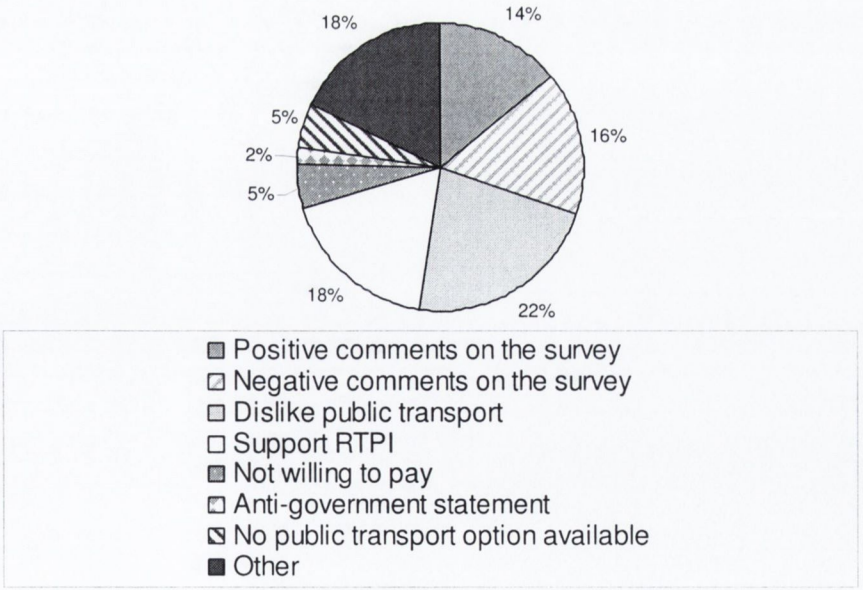
The qualitative comments from the survey were grouped into the following eight categories; positive comments on the survey, negative comments on the survey, dislike of public transport, support of real-time information, not willing to pay, anti-government, no

public transport option available and other. Figure 5-14 presents the percentage of the responses which fall into each category. Table 5-30 presents a sample of these responses.

An examination of these responses shows that 22% of all comments were anti-public transport comments. 18% of the comments indicated support of the introduction of real-time public transport information, the same amount of comments may be put into the 'other' category. These other comments cover a wide range of topics, a sample of some of the topics are presented below. Positive and negative comments on the survey itself accounted for 14% and 16% of all comments. The majority of negative comments referred to the length of the survey and the positive comments related to the concept of the research being conducted (a sample of these comments are presented in Table 5-30.

The remaining 12% of the responses was broken down between 5% indicating that they were not willing to pay for public transport information. 5% make anti-government remarks and 2% indicated that public transport was not an option. Table 5-30 contains a sample of the comments collected for each of these sections.

Figure 5-14 Breakdown of qualitative responses



(N=162)

Table 5-30 Selection of comments

Positive comments on the survey:
'Creative Questionnaire! But as I am a committed cyclist I would prefer more incentive being given to encourage people to get more exercise and enjoy the privilege!!'
'An interesting and well thought out survey'
Negative comments on the survey:
'Questions seemed to be too similar. The reason I wouldn't use a call centre is to do with waiting for the phone to be answered, but that idea is not available on the form.'
'The Questionnaire is very long!'
'This questionnaire was very long and would probably put people off replying to it.'
Dislike public transport:
'Public transport in Dublin is appalling. It is not integrated or linked between different sectors. i.e. Luas, bus etc. It is not flexible enough nor customer focussed. Lack of park & ride facilities at stations include bus is an outrageous situation.'
'Dublin transport need the following: 1. bus lanes 2. non-aggressive bus drivers, who smile on occasion 3. bus drivers who actually enjoy their job 4. bus drivers who don't take out their lives frustrations out on you! 5. bus lanes. 6. hand rails'
'Having lived abroad for many years and used public transport, I am very disappointed at the quality of public transport service provided in Dublin. The lack of information at stops and the impossibility of making logical connecting journeys across the city'
Support real-time information:
'Very interested in real-time travel information BUT it must be accurate. Recently an early morning news bulletin informed of a power failure on the DART line but it was ages before this was reflected in changes to the 'real time' information.'
'Real time information provision would encourage me to use public transport more often, particularly in bad weather. Billboards, such as those in DART stations, would be a useful method of displaying this information. To reduce costs/ vandalism, billboards could be placed at each major city centre bus terminus (eg College Street)'
'Real time information is key to public transport'
Not willing to pay:
'Public transport in Dublin is already rather expensive as it is in comparison to Paris or Milan or other cities that are currently providing real time information. To be charged more for provision of real time info would not be a welcomed move.'
Public transport in Ireland is far too expensive. Having lived and worked in Canada and travelled extensively within Europe and North Africa only proves my lack of confidence in Dublin transportation. Even undeveloped countries like Tunisia have a cheap'
Anti – government statement:
'WOULD LIKE TO SEE MUCH MORE GOVT. INVESTMENT IN PUBLIC TRANSPORT THROUGHOUT THE COUNTRY, ESPECIALLY THE DUBLIN / BELFAST LINE'
'If Dublin City Council insist on blocking transport through the city, by widening pathways, narrowing intersections and allowing building/construction to encroach further on to already narrow streets public transport will need more than real time info.'
No public transport option available:
'THERE IS NO PUBLIC TRABSPORT BETWEEN WHERE I LIVE AND WHERE I WORK'
'Frequent bus services on all routes would help to encourage more people leave their car at home. It's the uncertainty of travel time and bus routes that stop me from using public transport at weekends.'
Other:
'I work in Parnell sq. I have a pretty long walk down to the bus stop on the quays. By the time I get down there is always a huge queue. The buses are full and there is no reliability regarding getting home to two children. Even if a toll was introduced for Dublin I would willingly pay because a car will guarantee me getting home as a time I need to be home.'
'I note nothing was asked about integrated ticketing, which is obviously a good idea and should have been introduced well before now. Best of luck with your study.'
'Only an Act of God would cause me to use Public Transport, and I consider myself a lot more flexible than public transport.'

5.9 SUMMARY

This chapter presents a summary of the statistics collected from the main questionnaire used in this thesis. The results in this chapter include statistics on the following; mode of transport used, work patterns, location specific information, opinion of public transport information, opinion of the use of technology to access public transport information, socio-economic details and qualitative responses. The purpose of this chapter is to provide guidance when interpreting the variables which are analysed in chapters 6, 7 and 8. Therefore, the results presented are the general statistics collected from the questionnaire, and the analysis of these statistics is conducted in the subsequent chapters.

6 MODEL ESTIMATION INCORPORATING EXPLANATORY VARIABLES

6.1 INTRODUCTION

This chapter investigates the impact of explanatory variables on the models estimating the choice between transport information options. The purpose of this investigation is to ascertain how explanatory variables such as gender, income or age impact upon the choice of transport information option. The explanatory variables of interest are tested one-by-one to ascertain the impact of the explanatory variable upon the choice transport information option.

The base model results for each of the choice scenarios examined are presented in the first section. These base models provide an indication as to the performance of the variables used in the choice experiments contained in the survey. These base models are used to calibrate further models which are specified using the explanatory variables. The purpose of adding these variables is to firstly ascertain the impact of the variable in question, but to also strengthen the predictive power of the model. As the model incorporates more information on the respondent (such as gender, age or income) it enables the model to explain in greater detail the reasons behind individual choice. For example, those who drive may not derive the same benefit from transport information as those who use public transport on a regular basis. A range of variables are tested to provide a comprehensive review of which factors impact upon the choice of transport information option.

The variables analysed are grouped as follows 1) current travel patterns/characteristics, 2) socio-economic characteristics, 3) location specific characteristics, 4) access to technology characteristics and 5) work travel pattern variables. The variables in each of these groups are tested in sections 6.4, 6.5, 6.6, 6.7 and 6.8. In each of the sections the variables are examined and then combined to produce a model which includes some/all of the variables considered in that section. The purpose of this combination is to produce optimal model specifications which increase the explanatory power of the model. Section 6.9 presents models which are combined with explanatory variables from all of the five groups to provide enhanced models for each journey stage examined. These enhanced models represent optimal models in that they have the greater explanatory power and provide a

better indication as to the impact real-time information. The chapter concludes with a summary section, which presents the main findings of the chapter.

6.2 BASE MODELS

The first models to be presented in this chapter are the base models. A base model in choice modelling reports the results from the stated choice experiments contained in the survey. As the survey presented respondents with three choice scenarios the three base models are considered. In the interest of brevity, each of the choice scenarios will assume the following names:

- Stage One: information for pre-trip planning from home
- Stage Two: information available at bus stop/rail station
- Stage Three: information for pre-trip planning from work returning home

Utility functions are used to represent the benefit individuals derive from a good. This utility is assumed to be obtained from the characteristics of the good for example in the case of a mode of transport, the cost, time and comfort may be characteristics which would define utility (Train, 2004). In the case of this study, utility is defined by the following characteristics, wait time saved, cost (monetary cost of accessing information), and type information provided. The utility functions for the three models/stages are as follows:

Equation 6-1 Base model stage one

$$U_{net} = \alpha_1(TIME) + \alpha_2(COST) + \alpha_3(TYPE_OF_INFO)$$
$$U_{SMS} = \alpha_4(TIME) + \alpha_5(COST) + \alpha_6(TYPE_OF_INFO)$$
$$U_{call} = \alpha_7(TIME) + \alpha_8(COST) + \alpha_9(TYPE_OF_INFO)$$

Equation 6-2 Base model stage two

$$U_{PID} = \alpha_1(TIME) + \alpha_2(COST) + \alpha_3(TYPE_OF_INFO)$$
$$U_{SMS} = \alpha_4(TIME) + \alpha_5(COST) + \alpha_6(TYPE_OF_INFO)$$
$$U_{call} = \alpha_7(TIME) + \alpha_8(COST) + \alpha_9(TYPE_OF_INFO)$$

Equation 6-3 Base model stage three

$$U_{net} = \alpha_1(TIME) + \alpha_2(COST) + \alpha_3(TYPE_OF_INFO)$$
$$U_{SMS} = \alpha_4(TIME) + \alpha_5(COST) + \alpha_6(TYPE_OF_INFO)$$
$$U_{call} = \alpha_7(TIME) + \alpha_8(COST) + \alpha_9(TYPE_OF_INFO)$$

Where U_{net}, U_{SMS}, U_{call}, U_{PID} are the utilities derived from using the internet, mobile phone, call centre and passenger information display to obtain public transport information. TIME is the wait time saving in minutes, COST is the monetary cost of accessing the information, and TYPE_OF_INFO is the type of information they receive (static or real-time). The α's are the coefficients to be estimated by the multinomial logit models (MNL).

When examining the results from a MNL model it is necessary to ensure that the coefficients (α's) are statistically different from zero at the 90%, 95% or 99% confidence levels. To identify the significance values the *t*-ratio is used and it is presented next to each of the coefficients estimated in this chapter in brackets. Values for the *t*-ratio of 1.90 are significant at the 90% confidence level, 1.96 – 2.58 significant at the 95% confidence level and greater than 2.59, significant at the 99% confidence level (Mason et al, 2000).

It is also important that the $\rho^2(0)$ and $\rho^2(c)$ values are between 0.2 and 0.4 as this is an indication of a MNL model that has a good fit (Louviere et al, 2000 and Hensher et al, 2005). The $\rho^2(0)$ and $\rho^2(c)$ values are similar to the R^2 values used in regression model, with values ranging between 0.2 and 0.4 indicating a good model fit. The methods of calculating and interpreting $\rho^2(0)$ and $\rho^2(c)$ values is presented in chapter 3, section 3.8.3.

The final test to be examined is the likelihood ratio test. This test similar to the *F* test in regression, in that it details the overall performance of the model with the addition of new variables (see section 3.2 for an explanation). The value for this test is 3.84 for 1 degree of freedom at the 95% confidence level and 13.28 for 1 degree of freedom at the 99% confidence level; models which reach this value reject the null hypothesis (that the base model has a higher prediction power) (Ben Akiva, 1985). A detailed discussion of the outputs from a MNL model is presented in chapter three, section 3.8

The results of the base models are presented in table 6-1. The findings demonstrate that all coefficients are statistically different to zero, at least at the 90% level with the majority at the 99% level. All three models produce good $\rho^2(0)$ and $\rho^2(c)$ values of 0.211 and 0.203 at stage one, 0.209 and 0.201 at stage two and 0.215 and 0.208 at stage three.

An example of how the results should be interpreted is given here. Consider the set of equations below (equation 6-4). The utility an individual *i* derives from option *q* (in this case the internet) and is dependent upon the reduction in wait-time, the cost and the type of information provided by option *q*. The estimated α's are taken from table 6-1, from the coefficients for the internet from model M6-1. The impact the coefficients have upon the utility derived from using the internet is seen in the third line of the set of utility equations below (see equation 6-4). As the α estimated for a reduction in wait-time was found to have a negative value of -0.031, and the data imputed at this stage was -0.25 (representing a 25% reduction in wait time), the overall impact of a reduction in wait-time is found to be positive.

In the cost expression, the α was estimated to be -0.096, and the data entered for cost was positive (0.30 representing 30c for using the internet). The overall impact of cost on utility can be said to be negative. Finally, the α estimated for information type again was found to be negative (-0.453). As the data for choosing real-time information was -1, this results in the provision of real-time information having a positive impact upon utility.

Equation 6-4

$$U_{iq} = a_{wait}(reduction_in_wait-time) + a_{cost}(\cos t) + a_{\inf o}(\inf o_type)$$
$$U_{iq} = (-0.031(-0.25)) + (-0.096(0.30)) + (-0.453(-1))$$
$$U_{iq} = (0.008) + (-0.029) + (0.453)$$
$$U_{iq} = 0.432$$

The results at the first stage demonstrate that the call centre is deemed to provide the greatest benefit with regard to time saved (-0.037) followed by SMS and the internet with coefficient values of -0.035 and -0.031 respectively. The coefficient for internet cost is the most cost sensitive (-0.096) followed by call centre (-0.030). Receiving information by SMS had the lowest cost disutility of -0.024, demonstrating that cost of SMS information did not deter individuals from choosing it in comparison with the other two methods. The importance of transport information being provided is shown to be most significant in the case of call centre information with a coefficient estimated at -1.100. Of the three options considered at this stage, the provision of real-time information from the internet was found to be least significant in the case of information from the internet (-0.453).

The model estimates from the second stage show that passenger information display had the highest estimated coefficient for time saved (-0.058). The coefficients from the other two variables indicate a marginally higher value for time saved from an SMS of -0.046 compared to -0.041 from a call centre. As with the first stage SMS has the lowest disutility for cost (-0.036), followed by passenger information display (-0.039) and call centre (-0.045). At this second stage both the call centre and passenger information display have high negative coefficients for the type of information variable, indicating a strong requirement that information at this stage should be real-time information.

The results at the third stage show that the disutility of cost is least for the internet option, and highest with call centre. The coefficients for time saved demonstrate that using a call centre is deemed to provide the greatest benefit of time saved reporting a high positive coefficient of -0.048, followed by SMS -0.034 and the internet -0.028. The coefficient values for the type of information, demonstrate the highest and most significant coefficient value for SMS followed by the internet and call centre.

In the subsequent sections of this chapter the specific coefficient values for time saved, cost and information are not discussed with any of the other models. This is due to the large number of models examined and the fact that the added explanatory variables are the variables of interest.

Table 6-1 Base Model Estimates

	Variables	M6-1	M6-2	M6-3
		Stage One	Stage Two	Stage Three
Internet	Time saved	-0.031 (-2.1)*		-0.028 (-2.2)*
	Cost	-0.096 (-3.4)**		-0.036 (-6.9)**
	Information	-0.453 (-2.4)*		-0.658 (-3.6)**
SMS	Time saved	-0.035 (-2.5)*	-0.046 (-2.3)*	-0.034 (-2.6)**
	Cost	-0.024 (-5.9)**	-0.036 (-7.9)**	-0.037 (-7.8)**
	Information	-0.802 (-2.4)*	-1.098 (-5.6)**	-1.331 (-7.6)**
Call Centre	Time saved	-0.037 (-2.7)**	-0.041 (-2.1)*	-0.048 (-3.6)**
	Cost	-0.030 (-9.4)**	-0.045 (-9.9)**	-0.041 (-10.3)**
	Information	-1.100 (-3.2)**	-0.953 (-4.4)**	-0.641 (-3.8)**
PID	Time saved		-0.058 (-5.7)**	
	Cost		-0.039 (-9.7)**	
	Information		-1.049 (-4.9)**	
N		1980	1980	1980
$\rho^2(0)$		0.211	0.209	0.215
$\rho^2(c)$		0.203	0.201	0.208
Final likelihood		-1797.28	-1730.72	-1725.84

* Significant at the 95% confidence level, ** Significant at the 99% confidence level

6.3 ANALYSIS OF EXPLANATORY VARIABLES

The following sections examine the addition of one or more explanatory variables to the base model. The purpose of their inclusion is to examine the impacts of factors such as income, gender and mode of transport on the results for each of the different stages. The explanatory variables examined are defined in table 6-2.

Explanatory variables when incorporated into the base models can only interact with one or two of the utility equations. Therefore, if for example an income variable is introduced into a model and the highest coefficient value for the income variable is found to be when the variable is interacted with the utility equation for SMS, then the coefficient value for income and SMS is reported. In this particular example, it is then fair to say that all things being equal, those on higher incomes are more likely to choose SMS rather than the other options.

The real-time information option that a variable is interacted with is denoted in the table in which the variable is presented by a number in brackets following the variable. For example INCOME (1), is when income is interacted with the internet (with 1 indicating the first choice in the scenario being examined). The remaining options are not reported, unless they are found to be insignificant or report a different coefficient value. The results of the interaction with the other real-time information options are reported in appendix II. These results are not reported in this chapter, as to do so would result in an un-manageable amount of models being presented in this chapter.

The methods used in this chapter to analyse and interpret model coefficients presented in this chapter should be considered when interpreting the coefficients presented in chapters 7 and 8.

Table 6-2 Description of Explanatory Variables

Variable	Description
AGE	Categorical variable: respondents age values 1-5 represent: under 24, 25-34, 35-44, 45-54, 55 and over.
BBNET	Dummy variable: does the household have broadband, 1 if yes, and 0 otherwise
BUS	Dummy variable: those who use a bus to travel to work take a value of 1, otherwise 0
CARAV	Dummy variable: if car available equals 1 and if not 0
CONMOB	Dummy variable: if pay monthly contract equals 1, if pay-as-you-go equals 0
DRIVE	Dummy variable: those who either drive or are a passenger in a car on their journey to work take a value of 1, otherwise 0
DEPT	Categorical variable: respondents departure time the values 1-8 represent: before 06.30am, 06.30 – 07.00am, 07.00 – 07.30am, 07.30 – 08.00am, 08.00-08.30am, 08.30 – 09.00, 09.00 – 09.30 and after 09.30
FIXW	Dummy variable, if respondent has fixed set working hours equal to 1, 0 otherwise
GENDER	Dummy variable, 1 if male, 0 if female
HQBUS	Dummy variable: does the respondent live within a 10 minute walk of a bus service which uses a bus lane, 1 if yes and 0 otherwise
HQRAIL	Dummy variable: does the respondent live within a 10 minute walk of a rail service (light rail or heavy rail), 1 if yes and 0 otherwise
INCOME	Categorical variable: respondents annual income, 1-11 represent: less than €10,000, €10,001 - €20,000, €20,001 - €30,000, €30,001 - €40,000, €40,001 - €50,000, €50,001 - €60,000, €60,001 - €80,000, €80,001 - €100,000, €100,001 - €120,000, €120,001 - €140,000 and over €140,000
MULTI	Dummy variable: those that take more than one mode of public transport on their journey to work take a value of 1, otherwise 0
NETWRK	Dummy variable: if respondent has unlimited access to the internet at work, equals 1, 0 otherwise
PTTIME	Categorical variable: this variable is the sum of all the reported times to walk, wait, travel and walk when using public transport
RAIL	Dummy variable: those who use rail to travel to work take a value of 1, otherwise 0
WALKCY	Dummy variable: those that walk or cycle to work take a value of 1, otherwise 0
WALKSTOP	Categorical variable: where values 1 – 7 represent the following: 0-5 minutes, 5-10 minutes, 10-15 minutes, 15 – 20 minutes, 20 – 25 minutes, 25 – 30 minutes and more than 30 minutes
WAIT	Categorical variable: where values 1 – 7 represent the following: 0-5 minutes, 5-10 minutes, 10-15 minutes, 15 – 20 minutes, 20 – 25 minutes, 25 – 30 minutes and more than 30 minutes
ZONES	Categorical variable, where postal code zones in Ireland are grouped by proximity to the city centre. 1 = D1,2,7,8 2 = D 4, 6, 6w, 12 3 = D 3,5,9,10,14, 16 4 = D 17, 11, 15, 20, 22, 24, 18 5 = Outer counties (County Dublin, Kildare, Meath, Wicklow and Louth)

6.4 Estimation of Models with Current Mode of Transport Variable

This section examines the impact of mode of transport used and journey time on individuals choices for methods of accessing real-time information. The purpose of this examination is to ascertain how current travel patterns may impact upon choice, and to

identify those individuals who are likely to use each method of transport information examined in this study. All transport users are examined in this section, including car users. In the survey it asked respondents if they were to use public transport to travel to work, which method of transport information would they use. Therefore car users are examined as their responses will provide an insight into what type of information car users would derive the greatest benefit. This was considered to be important as it provides an insight as to what forms of real-time information they would require if using public transport.

6.4.1 MNL models incorporating mode of transport variables – stage one

This subsection examines the impact of current mode of transport on the results for stage one. The effect that the current mode of transport has on the choice of transport information option is an important aspect to examine, as it will provide insight into which group of transport users choose the various transport information options.

Four modes of transport walk/cycle, bus, rail and car are examined in this section. To examine each of these modes four dummy variables were created to represent the respondents that used each mode. The following variables were defined WALKCY, BUS, RAIL and DRIVE, for each of the modes of transport examined (detailed defined in table 6-2). A positive value for these mode variables indicates that the individuals that use the mode in question are more likely to derive a higher utility from transport information and vice versa.

The walk/cycle variable is tested in model M6-4 in table 6-3. The model produced $\rho^2(0)$ and $\rho^2(c)$ values of 0.230 and 0.201. The estimated likelihood ratio test was found to reject the null hypothesis at the 99% confidence level. The walk/cycle variable produces a negative coefficient value of -0.150 and is significant at the 95% confidence level (t-ratio of -2.5). This negative value indicates that that all things being equal individuals who do not walk/cycle are more likely to choose to receive transport information using SMS rather than from call centre or the internet.

The bus variable at stage one is examined in model M6-5 (see table 6-3). The model produces $\rho^2(0)$ and $\rho^2(c)$ values of 0.218 and 0.209, the likelihood ratio test rejects the null hypothesis at the 99% confidence level. The coefficient value for the bus variable is positive and significant at the 99% confidence level (t-ratio of 3.2). The interpretation of

this result suggests that all things being equal those respondents who travel to work by bus at stage one are more likely to choose to use the internet or SMS to receive real-time information.

The coefficient for rail was found to have a positive value of 0.122 and to be significant at the 95% levels with a *t*-ratio of 2.3 (see model M6-6, table 6-3). As with bus users with all things being equal this group of public transport users are more likely to choose to access transport information using SMS at the first stage. The $\rho^2(0)$ and $\rho^2(c)$ values for model M6-6 were estimated to be 0.220 and 0.206, and likelihood ratio test produces a value of 78.55, which rejects the null hypothesis at the 99% confidence level (see table 6-3) both of which indicate a reasonably good model of fit.

The coefficient for car users was found to have a negative value of -0.309 (see table 6-3). The value for the car coefficient was shown to be significant at the 99% confidence level with a *t*-ratio of -3.6 (see model M6-7 in table 6-3). This result is similar to the values found for the walk/cycle variable, in that car users are less likely to derive utility from real-time information, before they undertake their journey. The negative coefficient can be interpreted as non-car users are more likely to choose SMS to obtain real-time information, than the other options offered. Model M6-7 produced $\rho^2(0)$ and $\rho^2(c)$ values of 0.227 and 0.210, and the likelihood ratio test rejects the null hypothesis at the 99% confidence level, both values demonstrate a good model fit.

Table 6-3 MNL models incorporating mode specific variables – stage one

Variables		M6-4	M6-5	M6-6	M6-7
		Stage One			
Internet	Time saved	-0.030 (-3.9)**	-0.035 (-2.8)**	-0.037 (-3.7)**	-0.040 (-4.5)**
	Cost	-0.094 (-6.5)**	-0.083 (-3.6)**	-0.080 (-6.8)**	-0.074 (-4.6)**
	Information	-0.195 (-1.9)*	-0.357 (-1.9)*	-0.317 (-3.6)**	-0.218 (-2.0)*
SMS	Time saved	-0.040 (-5.6)**	-0.038 (-2.7)**	-0.037 (-6.5)**	-0.035 (-3.6)**
	Cost	-0.023 (-8.9)**	-0.024 (-5.7)**	-0.024 (-3.8)**	-0.024 (-8.2)**
	Information	-1.050 (-9.3)**	-0.902 (-4.6)**	-0.945 (-8.1)**	-1.053 (-7.5)**
Call Centre	Time saved	-0.033 (-4.6)**	-0.030 (-2.5)*	-0.026 (-5.5)**	-0.025 (-3.0)**
	Cost	-0.029 (-7.4)**	-0.029 (-8.9)**	-0.029 (-6.1)**	-0.029 (-6.2)**
	Information	-0.832 (-8.5)**	-0.979 (-5.1)**	-0.926 (-9.1)**	-0.816 (-6.0)**
WALKCY(2)		-0.150 (-2.5)*			
BUS(1)			0.390 (3.2)**		
RAIL(2)				0.122 (2.3)**	
CAR (3)					-0.309 (-3.6)**
N		1980	1980	1980	1980
$\rho^2(0)$		0.230	0.218	0.220	0.227
$\rho^2(c)$		0.201	0.209	0.206	0.210
Final Likelihood		-1768.25	-1753.26	-1758.01	-1754.58
Likelihood ratio test		58.07†	88.06†	78.55†	85.41†

(1) Internet (2) SMS (3) Call centre

* Significant at the 95% confidence level

** Significant at the 99% confidence level

† Null hypothesis rejected

6.4.2 MNL models incorporating mode of transport variables – stage two

The results from the inclusion of the walk/cycle variable in stage two are reported in model M6-8 (see table 6-4). The model produces $\rho^2(0)$ and $\rho^2(c)$values of 0.231 and 0.202 and the likelihood ratio test rejects the null hypothesis is rejected at the 99% confidence level (see table 6-12), indicating the model displays a good fit. The coefficient value for the walk/cycle was found to have a negative of -0.240 and to be significant at the 95% confidence level (*t*-value of -2.0). The negative coefficient demonstrates that at this stage those who do not walk or cycle all things being equal are more likely to use transport information using a call centre or SMS compared to the internet.

The bus user coefficient for the second stage is presented in model M6-9 in table 6-4. The model produced a positive coefficient of 0.173, which is significant at the 95% level for the bus variable. This result demonstrates that individuals who currently use the bus are more likely to choose to obtain transport information from a passenger information display or SMS while waiting for their public transport service to arrive. This model produced $\rho^2(0)$ and $\rho^2(c)$ values of 0.209 and 0.201, and the null hypothesis was rejected at the 99% confidence level, demonstrating a good model fit.

Table 6-4 displays the model estimates when the rail coefficient was incorporated into the base model M6-2. The $\rho^2(0)$ and $\rho^2(c)$ values estimated by this model were 0.203 and 0.197, indicating this model is a good measure of fit (see M6-10 in table 6-4). The likelihood ratio was found to reject the null hypothesis, indicating that the inclusion of the RAIL variable produces an improved model specification. The rail variable was found to have a positive value of 0.168 and to be significant at the 99% confidence level with a *t*-value of 4.5. This result demonstrates that rail users are more likely to use transport information from a passenger information display over the two other options presented at this stage.

The car user coefficient was found to have a negative value of -0.020 and to be significant at the 95% confidence level, with a t-ratio of -2.5 (see model M6-11 in table 6-4). This indicates that those who use the car are less likely to choose transport information option than those who do not drive all things being equal. The negative coefficient may be interpreted as those who do not drive to work are more likely to choose to access transport information from a passenger information display at this stage. The $\rho^2(0)$ and $\rho^2(c)$ values

were estimated to be 0.215 and 0.201 for this model, and the null hypothesis was rejected at the 99% confidence level, indicating a good model fit.

Table 6-4 MNL models incorporating mode specific variables – stage two

	Variables	M6-8	M6-9	M6-10	M6-11
		Stage Two			
PID	Time saved	-0.013 (-2.0)*	-0.060 (-8.2)**	-0.059 (-5.7)**	-0.013 (-3.3)**
	Cost	-0.041 (-10.3)**	-0.036 (-13.2)**	-0.036 (-9.5)**	-0.040 (-5.8)**
	Information	-0.404 (-2.6)**	-0.997 (-6.1)**	-0.896 (-3.9)**	-0.394 (-5.2)**
SMS	Time saved	-0.049 (-3.2)**	-0.026 (-2.5)*	-0.028 (-1.9)*	-0.049 (-2.9)**
	Cost	-0.035 (-7.2)**	-0.383 (-11.2)**	-0.038 (-7.8)**	-0.035 (-5.0)**
	Information	-1.690 (-7.3)**	-1.151 (-8.0)**	-1.272 (-6.2)**	-1.695 (-2.4)*
Call Centre	Time saved	-0.059 (-3.7)**	-0.059 (-2.1)*	-0.012 (-2.1)*	-0.059 (-2.7)**
	Cost	-0.034 (-8.4)**	-0.039 (-13.5)**	-0.038 (-9.5)**	-0.034 (-9.1)**
	Information	-0.502 (-2.1)*	-0.876 (-5.5)**	-0.784 (-3.5)**	-0.496 (-7.2)**
WALKCY (2)		-0.240 (-2.0)*			
BUS (1)			0.173 (2.0)*		
RAIL (1)				0.168(4.5)**	
CAR (1)					-0.020 (-2.5)*
N		1980	1980	1980	1980
ρ^2 *(0)*		0.231	0.209	0.203	0.215
ρ^2 *(c)*		0.202	0.201	0.197	0.201
Final Likelihood		-1794.80	-1706.68	-1711.79	-1723.22
Likelihood ratio test		71.83†	48.06†	37.86†	14.99†

(1) PID (2) SMS (3) Call centre

* Significant at the 95% confidence level

** Significant at the 99% confidence level

† Null hypothesis rejected

6.4.3 MNL model incorporating mode of transport variables – stage three

Table 6-5 details the results for stage three, with mode variables incorporated into the base model. The model estimates from this stage are similar to those for the two previous sections, in that public transport users are more likely to derive a greater benefit from the use transport information than those who walk/cycle or drive to work on a regular basis.

Model M6-12 estimates walk/cycle variable with the base model from stage three. The variable produced was found to have a negative coefficient of -0.223 and is significant at the 99% confidence level (t-ratio of -3.3) (see model M6-12 in table 6-5). This can be interpreted that those that do not walk/cycle are more likely than those who do, to choose to access real-time information, using SMS at this third stage. The model produced $\rho^2(0)$ and $\rho^2(c)$ values of 0.214 and 0.205, and likelihood ratio value of 9.97 rejects the null hypothesis, indicating a model of good fit (see model M6-12 in table 6-5).

Examining the results for the variable for walk/cycle across all three stages, all of the coefficient values are negative. It can be deduced from these results those who walk/cycle derive less utility from real-time information, compared to those who don't walk or cycle across all three stages.

The estimate for the bus coefficient at the third stage was found to have a positive of 0.132 and was significant at the 90% level (*t*-ratio of 1.9) (see model M6-13 in table 6-5). The likelihood ratio test produced a value of 53.74. This rejects the null hypothesis and the $\rho^2(0)$ and $\rho^2(c)$ values produced of 0.233 and 0.209, and both indicate a model of good fit. This value demonstrates that bus users at stage three are more likely to use transport information that those that don't use the bus. Furthermore, a similar result have been found across all three stages indicating that in all stages examined bus users derive a benefit from the use of real-time information.

The rail variable was found to be positive (0.192) and significant at the 99% confidence level for the third stage (see M6-14 in table 6-5). This result indicates that rail users at the third stage are more likely to choose to access transport information using SMS. The model specification produced $\rho^2(0)$ and $\rho^2(c)$ values of 0.210 and 0.201, the null hypothesis was also rejected at the 99% confidence level as the likelihood ratio was estimated at 16.02 (see table 6-12).

The model estimates for all three stages for the rail variable produced positive values. These positive values indicate that rail users derive a positive utility at all stages of their public transport trip.

The coefficient value for car users (see table 6-5, M6-15) was found to be significant at the 90% level (*t*-ratio is -1.9) and to have a negative coefficient value of -0.188. This result implies that car users derive less utility from transport information at this stage all things being equal. The negative value indicates that those respondents who do not drive are more likely to choose SMS as their method of accessing transport information when planning their trip home from work at this third stage. The estimated model produces good $\rho^2(0)$ and $\rho^2(c)$ values of 0.212 and 0.203. The likelihood ratio test produces a value of 8.59 which rejects the null hypothesis at the 95% confidence level.

Table 6-5 MNL models incorporating mode specific variables – stage three

	Variables	M6-12	M6-13	M6-14	M6-15
		Stage Three			
Internet	Time saved	-0.031 (-4.6)**	-0.030 (-4.4)**	-0.028 (-4.2)**	-0.028 (-2.9)**
	Cost	-0.428 (-5.1)**	-0.430 (-6.1)**	-0.452 (-13.6)**	-0.451 (-9.6)**
	Information	-1.064 (-9.1)**	-1.045 (-9.0)**	-0.657 (-6.9)**	-0.695 (-5.1)**
SMS	Time saved	-0.019 (-2.7)**	-0.015 (-1.9)*	-0.030 (-4.3)**	-0.028 (-2.8)**
	Cost	-0.039 (-7.3)**	-0.039 (-6.3)**	-0.036 (-4.5)**	-0.037 (-10.3)**
	Information	-0.851 (-7.1)**	-0.865 (-7.2)**	-1.310 (-4.2)**	-1.262 (-9.7)**
Call Centre	Time saved	-0.062 (-6.9)**	-0.062 (-7.0)**	-0.044 (-6.6)**	-0.046 (-4.8)**
	Cost	-0.038 (-6.2)**	-0.038 (-11.2)**	-0.039 (-9.3)**	-0.039 (-6.3)**
	Information	-1.046 (-8.4)**	-1.035 (-8.3)**	-0.586 (-6.6)**	-0.634 (-5.0)**
WALKCY (2)		-0.223 (-3.3)**			
BUS (2)			0.132 (1.9)*		
RAIL (2)				0.192 (2.8)**	
CAR (2)					-0.188 (-1.9)*
N		1980	1980	1980	1980
ρ^2 *(0)*		0.214	0.233	0.210	0.212
ρ^2 *(c)*		0.205	0.209	0.201	0.203
Final Likelihood		-1720.86	-1698.97	-1717.84	-1721.55
Likelihood ratio test		9.97†	53.74†	16.02†	8.59†

(1) Internet (2) SMS (3) Call centre

* Significant at the 95% confidence level

** Significant at the 99% confidence level

† Null hypothesis rejected

6.4.4 Multi-stage public transport trips

This section examines the impact of a taking a multi-stage public transport trip to arrive at work on the choice of transport information option. A multi-stage public transport trip is defined as someone who takes more than one public transport service to arrive at their place of work. The results in this section are based largely on Caulfield and O'Mahony (2007b). Table 6-6 presents the results from the model including a dummy variable 'MULTI'. This variable has a value of 1 if the respondent has taken a multi-stage public transport trip and 0 if not (defined in table 6-2). Therefore, a positive value would indicate that those who take a multi-stage public transport trip are more likely to choose the public transport information option being analysed, and vice versa.

The coefficient estimates for the MULTI variable at stage one was found to be significant at the 95% confidence level with a *t*-ratio value of 2.3, and positive with a coefficient value of 0.248 (see table 6-6, model M6-16). This result indicates that all things being equal respondents who take more than one public transport service to arrive at work are more likely to use the internet or SMS to access real-time information. The model specification produced $\rho^2(0)$ and $\rho^2(c)$ values of 0.212 and 0.201, and the likelihood ratio was estimated at 23.37, rejecting the null hypothesis at the 99% confidence level (see table 6-12). The $\rho^2(0)$ and $\rho^2(c)$ values and the likelihood ratio values both indicate that the model specified is an improvement on the base model.

The MULTI variable was found to be positive and significant at the 95% confidence level with a *t*-ratio of 2.0 (see table 6-6, model M6-17) at the second stage. This positive value suggests all things being equal that those who undertake a trip using more than one public transport service at the second stage are more likely to access real-time information, using a passenger information display. The $\rho^2(0)$ and $\rho^2(c)$ values of 0.209 and 0.201, and the rejection of the null hypothesis at the 99% confidence level, indicate the model specified demonstrates a good model specification.

The result for the MULTI variable at stage three is also estimated to have a positive and significant value. The coefficient is significant at the 95% confidence level (*t*-ratio of 2.2) and positive with a value of 0.460 (see table 6-6, model M6-18). This model was found to have a good fit with $\rho^2(0)$ and $\rho^2(c)$ values of 0.216 and 0.203. The likelihood ratio rejected the null hypothesis, indicating that the inclusion of the MULTI variable improves

the model specification at stage three. The results indicate that those individuals who take more than one public transport service are more likely to access real-time information, using SMS or a call centre, all things being equal.

The results from each of the three stages indicate that those respondents taking more than one mode of public transport to arrive at work are more likely to derive a benefit from the use real-time information.

Table 6-6 MNL models incorporating multi-stage trip variables

Variables		M6-16	M6-17	M6-18
		Stage One	Stage Two	Stage Three
Internet	Time saved	-0.034 (-2.5)*		-0.069 (-5.7)**
	Cost	-0.041 (-1.9)*		-0.040 (-5.2)**
	Information	-0.129 (-2.5)*		-1.080 (-4.6)**
SMS	Time saved	-0.039 (-2.4)*	-0.033 (-3.3)**	-0.013 (-1.9)*
	Cost	-0.025 (-4.8)**	-0.035 (-10.3)**	-0.036 (-6.0)**
	Information	-1.139 (-4.5)**	-1.118 (-7.7)**	-1.311 (-5.9)**
Call centre	Time saved	-0.037 (-2.8)**	-0.031 (-1.9)*	-0.017 (-1.9)*
	Cost	-0.031 (-7.7)**	-0.038 (-13.4)**	-0.048 (-8.8)**
	Information	-0.723 (-3.0)**	-1.135 (-7.1)**	-0.877 (-4.1)**
PID	Time saved		-0.046 (-6.5)**	
	Cost		-0.315 (-12.0)**	
	Information		-1.178 (-7.5)**	
MULTI (1)		0.248 (2.3)*		
MULTI (4)			0.139 (2.0)*	
MULTI (2)				0.460 (2.2)*
N		1980	1980	1980
ρ^2 *(0)*		0.212	0.209	0.216
ρ^2 *(c)*		0.201	0.201	0.203
Final Likelihood		-1785.60	-1714.20	-1708.44
Likelihood ratio test		23.37†	33.03†	34.81†

(1) Internet (2) SMS (3) Call centre (4) PID
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

6.4.5 Journey times for public transport trips

Journey time by public transport is examined in this section. Journey time is examined across the various sections of a public transport journey; walk time to stop/station, wait time at stop/station and then total journey time (from door to door). The results in this section are based on the work presented in Caulfield and O'Mahony (2007b).

A categorical variable was created for the walk time between home/work and stop/station called WALKSTOP. A positive value for this variable would indicate that as the walk time to stop/station increases so too does the utility for real-time information. This variable is defined in table 6-2.

The wait time variable is a categorical variable which it is defined in table 6-2. A positive value for WAIT would indicate as wait time increases, individuals are likely to derive a benefit from the use of transport information using the option chosen, and vice-versa.

'PTTIME' is a categorical variable that sums the reported wait, walk and journey times of respondents (this variable is defined in table 6-2). This variable sums the total time it takes a respondent to travel from their door to their office, taking in all stages of this journey. A positive value for PTTIME indicates as journey time by public transport increases so too does the utility derived for transport information and vice versa.

The WALKSTOP variable was examined at the first and third stages. The second stage was not tested as it is assumed that at this stage respondents are already at the stop/station. The estimated coefficient value for the WALKSTOP variable at the first stage was found to have a positive coefficient value of 0.128 and significant at the 99% level (t-ratio of 3.2) (see model M6-19 in table 6-7). The coefficient value indicates that as the time taken to walk to the stop increases the likelihood that the respondent will access transport information from SMS or call centres increases compared to the internet also increases. The model specification was found to provide a good measure of fit, as the ρ^2 (0) and ρ^2(c) values were estimated at 0.211 and 0.207, and the null hypothesis was rejected at the 99% confidence level.

A positive coefficient was also found at the third stage for walk from the work place to stop/station (0.104) (see model M6-24 in table 6-7). The coefficient value was estimated to be significant at the 95% confidence level (t-ratio of 2.0) (see model M6-24 in table 6-7). The ρ^2 (0) and ρ^2 (c) values of 0.214 and 0.209 and the rejection of the null hypothesis indicate that the inclusion of the WALKSTOP variable in model M6-24 produces an improved model specification. The positive coefficient value indicates that as the walk time from the place of work increases individuals are more likely to choose transport information using SMS.

Wait time at stop/station was examined at stages one and two. The third stage was tested but the model coefficients were found not to be significant, and the models were found not to provide a sufficient $\rho^2(0)$ or $\rho^2(c)$ values. Therefore, stages one and two are analysed with the WAIT variable and the results are presented in table 6-7.

The WAIT variable at stage one was found to be significant at the 95% confidence level (*t*-ratio 2.2), and to have a positive coefficient value of 0.313 (see model M6-20 in table 6-7). These results demonstrate that at the first stage as the wait time at stop/station increases, individuals are more likely to derive utility from transport information using SMS compared to the other options. The model specification produced $\rho^2(0)$ and $\rho^2(c)$ values of 0.208 and 0.201, which are within the bounds of acceptability. The estimated likelihood ratio test result of 65.69 rejects the null hypothesis at the 99% confidence level, demonstrating that the inclusion of the WAIT variable improves the model specification at this stage.

The WAIT coefficient was estimated to be significant at the 99% confidence level (*t*-ratio of 3.1) and positive with a value of 0.419 (see model M6-22 in table 6-7) at stage two. This indicates that as the wait time at stop/station increases the likelihood that an individual would choose passenger information display to obtain transport information as apposed to SMS or call centre also increases. This model was found to have $\rho^2(0)$ and $\rho^2(c)$ values of 0.209 and 0.197 respectively and to reject the null hypothesis (at the 99% confidence level) demonstrating that the model specification provides a good model fit. The estimated coefficient for WAIT at this stage when only incorporating call centre was found to be positive but not significant, indicating few individuals chose this option.

The total journey by public transport was tested at all three stages to examine if it impacts upon the choice of transport information option. A positive value for the PTTIME variable would indicate that as the total journey increases so too does the likelihood that the respondent would derive a benefit from the use real-time information.

The PTTIME variable at the first stage was estimated to be positive and significant at the 99% confidence level (*t*-ratio of 2.6) (see model M6-21, in table 6-7). The positive coefficient value of 0.364, demonstrates that as the public transport journey time increases, so too does the likelihood that the respondent will choose to obtain transport information

from SMS or call centre. Both the $\rho^2(0)$ and $\rho^2(c)$ values of 0.210 and 0.200 and the likelihood ratio value of 5.79 indicate that the model is a good measure of fit.

PTTIME at stage two was found to have a positive value of 0.824 and is significant at the 99% confidence level (*t*-ratio of 2.7) (see model M6-23, in table 6-7). The model specification was found to be a good measure of fit with ρ^2 (0) and ρ^2 (c) values of 0.241 and 0.213, and the rejection of the null hypothesis at the 99% confidence level. These results demonstrate that as journey time increases so too does the likelihood of the respondent choosing to use a passenger information display to obtain transport information.

Model M6-25 in table 6-7 details the results for the PTTIME variable at stage three. The estimates for the PTTIME variable were shown to be positive and significant at the 99% confidence level with a *t*-value of 5.5, at this third stage. Model M6-25 was found to have a good measure of fit as the ρ^2 (0) and ρ^2 (c) values were estimated to be 0.213 and 0.199. The results from this model demonstrate that as public transport journey time increases the likelihood that the respondent will use public transport information, using SMS as opposed to the other methods.

The results from all three stages produce positive results for the PTTIME variable. The coefficient values for the first two stages were higher than the third stage. This indicates that at the third stage respondents find transport information to be less of a benefit that at the first two stages.

Table 6-7 MNL models incorporating journey time variables

	Variables	M6-19	M6-20	M6-21	M6-22	M6-23	M6-24	M6-25
		Stage One			Stage Two		Stage Three	
Internet	Time saved	-0.037 (-2.6)**	-0.026 (-2.8)**	-0.031 (-3.0)**			-0.066 (-4.9)**	-0.027 (-1.9)*
	Cost	-0.017 (-1.9)*	-0.042 (-4.3)**	-0.022 (-1.9)*			-0.043 (-5.3)**	-0.036 (-4.1)**
	Information	-0.191 (-2.7)**	-0.178 (-2.0)*	-0.291 (-2.4)*			-0.946 (-3.6)**	-0.919 (-3.6)**
SMS	Time saved	-0.030 (-2.8)**	-0.038 (-2.2)*	-0.043 (-3.2)**	-0.032 (-1.9)*	-0.032 (-2.6)**	-0.013 (-2.7)**	-0.038 (-2.2)*
	Cost	-0.027 (-5.1)**	-0.025 (-4.7)**	-0.026 (-6.3)**	-0.035 (-5.6)**	-0.035 (-5.1)**	-0.033 (-5.3)**	-0.041 (-6.1)**
	Information	-1.460 (-5.3)**	-1.036 (-2.4)*	-1.030 (-5.2)**	-1.179 (-4.5)**	-1.503 (-5.2)**	-1.308 (-4.8)**	-0.997 (-3.8)**
Call centre	Time saved	-0.032 (-2.3)*	-0.043 (-2.5)*	-0.053 (-5.0)**	-0.040 (-3.3)**	-0.044 (-2.6)**	-0.030 (-2.1)*	-0.066 (-4.1)**
	Cost	-0.034 (-7.9)**	-0.032 (-7.3)**	-0.027 (-8.9)**	-0.041 (-7.6)**	-0.041 (-7.0)**	-0.044 (-8.0)**	-0.040 (-7.2)**
	Information	-0.405 (-1.9)*	-0.823 (-1.9)*	-0.846 (-4.4)**	-1.014 (-3.5)**	-0.692 (-2.2)*	-0.821 (-3.1)**	-1.033 (-4.0)**
PID	Time saved				-0.031 (-2.3)*	-0.052 (-3.3)**		
	Cost				-0.032 (-6.9)**	-0.042 (-7.5)**		
	Information				-1.081 (-3.8)**	-1.057 (-3.3)**		
WALKSTOP(2)		0.128 (3.2)**						
WALKSTOP (2)							0.104 (1.9)*	
WAIT(2)			0.313 (1.9)*					
WAIT(4)					0.419 (3.1)**			
PTTIME(3)				0.364 (2.6)**				0.196 (5.5)**
PTTIME(4)						0.824 (2.7)		
N		1980	1980	1980	1980	1980	1980	1980
ρ^2 *(0)*		0.211	0.208	0.210	0.209	0.241	0.214	0.213
ρ^2 *(c)*		0.207	0.201	0.200	0.197	0.213	0.209	0.199
Final Likelihood		-1770.05	-1764.43	-1794.40	-1732.15	-1724.07	-1741.66	-1712.63
Likelihood ratio test		54.46†	65.69†	5.77†	17.13†	18.70†	31.63†	26.42†

(1) Internet (2) SMS (3) Call centre (4) PID

* Significant at the 95% confidence level

** Significant at the 99% confidence level

† Null hypothesis rejected

6.4.6 Model combining current mode of transport variables

This section presents models which combine the explanatory variables detailed in the previous sections to produce a model with an increased explanatory power.

Each of the mode of transport variables were added to the base models to test for significance. The variables were added one at a time. When the variable was found not to be significant at the 95%, it was removed from the model specification. Model M6-26 was found to provide the highest significance levels for the coefficients examined and $\rho^2(0)$ and $\rho^2(c)$ values when combining the following mode choice variables, CAR, BUS, MULTI and PTTIME into the base model M6-1. The results of the calibrated model are presented in table 6-8.

The findings demonstrate each of the coefficients is significant at either the 95% or 99% confidence levels. The model specification demonstrates improved $\rho^2(0)$ and $\rho^2(c)$ values of 0.234 and 0.215 compared to 0.211 and 0.203 in the base model M6-1. The likelihood ratio test demonstrated a model specification improvement as the null hypothesis is rejected at the 99% confidence level. The results for this model demonstrate that the inclusion of mode of transport variables enhance the explanatory power of the model at this stage.

Table 6-8 MNL model combining mode of transport variables - stage one

Variables		M6-1	M6-26
		Base Model	**Stage One**
Internet	Time saved	-0.031 (-2.1)*	-0.027 (-3.7)**
	Cost	-0.096 (-3.4)**	-0.098 (-6.9)**
	Information	-0.453 (-2.4)*	-0.758 (-4.3)**
SMS	Time saved	-0.035 (-2.5)*	-0.055(-8.1)**
	Cost	-0.024 (-5.9)**	-0.028 (-13.6)**
	Information	-0.802 (-2.4)*	-0.555 (-3.2)**
Call centre	Time saved	-0.037 (-2.7)**	-0.048 (-7.0)**
	Cost	-0.030 (-9.4)**	-0.031 (-12.7)**
	Information	-1.100 (-3.2)**	-1.352 (-7.7)**
CAR (2)			-0.244 (-2.5)*
BUS (2)			0.210 (5.0)**
MULTI (1)			0.143 (4.5)**
PTTIME (3)			0.188 (2.9)**
N		1980	1980
$\rho^2(0)$		0.211	0.234
$\rho^2(c)$		0.203	0.215
Final Likelihood		-1797.28	-1784.80
Likelihood ratio test			24.97†

(1) Internet (2) SMS (3) Call centre

* Significant at the 95% confidence level

** Significant at the 99% confidence level

† Null hypothesis rejected

The following variables were introduced into model M6-2 (stage two base model), CAR, BUS, MULTI, PTTIME and WAIT. The results demonstrate that all of the coefficients are significant at either 95% or 99% confidence levels. The model produces an improvement in the $\rho^2(0)$ and $\rho^2(c)$ values from 0.209 and 0.201 in the base model M6-2 to 0.216 and 0.208 in M6-27 (see table 6-9). The combined model also demonstrates an improved model specification as the null hypothesis is rejected at the 99% confidence level. The results demonstrate an improvement in the predictive power of the model, demonstrating that the addition of the mode of choice variables improves the model specification.

Table 6-9 MNL model combining mode of transport variables - stage two

Variables		M6-2	M6-27
		Base Model	Stage Two
SMS	Time saved	-0.032 (-2.3)*	-0.039 (-6.0)**
	Cost	-0.036 (-7.9)**	-0.033 (-10.5)**
	Information	-1.098 (-5.6)**	-0.318 (-2.7)**
Call centre	Time saved	-0.027 (-2.1)*	-0.045 (-6.4)**
	Cost	-0.039 (-9.9)**	-0.034 (-11.8)**
	Information	-0.953 (-4.4)**	-1.844 (-9.4)**
PID	Time saved	-0.057 (-5.7)**	-0.015 (-2.4)*
	Cost	-0.036 (-9.7)**	-0.040 (-8.2)**
	Information	-1.049 (-4.9)**	-1.764 (-9.5)**
CAR (1)			-0.147 (-2.5)*
BUS (1)			0.158 (3.8)**
MULTI (3)			0.517 (2.6)**
PTTIME (2)			0.025 (2.8)**
WAIT (1)			0.020 (3.1)**
N		1980	1980
$\rho^2(0)$		0.209	0.216
$\rho^2(c)$		0.201	0.208
Final Likelihood		-1730.72	-1679.50
Likelihood ratio test			22.44†

(1) PID (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

The final model presented in this section examines a combination of mode of transport explanatory variables with the base from stage three. Model M6-28 in table 6-10 presents the results when CAR, BUS and MULTI are introduced as explanatory variables in the base model. The results demonstrate that all of the coefficients are significant at either the 95% or 99% confidence levels. The performance of the model has also improved as $\rho^2(0)$ and $\rho^2(c)$ values have increased from 0.215 and 0.208 in the base model to 0.220 and 0.211 in model M6-28, and the null hypothesis is rejected at the 99% confidence level. As with the previous two models the inclusion of the mode of transport variables have improved the specification of the model.

Table 6-10 MNL model combining mode of transport variables - stage three

Variables		M6-3	M6-28
		Base Model	**Stage Three**
Internet	Time saved	-0.028 (-2.2)*	-0.060 (-4.1)**
	Cost	-0.036 (-6.9)**	-0.081 (-12.8)**
	Information	-0.658 (-3.6)**	-0.681 (-7.9)**
SMS	Time saved	-0.034 (-2.6)**	-0.075 (-2.4)*
	Cost	-0.037 (-7.8)**	-0.043 (-10.3)**
	Information	-1.331 (-7.6)**	-1.319 (-10.8)**
Call centre	Time saved	-0.048 (-3.6)**	-0.024 (-5.6)**
	Cost	-0.041 (-10.3)**	-0.040 (-12.4)**
	Information	-0.641 (-3.8)**	-0.569 (-7.0)**
CAR (1)			-0.419 (-1.9)*
BUS (2)			0.546 (2.4)*
MULTI (1)			0.198 (2.8)**
N		1980	1980
$\rho^2(0)$		0.215	0.220
$\rho^2(c)$		0.208	0.211
Final Likelihood		-1725.84	-1713.80
Likelihood ratio test			33.83†

(1) Internet (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

6.5 Estimation of Models with Socio-economic Variables

This section examines the impact that socio-economic variables have upon the choice of transport information option. Variables for gender, age, income and car availability are analysed in this section.

6.5.1 Gender

In order to examine the impact of gender upon the utility of respondents a gender variable 'GENDER' was introduced into the model as a dummy variable (see table 6-2 for a full definition). A positive 'GENDER' value indicates a preference from males, and vice versa.

The gender variable was found to have a positive value of 0.197 at stage one, indicating that males are more likely to choose transport information at this stage, using either SMS or a call centre. The gender coefficient was estimated to be significant at the 95% confidence level (t-ratio of 2.9) and produced a ρ^2 (0) and ρ^2 (c) values of 0.235 and 0.208 (see model M6-29, in table 6-11). The $\rho^2(0)$ and ρ^2 (c) values combined with the likelihood

ratio result rejecting the null hypothesis at the 99% confidence level, both values indicate the model produced is a good measure of fit.

The results at the second stage show that females are more likely to choose transport information using a passenger information display all things being equal, as the coefficient value was found to have a negative value of -0.116 (see model M6-30, table 6-11). The coefficient for gender was found to be significant at the 95% confidence level (*t*-ratio of -2.0). The $\rho^2(0)$ and $\rho^2(c)$ values of 0.211 and 0.203 produced and the rejection of the null hypothesis at the 99% confidence level both indicate a model of good fit.

The results for the second stage are repeated in the third stage, as the gender variable coefficient was found to be negative and significant at the 99% level (*t*-ratio, -3.7) (see model M6-31 in table 6-11). The model estimates indicate that all things being equal, females are more likely to use transport information using SMS as apposed to the other two methods as this stage. The model specification produced $\rho^2(0)$ and $\rho^2(0)$ values of 0.217 and 0.210, these values combined with the rejection of the null hypothesise at the 95% confidence level, indicates a good model of fit.

Table 6-11 MNL models with gender variables

Variables		M6-29	M6-30	M6-31
		Stage One	Stage Two	Stage Three
Internet	Time saved	-0.022 (-1.9)*		-0.050 (-5.1)**
	Cost	-0.053 (-2.8)**		-0.040 (-6.4)**
	Information	-0.324 (-1.9)*		-0.793 (-4.7)**
SMS	Time saved	-0.043 (-3.3)**	-0.034 (-4.2)**	-0.017 (-2.5)*
	Cost	-0.024 (-5.8)**	-0.034 (-12.7)**	-0.039 (-8.3)**
	Information	-0.915 (-4.6)**	-1.094 (-9.6)**	-1.261 (-7.7)**
Call centre	Time saved	-0.041 (-3.7)**	-0.030 (-2.4)*	-0.026 (-2.6)**
	Cost	-0.031 (-9.6)**	-0.039 (-6.8)**	-0.043 (-10.5)**
	Information	-0.920 (-4.7)**	-0.958 (-7.6)**	-0.657 (-3.9)**
PID	Time saved		-0.050 (-8.6)**	
	Cost		-0.036 (-6.2)**	
	Information		-1.083 (-8.7)**	
GENDER (2)		0.197 (2.9)*		
GENDER (4)			-0.116 (-2.0)*	
GENDER (2)				-0.363 (-3.7)**
N		1980	1980	1980
ρ^2 *(0)*		0.235	0.211	0.217
ρ^2 *(c)*		0.208	0.203	0.210
Final Likelihood		-1776.33	-1713.35	-1722.58
Likelihood ratio test		44.89†	34.73†	6.53†

(1) Internet (2) SMS (3) Call centre (4) PID
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

6.5.2 Age

The variable 'AGE' is a categorical variable and is defined in table 6-2. A positive value for the age variable would indicate as age increases the likelihood the will use transport information also increases. Furthermore, a negative result would indicate that younger people are more likely to use the option analysed.

At the first stage the age coefficient was found to have a negative with a value of -0.503 and to be significant at the 95% confidence level (t-ratio of -2.3) (see model M6-32, table 6-12). This result indicates that all things being equal younger respondents are more likely to choose to access real-time information, using SMS as apposed to the internet or a call centre. The model specification was found to have a good model of fit, as the ρ^2 (0) and ρ^2 (c) values were within acceptable bounds and the null hypothesis was rejected at the 99% confidence level (see table 6-12).

The results for the second stage also reported a negative coefficient value. The age coefficient was estimated to be significant at the 99% confidence level (*t*-ratio of -4.1) (see model M6-33, in table 6-12). Similarly to the first stage the results demonstrate that all things being equal, younger respondents are more likely to choose the passenger information display option over SMS or call centre to receive public transport information. The model specification for M6-33 was found to have a $\rho^2(0)$ and ρ^2 (c) values of 0.209 and 0.204 respectively, and the null hypothesis is rejected at the 99% confidence level, both of which indicate a model of good specification.

At the third stage the age variable was estimated to be negative and significant at the 95% confidence level (*t*-ratio of -2.1) (see model M6-34, table 6-12). The model specification produced a model of good fit with $\rho^2(0)$ and ρ^2 (c) values of 0.217 and 0.209. The likelihood ratio indicates that the null hypothesis is rejected, demonstrating that the inclusion of the AGE variable improves the model specification at stage three. This result as with the other results indicates that younger respondents are more likely to choose to access transport information at this stage using the internet or SMS rather than a call centre.

Table 6-12 MNL models including age variables

Variables		M6-33 Stage One	M6-33 Stage Two	M6-34 Stage Three
Internet	Time saved	-0.021 (-3.9)**		-0.058 (-5.7)**
	Cost	-0.055 (-6.1)**		-0.036 (-5.7)**
	Information	-0.228 (-2.3)*		-0.089 (-4.5)**
SMS	Time saved	-0.043 (-7.2)**	-0.040 (-2.9)**	-0.070 (-2.5)*
	Cost	-0.024 (-13.1)**	-0.035 (-7.3)**	-0.040 (-8.5)**
	Information	-1.017 (-11.5)**	-1.026 (-6.2)**	-1.160 (-5.6)**
Call centre	Time saved	-0.041 (-8.2)**	-0.020 (-2.6)**	-0.022 (-2.1)*
	Cost	-0.299 (-12.0)**	-0.038 (-9.3)**	-0.043 (-10.5)**
	Information	-0.083 (-9.6)**	-0.844 (-3.8)**	-0.750 (-3.7)**
PID	Time saved		-0.036 (-3.3)**	
	Cost		-0.036 (-9.6)**	
	Information		-0.895 (-4.0)**	
AGE (2)		-0.503 (-2.3)*		
AGE (4)			-0.182 (-4.1)**	
AGE (1)				-0.114 (-2.1)*
N		1980	1980	1980
$\rho^2(0)$		0.212	0.209	0.217
$\rho^2(c)$		0.205	0.204	0.209
Final Likelihood		-1772.19	-1715.56	-1703.58
Likelihood ratio test		50.18†	30.31†	44.52†

(1) Internet (2) SMS (3) Call centre (4) PID
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

6.5.3 Income

Intuitively one would expect as income increases so too would the propensity to consume a good, in this case real-time information. A categorical variable called INCOME was created and is defined in table 6-2.

The models M6-35, M6-36 and M6-37 in table 6-13 each incorporate the INCOME variable with the base models from stages one, two and three. Each of the models produced $\rho^2(0)$ and $\rho^2(c)$ values which are improvements upon the base model results at all three stages. The likelihood ratio test results for models M6-35, M6-36 and M6-37 reject the null hypothesis for each of the models, demonstrating that these models have an improved predictive power compared to the base model in each case.

The income variable for the first stage was estimated to have a positive value of 0.411 which is significant at the 99% confidence level (*t*-ratio, of 3.9) (see model M6-35, in table

6-13). The positive result indicates that as income increases so too does the likelihood that individuals will choose transport information using SMS.

The income variable at stage two also reported a positive value of 0.103, and is significant at the 99% confidence level (*t*-value of 4.5) (see model M6-36 in table 6-13). The findings for this stage are similar to those found in stage one model, in that when income increases, so too does the probability that respondents will chose to access transport information using a passenger information display, all things being equal.

The model results for stage three with the inclusion of the income variable found a positive coefficient of 0.110 which is significant at the 99% confidence level (*t*-ratio of 5.0) (see model M6-37, in table 6-13). This result demonstrates the positive relationship between increasing income and the probability individuals will choose real time information from SMS rather than the other two options at this stage.

The results for the three stages found that as income increases so to does the likelihood that respondents will choose a transport information option, all things being equal.

Table 6-13 MNL models including income variables

Variables		M6-35	M6-36	M6-37
		Stage One	Stage Two	Stage Three
Internet	Time saved	-0.025 (-2.2)*		-0.040 (-6.9)**
	Cost	-0.047 (-2.5)*		-0.040 (-6.3)**
	Information	-0.455 (-2.0)*		-0.922 (-5.2)**
SMS	Time saved	-0.041 (-3.1)**	-0.043 (-3.1)**	-0.098 (-1.9)*
	Cost	-0.025 (-6.0)**	-0.034 (-7.2)**	-0.039 (-8.2)**
	Information	-1.267 (-5.4)**	-0.712 (-3.3)**	-1.044 (-5.8)**
Call centre	Time saved	-0.040 (-3.7)**	-0.025 (-2.0)*	-0.049 (-4.3)**
	Cost	-0.031 (-9.5)**	-0.037 (-9.1)**	-0.041 (-10.0)**
	Information	-0.581 (-2.5)*	-1.401 (-5.8)**	-0.948 (-5.2)**
PID	Time saved		-0.034 (-3.0)**	
	Cost		-0.037 (-9.6)**	
	Information		-1.412 (-6.1)**	
INCOME (2)		0.411 (3.9)**		
INCOME (4)			0.103 (4.5)**	
INCOME (2)				0.110 (5.0)**
N		1980	1980	1980
$\rho^2(0)$		0.236	0.212	0.217
$\rho^2(c)$		0.210	0.205	0.211
Final Likelihood		-1791.17	-1730.23	-1719.37
Likelihood ratio test		12.23†	5.97†	12.94†

(1) Internet (2) SMS (3) Call centre (4) PID
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

6.5.4 Car available

A car available dummy variable called CARAV was created to identify all those respondents who can travel to work each morning using a car (the variable is defined in table 6-2). A positive value for 'CARAV' would indicate that those individuals who do have a car available to drive to work derive a positive utility from transport information and vice versa.

The coefficient value for the car available variable was estimated to be negative and significant at the 90% confidence level (*t*-ratio of -2.2) at stage one (see model M6-38, in table 6-14). This result indicates that all things being equal those individuals with no car available are more likely to choose to access transport information using SMS at stage one. The model produced $\rho^2(0)$ and $\rho^2(c)$ values of 0.212 and 0.203, and rejected the null hypothesis, demonstrating that the inclusion of the CARAV variable at stage one, improves the model specification.

This result was also found at the second stage, where the car available coefficient was found to have a negative value of -0.319 and to be significant at the 99% confidence level with a *t*-ratio of -5.1 (see model M6-39 in table 6-14). This value indicates that all things being equal that individuals are more likely to use a passenger information display to obtain transport information rather than SMS or Call centre, if they have no car available for the trip at this stage. Model M6-39 was found to reject the null hypothesis, and the $\rho^2(0)$ and $\rho^2(c)$ values were found to be 0.211 and 0.202, respectively. As with the first stage, this demonstrates that the inclusion of the CARAV variable improves the model specification at this stage.

The results for stage three show that the car available coefficient was estimated to be negative and significant at the 99% confidence level (see model M6-40 in table 6-14). These model estimates are similar to those found at the first and second stages, in that individuals who have no car available are more likely to choose to access transport information (from SMS or call centre, rather than the internet), all things being equal. The $\rho^2(0)$ and $\rho^2(c)$ values were estimated to be 0.218 and 0.210 and the likelihood ratio rejected the null hypothesis demonstrating an improved model specification.

Table 6-14 MNL models including car available variables

Variables		M6-38	M6-39	M6-40
		Stage One	**Stage Two**	**Stage Three**
Internet	Time saved	-0.021 (-2.6)**		-0.045 (-4.4)**
	Cost	-0.052 (-3.5)**		-0.039 (-6.2)**
	Information	-0.020 (-2.6)**		-0.890 (-5.1)**
SMS	Time saved	-0.042 (-5.3)**	-0.043 (-3.1)**	-0.011 (-3.0)**
	Cost	-0.024 (-9.9)**	-0.034 (-7.2)**	-0.039 (-8.3)**
	Information	-1.029 (-8.7)**	-0.632 (-2.9)**	-1.100 (-6.1)**
Call centre	Time saved	-0.042 (-5.5)**	-0.028 (-2.2)*	-0.042 (-3.6)**
	Cost	-0.030 (-16.6)**	-0.037 (-9.1)**	-0.042 (-10.2)**
	Information	-0.809 (-7.1)**	-1.506 (-6.2)**	-0.846 (-4.7)**
PID	Time saved		-0.028 (-2.5)*	
	Cost		-0.037 (-9.7)**	
	Information		-1.497 (-6.5)**	
CARAV (2)		-0.685 (-2.2)*		
CARAV (4)			-0.319 (-5.1)**	
CARAV (3)				-0.199 (-3.4)**
N		1980	1980	1980
$\rho^2(0)$		0.212	0.211	0.218
$\rho^2(c)$		0.203	0.202	0.210
Final Likelihood		-1785.49	-1722.94	-1742.15
Likelihood ratio test		23.57†	15.54†	47.38†

(1) Internet (2) SMS (3) Call centre (4) PID
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

6.5.5 Models combing socio-economic variables

This section reports the impacts of combing the socio-economic variables examined in sections 6.5.1, 6.5.2, 6.5.3 and 6.5.4 on models estimating the choice of transport information option.

The model specification for stage one includes the following socio-economic explanatory variables, GENDER, AGE, INCOME and CARAV. The coefficients produced by the model (M6-41, in table 6-15) are significant at either the 95% or 99% confidence levels. The model also produces an improved $\rho^2(0)$ and $\rho^2(c)$ values of 0.231 and 0.207 compared to the 0.211 and 0.203 in the base model M6-1. This proves that the inclusion of these socio-economic variables improves the explanatory power of the model. The likelihood ratio value produced a value of 19.30 (see table 6-15) thereby rejecting the null hypothesis at the 99% confidence level.

Table 6-15 MNL model combining socio-economic variables - stage one

Variables		**M6-1**	**M6-41**
		Base Model	**Stage One**
Internet	Time saved	-0.032 (-2.3)*	-0.013 (-3.5)**
	Cost	-0.036 (-7.9)**	-0.037 (-2.0)*
	Information	-1.098 (-5.6)**	-0.557 (-2.9)**
SMS	Time saved	-0.027 (-2.1)*	-0.042 (-4.5)**
	Cost	-0.039 (-9.9)**	-0.023 (-8.5)**
	Information	-0.953 (-4.4)**	-1.268 (-7.3)**
Call centre	Time saved	-0.058 (-5.7)**	-0.031 (-3.2)**
	Cost	-0.036 (-9.7)**	-0.029 (-11.3)**
	Information	-1.050 (-4.9)**	-0.593 (-3.5)**
GENDER (2)			0.123 (3.7)**
AGE (3)			0.025 (2.9)**
INCOME (2)			0.124 (2.5)**
CARAV (1)			0.023 (2.5)**
N		1980	1980
$\rho^2(0)$		0.211	0.231
$\rho^2(c)$		0.203	0.207
Final Likelihood		-1797.28	-1787.63
Likelihood ratio test			19.30†

(1) Internet (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

The variables combined with the base model from stage two were GENDER, AGE, INCOME and CARAV. The addition of these models did increase the explanatory power of the model (see model M6-42, in table 6-16). Each of the coefficients was estimated to be significant at either the 95% or 99% confidence levels. The explanatory power of the model has increased. This is seen in the improvements in $\rho^2(0)$ and $\rho^2(c)$ values were from 0.209 and 0.201 in model M6-2 to 0.220 and 0.209 in model M6-42. The null hypothesis is rejected at the 95% confidence level, which demonstrates that the model estimated is an improvement on the base model.

Table 6-16 MNL model combining socio-economic variables - stage two

Variables		M6-2	M6-42
		Base Model	**Stage Two**
SMS	Time saved	-0.032 (-2.3)*	-0.042 (-4.8)**
	Cost	-0.036 (-7.9)**	-0.036 (-12.3)**
	Information	-1.098 (-5.6)**	-0.707 (-4.4)**
Call centre	Time saved	-0.027 (-2.1)*	-0.025 (-3.2)**
	Cost	-0.039 (-9.9)**	-0.036 (-14.3)**
	Information	-0.953 (-4.4)**	-1.423 (-8.3)**
PID	Time saved	-0.057 (-5.7)**	-0.032 (-4.6)**
	Cost	-0.036 (-9.7)**	-0.038 (-12.6)**
	Information	-1.049 (-4.9)**	-1.398 (-8.2)**
GENDER (1,2)			-0.068 (-2.1)*
AGE (2)			0.012 (4.0)**
INCOME (1,3)			0.151 (5.0)**
CARAV (1,2)			0.113 (2..9)**
N		1980	1980
$\rho^2(0)$		0.209	0.220
$\rho^2(c)$		0.201	0.209
Final Likelihood		-1730.72	-1726.53
Likelihood ratio test			8.38†

(1) PID (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

Model M6-43 incorporates a combination of socio-economic explanatory variables with the base model results from stage three. The following socio-economic variables GENDER, AGE, INCOME and CARAV are analysed. The model specification produces coefficients at either the 95% or 99% confidence levels (see model M6-43 in table 6-17). The model calibration estimates improvements in the $\rho^2(0)$ and $\rho^2(c)$ values of 0.233 and 0.219 compared with 0.215 and 0.208 in the base models. The combined model specification rejects the null hypothesis at the 99% confidence level. The coefficient signs are also consistent with the signs found when the variables were examined independently. These results demonstrate that there is an improvement in the model performance with the addition of the socio-economic variables.

Table 6-17 MNL model combining socio-economic variables - stage three

Variables		M6-3	M6-43
		Base Model	Stage Three
Internet	Time saved	-0.028 (-2.2)*	-0.023 (-3.0)**
	Cost	-0.036 (-6.9)**	-0.093 (-10.2)**
	Information	-0.658 (-3.6)**	-0.761 (-6.8)**
SMS	Time saved	-0.034 (-2.6)**	-0.022 (-2.8)**
	Cost	-0.037 (-7.8)**	-0.038 (-13.7)**
	Information	-1.331 (-7.6)**	-1.226 (-10.6)**
Call centre	Time saved	-0.048 (-3.6)**	-0.055 (-6.9)**
	Cost	-0.041 (-10.3)**	-0.040 (-12.7)**
	Information	-0.641 (-3.8)**	-0.775 (-7.2)**
GENDER (1)			-0.235 (-5.0)**
AGE (2)			0.228 (4.1)**
INCOME (3)			0.235 (6.1)**
CARAV (1)			-0.048 (-2.6)**
N		1980	1980
$\rho^2(0)$		0.215	0.233
$\rho^2(c)$		0.208	0.219
Final Likelihood		-1790.84	-1740.14
Likelihood ratio test			21.15†

(1) Internet (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

6.6 Estimation of Models using Location Specific Variables

This section examines how location specific variables impact upon the propensity to choose between the different transport information options. Two aspects of location are examined in this section, firstly the proximity of the respondents residence to a rail station/bus priority corridor and secondly the physical geographic location of the respondents residence. The results in this section are also presented in Caulfield and O'Mahony (2007c).

6.6.1 Proximity to high quality public transport

The proximity of residence to high quality public transport is examined in this section. High quality public transport is defined as either a high frequency bus corridor or a light rail/heavy rail service. This variable was examined to ascertain if utility derived by individuals who live near a high frequency public transport routes is different from those who live near a low frequency route.

The variables examining proximity to high quality public transport were tested on all three stages. The model results from the third stage found that the variables measuring proximity to high quality public transport routes were found to be insignificant. This may be due to the fact that proximity of residence to such routes only impacts at the first two stages on the journey. Therefore, the following results detail the impact of proximity to high quality public transport routes for stages one and two.

The coefficient value for HQBUS at stage one was found to have positive value of 0.161 and to be significant at the 95% confidence level (*t*-ratio of 2.0) (see model M6-44 in table 6-18). This result demonstrates that those living near a high quality bus service are more likely to use transport information using SMS. This result also indicates that those individuals who live near a high quality bus route derive a greater benefit from real-time information, compared to those who live near a low frequency route. The $\rho^2(0)$ and $\rho^2(c)$ values of 0.232 and 0.221 demonstrate that model M6-44 produces a good model fit. The model estimates also rejected the null hypothesis at the 99% confidence level, indicating an improvement on the base model.

The estimated value for the HQRAIL coefficient for stage one was found to have a negative value of -0.283 and to be significant at the 99% confidence level (*t*-ratio of -2.7) (see model M6-45 in table 6-18). This negative value indicates that those who do not live in close proximity to a rail service are more likely to access real-time information using SMS. This finding would seem to validate the assumption that those individuals living near a high frequency public transport service do not derive the same utility from public transport information as someone living near a low frequency service. The model specification for M6-45 reports a $\rho^2(0)$ value of 0.224 and a $\rho^2(c)$ value of 0.213, and the likelihood ratio rejected the null hypothesis at the 95% confidence level (see table 6-18) which indicates a reasonable model fit.

The estimated coefficient value for HQBUS at stage two found to have a negative value of -0.155, and also to be significant at the 90% confidence level, with a *t*-ratio of -1.9 (see model M6-46 in table 6-18). This result demonstrates that at the second stage those individuals who do not live within close proximity of a high quality bus service are more likely to choose to obtain transport information from a passenger information display. This result differs from the result found at the first stage. It could be concluded from this result that as individuals stand and wait at the bus stop where there is a high frequency of service

utility is derived from transport information than for those individuals who do not live near a high frequency bus service. The model specification for HQBUS at stage two found $\rho^2(0)$ and $\rho^2(0)$ values of 0.213 and 0.206, and rejects the null hypothesis at the 95% confidence level, which demonstrates the model is a good measure of fit.

The HQRAIL produced a negative coefficient of -0.107, at stage two (see model M6-47 in table 6-18). This coefficient was found to be significant at a 95% confidence level with a *t*-ratio of -2.1. The negative coefficient indicates that those individuals who do not live with in close proximity to a high quality rail service have are more likely to choose to access transport information using a passenger information display. The model rejects the null hypothesis at the 95% confidence level, and produces $\rho^2(0)$ and $\rho^2(c)$ values of 0.220 and 0.211, which demonstrate an improvement in model fit.

The interesting result in this section is the positive value for HQBUS at stage one. This positive value could be attributed to the fact that individuals at this stage perceive the frequency/reliability of rail to be greater than that of bus when planning their trip (as rail services was estimated with a negative value at this stage). However, it is shown that when respondents reach the bus stop the utility they derived from transport information drops (compared to those not living near a high quality bus service), and the result shows at this stage those that do not live near a high quality derive increased utility from real-time information.

Table 6-1 MNL models with proximity to high quality public transport route variables

	Variables	M6-44	M6-45	M6-46	M6-47
		Stage One		Stage Two	
Internet	Time saved	-0.023 (-2.5)*	-0.026 (-2.8)**		
	Cost	-0.049 (-2.9)**	-0.045 (-2.0)*		
	Information	-0.190 (-1.9)*	-0.209 (-2.6)**		
SMS	Time saved	-0.037 (-4.2)**	-0.053 (-2.7)**	-0.048 (-4.4)**	-0.051 (-5.8)**
	Cost	-0.025 (-9.4)**	-0.025 (-4.2)**	-0.040 (-10.3)**	-0.028 (-9.7)**
	Information	-1.022 (-4.6)**	-1.069 (-3.7)**	-1.026 (-6.5)**	-1.585 (-2.1)*
Call centre	Time saved	-0.046 (-5.3)**	-0.057 (-3.6)**	-0.056 (-2.3)*	-0.041 (-4.7)**
	Cost	-0.030 (-14.5)**	-0.030 (-6.6)**	-0.040 (-12.4)**	-0.023 (-11.2)**
	Information	-0.771 (-3.4)**	-0.763 (-2.7)**	-1.049 (-6.0)**	-0.422 (-7.1)**
PID	Time saved			-0.046 (-5.5)**	-0.023 (-2.0)*
	Cost			-0.035 (-11.6)**	-0.046 (-9.3)**
	Information			-1.247 (-7.3)**	-0.727 (-7.9)**
HQBUS (2)		0.161 (2.0)*			
HQBUS (4)				-0.155 (-1.9)*	
HQRAIL (2)			-0.283 (-2.7)**		
HQRAIL (4)					-0.107 (-2.1)*
N		1980	1980	1980	1980
$\rho^2(0)$		0.232	0.224	0.213	0.220
$\rho^2(c)$		0.221	0.213	0.206	0.211
Final Likelihood		-1786.29	-1778.44	-1727.76	-1725.08
Likelihood ratio test		21.98†	37.68†	5.91†	11.27†

(1) Internet (2) SMS (3) Call centre (4) PID

* Significant at the 95% confidence level

** Significant at the 99% confidence level

† Null hypothesis rejected

6.6.2 Geographical location of residence

The respondents were asked in the survey to indicate which Dublin postal zone or surrounding county they commute from on a daily basis. The purpose of this was to ascertain if residential location and proximity to the city centre impacted upon the choice of transport information option. Figure 6-1, presents a map of the 22 postal zones in the Dublin metropolitan area and the surrounding counties that were used in this study are detailed in figure 6-2. Ireland does not have an address specific postal code system like the UK. Therefore, to get an indication of locations travelled from it was necessary to use this aggregated postal code system. A categorical variable ZONE as defined in table 6-2, was used which groups the postal zones in to 5 categories. Zones closer to the city centre are represented with lower numbers and the highest numbers zones are those furthest away from the city centre as seen in figures 6-1 and 6-2. Therefore a positive result would suggest the further away from the city centre the respondent lives, the more benefit they derive from real-time information.

Figure 6-1 Location zones in the Dublin metropolitan area

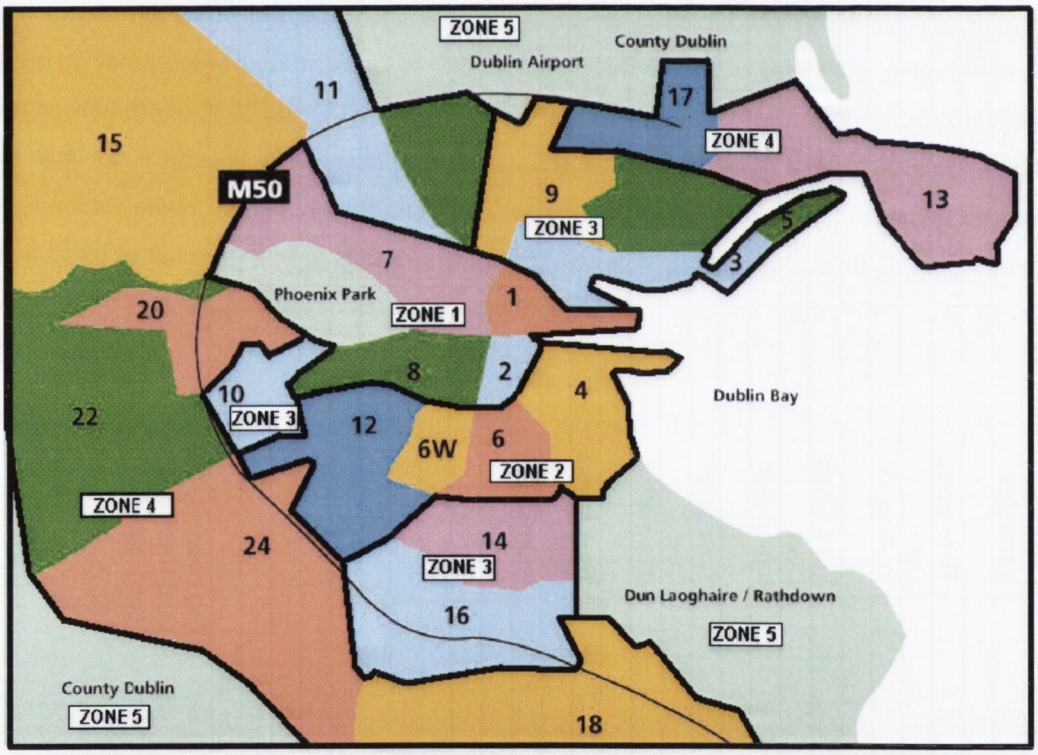


Figure 6-2 Map of zone 5



The population sampled was that of individuals who travel into the city centre to work each day. Therefore, it is assumed that respondents living in the outer zones travel a greater distance than those who are living in the closer zones on a daily basis. Based upon these assumptions a high coefficient value for the ZONE variable would indicate the further an individual has to travel, the more utility they derive from transport information option chosen.

The coefficient value for the ZONE variable for the first stage was found to have a positive value of 0.304 and to be significant at the 99% confidence level (see model M6-48, in table 6-19). This positive value indicates that all things being equal as the distance the respondent lives from their place of work increases so to does the likelihood that they will choose to access transport information using SMS rather than the two alternative methods. The likelihood ratio test for model M6-48 rejects the null hypothesis demonstrating that the inclusion of the ZONE variable improves the model specification. The $\rho^2(0)$ and $\rho^2(c)$ values of 0.219 and 0.205 also indicate that this model achieves a good model fit.

At the second stage the zone coefficient value was found to have a positive value of 0.667 and to be significant at the 95% confidence level with a *t*-ratio of 2.1 (see model M6-49 in table 6-19). This result implies that the likelihood that an individual will choose to use transport information (using a passenger information display) increases as the distance the

individual lives from the city centre increases. The $\rho^2(0)$ and $\rho^2(c)$ values of 0.217 and 0.209 and the rejection of the null hypothesis, both demonstrate that the inclusion of the ZONE variable at the second stage, improves the model specification.

The zone variable coefficient at the third stage was estimated to have a positive value of 0.120 and to be and significant at the 99% confidence level (see model M6-50, in table 6-19). The result is similar to the results found at stages one and two in that the further away from the city centre the individual resides the more likely it is that the individual will choose to access transport information using SMS. The likelihood ratio test rejects the null hypothesis, this combined with the estimated $\rho^2(0)$ and $\rho^2(c)$ values of 0.224 and 0.211, demonstrate an improvement in model specification.

The coefficient values for zone are highest for the first and second stages. The lower value at the third stage may indicate that at this stage individuals are less concerned with real-time information and are less likely to derive utility from transport information compared to the first two stages. The ZONE coefficient was found to be highest at the second stage while respondents were waiting for their service to arrive. This demonstrates that respondents, who live the greatest distance from their place of work, were found to derive the greatest benefit from real-time information.

Table 6-19 MNL model with residential zone variables

Variables		M6-48	M6-49	M6-50
		Stage One	Stage Two	Stage Three
Internet	Time saved	-0.200 (-2.4)*		-0.267 (-2.0)*
	Cost	-0.273 (-2.8)**		-0.445 (-6.7)**
	Information	-0.101 (-5.0)**		-0.558 (-3.0)**
SMS	Time saved	-0.438 (-5.4)**	-0.337 (-2.4)*	-0.282 (-2.1)*
	Cost	-0.260 (-10.8)**	-0.326 (-6.8)**	-0.353 (-7.4)**
	Information	-1.061 (-5.3)**	-1.128 (-5.6)**	-1.393 (-7.8)**
Call centre	Time saved	-0.434 (-5.6)**	-0.275 (-2.7)**	-0.442 (-3.3)**
	Cost	-0.300 (-16.0)**	-0.372 (-9.2)**	-0.394 (-9.7)**
	Information	-0.726 (-3.6)**	-0.905 (-4.1)**	-0.566 (-3.3)**
PID	Time saved		-0.444 (-4.4)**	
	Cost		-0.354 (-9.2)**	
	Information		-1.013 (-4.6)**	
ZONE (2)		0.304 (2.6)**		0.120 (3.7)**
ZONE (4)			0.667 (2.1)*	
N		1980	1980	1980
$\rho^2(0)$		0.219	0.217	0.224
$\rho^2(c)$		0.205	0.209	0.211
Final Likelihood		-1789.05	-1715.58	-1700.55
Likelihood ratio test		16.46†	30.28†	50.58†

(1) Internet (2) SMS (3) Call centre (4) PID
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

6.6.3 Models combining location variables

This section presents the results from the models which were estimated combining location variables.

Model M6-51 combines the location variables, HQBUS, HQRAIL and ZONE. The results in table 6-20 show that all coefficients are significant at either the 95% or 99% confidence levels. There is also an enhancement in the performance of the model with improvements in both the $\rho^2(0)$ and $\rho^2(c)$ values, from 0.211 and 0.203 in model M6-1 to 0.237 and 0.212 in model M6-51. The likelihood ratio test rejected the null hypothesis at the 99% confidence level, demonstrating the model specification of M6-51 is an improvement upon the base model. This indicates that the inclusion of these additional explanatory variables improves the overall explanatory power of the model.

Table 6-20 MNL model combining location variables - stage one

Variables		M6-1	M6-51
		Base Model	**Stage One**
Internet	Time saved	-0.028 (-2.2)*	-0.031 (-4.4)**
	Cost	-0.036 (-6.9)**	-0.088 (-6.6)**
	Information	-0.658 (-3.6)**	-0.218 (-2.0)*
SMS	Time saved	-0.034 (-2.6)**	-0.030 (-4.6)**
	Cost	-0.037 (-7.8)**	-0.026 (-13.3)**
	Information	-1.331 (-7.6)**	-1.102 (-11.3)**
Call centre	Time saved	-0.048 (-3.6)**	-0.036 (-5.6)**
	Cost	-0.041 (-10.3)**	-0.028 (-11.9)**
	Information	-0.641 (-3.8)**	-0.777 (-8.2)**
HQBUS (2)			0.149 (-3.1)**
HQRAIL (2)			-0.046 (-3.1)**
ZONE (1)			0.293 (2.0)*
N		1980	1980
$\rho^2(0)$		0.211	0.237
$\rho^2(c)$		0.203	0.212
Final Likelihood		-1797.28	-1781.29
Likelihood ratio test			31.98†

(1) Internet (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

The location variables examined at the second stage are HQBUS, HQRAIL and ZONE. Model M6-52 produces coefficients which are significant at either the 95% or 99% significance levels (see model M6-52 in table 6-21). The specification of the model produces and improved model compared to the base model, with greater $\rho^2(0)$ and $\rho^2(c)$ values of 0.217 and 0.206, which represent an improvement on the base mode values of 0.209 and 0.201 respectively. The model is also shown to achieve an improvement on the base model results as the likelihood ratio test rejected the null hypothesis at the 99% confidence level (see table 6-21).

Table 6-21 MNL model combining location variables - stage two

Variables		M6-2	M6-52
		Base Model	**Stage Two**
SMS	Time saved	-0.032 (-2.3)*	-0.049 (-7.3)**
	Cost	-0.036 (-7.9)**	-0.037 (-11.6)**
	Information	-1.098 (-5.6)**	-1.561 (-9.4)**
Call centre	Time saved	-0.027 (-2.1)*	-0.047 (-6.4)**
	Cost	-0.039 (-9.9)**	-0.036 (-8.8)**
	Information	-0.953 (-4.4)**	-0.656 (-5.8)**
PID	Time saved	-0.058 (-5.7)**	-0.023 (-3.6)**
	Cost	-0.036 (-9.7)**	-0.040 (-12.8)**
	Information	-1.049 (-4.9)**	-0.582 (-4.8)**
HQBUS (2)			-0.138 (-3.0)**
HQRAIL (1)			0.070 (4.0)**
ZONE (3)			0.022 (3.5)**
N		1980	1980
$\rho^2(0)$		0.209	0.217
$\rho^2(c)$		0.201	0.206
Final Likelihood		-1730.72	-1708.60
Likelihood ratio test			44.23†

(1) PID (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

6.7 Estimation of Models Using Access to Technology Variables

In order to access the transport information services examined in this study, individuals require access to several forms of information communications technology. To this extent access to the internet, a mobile phone or a phone (land line) are examined in this section.

6.7.1 Mobile phone contract type

In Ireland there are two types of payment for mobile phone usage. The first option is a pay up front option or pay-as-you-go. The second type is monthly bill pay, where the individual receives a bill at the end of the month for their mobile phone usage. It was thought that this variable would be interesting to test, to ascertain if mobile phone contract type would affect the choices made my individuals when accessing real-time information.

A dummy variable 'CONMOB' was introduced to the model as defined in table 6-2. The variable gives a value of 1 for all those individuals on a pay monthly contract and 0 for those on a pay-as-you-go contract. A positive result for the CONMOB variable would

indicate respondents with a monthly bill derive a greater utility from using transport information and vice versa.

The CONMOB variable was estimated to be positive with a coefficient value of 0.213 and significant at the 95% confidence level (*t*-ratio of 2.1) (see model M6-53, in table 6-22) at stage one. The positive value indicates that respondents with a pay monthly bill contract all things being equal are more likely to choose to access transport information from SMS as opposed to the internet or call centre. The specification for this first model incorporating the CONMOB variable was found to produce $\rho^2(0)$ and $\rho^2(c)$ values of 0.214 and 0.209. The likelihood ratio test rejected the null hypothesis demonstrating that the inclusion of the CONMOB variable improves the model specification at this stage.

At the second stage those with contract mobile phones were found to have a higher likelihood to choose transport information using SMS or a passenger information display as the coefficient was found to be positive and significant at the 95% confidence level (*t*-ratio of 2.5) (see model M6-55, in table 6-22). The $\rho^2(0)$ and $\rho^2(c)$ values of 0.215 and 0.207 demonstrate an good model fit. The likelihood ratio test result rejects the null hypothesis, indicating that the addition of the CONMOB variable and the rejection of the null hypotheses demonstrate a good model fit.

The CONMOB coefficient for stage three was also found to be positive and significant at the 95% confidence level (see model M6-56, in table 6-22). The $\rho^2(0)$ and $\rho^2(c)$ values of 0.222 and 0.213 and the rejection of the null hypothesis at the 99% confidence level, indicate a good model fit. At the third stage individuals with contract mobile phones were found to be more likely to choose real-time information, using SMS rather than a call centre or the internet, than individuals on a pay-as-you-go contract.

6.7.2 Broadband internet connection available

The availability of broadband (high-speed internet connection) internet at home is examined at this stage. A dummy variable BBNET was created to represent all those individual who have access to broadband internet at home (the variable is defined in table 6-2). A positive value for this variable indicates that those with broadband available are more likely to derive a higher utility from real-time information.

The coefficient for broadband available variable produced a positive coefficient value and was estimated to be significant at the 95% confidence level (see model M6-54, in table 6-22). This result indicates that those individuals, who have broadband available at the first stage, are more likely to use transport information using the internet rather than SMS or call centre than those individuals who do not have broadband. Model M6-54 produces $\rho^2(0)$ and $\rho^2(c)$ values of 0.219 and 0.206, and the likelihood ratio test also rejects the null hypothesis (at the 99% confidence level) which indicates an improvement in model specification.

6.7.3 Access to a phone at work

An important consideration to take into account when examining the final stage where individuals are travelling from work returning home is whether they have access to a phone and the internet at their place of work. This section examines the impact of that having unlimited access to a phone at work on the choice of transport information option at stage three. A dummy variable was created PWORK to represent those with access to a phone at work; this variable is defined in table 6-2. PWORK takes a value of 1 if there is unrestricted access to a phone at work, and 0 otherwise. Therefore, a positive result would me that those with unrestricted access are more likely to choose the transport information option being analysed.

The coefficient value for PWORK was estimated to be positive and significant at the 95% confidence level (see model M6-57, in table 6-22). This result indicates that those respondents who have unlimited access to a phone at work are more likely to choose to use real-time information, using a call centre or the internet. The model specified produced $\rho^2(0)$ and $\rho^2(c)$ values of 0.216 and 0.208, which are within the bounds of acceptability, and rejected the null hypothesis at the 99% confidence level. This demonstrates that the inclusion of the PWORK variable improves the model performance.

6.7.4 Access to the internet at work

The impact of having unrestricted access to the internet at work is examined in this section. A dummy variable called NETWRK was created to indicate if individuals have access to the internet at work. The variable has a positive value for individuals with unlimited access to the internet at work (this variable is defined in table 6-2). A positive coefficient value for NETWRK would indicate that those with unlimited access to the internet at work derive a higher utility from real-time information.

The NETWRK coefficient was estimated to have a positive value of 0.138 and to be significant at the 90% confidence level (*t*-ratio of 1.9) (see model M6-58, table 6-22). This positive value indicates that those individuals with unlimited access to the internet at work are more likely to choose transport information using the internet or SMS rather than call centre, than those with no access. The estimated $\rho^2(0)$ and $\rho^2(c)$ values of 0.223 and 0.217 demonstrates that the inclusion of the NETWRK variable improves the model fit. This is further seen with the rejection of the null hypothesis.

Table 6-22 MNL models with access to technology variables

Variables		M6-53	M6-54	M6-55	M6-56	M6-57	M6-58
		Stage One		Stage Two	Stage Three		
Internet	Time saved	-0.022 (-2.5)*	-0.020 (-2.3)*		-0.055 (-5.7)**	-0.062 (-8.1)**	-0.053 (-5.2)**
	Cost	-0.058 (-2.2)*	-0.046 (-1.9)*		-0.038 (-5.9)**	-0.036 (-11.2)**	-0.038 (-6.1)**
	Information	-0.464 (-3.3)**	-0.167 (-3.5)**		-0.757 (-4.4)**	-0.939 (-9.5)**	-0.856 (-5.0)**
SMS	Time saved	-0.043 (-3.1)**	-0.027 (-1.9)*	-0.033 (-4.8)**	-0.019 (-1.9)*	-0.065 (-2.3)*	-0.014 (-1.9)*
	Cost	-0.024 (-5.6)**	-0.026 (-5.8)**	-0.034 (-14.4)**	-0.039 (-8.2)**	-0.040 (-9.6)**	-0.039 (-8.2)**
	Information	-1.161 (-5.4)**	-1.148 (-3.1)**	-1.058 (-8.4)**	-1.295 (-7.4)**	-1.121 (-10.9)**	-1.176 (-6.6)**
Call centre	Time saved	-0.044 (-3.2)**	-0.040 (-2.7)**	-0.023 (-3.3)**	-0.018 (-1.9)*	-0.017 (-3.1)**	-0.026 (-2.3)*
	Cost – Call	-0.031 (-9.4)**	-0.031 (-8.7)**	-0.039 (-8.9)**	-0.044 (-10.6)**	-0.043 (-12.7)**	-0.043 (-10.5)**
	Information	-0.683 (-3.3)**	-0.767 (-2.0)*	-0.989 (-8.8)**	-0.653 (-3.8)**	-0.772 (-7.7)**	-0.767 (-4.3)**
PID	Time saved			-0.051 (-4.9)**			
	Cost			-0.035 (-8.4)**			
	Information			-1.133 (-10.3)**			
CONMOB (2)		0.213 (2.1)*			0.234 (2.2)*		
CONMOB (4)				0.661 (2.5)*			
BBNET (1)			0.183 (2.0)*				
PWORK (1)						0.140 (2.2)*	
NETWRK (1)							0.138 (1.9)*
N		1980	1980	1980	1980	1980	1980
ρ^2 *(0)*		0.214	0.219	0.215	0.222	0.216	0.223
ρ^2 *(c)*		0.209	0.206	0.207	0.213	0.208	0.217
Final Likelihood		-1797.05	-1772.57	-1721.08	-1712.59	-1717.42	-1720.65
Likelihood ratio test		7.45†	49.42†	19.28†	26.50†	16.84†	10.37†

(1) Internet (2) SMS (3) Call centre (4) PID

* Significant at the 95% confidence level

** Significant at the 99% confidence level

† Null hypothesis rejected

6.7.5 Models combining access to technology variables

This section examines models combining of access to technology variables. Stages one and three are the examined in this section, stage two is omitted as it was the only stage were only one variable was examined.

The CONMOB and BBNET variables are combined with the results for the base model for stage one to ascertain if it produces an improvement in model performance. The coefficients produced by model M6-59 in table 6-23 are significant at either the 95% or 99% confidence level. The $\rho^2(0)$ and $\rho^2(c)$ values of 0.238 and 0.215 in model M6-59 show an improvement compared to the values estimated by the base model M6-1 of 0.211 and 0.203. The results of the likelihood test demonstrate that this combination model produces a better model specification than the base model as the null hypothesis is rejected at the 99% confidence level (see table 6-23).

Table 6-23 MNL models combining access to technology variables – stage one

Variables		M6-1	M6-59
		Base Model	Stage One
Internet	Time saved	-0.028 (-2.2)*	-0.028 (-3.6)**
	Cost	-0.036 (-6.9)**	-0.099 (-6.7)**
	Information	-0.658 (-3.6)**	-0.925 (-2.8)**
SMS	Time saved	-0.034 (-2.6)**	-0.030 (-4.1)**
	Cost	-0.037 (-7.8)**	-0.025 (-11.6)**
	Information	-1.331 (-7.6)**	-1.216 (-8.9)**
Call centre	Time saved	-0.048 (-3.6)**	-0.035 (-4.8)**
	Cost	-0.041 (-10.3)**	-0.031 (-8.7)**
	Information	-0.641 (-3.8)**	-0.716 (-7.1)**
CONMOB (3)			0.134 (4.2)**
BBNET (1)			0.106 (2.2)*
N		1980	1980
$\rho^2(0)$		0.211	0.238
$\rho^2(c)$		0.203	0.215
Final Likelihood		-1797.28	-1788.12
Likelihood ratio test			18.31†

(1) Internet (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

The model calibrated for the stage three results includes the following explanatory variables, CONMOB, PWORK and NETWRK. The model estimates demonstrate that the inclusion of these variables produces a better model specification as the $\rho^2(0)$ and $\rho^2(c)$ values estimated, 0.215 and 0.205, which is an improvement on the base results of 0.209

and 0.201 (see model M6-60 in table 6-24). The combined model also produces significance levels all either at the 95% or 99% confidence level. The null hypothesis is rejected at the 99% confidence level, which demonstrates an improvement on the base model.

Table 6-24 MNL models combining access to technology variables – stage three

Variables		M6-3	M6-60
		Base Model	Stage Three
Internet	Time saved	-0.028 (-2.2)*	-0.030 (-5.1)**
	Cost	-0.036 (-6.9)**	-0.097 (-4.7)**
	Information	-0.658 (-3.6)**	-0.597 (-7.3)**
SMS	Time saved	-0.034 (-2.6)**	-0.036 (-6.0)**
	Cost	-0.037 (-7.8)**	-0.037 (-7.5)**
	Information	-1.331 (-7.6)**	-1.404 (-12.5)**
Call centre	Time saved	-0.048 (-3.6)**	-0.040 (-6.8)**
	Cost	-0.041 (-10.3)**	-0.042 (-12.9)**
	Information	-0.641 (-3.8)**	-0.617 (-8.0)**
CONMOB (2)			0.174 (4.9)**
PWORK (3)			0.412 (2.5)*
NETWORK (1)			0.594 (2.9)**
N		1980	1980
$\rho^2(0)$		0.209	0.215
$\rho^2(c)$		0.201	0.205
Final Likelihood		-1725.84	-1715.30
Likelihood ratio test			21.09†

(1) Internet (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

6.8 Estimation of Models with Work Pattern Variables

This section examines various aspects of an individual's journey to work on their choice of transport information option. Departure time from home and working hours are examined in this section. These factors were examined to ascertain if they impact upon the choice for transport information option.

6.8.1 Departure time

The first work pattern variable to be examined is daily departure time from place of residence. The purpose of examining this variable is to ascertain if departure time impacts upon an individual's choice between transport information options. A categorical variable for departure time DEPT was created and is defined in table 6-2. Given the definition of the variable a negative or low coefficient value would indicate those who depart early

derive a higher utility from transport information than those who depart later. Therefore a higher coefficient value for DEPT would indicate those that depart for work later obtain a greater benefit those that depart earlier.

DEPT was tested upon the results from stage three to ascertain if an earlier departure time in the morning impacted upon individuals choices when planning their trip home. The values were found not to be significant. It was therefore concluded that departure time did not impact upon the choice of transport information option at the third stage. Therefore, the models in this section combine the DEPT variable with the base models from stages one and two.

The departure time variable was found to be positive and significant (at the 99% confidence level, *t*-ratio of 2.6) for the first stage (see model M6-61, in table 6-25). This result demonstrates that as the departure time increases individuals are more likely to choose to access transport information from SMS rather than the internet or call centre. The model specification produced a good measure of fit with $\rho^2(0)$ and $\rho^2(0)$ values of 0.216 and 0.209. The likelihood ratio test rejects the null hypothesis (at the 99% confidence level) indicating this model specification has increased explanatory power, of the base model M6-1.

The results for departure time at the second stage were found to be significant at the 99% confidence level (*t*-ratio of 4.3) and positive with a value of 0.140 (see model M6-63 in table 6-25). As with the first stage, as departure time increases so too does the likelihood that the individual will choose the option passenger information display to obtain public transport information. The inclusion of the DEPT variable at this stage was shown to improve the model specification with the rejection of the null hypothesis and the $\rho^2(0)$ and $\rho^2(c)$ values of 0.218 and 0.210.

Both stages were found to have a positive relationship between departure time and choice of real-time information. As previously stated this relationship indicates that individuals that depart later to arrive at work are more likely to derive a higher utility from real-time information.

6.8.2 Working hours

This section details the impact of working hours on the choice of transport information option. The dummy variable FIXW was created to represent those individuals that have to arrive at work at a specific time each day. This variable will test the results to examine if those on fixed start or flexible start times are more likely to use real-time information. The dummy variable FIXW is defined in table 6-2. A positive value for the FIXW variable would indicate that those individuals that have to arrive at work at a specific time are more likely to use real-time information and vice versa.

The findings for FIXW variable at stage one were found to be negative and significant at the 99% confidence level with a *t*-ratio of -3.0 (see model M6-63, table 6-25). The coefficient value indicates that those individuals who do not work to a fixed schedule are more likely to choose to access transport information using SMS rather than the internet or a call centre. This result would seem to make intuitive sense as those individuals who have variable working hours may require real-time information, as they may be less familiar with public transport schedules. The inclusion of the FIXW variable in model M6-62 improves the model specification, as the null hypothesis is rejected and it produces improved $\rho^2(0)$ and $\rho^2(c)$ values of 0.220 and 0.214.

At the second stage the FIXW variable was also found to be negative and significant at the 95% confidence level (*t*-ratio of -2.1) (see model M6-64, in table 6-25). This model demonstrates that individuals who do not have a fixed working schedule are more likely to choose real-time transport information using a passenger information display. As with the inclusion of the FIXW variable at the first stage, its inclusion at the second stage results in an improvement in model specification. The likelihood ratio rejects the null hypothesis and the $\rho^2(0)$ and $\rho^2(c)$ values 0.211 and 0.204, indicating an improvement in model specification.

The FIXW coefficient was found to be negative (-0.121) and significant at the 99% confidence level (*t*-ratio of -2.6) at the third stage. Again at the third stage those who can leave work at different times each day were found to be more likely to choose transport information using the internet or SMS over a call centre than those on fixed work schedules. The estimated $\rho^2(0)$ and $\rho^2(c)$ values of 0.225 and 0.217 and the rejection of the null hypothesis demonstrates that the inclusion of the FIXW variable at stage three improves the model specification.

Table 6-25 MNL models with work pattern variables

	Variables	M6-61	M6-62	M6-63	M6-64	M6-65
		Stage One		Stage Two		Stage Three
Internet	Time saved	-0.249 (-3.0)**	-0.272 (-2.3)*			-0.255 (-4.7)**
	Cost	-0.358 (-2.7)**	-0.284 (-2.1)*			-0.435 (-6.4)**
	Information	-0.438 (-2.2)*	-0.996 (-4.0)**			-0.644 (-8.6)**
SMS	Time saved	-0.417 (-4.3)**	-0.382 (-2.9)**	-0.386 (-2.7)**	-0.495 (-6.0)**	-0.359 (-6.7)**
	Cost	-0.246 (-8.1)**	-0.260 (-6.3)**	-0.357 (-7.4)**	-0.339 (-12.3)**	-0.373 (-9.1)**
	Information	-1.225 (-7.3)**	-1.214 (-5.9)**	-0.731 (-3.4)**	-1.632 (-11.9)**	-1.350 (-8.4)**
Call centre	Time saved	-0.395 (-5.1)**	-0.381 (-3.5)**	-0.293 (-2.2)*	-0.531 (-5.9)**	-0.475 (-8.7)**
	Cost	-0.296 (-12.7)**	-0.302 (-9.3)**	-0.433 (-10.0)**	-0.374 (-5.5)**	-0.436 (-5.6)**
	Information	-0.669 (-4.2)**	-0.629 (-3.2)**	-1.378 (-5.9)**	-0.545 (-3.9)**	-0.589 (-8.4)**
PID	Time saved			-0.285 (-2.5)**	-0.664 (-4.8)**	
	Cost			-0.366 (-9.5)**	-0.377 (-7.0)**	
	Information			-1.449 (-6.3)**	-0.494 (-3.3)**	
DEPT(2)		0.440 (2.6)**				
DEPT (4)				0.140 (4.3)**		
FIXW (2)			-0.312 (-3.0)**			
FIXW (4)					-0.146 (-2.1)*	
FIXW (1)						-0.121 (-2.6)**
N		1890	1890	1890	1890	1890
$\rho^2(0)$		0.216	0.220	0.218	0.211	0.225
$\rho^2(c)$		0.209	0.214	0.210	0.204	0.217
Final Likelihood		-1777.43	-1781.76	-1717.90	-1724.57	-1721.15
Likelihood ratio test		39.69†	31.03†	25.65†	12.29†	8.63†

(1) Internet (2) SMS (3) Call centre (4) PID

* Significant at the 95% confidence level

** Significant at the 99% confidence level

† Null hypothesis rejected

6.8.3 Models combining work pattern variables

This section presents the models where work pattern variables have been combined, to ascertain the effect of this on the performance of the model. The models presented report where improvements in the explanatory power of the model have been achieved. Stages one and two are examined in this section; stage three is omitted as only one explanatory variable (FIXW) was examined at this stage.

Model M6-66 combines the DEPT and FIXW variables to produce a model with an improved specification from the base mode M6-1 from stage one (see table 6-26). The coefficients produced are significant at either the 95% or 99% confidence levels. The model specification estimates a likelihood ratio test value of 16.36, which demonstrates that the null hypothesis has been rejected at the 99% confidence level. This model specification also demonstrates improvements in both $\rho^2(0)$ and $\rho^2(c)$ values, from 0.211 and 0.203 in model M6-1 to 0.228 and 0.214 in model M6-66. This indicates that model M6-66 has improved explanatory power over the base model. The model also rejects the null hypothesis at the 99% confidence level (see table 6-26).

Table 6-26 MNL model combining work pattern variable – stage one

Variables		**M6-1**	**M6-66**
		Base Model	**Stage One**
Internet	Time saved	-0.028 (-2.2)*	-0.033 (-2.2)*
	Cost	-0.036 (-6.9)**	-0.094 (-3.3)**
	Information	-0.658 (-3.6)**	-0.458 (-2.7)**
SMS	Time saved	-0.034 (-2.6)**	-0.035 (-2.4)*
	Cost	-0.037 (-7.8)**	-0.024 (-7.5)**
	Information	-1.331 (-7.6)**	-1.117 (-5.6)**
Call centre	Time saved	-0.048 (-3.6)**	-0.037 (-2.6)**
	Cost	-0.041 (-10.3)**	-0.030 (-9.1)**
	Information	-0.641 (-3.8)**	-0.791 (-4.2)**
DEPT (1)			0.085 (2.7)**
FIXW (3)			-0.054 (-5.1)**
N		1980	1980
$\rho^2(0)$		0.211	0.228
$\rho^2(c)$		0.203	0.214
Final Likelihood		-1797.28	-1789.10
Likelihood ratio test			16.36†

(1) Internet (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

The same work pattern variables (DEPT and FIXW) are combined with the results from stage three and are presented in model M6-67 in table 6-27. The specified model demonstrates an increase in explanatory power as the $\rho^2(0)$ and $\rho^2(c)$ values of 0.238 and 0.214 are greater than the 0.209 and 0.201 estimated by the base model M6-2 (see model M6-67 in table 6-27). The model also produces coefficients significant at the 99% significance level. The null hypothesis was also rejected which indicates the combined model has demonstrated an improved explanatory power. These improvements show that model M6-67 has an improved explanatory power compared to the base model.

Table 6-27 MNL model combining work pattern variable – stage two

Variables		**M6-2**	**M6-67**
		Base Model	**Stage Two**
SMS	Time saved	-0.032 (-2.3)*	-0.035 (-5.0)**
	Cost	-0.036 (-7.9)**	-0.024 (-11.5)**
	Information	-1.098 (-5.6)**	-1.124 (-8.6)**
Call centre	Time saved	-0.027 (-2.1)*	-0.038 (-6.2)**
	Cost	-0.039 (-9.9)**	-0.030 (-11.8)**
	Information	-0.953 (-4.4)**	-0.079 (-8.4)**
PID	Time saved	-0.058 (-5.7)**	-0.032 (-5.2)**
	Cost	-0.036 (-9.7)**	-0.094 (-8.1)**
	Information	-1.049 (-4.9)**	-0.148 (-2.4)*
DEPT (1)			0.083 (8.4)**
FIXW (2)			-0.056 (-3.3)**
N		1980	1980
$\rho^2(0)$		0.209	0.238
$\rho^2(c)$		0.201	0.214
Final Likelihood		-1730.72	-1709.10
Likelihood ratio test			43.24†

(1) PID (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

6.9 MODELS COMBINING EXPLANATORY VARIABLES

This section utilises the models produced in sections 6.4, 6.5, 6.6, 6.7 and 6.8 to combine the results and produce a single model for each stage which incorporates the maximum number of explanatory variables. As in the previous sections, variables have been added to the base model one by one to produce an optimal model with higher $\rho^2(0)$ and $\rho^2(c)$ values that the base model, whilst keeping all the coefficients significant.

6.9.1 Combination of explanatory variables model – stage one

The following variables were added to the base model M6-1 CAR, BUS, WAIT, PTTIME, GENDER, AGE, INCOME, CARAV, ZONE and DEPT. As previously stated the purpose of including these variables was to increase the explanatory power of the model.

The findings demonstrate that model M6-68 presents an improvement on the base model M6-1. There is an improvement in the $\rho^2(0)$ and $\rho^2(c)$ values from 0.211 and 0.203 in the base model M6-1 to 0.254 and 0.230 in model M6-68 (see table 6-28). The likelihood ratio test produces a value of 31.89 (see table 6-28) demonstrating that the null hypothesis was rejected at the 99% confidence level and that the model demonstrates is an improvement on the base model. Each of the coefficients in the model are significant at the 90%, 95% or 99% confidence levels. The results from the model reveal an increased explanatory power of the model, as the model includes a greater level of detail on the respondent.

Table 6-28 MNL model combining explanatory variables – stage one

Variables		**M6-1**	**M6-68**
		Base Model	**Stage One**
Internet	Time saved	-0.028 (-2.2)*	-0.043 (-5.5)**
	Cost	-0.036 (-6.9)**	-0.062 (-4.5)**
	Information	-0.658 (-3.6)**	-0.532 (-2.0)*
SMS	Time saved	-0.034 (-2.6)**	-0.041 (-4.8)**
	Cost	-0.037 (-7.8)**	-0.029 (-11.3)**
	Information	-1.331 (-7.6)**	-1.546 (-10.0)**
Call centre	Time saved	-0.048 (3.6)**	-0.034 (-4.8)**
	Cost	-0.041 (-10.3)**	-0.032 (-7.1)**
	Information	-0.641 (3.8)**	-0.403 (-2.7)**
CAR (1)			-0.477 (-5.6)**
BUS (2)			0.215 (3.0)**
WAIT (2)			0.091 (2.8)**
PTTIME (3)			0.314 (2.9)**
GENDER (3)			0.115 (4.0)**
AGE (1)			-0.250 (2.4)*
INCOME (2)			0.079 (5.7)**
CARAV (3)			-0.066 (-2.7)**
ZONE (2)			0.043 (3.0)**
DEPT (1)			0.137 (1.9)*
N		1980	1980
$\rho^2(0)$		0.211	0.254
$\rho^2(c)$		0.203	0.230
Final Likelihood		-1797.28	-1781.33
Likelihood ratio test			31.89†

(1) Internet (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

6.9.2 Combination of explanatory variables model – stage two

The model specification for the second stage includes the following explanatory variables, CAR, BUS, WAIT, PTTIME, GENDER, AGE, INCOME, CARAV, ZONE, CONMOB and DEPT.

The inclusion of these variables has shown an improvement in the explanatory power of the model results for stage two. The coefficients estimated are significant at either the 95% or 99% confidence levels and the signs of these coefficients correspond with the findings in previous sections of this chapter. The likelihood ratio test produced a result of 23.28, thereby rejecting the null hypothesis at the 99% confidence level. The $\rho^2(0)$ and $\rho^2(c)$ values also demonstrate an improvement from the base results of 0.209 and 0.201, to 0.238 and 0.214 respectively (see table 6-29). These enhancements demonstrate that model M6-69 has an improved explanatory power compared to the base model. The coefficient values estimated are consistent with the model estimates when the variables were examined individually.

Table 6-29 MNL model combining explanatory variables – stage two

Variables		**M6-2**	**M6-69**
		Base Model	**Stage Two**
SMS	Time saved	-0.032 (2.3)*	-0.031 (-4.6)**
	Cost	-0.036 (-7.9)**	-0.044 (-8.0)**
	Information	-1.098 (5.6)**	-0.997 (-7.8)**
Call centre	Time saved	-0.027 (2.1)*	-0.013 (-2.3)*
	Cost	-0.039 (-9.9)**	-0.039 (-11.9)**
	Information	-0.953 (4.4)**	-1.179 (-8.8)**
PID	Time saved	-0.058 (5.7)**	-0.044 (-8.2)**
	Cost	-0.036 (-9.7)**	-0.034 (-8.8)**
	Information	-1.049 (4.9)**	-1.265 (-9.4)**
CAR (2)			-0.693 (-2.1)*
BUS (1)			0.165 (3.5)**
WAIT (1)			0.115 (4.7)**
PTTIME (3)			0.114 (2.1)*
GENDER (2)			-0.132 (2.0)*
AGE (2)			-0.153 (-2.2)*
INCOME (3)			0.249 (2.6)**
CARAV (1)			0.015 (3.7)**
ZONE (1)			0.374 (3.3)**
CONMOB (3)			0.194 (2.5)*
DEPT (3)			0.127 (2.0)*
N		1980	1980
$\rho^2(0)$		0.209	0.238
$\rho^2(c)$		0.201	0.214
Final Likelihood		-1730.72	-1719.08
Likelihood ratio test			23.28†

(1) PID (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

6.9.3 Combination of explanatory variables model – stage three

The following explanatory variables CAR, BUS, PTTIME, GENDER, AGE, INCOME, CARAV, ZONE, CONMOB and FIXW are introduced to the stage three base model M6-3.

Each of the coefficients incorporated in the model are significant either at 95% or 99% confidence levels, and the coefficient signs are consistent with the findings in the previous sections. The $\rho^2(0)$ and $\rho^2(c)$ values demonstrate an improvement on the values in the base model of 0.263 and 0.213 in model M6-70 compared to 0.215 and 0.208 in the model M6-3 (see table 6-30). The null hypothesis is also rejected at the 99% confidence level, demonstrating the model specification of M6-70 is an improvement on the base model.

Table 6-30 MNL model combining explanatory variables – stage three

Variables		M6-3	M6-70
		Base Model	Stage Three
Internet	Time saved	-0.028 (-2.2)*	-0.033 (-4.6)**
	Cost	-0.036 (-6.9)**	-0.097 (-12.6)**
	Information	-0.658 (-3.6)**	-0.683 (-7.1)**
SMS	Time saved	-0.034 (-2.6)**	-0.010 (-2.5)*
	Cost	-0.037 (-7.8)**	-0.046 (-10.8)**
	Information	-1.331 (-7.6)**	-1.443 (-5.2)**
Call centre	Time saved	-0.048 (-3.6)**	-0.048 (-7.7)**
	Cost	-0.041 (-10.3)**	-0.038 (-12.1)**
	Information	-0.641 (-3.8)**	-0.669 (-7.4)**
CAR (2)			-0.132 (-2.4)*
BUS (1)			0.550 (2.3)*
PTTIME (2)			0.284 (3.1)**
GENDER (3)			-0.358 (-2.6)**
AGE (2)			-0.220 (-2.8)**
INCOME (2)			0.267 (7.0)**
CARAV (1)			-0.281 (-2.5)*
ZONE (2)			0.061 (2.1)*
CONMOB (3)			0.067 (2.0)*
FIXW (2)			-0.111 (-6.6)**
N		1980	1980
$\rho^2(0)$		0.215	0.263
$\rho^2(c)$		0.208	0.213
Final Likelihood		-1725.84	-1705.78
Likelihood ratio test			40.13†

(1) Internet (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

6.10 SUMMARY

In this study respondents chose between options of accessing real-time information. MNL models have been specified to analyse these choices in this chapter. Whilst this chapter has not examined the relationships between each of the choices in great detail, it has instead concentrated on how explanatory variables impact upon the options of transport information chosen. A comprehensive examination of the options chosen at each stage is presented in chapter 9.

This chapter examined five sets of explanatory variables to ascertain how they impact upon the choice of transport information option. The examination of each of these five areas has provided insights as to the subsections of society that would derive the most benefit from the introduction of a system of real-time information.

The mode of transport variables demonstrate that those individuals who currently use public transport derive a greater utility, than those who cycle, walk or drive. Respondents who use more than one public transport service to travel to work on a daily basis were also found to derive a higher utility than those individuals who do not. The model estimates results also demonstrate a positive relationship between walk time to the stop/station, wait time (at stop/station) and journey time by car or public transport, and the choice of transport information option, indicating as these increase individuals are increasingly likely to derive benefits from the choice of transport information option.

The socio-economic explanatory variables demonstrated that, younger individuals are more likely to derive a higher utility from real-time information. Males were found to be more likely to derive a higher utility from transport information at the first stage, whereas females were found to derive a higher utility at stages two and three. The relationship between income and the utility derived from transport information was found to be positive, illustrating as income increases, so too does benefit gained from real-time information. Finally the availability of a car for the work trip was also found to demonstrate negative relationship, indicating those with no car available were more likely to choose a transport information option.

The location of residences and their proximity to public transport services was proven to impact upon the utility for real-time information. The results show that individuals who do not live near a high frequency mode of public transport such as a rail service or a high quality bus service are more likely to derive a benefit from real-time information. This is assumed to be due to the lower frequency of the service within close proximity to their residence. Geographically is has been show that individuals who travel greater distances to the city centre are also more likely to derive a higher utility from real-time information.

Access to technology was also examined and shown to impact upon the utility derived from real-time information. The existence of a broadband internet connection (at home) increases the likelihood that the individual will derive a higher utility from real-time information. Mobile phone contract type was proven to impact upon the utility derived, with those individuals with pay monthly contracts more likely to enjoy a benefit from real-time information. At the third stage access to a phone and the internet at the work place was shown to increase the likelihood individuals will choose to access real-time information.

Working patterns were the final set of explanatory variables examined in this chapter. The results demonstrate that those respondents with a later departure time are more likely to derive a higher utility from real-time information. Also individuals who work flexible hours are more likely to derive a higher utility from real-time information.

Parallel to the examination of the explanatory variables examined, the models of prediction have been strengthened with the inclusion of these variables. The final set of models in section 6.9 demonstrate the highest explanatory power, as they have been estimated with the most significant $\rho^2(0)$ and $\rho^2(c)$ values. These models are termed optimal models due to the increase explanatory power of the models specification.

7 MODEL ESTIMATION INCORPORATING ATTITUDINAL RESPONSE VARIABLES

7.1 INTRODUCTION

This chapter estimates MNL models which include attitudinal response variables. These models were produced to examine what, if any, impact perceptions and attitudes have upon the choice of public transport information option. In the survey respondents were asked to complete four sets of questions to obtain the attitudinal responses analysed in this chapter.

The analysis in this chapter differs to that in chapter 6, in that the attitudinal variables are included not in the base models but in models M6-68, M6-69 and M6-70 (final models estimated in chapter 6). These models have been used because they were proven to have higher explanatory power than the original base models defined in chapter 6 (see section 3.8 for more detail on this approach).

The first set of attitudinal variables examined relate to frustration with various aspects of public transport. Frustration in this sense focuses upon aspects of public transport, which could be improved with the introduction of real-time public transport information. These variables were analysed to ascertain if there is a relationship between frustration and the choice of public transport information option.

The convenience with which one associates accessing public transport information from the various the methods of technology (the internet, mobile phone, passenger information display and land line) examined in this study are presented in section 7.4. These variables were tested to ascertain if there is a relationship between the convenience associated with using the different technologies and the choice of public transport information option.

The perceived quality of current public transport information options is examined in section 7.5. These variables were analysed to determine if there is a link between opinions about the current public transport information available and the choice of public transport information option presented in the survey.

The final set of variables to be examined in this chapter relate to the frequency at which respondents currently consult public transport information. These variables were examined to determine if the frequency at which individuals currently consult public transport information impacts upon their choice of public transport information option.

Models combining the attitudinal variables estimated in this chapter with the explanatory variables examined in chapter 6 are presented in the section 7.7. The purpose of producing these models, as before, is to improve the explanatory power of the earlier models. The chapter concludes with a summary section which consolidates the main findings presented this chapter.

7.2 INCORPORATING ATTITUDINAL VARIABLES INTO THE MNL MODELS

This section describes the methods used to analyse the attitudinal responses collected in the survey.

7.2.1 Base models – with attitudinal variables

The base models used in this chapter are the final models estimated in chapter 6 (see Table 7.1). These models were used as base models because they were demonstrated to achieve the best model performance, as shown in the previous chapter. The attitudinal variables are added to these models to ascertain if the addition of these variables improves the model specification.

As the base models have changed, so too has the estimation of the likelihood ratios of each. The likelihood ratio is calculated using the final likelihood statistic from the base models in Table 7.1, as opposed to the original base models. The purpose of using these new base model final likelihood statistics was to measure improvements on the new base models as opposed to the old base models (see section 3.8 in chapter 3 for a full explanation).

From this point forward models M6-68, M6-69 and M6-70 will be referred to as base model 1, base model 2 and base model 3 respectively (see Table7-1).

Improvements in the models in this chapter are measured using the same criteria as in chapter 6, namely improvements in the $\rho^2(0)$ and $\rho^2(c)$ values and the rejection of the null

hypothesis in the likelihood ratio test. The likelihood ratio test compares one two models, the model with the additional variables and the original base model, the rejection of this hypothesis indicates that the newly estimated model has an improved model specification.

Table7-1 Base models including explanatory variables

Variables		Base model 1	Base model 2	Base model 3
		Stage One	Stage Two	Stage Three
Internet	Wait time saved	-0.043 (-5.5)**		-0.033 (-4.6)**
	Cost	-0.062 (-4.5)**		-0.097 (-12.6)**
	Information	-0.532 (-2.0)*		-0.683 (-7.1)**
SMS	Wait time saved	-0.041 (-4.8)**	-0.031 (-4.6)**	-0.010 (-2.5)**
	Cost	-0.029 (-11.3)**	-0.044 (-8.0)**	-0.046 (-10.8)**
	Information	-1.555 (-10.0)**	0.997 (-7.8)**	-1.443 (-5.2)**
Call centre	Wait time saved	-0.034 (-4.8)**	-0.013 (-2.3)*	-0.048 (-7.7)**
	Cost	-0.032 (-7.1)**	-0.039 (-11.9)**	-0.038 (-12.1)**
	Information	-0.403 (-2.7)**	-1.180 (-8.8)**	-0.669 (-7.4)**
PID	Wait time saved		-0.043 (-8.2)**	
	Cost		-0.034 (-8.8)**	
	Information		-1.265 (-9.4)**	
CAR (1)		-0.477 (-5.6)**		
CAR (2)			-0.693 (-2.1)*	-0.132 (-2.4)*
BUS (2)		0.215 (3.0)**		
BUS (4)			0.165 (3.5)**	
BUS (1)				0.550 (2.3)*
WAIT (2)		0.091 (2.8)**		
WAIT (4)			0.115 (4.7)**	
PTTIME (3)		0.314 (2.9)**	0.114 (2.1)*	
PTTIME (2)				0.284 (3.1)**
GENDER (3)		0.115 (4.0)**		-0.358 (-2.6)**
GENDER (2)			-0.132 (-2.0)*	
AGE (1)		-0.250 (2.4)**		
AGE (2)			-0.153 (-2.2)*	-0.220 (-2.8)**
INCOME (2)		0.079 (5.7)**		0.267 (7.0)**
INCOME (3)			0.249 (2.6)*	
CARAV (1)				-0.281 (-2.5)*
CARAV (3)		-0.066 (-2.7)**		
CARAV (4)			0.015 (3.7)	
ZONE (2)		0.043 (3.0)**		0.061 (2.1)*
ZONE (4)			0.374 (3.3)	
CONMOB (3)			0.194 (2.5)	0.067 (2.0)*
DEPT (1)		0.137 (1.9)*		
DEPT (3)			0.127 (2.0)	
FIXW (2)				-0.111 (-6.6)**
N		1980	1980	1980
$\rho^2(0)$		0.254	0.248	0.263
$\rho^2(c)$		0.230	0.214	0.213
Final Likelihood		-1781.33	-1719.08	-1705.78

(1) Internet (2) SMS (3) Call centre (4) PID

* Significant at the 95% confidence level

** Significant at the 99% confidence level

7.2.2 Defining attitudinal variables

The attitudinal variables examined in this chapter are defined in Table 7-2. Explanatory variables from chapter 6 are presented in this chapter. Definitions of these variables may be found in table 6-2.

Table 7-2 Description of attitudinal variables

Variable	Description
CONV1	Categorical variable: convenience of using the internet to access real-time transport information, values 1, 0, -1 represent convenient, no opinion and inconvenient
CONV2	Categorical variable: convenience of using a mobile phone to access real-time transport information, values 1, 0, -1 represent convenient, no opinion and inconvenient
CONV3	Categorical variable: convenience of using a land line to access real-time transport information, values 1, 0, -1 represent convenient, no opinion and inconvenient
CONV4	Categorical variable: convenience of using a PID to access real-time transport information, values 1, 0, -1 represent convenient, no opinion and inconvenient
CONVN1	Categorical variable: sums the individual reported values for CONV1, CONV2, CONV3 into one variable
CONVN2	Categorical variable: sums the individual reported values for CONV2, CONV4 into one variable
FRU1	Categorical variable: frustration with uncertainty of time of public transport service arrival, values 1, 0, -1 represent very frustrated, no opinion and not frustrated
FRU2	Categorical variable: frustration with uncertainty if a specific public transport service has passed a specific stop, values 1, 0, -1 represent very frustrated, no opinion and not frustrated
FRU3	Categorical variable: frustration with uncertainty of departure time, values 1, 0, -1 represent very frustrated, no opinion and not frustrating
FRUST	Categorical variable: sums the individual reported values for FRU1, FRU2 and FRU3 into one variable
PER1	Categorical variable: perceived quality of maps provided currently at bus stops/train stations, values 2, 1, 0, -1, -2 represent very good, good, no opinion, poor and very poor
PER2	Categorical variable: perceived quality of time tables provided currently at bus stops/train stations, values 2, 1, 0, -1, -2 represent very good, good, no opinion, poor and very poor
PER3	Categorical variable: perceived quality of public transport websites, values 2, 1, 0, -1, -2 represent very good, good, no opinion, poor and very poor
PER4	Categorical variable: perceived quality of available real-time information, values 2, 1, 0, -1, -2 represent very good, good, no opinion, poor and very poor
PERSEP	Categorical variable: sums the individual reported values for PER1, PER2, PER3 and PER4 into one variable
USE1	Categorical variable: frequency at which public transport information is currently consulted when planning a trip from home to work, values 1, 0 represent regularly/sometimes and seldom/never
USE2	Categorical variable: frequency at which public transport information is currently consulted when at stop/station, values 1, 0 represent regularly/sometimes and seldom/never
USE3	Categorical variable: frequency at which public transport information is currently consulted when planning a trip from work to home, values 1, 0 represent regularly/sometimes and seldom/never

7.3 ESTIMATION OF MODELS INCLUDING FRUSTRATION VARIABLES

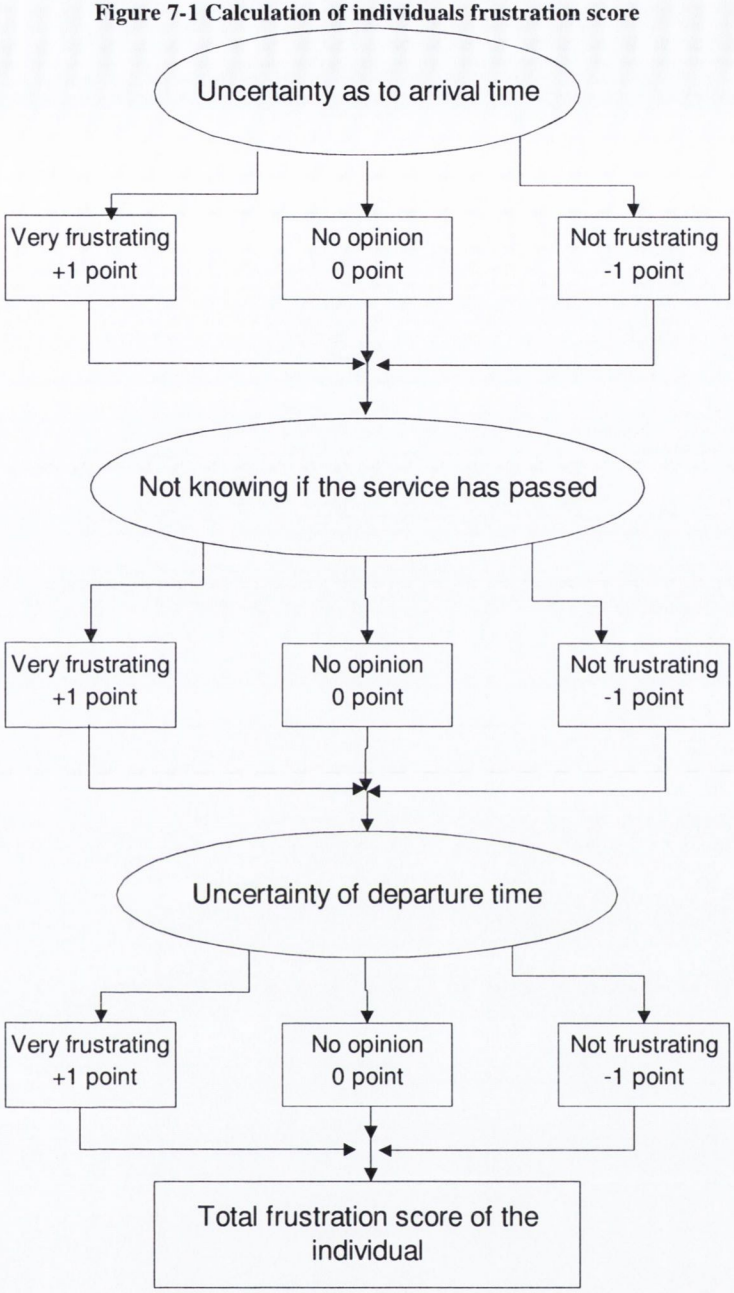
This section reports the model estimates for the frustration variables for each of the stages examined.

7.3.1 Definition of frustration

The following frustration variables were examined; FRU1, frustration with not knowing when bus/train will arrive, FRU2, frustration with not knowing if a specific bus/train has passed and FRU3 frustration with missing a service due to uncertainty of departure time (these variables are defined in Table 7-2). The purpose of analysing these aspects of frustration with public transport as opposed to other aspects such as frequency, comfort or cost etc, was that the sources of the frustration examined could be remedied with the use of real-time public transport information.

The frustration variables were initially tested as a set of separate variables in one model to examine what impact they have upon the choice of real-time public transport information option. The individual frustration variables where not found to be significant, when treated as a set of individual variables. Therefore, a new variable summing the individual frustration variables was created called FRUST (defined in Table 7-2). The FRUST variable adds the individual frustration scores of the respondent, adding them to produce a combined frustration score (see Figure 7-1). If the respondent indicates for example, not knowing the arrival time is frustrating; it is indicated by a +1 which is then added to their responses to the other two questions, to calculate the total frustration score. Therefore, the final frustration score of the individual is the sum of the responses to each of the individual questions (see section 3.7.3 for a discussion on the application of this method).

Figure 7-1 Calculation of individuals frustration score



7.3.2 MNL models including frustration variables – stage one

Model M7-1 incorporates the frustration variables FRU1, FRU2 and FRU3 with the model specification for base model 1 (see Table 7-3). The findings demonstrate that when the frustration variables are analysed individually, the coefficients were found not to be significant even at the 90% confidence level. Model M7-1 produced lower $\rho^2(0)$ and $\rho^2(c)$ values of 0.251 and 0.221 compared to 0.254 and 0.230 in base model 1. These results

demonstrate that the model estimated does not improve upon the base model 1. This is proven to be the case as the null hypothesis is accepted with the likelihood ratio test statistic estimated to be -18.39 (see Table 7-3).

The introduction of the FRUST variable in model M7-2 produces a coefficient value which is significant at the 95% confidence level (*t*-ratio of 2.1) (see Table 7-3). The coefficient value was also reported to be positive, which indicates that as the frustration score increases, so too does the likelihood that the individual will choose SMS to access public transport information at stage one. This result demonstrates that the higher the frustration the individual experiences when using public transport, the more likely they are to choose to access real-time public transport information using SMS.

The model demonstrates an improvement compared with model 1, as the estimated $\rho^2(0)$ and $\rho^2(c)$ values of 0.263 and 0.237 are greater than 0.254 and 0.230 values estimated in the base model, which demonstrates a better model specification. The estimated likelihood ratio test produces a value of 26.49, which rejects the null hypothesis at the 99% confidence level, signifying that model M7-2 is an improvement upon base model 1 (see Table 7-3).

Table 7-3 MNL models including frustration variables – stage one

Variables		Base Model 1	M7-1	M7-2
		Stage One		
Internet	Wait time saved	-0.043 (-5.5)**	-0.038 (-7.2)**	-0.034 (-5.2)**
	Cost	-0.062 (-4.5)**	-0.068 (-2.7)**	-0.046 (-3.4)**
	Information	-0.532 (-2.0)*	-0.415 (-2.3)*	-0.588 (-3.6)**
SMS	Wait time saved	-0.041 (-4.8)**	-0.042 (-7.4)**	-0.051 (-6.6)**
	Cost	-0.029 (-11.3)**	-0.028 (-5.6)**	-0.023 (-10.0)**
	Information	-1.546 (-10.0)**	-1.506 (-13.6)**	-1.315 (-9.0)**
Call centre	Wait time saved	-0.034 (-4.8)**	-0.035 (-7.3)**	-0.051 (-7.4)**
	Cost	-0.032 (-7.1)**	-0.033 (-5.7)**	-0.032 (-9.1)**
	Information	-0.403 (-2.7)**	-0.452 (-4.2)**	-0.620 (-4.3)**
CAR (1)		-0.477 (-5.6)**	-0.487 (-8.5)**	-0.414 (-5.9)**
BUS (2)		0.215 (3.0)**	0.218 (4.6)	0.355 (2.4)*
WAIT (2)		0.091 (2.8)**	0.086 (3.9)**	0.117 (4.3)**
PTTIME (3)		0.314 (2.9)**	0.277 (3.7)**	0.344 (3.6)**
GENDER (3)		0.115 (4.0)**	0.078 (3.8)**	0.090 (4.0)**
AGE (1)		-0.245 (-2.4)**	-0.039 (-3.2)**	-0.050 (-3.3)**
INCOME (2)		0.079 (5.7)**	0.070 (7.3)**	0.049 (3.7)**
CARAV (3)		-0.066 (-2.7)**	-0.032 (-2.4)*	-0.066 (-2.3)*
ZONE (2)		0.043 (3.0)**	0.043 (3.4)**	0.023 (2.5)**
DEPT (1)		0.137 (1.9)*	0.036 (3.9)**	0.015 (2.7)**
FRU1 (2)			0.020 (1.5)	
FRU2 (1)			0.002 (0.3)	
FRU3 (3)			0.009 (1.4)	
FRUST (2)				0.124 (2.1)*
N		1980	1980	1980
$\rho^2(0)$		0.254	0.251	0.263
$\rho^2(c)$		0.230	0.221	0.237
Final Likelihood		-1781.33	-1790.53	-1768.09
Likelihood ratio test			-18.39	26.49†

(1) Internet (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

7.3.3 MNL models including frustration variables – stage two

Model M7-3 combines the individual frustration variables with base model 2 (see Table 7-4) The results from model M7-3, as with the first stage show that the individual frustration variables were found not to be significant. However, the inclusion of these variables did result in an improvement in the model specification as the $\rho^2(0)$ and $\rho^2(c)$ values of 0.256 and 0.211 were found to demonstrate an improvement upon those estimated for base model 2 of 0.248 and 0.214 (see Table 7-4). The estimated likelihood ratio of 4.41 rejects the null hypothesis at the 95% confidence level (see) indicating that even though the

coefficients estimated are not significant, the model specification is an improvement on base model 2.

Model M7-4 introduces the FRUST variable to the model specification for base model 2 (see table 7-4). The coefficient values for this variable were estimated to be positive and significant at the 95% confidence level (*t*-ratio of 2.0) (see Table 7-4). This positive result indicates that as frustration with public transport increases so too does the likelihood that the individual will choose to access public transport information using passenger information display. Model M7-4 also achieves an improvement in model specification compared to base model 2, as the $\rho^2(0)$ and $\rho^2(c)$ values of 0.267 and 0.220 are an improvement on 0.248 and 0.214 estimated in base model 2. The model design is proven to display an advance on base model 2, as likelihood ratio of 20.39 rejects the null hypothesis at the 99% confidence level (see table 7-4).

Table 7-4 MNL model including frustration variables-stage two

Variables		Base model 2	M7-3	M7-4
		Stage Two		
SMS	Wait time saved	-0.031 (-4.6)**	-0.035 (-4.0)**	-0.040 (-4.6)**
	Cost	-0.044 (-8.0)**	-0.037 (-10.2)**	-0.036 (-9.2)**
	Information	-0.997 (-7.8)**	-0.974 (-5.9)**	-0.741 (-4.6)**
Call centre	Wait time saved	-0.013 (-2.3)*	-0.014 (-2.7)**	-0.022 (-2.8)**
	Cost	-0.039 (-11.9)**	-0.037 (-5.0)**	-0.037 (-9.4)**
	Information	-1.179 (-8.8)**	-1.110 (-6.3)**	-1.369 (-7.9)**
PID	Wait time saved	-0.044 (-8.2)	-0.043 (-6.2)**	-0.037 (-5.3)**
	Cost	-0.034 (-8.8)	-0.037 (-5.6)**	-0.038 (-6.0)**
	Information	-1.265 (-9.4)	-1.159 (-6.6)**	-1.403 (-8.2)**
CAR (2)		-0.693 (-2.1)	-0.204 (-2.3)*	-0.167 (-3.0)**
BUS (1)		0.165 (3.5)	0.112 (2.0)*	0.113 (2.1)*
WAIT (1)		0.115 (4.7)	0.102 (3.6)**	0.107 (3.8)**
PTTIME (3)		0.114 (2.1)	0.028 (2.8)**	0.029 (2.9)**
GENDER (2)		-0.132 (-2.0)	0.049 (2.1)*	0.029 (3.9)**
AGE (2)		-0.153 (-2.2)	-0.078 (-4.0)**	-0.144 (-2.1)*
INCOME (3)		0.249 (2.6)	0.106 (2.7)**	0.345 (2.5)**
CARAV (1)		-0.015 (-3.7)	-0.090 (-2.8)**	-0.012 (-5.9)**
ZONE (1)		0.374 (3.3)	0.019 (1.9)*	0.039 (3.3)**
CONMOB (3)		0.194 (2.5)	0.014 (3.8)**	0.033 (2.3)*
DEPT (3)		0.127 (2.0)	0.053 (2.6)**	0.033 (6.0)**
FRU1 (3)			0.056 (1.0)	
FRU2 (2)			0.115 (1.5)	
FRU3 (1)			0.101 (1.3)	
FRUST (1)				0.174 (2.0)*
N		1980	1980	1980
$\rho^2(0)$		0.248	0.256	0.267
$\rho^2(c)$		0.214	0.211	0.220
Final Likelihood		-1719.08	-1716.87	-1708.89
Likelihood ratio test			4.41	20.39†

(1) PID (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

7.3.4 MNL models including frustration variables – stage three

The coefficient values for the individual frustration variables at stage three are estimated in Model M7-5 (see Table 7-5). The estimated individual coefficients for frustration produce positive values, however these coefficients were not found to be significant (see Table 7-5). The model produces an improvement in the $\rho^2(0)$ and $\rho^2(c)$ values from 0.263 and 0.213 in base model 3 to 0.274 and 0.224 in model M7-5. The null hypothesis was

rejected at the 95% confidence level, as the likelihood ratio was estimated to be 7.65 (see Table 7-5). The improvement in the $\rho^2(0)$ and $\rho^2(c)$ values and the rejection of the null hypothesis demonstrate that although the frustration variables were not estimated to be significant, there inclusion did improve the model performance.

Model M7-6 incorporates the FRUST variable with the model specification for base model 3. As with the other stages, the FRUST variable was estimated to be positive and significant at the 99% confidence level with a *t*-ratio if 7.0 (see Table 7-5). This result indicates that as the frustration score increases so too does the likelihood that the respondent will choose to obtain public transport information from the internet at this stage. Model M7-6 produces an enhancement in the explanatory power of the model, as both the $\rho^2(0)$ and $\rho^2(c)$ of 0.297 and 0.250 demonstrate improvements upon the results estimated in base model 3 of 0.263 and 0.213. The estimated likelihood ratio of 14.38 rejects the null hypothesis at the 99% confidence level (see Table 7-5). The model performance statistics both indicate that the introduction of the FRUST variable improves the model specification and that frustration with public transport influences the choice of public transport information option.

The model estimates for the FRUST variable were found to be highest at stage two. This indicates that the frustration experienced while waiting for a public transport service to arrive has a more significant impact upon choice of real-time information option compared to the other two stages.

Table 7-5 MNL model including frustration variables – stage three

Variables		Base model 3	M7-5	M7-6
			Stage Three	
Internet	Wait time saved	-0.033 (-4.6)**	-0.016 (-2.7)**	-0.028 (-4.9)**
	Cost	-0.097 (-12.6)**	-0.011 (-14.4)**	-0.028 (-10.3)**
	Information	-0.683 (-7.1)**	-0.804 (-8.3)**	-0.745 (-7.7)**
SMS	Wait time saved	-0.010 (-2.5)*	-0.023 (-3.6)**	-0.012 (-1.9)*
	Cost	-0.046 (-10.8)**	-0.046 (-8.8)**	-0.048 (-8.9)**
	Information	-1.443 (-5.2)**	-1.288 (-6.3)**	-1.432 (-5.5)**
Call centre	Wait time saved	-0.048 (-7.7)**	-0.056 (-5.3)**	-0.048 (-8.8)**
	Cost	-0.038 (-12.1)**	-0.037(-12.5)**	-0.037 (-7.2)**
	Information	-0.669 (-7.4)**	-0.805 (-8.7)**	-0.716 (-7.9)**
CAR (2)		-0.132 (-2.4)*	-0.166 (-3.0)**	-0.123 (-2.3)*
BUS (1)		0.550 (2.3)*	0.410 (2.9)**	0.334 (8.0)**
GENDER (3)		-0.358 (-2.6)**	-0.028 (-2.1)*	-0.023 (-9.0)**
AGE (2)		0.219 (2.8)**	-0.029 (-4.3)**	-0.112 (-8.1)**
INCOME (2)		0.267 (7.0)**	0.065 (6.3)**	0.162 (2.2)*
CARAV (1)		-0.281 (-2.5)**	-0.145 (-2.4)**	-0.359 (-3.5)**
ZONE (2)		0.061 (2.1)*	0.042 (2.7)**	0.016 (3.7)**
CONMOB (3)		0.067 (2.0)*	0.039 (5.0)**	0.038 (9.2)**
FIXW (2)		-0.111 (-6.6)**	-0.077 (2.4)*	-0.099 (-3.5)**
FRU1 (3)			0.039 (1.0)	
FRU2 (2)			0.072 (1.2)	
FRU3 (1)			0.080 (0.9)	
FRUST (1)				0.120 (7.0)**
N		1980	1980	
ρ^2 *(0)*		0.263	0.274	0.297
ρ^2 *(c)*		0.213	0.224	0.250
Final Likelihood		-1705.78	-1701.95	-1698.59
Likelihood ratio test			7.65†	14.38†

(1) Internet (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

7.4 Estimation of Models Including Convenience Variables

This section incorporates variables which represent how convenient individuals find it to access public transport information from the different methods of technology examined in this study. The purpose of examining these variables was to ascertain if an individual finds it convenient to access information from these methods how it impacts upon their choice of public transport information option.

7.4.1 Definition of the convenience variable

In the survey respondents were asked to rate the convenience of using the internet, SMS, a call centre and passenger information display to access public transport information. The variables created to measure convenience take a value of 1, if considered convenient, 0, if no opinion, and -1 if inconvenient. Given the specification of the variable, a positive coefficient value would indicate those individuals who find it convenient to use the various technologies are more likely to choose the public transport information option being examined.

Four variables were created to measure convenience of access to public transport information. CONV1, convenience of using the internet, CONV2, convenience of using SMS, CONV3, convenience of using a land line (to contact a call centre) and CONV4 the convenience associated with using a passenger information display (each variable is defined in table 7.2). As with the frustration variables the individual convenience variables have been combined to create two variables, CONVN1 and CONVN2 (defined in Table 7-2). The purpose of having two variables is that the methods of technology available to the respondent at each of the stages of a public transport trip examined in this study differ. CONVN1 includes convenience associated with using the internet; mobile phone and land line, examined at stages one and three (see Figure 7-2). The second variable CONVN2 examines the convenience of using passenger information display and mobile phone at stage two (see Figure 7-3).

Figure 7-2 Calculation of the CONVN1 score

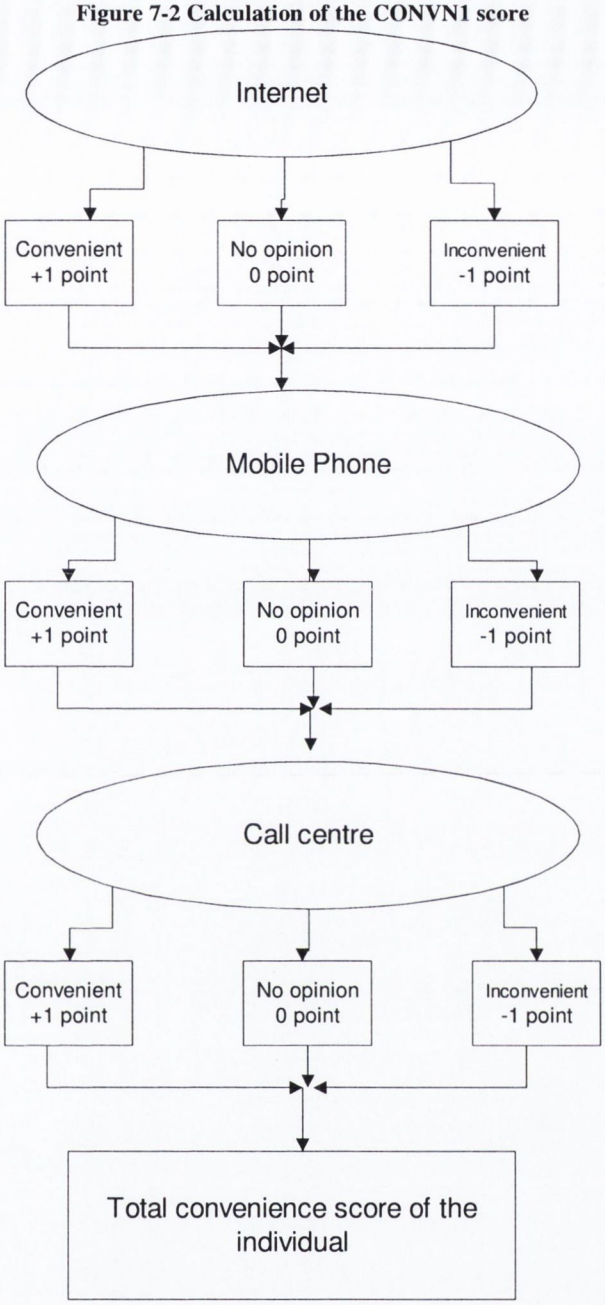
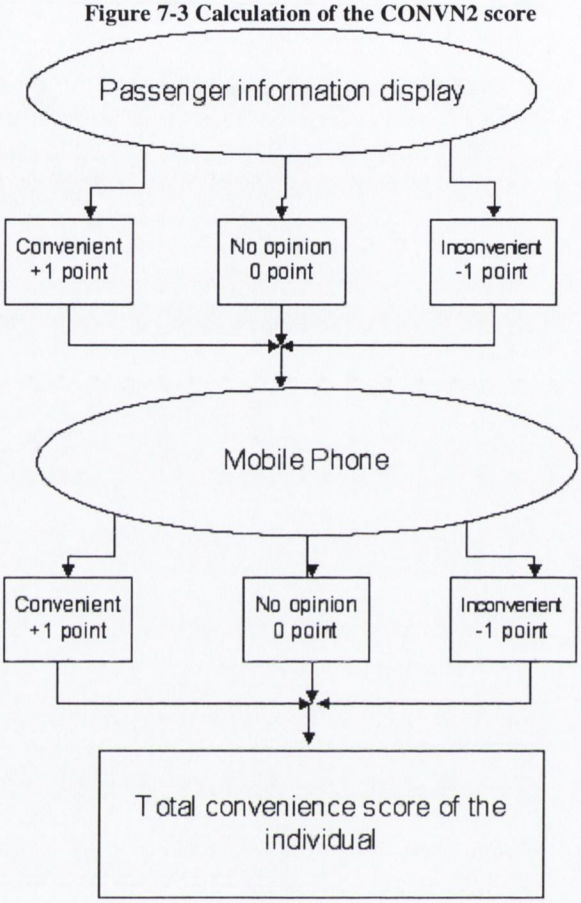


Figure 7-3 Calculation of the CONVN2 score



7.4.2 MNL models including convenience variables – stage one

The models estimated to measure the impact of the convenience variables at stage one are presented in Table 7-6. The estimates for CONV1, CONV2 and CONV3 were all found to be positive, but not significant, even at the 90% confidence level (see model M7-7 in Table 7-6). Model M7-7 produced an improvement in the $\rho^2(0)$ and $\rho^2(c)$ values of 0.256 and 0.233 compared to 0.254 and 0.230 in the base model 1. The null hypothesis was rejected at the 95% confidence level as the likelihood ratio was estimated to be 7.58 (see Table 7-6). This demonstrates that although the model specification did not estimate significant CONV variables, their inclusion has improved the model performance at the first stage.

As the individual convenience variables failed to produce significant coefficient values, the CONVN1 variable was introduced into base model 1. The CONVN1 variable was found to be positive and significant at the 99% confidence level (see model M7-8 in Table 7-6). This positive value indicates that as the convenience score increases so too does the

likelihood that the respondent will choose to access public transport information using SMS rather than the internet or a call centre. This result suggests at stage one respondents find accessing public transport information via SMS/mobile phone to be the most convenient method.

Model M7-8 demonstrated an improvement in the $\rho^2(0)$ and $\rho^2(c)$ values, as they increased from 0.254 and 0.230 in base model 1 compared to 0.258 and 0.240 in model M7-8. The improvements in the $\rho^2(0)$ and $\rho^2(c)$ values and the rejection of the null hypothesis at the 99% confidence level (likelihood ratio was estimate to be 26.59), demonstrate that the model specification has been enhanced with the inclusion of CONVN1 variable.

Table 7-6 MNL models including convenience variables – stage one

Variables		Base model 1	M7-7	M7-8
		Stage One		
Internet	Wait time saved	-0.043 (-5.5)**	-0.039 (-5.5)**	-0.039 (-4.5)**
	Cost	-0.062 (-4.5)**	-0.077 (-6.0)**	-0.066 (-5.3)**
	Information	-0.532 (-2.0)*	-0.980 (-2.6)**	-0.947 (-3.9)**
SMS	Wait time saved	-0.041 (-4.8)**	-0.040 (-5.2)**	-0.043 (-5.6)**
	Cost	-0.029 (-11.3)**	-0.028 (-12.2)**	-0.029 (-12.8)**
	Information	-1.546 (-10.0)**	-1.431 (-9.9)**	-1.409 (-9.6)**
Call centre	Wait time saved	-0.034 (-4.8)**	-0.030 (-4.4)**	-0.037 (-5.6)**
	Cost	-0.032 (-7.1)**	-0.032 (-9.1)**	-0.032 (-9.4)**
	Information	-0.403 (-2.7)**	-0.528 (-3.7)**	-0.562 (3.8)**
CAR (1)		-0.477 (-5.6)**	-0.489 (-6.5)**	-0.490 (-6.2)**
BUS (2)		0.215 (3.0)**	0.225 (2.6)**	0.221 (3.5)**
WAIT (2)		0.091 (2.8)**	0.132 (2.5)*	0.081 (2.8)**
PTTIME (3)		0.314 (2.9)**	0.255 (2.6)**	0.291 (3.3)**
GENDER (3)		0.115 (4.0)**	0.095 (2.0)*	0.115 (4.5)**
AGE (1)		-0.245 (-2.4)*	-0.028 (-2.7)**	-0.026 (-2.6)**
INCOME (2)		0.079 (5.7)**	0.088 (6.7)**	0.069 (5.3)**
CARAV (3)		-0.066 (-2.7)**	-0.081 (-3.2)**	-0.066 (-2.2)*
ZONE (2)		0.043 (3.0)**	0.026 (2.0)*	0.018 (2.1)*
DEPT (1)		0.137 (1.9)*	0.142 (2.1)*	0.159 (2.7)**
CONV1(1)			0.040 (1.6)	
CONV2(2)			0.020 (1.2)	
CONV3(3)			0.027 (1.7)	
CONVN1 (2)				0.113 (2.8)**
N		1980	1980	1980
$\rho^2(0)$		0.254	0.256	0.258
$\rho^2(c)$		0.230	0.233	0.240
Final Likelihood		-1781.33	-1777.54	-1768.05
Likelihood ratio test			7.58†	26.59†

(1) Internet (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

7.4.3 MNL models including convenience variables – stage two

The models estimated including convenience variables at stage two are reported in Table 7-7. The findings demonstrate that the individual variables representing convenience were found to be positive, but not significant (see model M7-9 in Table 7-7). The model specification did however demonstrate an improvement, as the $\rho^2(0)$ and $\rho^2(c)$ values of 0.257 and 0.219 estimated for model M7-9 compared to the values of 0.248 and 0.214

estimated for base model 2. The estimated likelihood ratio of 56.18 rejects the null hypothesis at the 99% confidence level (see Table 7-7).

Model M7-10 estimates positive value for CONVN2, which was also found to be positive at the 95% confidence level (*t*-ratio of 2.3) (see Table 7-7). This positive value indicates that as the convenience score increases so too does the likelihood the respondent will choose to access public transport information using passenger information display. Model M7-10 demonstrates an improvement upon base model 2, as the estimated $\rho^2(0)$ and $\rho^2(c)$ values of 0.267 and 0.221 are higher than the 0.248 and 0.214 found in base model 2 (see Table 7-7). The likelihood ratio of 48.06 rejects the null hypothesis at the 99% confidence level. These results show that the introduction of the CONVN2 variable improves the model specification and the explanatory power of the model at stage two.

Table 7-7 MNL models including convenience variables – stage two

Variables		Base model 2	M7-9	M7-10
		Stage Two		
SMS	Wait time saved	-0.031 (-4.6)**	-0.033 (-4.8)**	-0.032 (-4.3)**
	Cost	-0.044 (-8.0)**	-0.043 (-7.7)**	-0.044 (-6.5)**
	Information	-0.997 (-7.8)**	-0.996 (-8.9)**	-1.100 (-7.7)**
Call centre	Wait time saved	-0.013 (-2.3)*	-0.017 (-2.7)**	-0.014 (-2.1)*
	Cost	-0.039 (-11.9)**	-0.040 (-9.1)**	-0.039 (-7.4)**
	Information	-1.179 (8.8)**	-1.209 (-8.9)**	-1.061 (-7.0)**
PID	Wait time saved	-0.044 (-8.2)**	-0.039 (-7.2)**	-0.043 (-4.1)**
	Cost	-0.034 (-8.8)**	-0.034 (-8.5)**	-0.034 (-8.1)**
	Information	-1.265 (-9.4)**	-1.238 (-9.1)**	1.164 (-7.8)**
CAR (2)		-0.693 (-2.1)*	-0.542 (2.0)*	-0.328 (-2.5)*
BUS (1)		0.165 (3.5)**	0.172 (3.7)**	0.168 (3.3)**
WAIT (1)		0.115 (4.7)**	0.112 (4.5)**	0.116 (4.4)**
PTTIME (3)		0.114 (2.1)*	0.221 (3.0)**	0.205 (2.8)**
GENDER (2)		-0.132 (2.0)*	-0.157 (-2.7)**	-0.366 (-2.8)**
AGE (2)		-0.153 (-2.2)**	-0.144 (-2.1)*	-0.127 (-2.8)**
INCOME (3)		0.249 (2.6)**	0.143 (2.9)**	0.285 (2.4)*
CARAV (1)		-0.015 (3.7)**	-0.030 (-4.5)**	-0.076 (-3.0)**
ZONE (1)		0.374 (3.3)**	0.588 (3.6)**	0.546 (3.6)**
CONMOB (3)		0.194 (2.5)*	0.188 (3.1)**	0.178 (3.4)**
DEPT (3)		0.127 (2.0)*	0.384 (3.2)**	0.293 (2.6)**
CONV2 (2)			0.032 (0.6)	
CONV4 (1)			0.018 (1.5)	
CONVN2 (1)				0.111 (2.3)*
N		1980	1980	1980
$\rho^2(0)$		0.248	0.257	0.267
$\rho^2(c)$		0.214	0.219	0.221
Final Likelihood		-1719.08	-1690.99	-1695.05
Likelihood ratio test			56.18†	48.06†

(1) PID (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

7.4.4 MNL models including convenience variables – stage three

Model M7-11 combines CONV1, CONV2 and CONV3 with the specification for base model 3 (see Table 7-8). The coefficient values for the convenience variables were found to be positive, however, not at any significance level (see model M7-11 in Table 7-8). The specification for model M7-11 did not produce an improvement in model performance as the estimated $\rho^2(0)$ and $\rho^2(c)$ values of 0.257 and 0.207 are lower than 0.263 and 0.213 values estimated for base model 3. The likelihood ratio test produced a value of -39.42,

which accepts the null hypothesis, demonstrating that the model specification for model M7-11 is not an improvement in the model specification.

As the individual variables failed to produce significant results, the CONVN1 variable was introduced to the model specification at stage three. CONVN1 was found to produce a positive coefficient, which was also estimated to be significant at the 99% confidence level with a *t*-ratio of 7.1 (see model M7-12 in Table 7-8). This result demonstrates that as the convenience score increases so too does the likelihood that the respondents will choose to access public transport information from SMS at stage three. The introduction of the CONVN1 variable improves the model performance as the estimated $\rho^2(0)$ and $\rho^2(c)$ values of 0.289 and 0.259 are an enhancement on the values of 0.263 and 0.213 in base model 3. The null hypothesis is rejected at the 95% confidence level as the likelihood ratio is estimated at 11.45 (see Table 7-8). This proves that the inclusion of variables representing convenience improves the model performance and the explanatory power of the model.

A comparison between the three stages demonstrates that at the third stage the convenience variable was estimated to have the highest coefficient value. This indicates at the third stage convenience of using the various technologies to access transport information has the greatest impact upon choice of public transport information option. This may be attributed to the fact that individuals have a greater access to the internet and land line, as they are assumed to be based in an office at this stage.

Table 7-8 MNL models incorporating convenience variables – stage three

Variables		Base model 3	M7-11	M7-12
		Stage Three		
Internet	Wait time saved	-0.032 (-4.6)**	-0.036 (-5.6)**	-0.046 (-8.5)**
	Cost	-0.097 (-12.6)**	-0.092 (-12.5)**	-0.087 (-11.9)**
	Information	-0.683 (-7.1)**	-0.758 (-7.7)**	-0.645 (-6.5)**
SMS	Wait time saved	-0.010 (-2.5)*	-0.015 (-2.3)*	-0.011 (-2.6)**
	Cost	-0.046 (-10.8)**	-0.045 (-10.8)**	-0.050 (-12.4)**
	Information	-1.443 (-5.2)**	-1.310 (-3.1)**	-1.535 (-5.6)**
Call centre	Wait time saved	-0.048 (-7.7)**	-0.027 (-5.3)**	-0.026 (-5.4)**
	Cost	-0.038 (-12.1)**	-0.038 (-12.1)**	-0.039 (-12.8)**
	Information	-0.669 (-7.4)**	-0.694 (-7.5)**	-0.541 (-5.8)**
CAR (2)		-0.132 (-2.4)*	-0.634 (-2.1)*	-0.566 (-1.9)*
BUS (1)		0.550 (2.3)*	0.484 (2.1)*	0.664 (2.5)*
GENDER (3)		-0.358 (-2.6)**	-0.162 (-2.3)*	-0.191 (-1.9)*
AGE (2)		0.220 (2.8)**	-0.275 (-2.5)*	-0.402 (-2.8)**
INCOME (2)		0.267 (7.0)**	0.046 (3.9)**	0.020 (2.0)*
CARAV (1)		-0.281 (-2.5)*	0.467 (-2.2)*	-0.396 (-3.0)**
ZONE (2)		0.061 (2.1)*	0.067 (4.3)**	0.053 (3.1)**
CONMOB (3)		0.067 (2.0)*	0.076 (3.6)**	0.033 (2.7)**
FIXW (2)		-0.111 (-6.6)**	-0.288 (-6.2)**	-0.268 (-5.1)**
CONV1 (1)			0.086 (1.5)	
CONV2 (2)			0.077 (1.3)	
CONV3 (3)			0.013 (0.5)	
CONVN1 (2)				0.125 (7.1)**
N		1980	1980	1980
$\rho^2(0)$		0.263	0.257	0.289
$\rho^2(c)$		0.213	0.207	0.259
Final Likelihood		-1705.78	-1725.47	-1700.05
Likelihood ratio test			-39.42	11.45†

(1) Internet (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

7.5 Estimation of Models Including Perceived Quality of Public Transport Information Variables

Models which include variables that measure the perceived quality of the current public transport information sources available are presented in this section. The purpose of examining the impact of these variables is to ascertain how perceptions of current sources of information influence the choice between public transport information options.

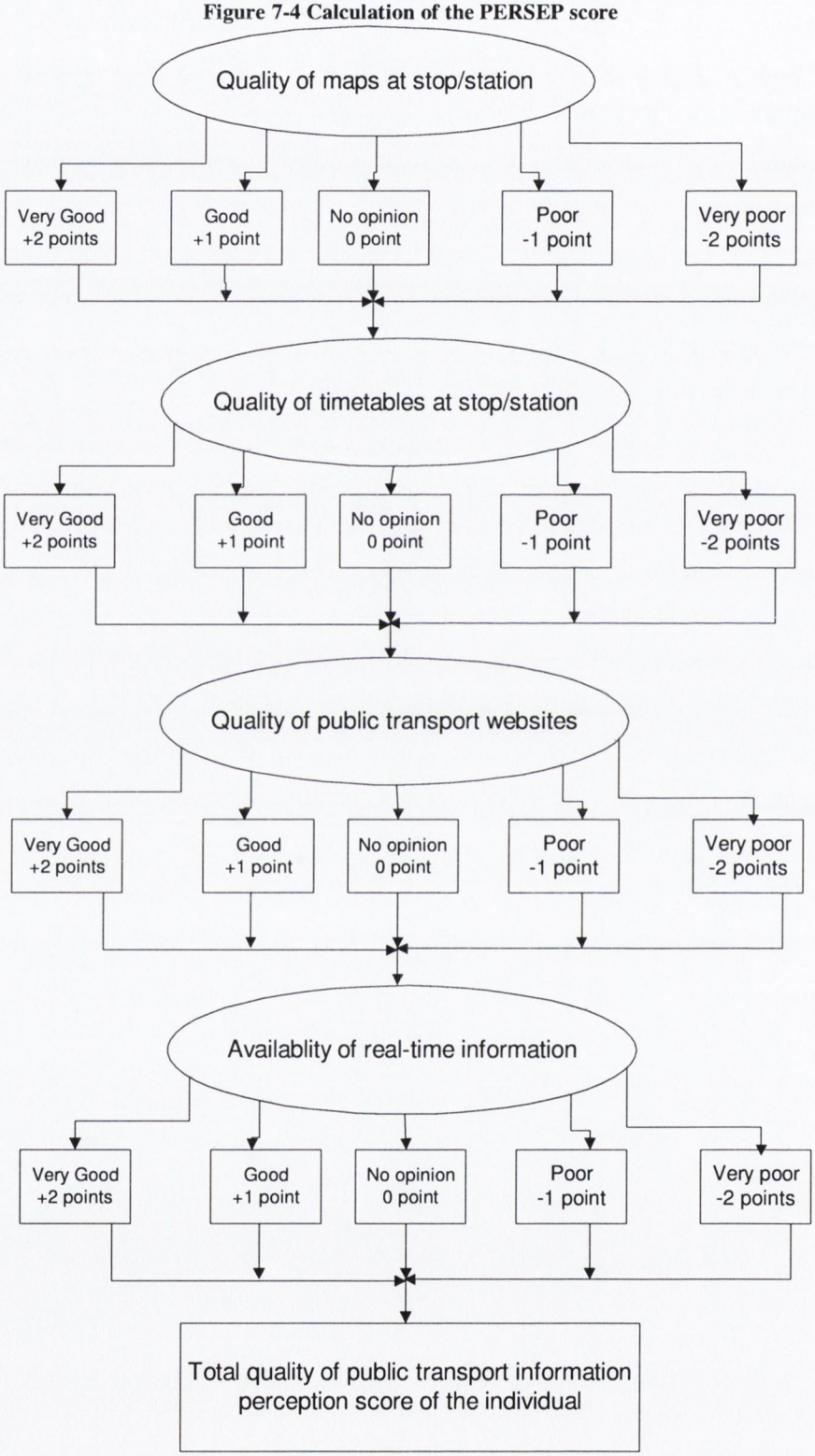
7.5.1 Definition of the perceived quality variable of information

Survey respondents were asked how they perceive the quality of the following four methods of accessing public transport information; maps provided at stops/stations, timetables at stops/stations, public transport websites and the availability of real-time information. In the survey, respondents were asked to rate quality of these sources of information using the following ratings; very good, good, no opinion, poor and very poor. The ratings for these variables use a scale of between +2 and -2, with very good and good taking positive values of 2 and 1. The negative perceptions of poor and very poor take the values of -1 and -2, and 0 for those with no opinion. Given the definition of the variable, a negative coefficient value indicates that those individuals who have a poor perception of the current sources of public transport information may be said to derive a higher utility from public transport information.

Four perception variables were created; PER1, PER2, PER3 and PER4. These variables represent the perceived quality associated with obtaining information from the four methods mentioned above (these variables are defined in table 7.2).

A further variable, PERSEP is defined as the variable which combines PER1, PER2, PER3 and PER4. The purpose of this variable is to produce a single variable which measures the overall perception of current methods of accessing public transport information. The total perception of the quality of public transport information was created by adding the four variables together, and obtaining a quality perception value, PERSEP, as shown in Figure 7-4.

Figure 7-4 Calculation of the PERSEP score



7.5.2 MNL models including perceived quality of information variable – stage one

The model estimates which incorporate the perception variables with the model specification for base model 1 are presented in Table 7-9. Model M7-13, estimates the impact of the four perception of quality of information variables on the results for stage one. The findings show that the perception coefficients have a negative value, however they were not found to be significant (see in Table 7-9). The model specification demonstrates that the $\rho^2(0)$ and $\rho^2(c)$ values for model M7-13 of 0.241 and 0.216 are lower than the values of 0.254 and 0.230 estimated for base model 1. The estimated likelihood ratio of -39.45 rejected the null hypothesis (see in Table 7-9). This demonstrates that the addition of the variables does not represent an improvement in the model specification.

Model M7-14 incorporates the PERSEP variable with the results from stage one (see Table 7-9). The PERSEP variable was found to be negative and significant at the 99% confidence level with a reported *t*-ratio of -4.0. This negative value indicates that individuals who have a negative perception of the current methods of public transport information provision are more likely to choose to obtain public transport information using SMS at stage one. The model specification estimates an improvement in the $\rho^2(0)$ and $\rho^2(c)$ values of 0.255 and 0.231 in model M7-14 compared to 0.254 and 0.230 in base model 1. The null hypothesis is rejected at the 95% confidence level, as the likelihood ratio was estimated at 9.72, indicating an improvement in the model performance. These results show that the inclusion of the perception of quality of information variables improves the model specification. The findings reveal that those with a poor opinion of the current sources of public transport information are more likely to choose public transport information using SMS.

Table 7-9 MNL models incorporating perceived quality of information variables –stage one

Variables		Base model 1	M7-13	M7-14
		Stage One		
Internet	Wait time saved	-0.043 (-5.5)**	-0.033 (-5.2)**	-0.046 (-8.2)**
	Cost	-0.063 (-4.5)**	-0.056 (-4.8)**	-0.073 (-7.1)**
	Information	-0.532 (-2.0)*	-0.525 (-4.0)**	-0.504 (-2.7)**
SMS	Wait time saved	-0.041 (-4.8)**	-0.049 (-6.9)**	-0.038 (-4.6)**
	Cost	-0.029 (-11.3)**	-0.029 (-13.6)**	-0.025 (-13.1)**
	Information	-1.546 (-10.0)**	-1.599 (-12.1)**	-1.506 (-13.6)**
Call centre	Wait time saved	-0.034 (-4.8)**	-0.037 (-6.1)**	-0.026 (-5.1)**
	Cost	-0.032 (-7.1)**	-0.032 (-8.2)**	-0.031 (-6.1)**
	Information	-0.403 (-2.7)**	-0.330 (-2.6)**	-0.365 (-3.3)**
CAR (1)		-0.477 (-5.6)**	-0.500 (-7.1)**	-0.216 (-4.0)**
BUS (2)		0.215 (3.0)**	0.224 (3.9)**	0.189 (2.0)*
WAIT (2)		0.091 (2.8)**	0.094 (3.5)**	0.101 (4.7)**
PTTIME (3)		0.314 (2.9)**	0.308 (3.5)**	0.211(2.7)**
GENDER (3)		0.115 (4.0)**	0.103 (4.1)**	0.112 (6.2)**
AGE (1)		-0.250 (-2.4)*	-0.379 (-2.6)**	-0.172 (-2.5)*
INCOME (2)		0.079 (5.7)**	0.073 (6.1)**	0.085 (7.9)**
CARAV (3)		-0.066 (-2.7)**	-0.022 (-3.8)**	-0.020 (-3.5)**
ZONE (2)		0.043 (3.0)**	0.017 (2.1)*	0.015 (2.3)*
DEPT (1)		0.137 (1.9)*	0.086 (2.8)**	0.049 (2.1)*
PER1 (1)			-0.016 (-1.6)	
PER2 (3)			-0.019 (-1.2)	
PER3 (2)			-0.021 (-1.3)	
PER4 (2)			-0.024 (-1.8)	
PERSEP (2)				-0.137 (-4.0)**
N		1980	1980	1980
$\rho^2(0)$		0.254	0.241	0.255
$\rho^2(c)$		0.230	0.216	0.231
Final Likelihood		-1781.33	-1801.06	-1776.47
Likelihood ratio test			-39.45	9.72†

(1) Internet (2) SMS (3) Call centre

* Significant at the 95% confidence level

** Significant at the 99% confidence level

† Null hypothesis rejected

7.5.3 MNL models including perceived quality of information variable – stage two

Table 7-10 presents the model estimates, which include variables representing perception of the quality of information available for stage two. Model M7-15 incorporates the perception variables with the model specification for base model 2. The coefficients for the PER variables were found to be negative. However none of the variables were found to significant (see Table 7-10). The model specification does not improve upon the base model 2 results, as the $\rho^2(0)$ and $\rho^2(c)$ values of 0.239 and 0.205 were estimated to have

lower values than those estimated for base model 2 of 0.248 and 0.214. Model M7-15 did not to improve upon the performance of base model 2 as the null hypothesis is accepted, as the likelihood ratio was estimated to be -22.31 (see Table 7-10).

Model M7-16 estimates the value of the PERSEP variable with the model specification for base model 2 (see Table 7-10). The coefficient value for PERSEP was estimated to be negative and significant at the 95% confidence level (t-ratio of -2.5). As with the first stage, the negative coefficient demonstrates that those respondents who have a poor perception of the current information available are more likely to demand public transport information using a passenger information display. The $\rho^2(0)$ and ρ^2 (c)values were estimated at 0.260 and 0.218, which are greater than those estimated from base model 2 of 0.248 and 0.214 respectively, demonstrating an improvement in the model specification (see Table 7-10). The likelihood ratio test was estimated to be 18.58 which, rejects the null hypothesis at the 99% confidence level proving that the model specification is an improvement upon the base model.

Table 7-10 MNL models including perception of the quality of information variables – stage two

Variables		Base model 2	M7-15	M7-16
		Stage Two		
SMS	Wait time saved	-0.031 (-4.6)**	-0.036 (-6.7)**	-0.040 (-4.6)**
	Cost	-0.044 (-8.0)**	-0.045 (-8.3)**	-0.036 (-10.2)**
	Information	-0.997 (-7.8)**	-1.090 (-5.1)**	-0.793 (-5.0)**
Call centre	Wait time saved	-0.013 (-2.3)*	-0.012 (-2.5)*	-0.022 (-2.7)**
	Cost	-0.039 (-11.9)**	-0.038 (-6.3)**	-0.037 (-5.1)**
	Information	-1.179 (-8.8)**	-1.091 (-5.8)**	-1.316 (-7.7)**
PID	Wait time saved	-0.044 (-8.2)**	-0.039 (-4.9)**	-0.038 (-5.4)**
	Cost	-0.034 (-8.8)**	-0.033 (-3.1)**	-0.038 (-6.1)**
	Information	-1.265 (-9.4)**	-1.173 (-10.8)**	-1.352 (-7.9)**
CAR (2)		-0.693 (-2.1)*	-0.459 (-2.0)*	-0.015 (-2.4)*
BUS (1)		0.165 (3.5)**	0.173 (4.8)**	0.110 (2.0)*
WAIT (1)		0.115 (4.7)**	0.120 (6.2)**	0.108 (3.8)**
PTTIME (3)		0.114 (2.1)*	0.171 (2.0)*	0.272 (2.7)**
GENDER (2)		-0.132 (-2.0)*	-0.290 (-2.8)**	-0.014 (-4.0)**
AGE (2)		-0.153 (-2.2)*	-0.020 (-2.2)*	-0.020 (-2.0)*
INCOME (3)		0.249 (2.6)**	0.339 (3.4)**	0.208 (6.1)**
CARAV (1)		-0.015 (-3.7)**	-0.019 (-2.8)**	-0.020 (-5.6)**
ZONE (1)		0.374 (3.3)**	0.347 (6.4)**	0.388 (5.2)**
CONMOB (3)		0.194 (2.5)*	0.095 (2.7)**	0.090 (2.6)**
DEPT (3)		0.127 (2.0)*	0.212 (3.0)**	0.254 (1.9)*
PER1 (2)			-0.047 (-1.8)	
PER2 (3)			-0.052 (-1.1)	
PER3 (1)			-0.015 (-1.7)	
PER4 (1)			-0.021 (-0.9)	
PERSEP (1)				-0.106 (-2.5)*
N		1980	1980	1980
$\rho^2(0)$		0.248	0.239	0.260
$\rho^2(c)$		0.214	0.205	0.218
Final Likelihood		-1719.08	-1730.23	-1709.78
Likelihood ratio test			-22.31	18.58†

(1) PID (2) SMS (3) Call centre

* Significant at the 95% confidence level

** Significant at the 99% confidence level

† Null hypothesis rejected

7.5.4 MNL models including perceived quality of information variable – stage three

The results which include the perception of the quality of information variables with base model 3 are presented in Table 7-11. Model M7-17 presents the model estimates which include the individual perception variables PER1, PER2, PER3 and PER4 for stage three. The coefficients are found to be negative but not significant (even at the 90% confidence level) (see Table 7-11). Model M7-17 found an improvement in the $\rho^2(0)$ and $\rho^2(c)$ from

0.263 and 0.213 in the base model to 0.281 and 0.257 in model M7-17. The estimated likelihood ratio of 60.05 rejects the null hypothesis at the 99% confidence level, indicating that although the coefficients were not found to be significant, their introduction did improve the model specification.

Model M7-18 incorporates the PERSEP variable with the model specification for base model 3. The estimated coefficient for PERSEP was found to be negative and significant at the 99% confidence level with a *t*-ratio of -5.1 (see Table 7-11). This negative value indicates that at the third stage, those with a negative perception of the quality of public transport information are more likely to use SMS rather than a call centre or the internet to access public transport information. Model M7-18 demonstrates an improvement upon base model 3, as there is an increase in the $\rho^2(0)$ and $\rho^2(c)$ values from 0.263 and 0.213 in base model 3 to 0.294 and 0.264. These results demonstrate that the introduction of perception variables improves the predictive power of the model estimates, which is proven with the rejection of the null hypothesis at the 99% confidence level as the likelihood ratio was estimated to be 34.18 (see Table 7-11).

The PERSEP coefficient was found to have the highest coefficient value at the third stage. This indicates that a negative perception of the current methods of public transport information available has the greatest impact upon the choice of public transport information option when respondents are planning their journey from work returning home.

Table 7-11 MNL models incorporating perception of quality of information variable-stage three

Variables		Base model 3	M7-17	M7-18
		Stage Three		
Internet	Wait time saved	-0.033 (-4.6)**	-0.028 (-3.4)**	-0.031 (-4.9)**
	Cost	-0.097 (-12.6)**	-0.094 (-13.2)**	-0.080 (-12.5)**
	Information	-0.683 (-7.1)**	-0.829 (-9.1)**	-0.781 (-7.4)**
SMS	Wait time saved	-0.010 (-2.5)*	-0.024 (-3.9)**	-0.017 (-2.4)*
	Cost	-0.046 (-10.8)**	-0.041 (-7.5)**	-0.048 (-8.0)**
	Information	-1.443 (-5.2)**	-1.239 (-6.3)**	-1.404 (-7.6)**
Call centre	Wait time saved	-0.048 (-7.7)**	-0.051 (-9.1)**	-0.042 (-7.0)**
	Cost	-0.038 (-12.1)**	-0.040 (-10.5)**	-0.038 (-9.1)**
	Information	-0.669 (-7.4)**	-0.871 (-8.9)**	-0.713 (-7.2)**
CAR (2)		-0.132 (-2.4)*	-0.201 (-3.7)**	-0.142 (-2.4)*
BUS (1)		0.550 (2.3)*	0.429 (2.9)**	0.381 (6.0)**
GENDER (3)		-0.358 (-2.6)**	-0.269 (-2.3)*	-0.352 (-2.1)*
AGE (2)		0.220 (2.8)**	-0.104 (-8.1)**	-0.110 (-7.2)**
INCOME (2)		0.267 (7.0)**	0.254 (5.5)**	0.168 (2.0)*
CARAV (1)		-0.281 (-2.5)*	-0.183 (-2.7)**	-0.095 (-3.0)**
ZONE (2)		0.061 (2.1)*	0.027 (2.7)**	0.018 (3.9)**
CONMOB (3)		0.067 (2.0)*	0.076 (2.1)*	0.030 (2.7)**
FIXW (2)		-0.111 (-6.6)**	-0.273 (-5.0)**	-0.294 (-2.6)**
PER1			-0.037 (-1.4)	
PER2			-0.018 (-0.9)	
PER3			-0.014 (-1.4)	
PER4			-0.028 (-1.2)	
PERSEP (3)				-0.154 (-5.1)**
N		1980	1980	1980
$\rho^2(0)$		0.263	0.281	0.294
$\rho^2(c)$		0.213	0.257	0.264
Final Likelihood		-1705.78	-1689.05	-1701.99
Likelihood ratio test			60.05†	34.18†

(1) Internet (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

7.6 Estimation of Models Including Current Use of Transport Information Variables

This section includes variables which represent the frequency with which respondents currently consult public transport information.

Survey respondents were asked at each stage how often they currently consult public transport information. The answers to each stage are used to create three frequencies of use; variables USE1, USE2 and USE3. These variables represent the frequency at which respondents currently consult public transport information at stages one, two and three. The variable takes a negative value if respondents indicated that they never or seldom use transport information, and a positive value if they regularly or sometimes consult public transport information (the variables are defined in table 7-2).

7.6.1 MNL models including current use of public transport information – stage one

Model M7-19 in Table 7-12 presents the model estimates when the USE1 variable is introduced into the model specification for base model 1. The model produces a negative and significant coefficient for USE1 (significant at the 99% confidence level with a *t*-ratio of -2.8) see Table 7-12. This result suggests that those individuals who currently do not consult any form of public transport information at stage one are more likely to choose to obtain information using SMS than those who regularly consult public transport information.

Model M7-19 produces $\rho^2(0)$ and $\rho^2(c)$ values of 0.255 and 0.231 which are an improvement on the 0.254 and 0.231 estimated for base model 1. The estimate likelihood ratio of 5.51 rejects the null hypothesis at the 95% confidence level (see Table 7-12); this demonstrates that the inclusion of the USE1 variable improves the model specification at stage one.

7.6.2 MNL models including current use of public transport information – stage two

The frequency with which respondents consult public transport information at the second stage is examined in model M7-20 in Table 7-12. The estimated coefficient value for USE2 was found to be negative and significant at the 95% confidence level (*t*-ratio of -2.5). This result shows as those individuals who currently do not consult any form or public transport information at stage two, are more likely to choose to access public transport information using a passenger information display rather than a call centre or SMS.

Model M7-20 achieves an improvement in model specification as the $\rho^2(0)$ and $\rho^2(c)$ values of 0.258 and 0.219 are within the acceptable range and demonstrate an improvement upon base model 2 values of 0.248 and 0.214. The estimated model produces a likelihood ratio of 16.15, which rejects the null hypothesis at the 99% confidence level (see Table 7-12).

7.6.3 MNL models including current use of public transport information – stage three

Model M7-21 estimates the impact of the USE3 variable, on the results of base model 3 specification (see Table 7-12). The coefficient value for USE3 was estimated to be negative and significant at the 99% confidence level (*t*-ratio of -4.6). As with the previous two stages, this negative coefficient may be interpreted as those individuals who currently do not access public transport information at stage three are more likely to choose to access public transport information using SMS as this stage.

The model specification for M7-21 demonstrates an improvement upon base model 3, as the $\rho^2(0)$ and $\rho^2(c)$ values of 0.295 and 0.265 are greater than the 0.263 and 0.213 in base model 3. The improvement in model specification is confirmed by the rejection of the null hypothesis at the 99% confidence level as the likelihood ratio was estimated to be 33.13 (see Table 7-12).

A comparison between the three stages demonstrates that at the second stage, the current use of public transport information has the highest negative coefficient, compared to the values from stages one and three. This indicates that at the second stage, the current use of public transport information variable has the highest impact upon the choice of public transport information.

Table 7-12 MNL models incorporating current use of public transport information variables

Variables		M7-19	M7-20	M7-21
		Stage One	Stage Two	Stage Three
Internet	Wait time saved	-0.037 (-9.2)**		-0.035 (-5.8)**
	Cost	-0.075 (-10.3)**		-0.010 (-12.2)***
	Information	-0.109 (-2.1)*		-0.710 (-6.7)**
SMS	Wait time saved	-0.040 (-8.9)**	-0.027 (-3.6)**	-0.026 (-2.6)**
	Cost	-0.030 (-12.5)**	-0.045 (-6.8)**	-0.046 (-7.1)**
	Information	-1.413 (-7.3)**	-1.158 (-8.4)**	-1.432 (-8.3)**
Call centre	Wait time saved	-0.034 (-9.1)**	-0.012 (-1.9)*	-0.042 (-7.2)**
	Cost	-0.032 (-6.3)**	-0.039 (-7.2)**	-0.039 (-9.5)**
	Information	-0.555 (-7.1)**	-1.036 (-7.1)**	-0.665 (-6.7)**
PID			-0.041 (-6.9)**	
			-0.033 (-6.6)**	
			-1.127 (-7.2)**	
CAR (1)		-0.452 (-5.1)**		
CAR (2)			-0.475 (-2.8)**	-0.114 (-1.9)*
BUS (2)		0.231 (6.2)**		
BUS (4)			0.170 (3.3)**	0.416 (2.3)*
BUS (1)		0.049 (3.1)**		
WAIT (2)			0.109 (4.1)**	
WAIT (4)		0.244 (4.2)**	0.425 (4.0)**	
PTTIME (3)				0.195 (1.9)*
PTTIME (2)		0.101 (6.7)**		-0.307 (-2.4)*
GENDER (3)			-0.113 (-6.0)**	
GENDER (2)		-0.142 (-2.5)		
AGE (1)			-0.140 (-2.0)*	-0.234 (-2.7)**
AGE (2)		0.082 (8.0)		0.082 (6.9)**
INCOME (2)			0.201 (2.5)*	
INCOME (3)		-0.075 (-5.7)		-0.528 (-2.4)*
CARAV (1)			-0.013 (-2.1)*	
CARAV (3)		0.015(2.6)		0.087 (2.4)*
CARAV (4)			0.443 (2.9)**	
ZONE (2)			0.147 (2.1)*	0.161 (3.0)
ZONE (4)		0.272 (4.8)		
CONMOB (3)			0.121 (2.3)*	
DEPT (1)				-0.140 (-2.3)
DEPT (3)		-0.026 (-2.8)		
FIXW (2)			-0.088 (-2.5)*	
USE1 (2)		-0.039 (-2.8)		
USE2 (4)			-0.058 (-2.5)*	
USE3 (2)				-0.030 (-4.6)
N		1980	1980	1980
$\rho^2(0)$		0.255	0.258	0.295
$\rho^2(c)$		0.231	0.219	0.265
Final Likelihood		-1778.58	-1711.00	-1689.21
Likelihood ratio test		5.51†	16.15†	33.13†

(1) Internet (2) SMS (3) Call centre (4) PID, * Significant at the 95% confidence level, ** Significant at the 99% confidence level, † Null hypothesis rejected

7.7 ESTIMATION OF MODELS INCLUDING ATTITUDINAL AND EXPLANATORY VARIABLES

The models presented in this section incorporate both explanatory and attitudinal variables to enhance the model specification and increase the explanatory power of the models.

7.7.1 MNL models incorporating explanatory and attitudinal variables – stage one

Model M7-22 incorporates the explanatory variables from base model 1 with the following attitudinal variables: FRUST, CONVN1, PERSEP and USE1. The purpose of creating this model is to ascertain if the model produced is an improvement upon base model 1. Model M7-22 produces coefficient values which are consistent with those estimated by the base model and each of the coefficient values are significant at either the 95% or 99% confidence levels (see Table 7-13). The coefficients produced are also consistent with the values estimated in the previous models. Model M7-22 demonstrates an improvement in the $\rho^2(0)$ and $\rho^2(c)$ values from 0.254 and 0.230 in the base model to 0.268 and 0.239. The estimated likelihood ratio of 20.69 rejects the null hypothesis at the 99% confidence level (see Table 7-13). This improvement demonstrates that the inclusion of these attitudinal variables enhances the model specification.

Table 7-13 MNL model incorporating explanatory and attitudinal variables – stage one

Variables		Base model 1	M7-22
		Stage One	
Internet	Wait time saved	-0.043 (-5.5)**	-0.040 (-5.6)**
	Cost	-0.064 (-4.5)**	-0.040 (-5.5)**
	Information	-0.532 (-2.0)*	-0.852 (-3.1)**
SMS	Wait time saved	-0.041 (-4.8)**	-0.042 (-5.4)**
	Cost	-0.029 (-11.3)**	-0.035 (-12.9)**
	Information	-1.546 (-10.0)**	-0.997 (-10.4)**
Call centre	Wait time saved	-0.034 (-4.8)**	-0.032 (-4.9)**
	Cost	-0.032 (-7.1)**	-0.039 (-9.2)**
	Information	-0.403 (-2.7)**	-0.377 (-2.5)**
CAR (1)		-0.477 (-5.6)**	-0.276 (-6.3)**
BUS (2)		0.215 (3.0)**	0.243 (3.7)**
WAIT (2)		0.091 (2.8)**	0.066 (2.2)*
PTTIME (3)		0.314 (2.9)**	0.167 (2.7)**
GENDER (3)		0.115 (4.0)**	0.161 (3.5)**
AGE (1)		-0.250 (-2.4)*	-0.284 (-2.9)**
INCOME (2)		0.079 (5.7)**	0.082 (6.0)**
CARAV (3)		-0.066 (-2.7)**	-0.011 (-3.0)**
ZONE (2)		0.043 (3.0)**	0.050 (3.3)**
DEPT (1)		0.137 (1.9)*	0.245 (2.0)*
FRUST (1)			0.068 (6.2)**
CONVN1 (2)			0.041 (4.6)**
PERSEP (2)			-0.097 (-2.5)*
USE1 (2)			-0.034 (-2.6)**
N		1980	1980
$\rho^2(0)$		0.254	0.268
$\rho^2(c)$		0.230	0.239
Final Likelihood		-1781.33	-1770.99
Likelihood ratio test			20.69†

(1) Internet (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

7.7.2 MNL models incorporating explanatory and attitudinal variables – stage two

The attitudinal variables FRUST, CONVN2, PERSEP and USE2 are incorporated into base model 2 specification, to estimate model M7-23. Model M7-23 produces an improvement on the base model, as the $\rho^2(0)$ and $\rho^2(c)$ values of 0.259 and 0.219 are greater than those produced by base model 2 of 0.248 and 0.214 respectively (see Table 7-14). The model specification is demonstrated to be an improvement upon the base model as the null hypothesis has been rejected at the 99% confidence level, as the likelihood ratio was estimated to be 14.40 (see Table 7-14). The coefficient estimates are also constant with those found when in the base model. The model produced demonstrates

that the addition of the attitudinal variables to base model 2 improves the model specification and the explanatory power of the model.

Table 7-14 MNL model incorporating explanatory and attitudinal variables – stage two

Variables		Base model 2	M7-23
		Stage Two	
SMS	Wait time saved	-0.031 (-4.6)**	-0.032 (-4.3)**
	Cost	-0.043 (-8.0)**	-0.044 (-6.1)**
	Information	-0.997 (-7.8)**	-0.879 (-7.3)**
Call centre	Wait time saved	-0.013 (-2.3)*	-0.017 (2.6)**
	Cost	-0.039 (-11.9)**	-0.068 (-7.6)**
	Information	-1.179 (-8.8)**	-1.110 (-7.2)**
PID	Wait time saved	-0.044 (-8.2)**	-0.043 (-7.1)**
	Cost	-0.034 (-8.8)**	-0.044 (-9.6)**
	Information	-1.265 (-9.4)**	-0.947 (-7.8)**
CAR (2)		-0.693 (-2.1)*	-0.328 (-2.0)*
BUS (1)		0.165 (3.5)**	0.152 (2.9)**
WAIT (1)		0.115 (4.7)**	0.112 (4.1)**
PTTIME (3)		0.114 (2.1)*	0.233 (3.1)**
GENDER (2)		-0.132 (-2.0)*	-0.265 (-1.9)*
AGE (2)		-0.153 (-2.2)*	-0.183 (-2.1)*
INCOME (3)		0.249 (2.6)**	0.254 (2.0)*
CARAV (1)		0.015 (3.7)**	-0.011 (-2.1)*
ZONE (1)		0.374 (3.3)**	0.405 (4.0)**
CONMOB (3)		0.194 (2.5)*	0.149 (2.5)*
DEPT (3)		0.127 (2.0)*	0.316 (2.8)**
FRUST (2)			0.049 (2.6)**
CONVN2 (1)			0.019 (3.0)**
PERSEP (1)			-0.021 (-3.9)**
USE2 (1)			-0.054 (-3.1)**
N		1980	1980
$\rho^2(0)$		0.248	0.259
$\rho^2(c)$		0.214	0.219
Final Likelihood		-1719.08	-1711.87
Likelihood ratio test			14.40†

(1) PID (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

7.7.3 MNL models incorporating explanatory and attitudinal variables – stage three

At the third stage FRUST, CONVN1, PERSEP and USE3 are introduced into the model specification for base model 3 (see Table 7-15). The estimated model M7-24 produces an enhanced specification compared to base model 3 as the $\rho^2(0)$ and $\rho^2(c)$ values estimated are higher than in the base model (see Table 7-15). The likelihood ratio was estimated to be 21.27 which rejects the null hypothesis at the 99% confidence level, which represents an

improvement in the model specification (see Table 7-15). The coefficients presented in the model are consistent with the estimated coefficients in the previous models, and were found to be significant at either the 95% or 99% confidence levels.

The improvement in the $\rho^2(0)$ and $\rho^2(c)$ values and the rejection of the null hypothesis proves that the introduction of the attitudinal variables into base model 3 improves the specification and the estimates produced by the model for stage three.

Table 7-15 MNL models incorporating attitudinal and explanatory variables – stage three

Variables		**Base model 3**	**M7-24**
		Stage Three	
Internet	Wait time saved	-0.033 (-4.6)**	-0.022 (-3.5)**
	Cost	-0.097 (-12.6)**	-0.041 (-13.6)**
	Information	-0.683 (-7.1)**	-0.514 (-7.6)**
SMS	Wait time saved	-0.010 (-2.5)*	-0.024 (-3.4)**
	Cost	-0.046 (-10.8)**	-0.044 (-7.6)**
	Information	-1.443 (-5.2)**	-1.109 (-7.2)**
Call centre	Wait time saved	-0.048 (-7.7)**	-0.050 (-8.3)**
	Cost	-0.038 (-12.1)**	-0.037 (-8.7)**
	Information	-0.669 (-7.4)**	-0.782 (-7.9)**
CAR (2)		-0.132 (-2.4)*	-0.147 (-2.4)*
BUS (1)		0.550 (2.3)*	0.315 (7.0)**
GENDER (3)		-0.358 (-2.6)**	-0.162 (-5.4)**
AGE (2)		0.220 (2.8)**	-0.267 (9.3)**
INCOME (2)		0.267 (7.0)**	0.173 (5.2)**
CARAV (1)		-0.281 (-2.5)*	-0.144 (-2.1)*
ZONE (2)		0.061 (2.1)*	0.477 (2.9)**
CONMOB (3)		0.067 (2.0)*	0.033 (2.1)*
FIXW (2)		-0.111 (-6.6)**	-0.175 (-4.0)**
FRUST (2)			0.010 (2.6)**
CONVN1 (1)			0.024 (9.0)**
PERSEP (3)			-0.018 (-3.8)**
USE3 (2)			-0.036 (-2.0)*
N		1980	1980
$\rho^2(0)$		0.263	0.296
$\rho^2(c)$		0.213	0.267
Final Likelihood		-1705.78	-1695.14
Likelihood ratio test			21.27†

(1) Internet (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level
† Null hypothesis rejected

7.8 SUMMARY

This chapter builds upon the analysis presented in chapter 6, combining attitudinal variables with the final models produced in chapter 6. The combination of explanatory variables with attitudinal variables was completed to provide an overall picture of the main factors which can be said to influence the choice of public transport information options. In this chapter, four sets of attitudinal variables have been introduced into the models to provide a further insight as to the motivation behind the choices made by individuals.

Variables relating to frustration with public transport were the first set of attitudinal variables examined in this chapter. Frustration was measured in the context of uncertainty of time of arrival and departure times. The estimated model coefficients demonstrated that frustration with public transport did have an impact upon the choices made by individuals. The results indicate that the second stage is when frustration has the greatest impact as the coefficient value was found to be highest at this stage.

The convenience associated with using the various methods of technology examined in this research was examined in section 7.4. The motivation to examine these variables was to ascertain if individuals deem it convenient to access public transport information from these sources and how it may impact upon their choice of public transport information options. The results demonstrate that the convenience with which one can access public transport information using the various methods of technology examined does impact upon choice. The model estimates demonstrate that individuals who find it convenient to use the different technologies are more likely to choose one of the public transport information options. The coefficients for convenience demonstrate that at the third stage, the convenience variable was estimated to have the highest coefficient value, indicating at this stage convenience has the largest impact upon choice of public transport information option.

Variables representing the perceived quality of the current public transport available were the third set of variables to be examined in this chapter. These variables were analysed to examine if current perceptions of public transport information would affect the choice of public transport information option. The results demonstrated that those individuals who had a poor perception of public transport information were more likely to choose one of the public transport information options, than those individuals who had a positive

perception. The coefficient values demonstrated at the third stage that perception of current public transport information had the greatest impact.

The final set of attitudinal variables examined pertains to the frequency at which individuals currently access transport information. It was decided to examine these variables to ascertain if the frequency at which individuals currently consult would impact upon their choice or public transport information option. The results demonstrate that those individuals who currently do not use public transport information were more likely to choose an option of real-time information. The coefficient values demonstrate that at the first stage the current use of public transport information has the most significant impact at this stage compared to the other three stages.

The final models presented in this chapter combine the attitudinal variables examined in this chapter with the explanatory variables from chapter 6. The models estimated produce the strongest model specification, and have the highest explanatory power of all the other models in this thesis. Given that these models demonstrate the best model performance statistics, it is these final models that will be used for the analysis conducted in chapter eight.

8 INTERPRETATION OF THE BEHAVIOURAL OUTPUTS FROM THE CHOICE MODELS

8.1 INTRODUCTION

This chapter presents the behavioural outputs from the models, which were estimated in chapters 6 and 7. The utility coefficients from those models are used, in this chapter, to produce elasticities of choice estimates and willingness to pay amounts for real-time public transport information options. The first section segments the models by the mode of transport used by the respondent. The purpose of segmenting these models was to produce utility coefficients directly attributable to the mode of transport used by the respondent. This enables different user groups to be compared, and to determine which user group derives the greatest benefit from real-time public transport information.

Following on from this segmentation elasticises of choice estimates for the cost of public transport information and wait-time saved is detailed. Elasticities which are reported in this chapter examine the sensitivity of the options chosen to a 1% increase in either the wait-time saved or the cost of using one of the real-time information options. The reported willingness to pay amounts for real-time public transport information are presented in section 8.4.

Section 8.5 presents the findings of the tests conducted to examine whether the estimated models violate the Independence from Irrelevant Alternatives property (see section 3.8.5 in Chapter 3 for a full description). Section 8.6 estimates several nested model structures which test for correlation within the model. The final section of this chapter puts the findings presented in this chapter into a policymaking context to demonstrate the how to practically apply the results. The chapter concludes with a summary section.

8.2 SEGMENTED MNL MODELS BY MODE OF TRANSPORT

In this section the MNL models from chapter 7 are segmented by mode of transport used by respondent. The purpose of segmenting the models is to compare the preferences of users of different modes of transport. The sub-sections of the dataset are used to run model estimates which pertain to the characteristic defining that sub-section, for example public

transport users. A detailed explanation of the segmentation approach is outlined in section 3.9.1.

The segmented models are used to produce elasticities of choice and willingness to pay estimates for bus, rail and car users. Although the transport information examined in this study relates to public transport information, it was decided that car users should be included in the sample for a number of reasons. Firstly, the questionnaire addressed car users and asked them if they were to use public transport, which real-time information option would they choose. Secondly, as one of the main purposes of real-time information is to make public transport more attractive to car users, it was decided that it was important to capture the preferences of the car user group.

8.2.1 Segmented MNL models by mode of transport – stage one

Table 8-1 presents the models estimated in chapter 7 segmented by mode of travel. As stated previously three modes of transport examined namely, bus, rail and car.

The model specification for each of the models demonstrate good $\rho^2(0)$ and $\rho^2(c)$ values for the base model were 0.286 and 0.239, and 0.319 and 0.289 for Base Model 1 BUS, 0.265 and 0.222 for Base Model 1 RAIL and finally 0.263 and 0.233 for Base Model 1 CAR. In the case of the bus segment the models were found to have higher $\rho^2(0)$ and $\rho^2(c)$ values than Base Model 1.

To recap on how to interpret the coefficients an example is given below. Consider the set of equations below (equation 8-1). The utility an individual i derives from option q (in this case the SMS) and is dependent upon the reduction in wait-time, the cost and the type of information provided by option q. The estimated α's are taken from table 8-1, from the coefficients for the internet from model M6-1. The impact the coefficients have upon the utility derived from using the internet is seen in the third line of the set of utility equations below (see equation 8-1). As the α estimated for a reduction in wait-time was found to have a negative value of -0.042, and the data imputed at this stage was -0.25 (representing a 25% reduction in wait time), the overall impact of a reduction in wait-time is found to be positive.

In the cost expression, the α was estimated to be -0.039, and the data entered for cost was positive (0.30 representing 30c for using the internet). The overall impact of cost on utility

can be said to be negative. Finally, the α estimated for information type again was found to be negative (-0.997). As the data for choosing real-time information was -1, this results in the provision of real-time information having a positive impact upon utility.

Equation 8-1

$$U_{iq} = a_{wait}(reduction_in_wait-time) + a_{cost}(\cos t) + a_{\inf o}(\inf o_type)$$
$$U_{iq} = (-0.042(-0.25)) + (-0.035(0.30)) + (-0.997(-1))$$
$$U_{iq} = (0.0105) + (-0.0105) + (0.997)$$
$$U_{iq} = 0.997$$

The wait-time saved coefficient for the internet variable was estimated to be negative and significant (all at the 99% confidence interval) for all three modes at stage one. Bus users were found to have the highest coefficient value of -0.052; car users were estimated to have the lowest of -0.020. This result indicates that at stage one, bus users derive a higher utility from real-time information from the internet compared to rail or car users.

The cost coefficients for the internet option were found to be negative for each of the models and significant at the 99% confidence level (see Table 8-1). The cost of information estimates demonstrate that cost causes the least disutility for bus users, as the coefficient estimated to have the lowest negative coefficient of -0.035, compared to -0.040 for rail users and -0.041 for car users. The estimated cost coefficients demonstrate that bus users perceive paying for real-time information from the internet to be less of a burden that the other two groups. The cost information estimates for each of the user groups display little difference coefficient values. While bus users were found to have the lowest coefficient value, it is fair to say cost impacts upon all users more or less equally.

The utility derived from the provision of real-time information from the internet was demonstrated to be highest for bus users with an estimated coefficient of -0.915. The information coefficients were found to be negative and significant at the 95% or 99% confidence levels (see Table 8-1). Car users were estimated to derive the least utility from this option.

The coefficients for provision of information via the internet for bus users was estimated to be -0.915, the rail user coefficient was found to be -0.548 and the car user coefficient was estimated to be -0.291 (see Table 8-1). Overall the results from the provision of real-time

information via the internet show that bus and rail users derive a higher benefit to that of car users. However, when examining the differences between the two public transport modes, bus users are found to derive a greater benefit compared to rail users. This finding suggests that bus users have a higher information requirement compared to rail users.

The wait-time saved coefficients for use of SMS information at stage one was found to be negative and significant at the 99% confidence level (see Table 8-1). As with the wait-time saved coefficients for the internet, bus users were found to derive the highest benefit from the use of SMS, as the time saved coefficient of -0.053, is higher than that of the other user groups. The rail user coefficient was estimated to be -0.048 and the car user coefficient were found to be -0.014. The bus user coefficient was found to be marginally higher than the rail user coefficient, demonstrating that both user groups derive a similar benefit from the using SMS to obtain real-time public transport information.

The cost of SMS information coefficients was estimated to be negative and significant at the 99% confidence level for all four models. Bus users were found to be least likely to object to paying for information from an SMS as the cost coefficient was estimated to be lowest for bus users and highest for car users with an estimated coefficient of -0.026 (see Table 8-1). The rail user coefficient was found to be just marginally higher (-0.028), this demonstrating both rail and bus users both experience a similar disutility when paying for information via a SMS.

The coefficients estimated for the SMS information variable were found to be negative and significant at the 99% confidence level for all models (see Table 8-1). The utility derived from the information coefficient was estimated to be substantially higher for bus users of -0945 and rail users -0.782, compared to that of car coefficient of -0.643. Comparing the two modes of public transport examined, bus users were found to derive a higher utility compared to rail users.

The wait-time saved coefficients for call centres were estimated to be negative and significant at the 99% confidence level for all user groups (see Table 8-1). The estimates show that bus users again derive a higher utility from wait-time saved, with an estimated coefficient of -0.036. The rail user coefficient of -0.035 is almost identical to that of the bus user, demonstrating that both sets of public transport users derive more or less equal benefits from wait-time saved related to the call centre option. Car users were once again

found to derive the least benefit from wait-time saved from a call centre at this first stage, with an estimated coefficient of -0.21.

The coefficient values for the type of information to be provided by call centre information (real-time information or static information) were estimated to be negative and significant at either the 95% or 99% confidence levels (see Table 8-1). A comparison between the different modes of transport demonstrates that bus and rail users derive similar utility from the provision of real-time information using a call centre, with estimated coefficients of -0.493 and -0.473 respectively. As with the information coefficient for the internet, car users were found to have the lowest value of -0.362, and therefore derive the least utility from real-time information provided by a call centre.

The results from the call centre variables demonstrate that as with the other two options examined at this stage, bus users derive the highest utility from the provision of transport information using a call centre. The disutility of cost associated with using a call centre was found to be lowest for bus users, followed by rail and car users.

Information provided by SMS was found to provide the highest utility for wait-time saved, when comparing all of the real-time information options examined at this stage. This result is true regardless of mode of transport used. The internet was estimated to provide the second highest coefficient values for wait-time saved, followed by information provided by a call centre. The cost coefficient for SMS also shows bus users have lowest cost disutility, followed by the internet and call centre. This can be seen by examining the base model one cost coefficients of -0.040 for the internet, -0.024 for SMS and -0.039 for a call centre (see Base Model 1, Table 8-1). The difference between the cost coefficients demonstrates that there was very little difference between the internet and the SMS coefficients. This indicates that respondents considered the disutility of paying for information from an SMS and the internet to be more or less equal.

The cost coefficients demonstrate that the disutility is lowest with SMS, indicating that respondents do not find paying for transport information using SMS as much a disutility as they do from the other two methods. Finally the coefficients for information show that SMS users derive the highest utility from the information provided being real-time information.

The preference for using SMS at this stage may be related to the convenience associated with using this option to derive real-time information. As this is a stage where time is at a premium, the instant nature of receiving an SMS may be more appealing to respondents, rather than logging on to the internet or phoning a call centre.

Table 8-1 MNL models including segmented mode options – stage one

Variables		Base Model 1	Base Model 1 BUS	Base Model1 RAIL	Base Model 1 CAR
		Stage One			
Internet	Wait-time saved	-0.040 (-5.6)**	-0.052 (-3.4)**	-0.031 (-3.1)**	-0.020 (-2.7)**
	Cost	-0.040 (-5.5)**	-0.035 (-4.2)**	-0.040 (-5.0)**	-0.041 (-4.7)**
	Information	-0.852 (-3.1)**	-0.915 (-6.2)**	-0.548 (-7.7)**	-0.291 (-2.1)*
SMS	Wait-time saved	-0.042 (-5.4)**	-0.053 (-5.1)**	-0.048 (-2.1)*	-0.014 (-3.4)**
	Cost	-0.024 (-12.9)**	-0.026 (-7.9)**	-0.028 (-2.6)**	-0.050 (-7.4)**
	Information	-0.997 (-10.4)**	-0.945 (-5.6)**	-0.782 (-3.9)**	-0.643 (-5.2)**
Call centre	Wait-time saved	-0.032 (-4.9)**	-0.036 (-2.6)**	-0.035 (-3.1)**	-0.021 (-2.8)**
	Cost	-0.039 (-9.2)**	-0.021 (-11.1)**	-0.028 (-3.9)**	-0.048 (-10.0)**
	Information	-0.377 (-2.5)**	-0.493 (-5.1)**	-0.473 (-2.1)*	-0.362 (-2.3)*
CAR (2)		-0.276 (-6.3)**	-0.310(-2.1)*	-0.324 (-1.9)*	-0.471 (4.2)**
BUS (1)		0.243 (3.7)**	0.457 (5.2)**	0.124 (4.7)**	0.471 (3.2)**
WAIT (1)		0.066 (2.2)*	0.174 (3.0)**	0.264 (2.7)**	0.091 (2.4)*
PTTIME (3)		0.167 (2.7)**	0.474 (2.5)*	0.125 (3.2)**	0.107 (1.9)*
GENDER (3)		0.161 (3.5)**	0.563 (6.5)**	0.506 (3.9)**	0.117 (2.2)*
AGE (2)		-0.284 (-2.9)**	-0.153 (-3.8)**	-0.112 (-1.9)*	-0.667(-2.5)*
INCOME (3)		0.082 (6.0)**	0.200 (6.6)**	0.328 (5.2)**	0.196 (6.4)**
CARAV (1)		-0.010 (-3.0)**			
ZONE (2)		0.050 (3.3)**	0.083 (2.3)*	0.024 (3.1)**	0.021 (6.1)**
DEPT (1)		0.2448 (2.0)*	0.179 (6.0)**	0.205 (3.3)**	0.153 (3.7)**
FRUST (2)		0.068 (6.2)**	0.085 (2.6)**	0.021 (3.8)**	0.018 (7.0)**
CONVN1 (2)		0.040 (4.6)**	0.059 (2.1)*	0.029 (5.0)**	0.040 (5.0)**
PERSEP (3)		-0.097 (-2.5)*	-0.078 (-5.5)**	-0.208 (-6.0)**	0.039 (2.0)*
USE1(3)		-0.034 (-2.6)**	-0.012 (-4.1)**	0.014 (2.8)	0.040 (3.7)**
N		1980	542	440	484
ρ^2 *(0)*		0.268	0.319	0.265	0.263
ρ^2 (c)		0.239	0.289	0.222	0.233

(1) Internet (2) SMS (3) Call centre

* Significant at the 95% confidence level

** Significant at the 99% confidence level

8.2.2 Segmented MNL models by mode of transport – stage two

Table 8-2 presents the model estimates from stage two when base model 2 was segmented by modes of transport.

The model specifications for all three models produce good $\rho^2(0)$ and $\rho^2(c)$ values. The base model 2 $\rho^2(0)$ and $\rho^2(c)$ values were estimate to be 0.259 and 0.219, the values for base model 2 BUS were 0.253 and 0.214. The base model 2 rail $\rho^2(0)$ and $\rho^2(c)$ values were found to be 0.246 and 0.203 and the base model 2 car values were 0.236 and 0.203 respectively. However, none of the $\rho^2(0)$ and $\rho^2(c)$ values are higher than those estimated for base model 2.

The estimated coefficients for wait-time saved for the SMS option were found to be negative and significant at the 99% confidence level (see Table 8-2). The reduction in wait time coefficient for bus users was found to be -0.034, and -0.027 and -0.021 for the rail user and car user models respectively. These estimates demonstrate that bus users derive the highest utility from wait-time saved compared to rail and car users. Furthermore rail users derive a higher benefit from wait-time saved compared to car users.

The coefficients for cost of SMS information were found to be negative and significant at the 99% confidence level (see Table 8-2). Bus users were shown to have the lowest cost disutility (-0.042), compared to rail and car users (-0.053 and -0.087 respectively). The estimated cost coefficients indicate that bus users are the least likely to object to paying for information, via SMS at stage two followed then by rail and car users. The difference between the rail and bus users at this stage again was found to be minimal. This indicates that both rail and bus user groups perceive the cost of using SMS to obtain real-time public transport information to be equal.

The information coefficient for SMS was estimated to be highest for bus users (-1.062), followed by rail (-1.018) and car users (-0.781) (see Table 8-2). These findings suggest that as with the other real-time information options, bus users derive the highest benefit from real-time information provided via SMS at this second stage. The coefficient values for SMS at the second stage are notably higher than that of the values estimated at the first stage of, -0.945, -0.782 and -0.643 for bus, rail and car users respectively. This

demonstrates that respondents derive a greater benefit from real-time information via SMS at stage two (at the bus stop/train station) than at the first stage.

The coefficients for wait-time saved using a call centre were found to be negative and significant at either the 95% or 99% confidence intervals (see Table 8-2). Bus users were estimated to derive the highest utility from wait-time saved with an estimated coefficient of -0.031. The wait-time saved coefficient for rail users (-0.023) was found to be marginally higher than the coefficient for car users (-0.019). These findings indicate that bus users derive the highest benefit from a reduction in wait-time while at their bus stop. The higher preference for a reduction in wait-time by bus users compared to rail users may be attributed to the perceived lack of reliability in arrival of bus services relative to rail services. A comparison between the rail user coefficient and the car user coefficient shows that there is very little difference in the estimated values. This finding indicates that both user groups derive a similar benefit from a reduction in wait time associated with using an SMS.

The cost coefficients for information provision via a call centre were shown to be negative and significant at the 99% confidence level in each of the segmented models. The rail user model was found to have the lowest cost coefficient (-0.045), followed by bus (-0.055) and car users (-0.085). These cost coefficients indicate that bus users are less likely to object to paying to use the call centre option compared to rail users. This finding suggests that bus users are less likely to be willing to pay for information via a call centre than rail users while at their bus stop. This is an interesting result as the other cost coefficients for the other options found that bus users were more likely to be willing to pay for the various real-time information options. One possible explanation for this result is that at this stage bus users perceive the call centre option to be the least attractive.

The wait-time saved coefficient estimates for passenger information display were estimated to be negative and significant at the 95% or 99% confidence levels (see Table 8-2). The bus user model produced the highest negative coefficient (-0.088), followed by rail users (-0.042) and car users (-0.026). This result demonstrates that bus users derive the highest utility from the provision of information via a passenger information display while at stop/station. This finding shows that time saving is most important to bus users compared to rail users, and may be attributed to the differences in the perceived reliability of bus compared to rail.

The cost coefficients in relation to information provision via passenger information display were found to be negative and significant at the 99% confidence level (see Table 8-2). The disutility of cost was found to be lowest for bus users with an estimated coefficient of -0.38, followed by rail users (-0.039) and car users (-0.048). The coefficients for bus and rail users were estimated to be very similar. This demonstrates both groups have a similar willingness to pay for real-time information from a passenger information display. This finding demonstrates that public transport users are more open to paying for the provision of at-stop/station information provided via a passenger information display, compared to car users.

The information coefficients for the provision of information via a passenger information display at the at stop/station stage were found to be negative and significant at the 99% confidence level for all models (see Table 8-2). A negative value implies a preference for real-time information rather than static information. Of the estimated coefficients, bus users were found to have the highest value (-1.215), followed by rail and car users with coefficients of -1.037 and -0.501 respectively. These findings demonstrate that bus users derive a higher benefit from the provision of real-time information being provided via a passenger information display at stage two than the other user groups.

At stage two, a comparison between the methods of receiving public transport information demonstrates that all three user groups derive the highest utility for wait-time saved when the information is provided via a passenger information display rather than using an SMS or a call centre. Furthermore, utility derived from wait-time saved when the information is provided via a SMS was found to be higher than that estimated for call centre; the cost coefficients reveal that SMS has the lowest estimated disutility, followed by passenger information display and call centre. This indicates that individuals are more likely to pay for transport information via SMS as opposed to passenger information display or call centre.

Table 8-2 MNL models including segmented mode options-stage two

Variables		Base Model 2	Base Model 2 BUS	Base Model 2 RAIL	Base Model 2 CAR
		Stage Two			
SMS	Wait-time saved	-0.032 (-4.3)**	-0.034 (-5.6)**	-0.027 (-3.6)**	-0.021 (-5.0)**
	Cost	-0.044 (-6.1)**	-0.042 (-4.8)**	-0.053 (-2.7)**	-0.087 (-7.6)**
	Information	-0.879 (-7.3)**	-1.062 (-2.0)*	-1.018 (-6.7)**	-0.781 (-4.9)**
Call Centre	Wait-time saved	-0.017 (-2.6)**	-0.031 (-2.1)*	-0.023 (-4.4)**	-0.019 (-4.4)**
	Cost	-0.068 (-7.6)**	-0.055 (-7.3)**	-0.045 (-2.7)**	-0.085 (-8.8)**
	Information	-1.110 (-7.2)**	-1.172 (-7.6)**	-0.848 (-3.7)**	-0.707 (-2.2)*
PID	Wait-time saved	-0.043 (-7.1)**	-0.088 (-2.3)*	-0.042 (-4.1)**	-0.026 (-2.3)*
	Cost	-0.044 (-9.6)**	-0.038 (-9.4)**	-0.039 (-4.2)**	-0.048 (-9.5)**
	Information	-0.947 (-7.8)**	-1.215 (-9.5)**	-1.037 (-2.8)**	-0.510 (-2.6)**
CAR (2)		-0.328 (-2.0)*	-0.174 (-2.9)**	-0.214(-1.9)*	-0.407(2.4)*
BUS (1)		0.152 (2.9)**	0.441 (5.1)**	0.571 (2.1)*	0.141(1.9)*
WAIT (1)		0.112 (4.1)**	0.496 (9.1)**	0.309 (1.9)*	0.017(1.9)*
PTTIME (3)		0.233 (3.1)**	0.295 (2.7)**	0.389 (2.1)*	0.178(2.2)*
GENDER (2)		-0.265 (-1.9)*	-0.362 (-3.9)**	-0.164 (-2.1)*	-0.228 (-2.7)**
AGE (2)		-0.183 (-2.1)*	-0.197 (-5.0)**	-0.176 (-5.1)**	0.111 (2.0)*
INCOME (3)		0.254 (2.0)*	0.147 (4.7)**	0.099 (6.1)**	0.317 (3.1)**
CARAV (1)		-0.011 (-2.1)*	-0.112 (-1.9)*	-0.107 (-2.0)*	-0.412(3.7)**
ZONE (1)		0.405 (4.0)**	0.135 (3.3)**	0.208 (3.9)**	0.326 (2.2)*
CONMOB (3)		0.149 (2.5)*	0.281 (2.0)*	0.161 (3.7)**	0.069 (9.0)**
DEPT (3)		0.316 (2.8)**	0.218 (2.1)*	0.108 (3.3)**	0.300 (2.7)**
FRUST (1)		0.048 (2.6)**	0.058 (2.0)*	0.035 (2.4)*	0.017 (5.0)**
CONVN2 (2)		0.019 (3.0)**	0.013 (2.8)**	0.012 (1.9)*	0.064 (2.3)*
PERSEP (3)		-0.021 (-3.9)**	-0.015 (-3.9)**	-0.027 (-2.0)*	-0.056 (-2.7)**
USE2		-0.054 (-3.1)**	-0.038 (-3.3)**	-0.067 (-4.1)**	-0.459 (-2.0)*
N		1980	542	440	484
ρ^2 *(0)*		0.259	0.253	0.246	0.236
ρ^2 (c)		0.219	0.214	0.203	0.203

(1) SMS (2) Call Centre (3) PID, * Significant at the 95% confidence level, ** Significant at the 99% confidence level

8.2.3 Segmented MNL models by mode of transport – stage three

The coefficient estimates from the segmented mode of transport models for stage three are presented in table 8-3. The table presents, base model 3, base model 3 BUS, base model 3 RAIL and base model 3 CAR.

The $\rho^2(0)$ and $\rho^2(c)$ values produce by base model 3 BUS were 0.301 and 0.266, the values for the base model RAIL model were 0.362 and 0.313 and 0.272 and 0.239 for the car user model. Higher $\rho^2(0)$ and $\rho^2(c)$ values are estimated for the bus and rail models, which indicates an improvement over the base model 3. Lower $\rho^2(0)$ and $\rho^2(c)$ values were estimated for the car user model than for the base model; however the values are still within an acceptable range.

The model estimates for savings in wait-time when the internet is used to obtain real-time public transport information were found to be significant at either the 95% or 99% confidence level (see table 8.3). The coefficient estimates illustrate that bus users derive the highest utility from wait-time savings (-0.052), followed by rail and car users with coefficients of -0.028 and -0.021 respectively. As with the other stages, this finding shows that bus users are more likely to perceive a benefit in a reduction of wait-time compared to the other user groups. The coefficients for rail and car users in this model were found to be similar indicating that both user groups derive a similar benefit from a reduction in wait time.

The cost coefficients for information provision via the internet were estimated to be negative and significant at the 99% confidence level (see table 8.3). This indicates that users are less likely to choose this option when the cost rises. The lowest disutility was found for bus users (-0.059), followed by rail (-0.062) and car users (-0.068). The estimated coefficients demonstrate that each of the user groups were more or less equally likely to object to paying for information via the internet.

The wait-time saved coefficients for information provision via SMS were found to be negative and significant at the 95% and 99% confidence levels (see table 8.3). This indicates that respondents derive a benefit from a decrease in wait-time. The results demonstrate that bus users derive the highest utility from accessing public transport information using SMS, as this group was found to have the highest coefficient (-0.040).

The findings show that rail users derive a higher benefit than car users at this stage, with coefficients of -0.034 and -0.029 respectively. As with the findings related to the wait-time coefficient for SMS from stages one and two, the findings from the third stage also show that bus users derive the highest benefit from a reduction in wait-time. However, one should note that at this stage the coefficient values for rail and car users were found to be similar, demonstrating that at the third stage all user groups are likely to derive a similar benefit from a reduction in wait time.

The costs coefficients for information provision via a SMS were found to be negative and significant at the 99% confidence level (see table 8.3). The lowest coefficient value was attributes to bus users (-0.034), followed by rail users (-0.041) and car users (-0.045), which demonstrates that car users are less likely to pay for information provided via SMS compared to bus and rail users. The cost coefficients for each of the user groups were found to be similar, indicating cost impacts upon all users equally at this stage.

The information coefficients for SMS at stage three were found to be negative and significant at the 99% confidence level (see table 8-3). The estimates show bus users to derive the highest utility from real-time information (-1.141), followed by rail (-1.140) and car users (-0.826). The coefficient for car users of -0.862 is noticeably lower than the estimates of -1.141 and -1.140 for bus and rail users respectively. These results demonstrate that car users derive less utility at this stage. This could be attributed to car users' poor perception of public transport, and therefore are less likely to derive a benefit from real-time information. The bus and rail coefficients were found to be very similar, which indicates that both public transport user groups derive a similar benefit from real-time information provided by SMS at stage three.

Receiving real-time public transport information via SMS was found to have the highest utility at stage three for all modes of transport. Call centre was found to derive the second highest utility, followed by the internet.

Table 8-3 MNL models including segmented mode options-stage three

Variables		Base Model 3	Base Model 3 BUS	Base Model 3 RAIL	Base Model 3 CAR
		Stage Three			
Internet	Wait-time saved	-0.022 (-3.5)**	-0.052 (-4.7)**	-0.028 (-2.1)*	-0.021 (-2.8)**
	Cost	-0.051 (-13.6)**	-0.059 (-7.3)**	-0.062 (-3.9)**	-0.068 (-7.5)**
	Information	-0.514 (-7.6)**	-0.913 (-6.5)**	-0.771 (-3.9)**	-0.457 (-2.8)**
SMS	Wait-time saved	-0.024 (-3.4)**	-0.040 (-3.3)**	-0.034 (-2.0)*	-0.029 (-6.2)**
	Cost	-0.044 (-7.6)**	-0.034 (-7.0)**	-0.041 (-2.6)**	-0.045 (-9.6)**
	Information	-1.109 (-7.2)**	-1.141 (-6.6)**	-1.140 (-4.8)**	-0.826 (-6.5)**
Call Centre	Wait-time saved	-0.050 (-8.3)**	-0.033 (2.8)**	-0.023 (-6.1)**	-0.018 (-3.8)**
	Cost	-0.037 (-8.7)**	-0.036 (-11.6)**	-0.051 (-5.2)**	-0.055 (-2.4)*
	Information	-0.782 (-7.9)**	-0.922 (-3.4)**	-1.149 (-5.8)**	-0.428 (-2.1)*
CAR (2)		-0.147 (-2.4)*	-0.087(-1.9)*	-0.101(-2.4)*	-0.412(-2.7)**
BUS (1)		0.315 (7.0)**	0.478(5.0)**	0.145(1.9)*	0.074(1.9)*
PTTIME (3)		0.255 (4.9)**	0.474(2.2)*	0.321(2.5)*	0.148(2.0)*
GENDER (3)		-0.162 (-5.4)**	-0.145 (-2.2)*	-0.194 (-7.1)**	-0.367 (-2.8)**
AGE (2)		-0.267 (9.3)**	-0.217 (-3.2)**	-0.021 (-2.7)**	-0.207 (-8.8)**
INCOME (3)		0.173 (5.2)**	0.117 (6.1)**	0.019 (3.5)**	0.191 (3.7)**
CARAV (1)		-0.144 (-2.1)*	-0.471(3.1)**	-0.241(-1.9)*	-0.471(-7.1)**
ZONE (2)		0.477 (2.9)**	0.508 (2.1)*	0.581 (2.7)**	0.121 (2.4)*
CONMOB (3)		0.034 (2.1)*	0.296 (4.1)**	0.208 (2.2)*	0.063 (2.1)*
FIXW (2)		-0.175 (-4.0)**	-0.502 (-2.5)*	-0.572 (-4.2)**	-0.144 (-1.9)*
FRUST (2)		0.010 (2.6)**	0.027 (2.5)*	0.015 (5.2)**	0.020 (3.3)**
CONVN1 (2)		0.024 (9.0)**	0.016 (1.9)*	0.057 (1.9)*	0.055 (4.4)**
PERSEP (3)		-0.018 (-3.8)**	-0.016 (-4.4)**	-0.036 (-2.5)*	-0.042 (-2.5)*
USE3		-0.036 (-2.0)*	-0.014 (-5.1)**	-0.030 (-4.7)**	-0.056 (-2.8)**
N		1980	542	440	484
$\rho^2(0)$		0.296	0.301	0.362	0.272
$\rho^2(c)$		0.267	0.266	0.313	0.239

(1) Internet (2) SMS (3) Call centre, * Significant at the 95% confidence level, ** Significant at the 99% confidence level

8.3 Estimated Direct Elasticities of Choice

This section presents the estimated elasticities of choice for cost and wait-time saved for the different real-time public transport information options across the three stages examined. Direct point elasticity measures the percentage change in probability of choosing a particular alternative in the choice set with respect to a given percentage change in an attribute of that same observed alternative (Hensher et al, 2005). A detailed discussion of the process of estimating direct point elasticity may be found in section 3.9.2. The first three sub-sections estimate the direct point elasticities for the cost and wait-timed saved. The internet and passenger information display were not examined as these options were not examined across all three stages.

8.3.1 Estimated elasticities of choice-stage one

At the first stage elasticities were calculated using base model 1, base model 1 BUS, base model 1 RAIL and base model 1 CAR. Table 8-4 details the wait-time saved and cost elasticities for the four models analysed.

The estimated elasticities for wait-time when information is provided via the internet were found to be positive. Base model 1, which represents all user groups, demonstrates that a 1% increase in wait-time saved would result in a 0.32% increase in the probability that the respondent would choose to access transport information via the internet (see Table 8-4). Rail users were found to have the highest elasticity (0.55), followed by bus and car users with elasticity values of 0.39 and 0.16 respectively. This result suggests that if wait time saved were to increase by 1%, rail users would be more likely to use the internet to obtain real-time public transport information.

The cost estimates for information provision via the internet, at stage one, show that a 1% increase in cost is more likely to deter public transport users from choosing the internet, with elasticities of -0.46 and -0.29 for bus and rail users respectively. The overall elasticity estimate using the results from base model 1 shows that a 1% increase in the cost of accessing public transport information via the internet results in a decrease of 0.37% in the probability that a respondent will choose to access transport information via this source (see Table 8-4).

The elasticity estimates for wait-time saved using SMS were found to be highest for bus and rail users, demonstrating that public transport users derive a higher benefit from increase in wait-time saved compared to car users. The base model 1 estimate shows that a 1% increase in the wait-time saved results in an increase of 0.34% in the probability that respondents would choose to use SMS at stage one. The cost of SMS estimates demonstrate that bus users had the lowest negative elasticity of -0.21, demonstrating that a 1% increase in cost would not affect bus users choices as much as rail and car users given the higher elasticities of -0.25 and -0.29 respectively. The elasticities for the cost of SMS were found to be similar for all user groups, indicating a 1% increase in cost would have a similar impact upon all user groups.

The elasticity estimates for call centre for wait-time saved shows that bus users followed by rail and car users are most likely to choose to access information from a call centre, if the wait-time saved increased by 1% (see Table 8-4). The base model 1 estimate demonstrates that an increase in wait-time saved by 1% would result in a 0.19% - does not match figure in table increase in the probability that respondents will choose to use a call centre.

The cost estimates for using a call centre to access real-time public transport information shows that, cost is most likely to deter bus users, followed then by car and rail users, from accessing transport information from a call centre. The base model results demonstrate that a 1% increase in price would result in a decrease of 0.24% in the probability that respondents would choose to access real-time information using this option. A comparison between the three user groups demonstrates that bus users are the least likely to change their option given a 1% increase in the cost of call centre.

The elasticities show that SMS is the least cost sensitive of all of the options examined at stage one. Bus users were found to have the lowest cost elasticities for SMS and call centre, with rail users having the lowest for cost elasticity for the internet. The wait-time saved elasticities where found to be highest for SMS, indicating that as the wait-time saved increases on this option, more individuals are likely to choose this option at stage one. The results for SMS reveal that the respondents, regardless of mode of transport used, find this option of receiving real-time information at the first stage to be the most beneficial. One possible reason for this choice is that respondents perceive SMS to be a more convenient method of receiving real-time information when planning their trip from home to work.

Table 8-4 Elasticities of choice - stage one

Coefficient		Base Model 1	Base Model 1 BUS	Base Model 1 RAIL	Base Model 1 CAR
Internet	Wait-time saved	0.32	0.39	0.55	0.16
	Cost	-0.37	-0.46	-0.29	-0.53
SMS	Wait-time saved	0.34	0.40	0.36	0.25
	Cost	-0.21	-0.21	-0.25	-0.29
Call Centre	Wait-time saved	0.19	0.20	0.15	0.04
	Cost	-0.24	-0.20	-0.23	-0.27

8.3.2 Estimated elasticities of choice-stage two

The estimated elasticity values for stage two are reported in table 8-5. As in the previous section values were estimated from base model 2, base model 2 BUS, base model 2 RAIL and base model 2 CAR for wait-time saved and cost coefficients.

The wait-time saved estimates for passenger information display were found to be positive, with bus users having the highest reported positive elasticity. The bus user coefficient of 0.51 indicates that for a 1% increase in wait-time saved, the probability of bus users choosing passenger information display increases by 0.50% (see table 8-5). Rail user estimates for time saved was found to be higher than that of the car users, with elasticities of 0.14 and 0.07 respectively. This finding demonstrates that a 1% increase in time saved from a passenger information display is least likely to result in car users choosing to use a passenger information display. This is an intuitive finding as it suggests that public transport users are more likely to choose to use a passenger information display as the wait-time saved increases. Of the two public transport users, bus users were found to be more likely to choose to obtain transport information from a passenger information display as a result of a 1% increase in wait-time saved. This result shows that bus users derive a higher benefit from wait-time saved compared to rail users.

The cost coefficients were estimated to be negative, indicating that as price goes up by 1%, respondents are less likely to choose passenger information display. The results show that bus users had the lowest negative elasticity of -0.23, indicating that an increase in the cost of using a passenger information display would least affect bus users. The rail user elasticity was estimated to be -0.27 and the car user elasticity -0.35. These results show

that the rail user elasticity was very similar to the bus user estimate, indicating both user groups are more or less equally likely to decide not to use a passenger information display if the cost per trip were to increase.

The wait-time saved elasticity estimates for SMS were found to be positive. The bus user group reported the highest elasticity for wait-time saved of 0.33, indicating that if there was a 1% increase in wait-time saved, this would result in a 0.33% increase in the probability that bus users will choose to use SMS (see table 8-5). Car users were found to have a slightly higher positive elasticity of 0.154 compared to rail users of 0.144 at this second stage.

The cost elasticities for SMS were found to be negative for all modes examined. The base model 2 estimate of -0.26 indicates that if cost were to increase by 1%, the likelihood that respondents will choose SMS will fall by 0.26% (see table 8-5). The elasticity values for bus, rail and car users were found to be -0.17, -0.24 and -0.31 respectively. The results for cost demonstrate that bus users would be the least likely of the user groups not to choose an alternative method of receiving real-time public transport information given an increase in the cost of SMS. Therefore, the bus user group can be said to be the least sensitive to an increase in the cost of SMS followed by rail and car users.

The elasticity estimates for wait-time saved for call centre at stage two were estimated to be positive. The bus user group estimate of 0.21 was found to be higher than rail users (0.13) and car users (0.09) (see table 8-5). The base model 2 estimate of 0.12 indicates that if wait-time saved increased by 1%, it would result in a 0.12% increase in the probability that the respondent will choose to use a call centre. These results show that as the wait-time associated with using a call centre increases so too does the likelihood that individuals will choose to access public transport information via a call centre.

The cost elasticities for using a call centre for base model 2 was estimated to be -0.29 (see table 8-5). This finding indicates that a 1% increase in cost of a call centre will result in a 0.29% decrease in the likelihood respondents will choose to access transport information using a call centre at this stage. The model estimates show that bus users had the lowest estimated cost elasticity of -0.20 and car users the highest (-0.29), indicating an increase in cost more likely to deter car users compared to bus users. As with the previous findings from this stage, bus users were found to be the least cost sensitive to an increase in the cost of a call centre, followed by rail and car users to an increase in the cost of a call centre.

The elasticities estimated at stage two demonstrate that passenger information displays were found to have the lowest cost disutility, and the highest wait-time saved utility at stage two. This indicates that at stage two respondents derive the most benefit from using a passenger information display to obtain real-time public transport information. SMS was found to have the second highest wait-time saved elasticity and lowest cost disutility. This demonstrates that similar to the findings from stage one, that this user group derived the most benefit from real-time information at this stage.

Table 8-5 Elasticities of choice - stage two

Coefficient		Base Model 2	Base Model 2 BUS	Base Model 2 RAIL	Base Model 2 CAR
PID	Wait-time saved	0.21	0.51	0.14	0.07
	Cost	-0.24	-0.23	-0.27	-0.35
SMS	Wait-time saved	0.14	0.33	0.14	0.15
	Cost	-0.26	-0.17	-0.24	-0.31
Call Centre	Wait-time saved	0.12	0.21	0.13	0.09
	Cost	-0.29	-0.20	-0.23	-0.29

8.3.3 Estimated elasticities of choice - stage three

The elasticity estimates for wait-time saved and cost for stage three are presented in Table 8-6. The estimates are segmented between bus, rail and car user groups.

The estimates for wait-time saved associated with using the internet demonstrates that bus users have the highest positive elasticity coefficient of 0.12 (see Table 8-6). This result suggests that if wait-time saved were to increase by 1%, the probability that bus users will choose the internet will increase by 0.12%. Rail users were found to have the second highest value of 0.10 followed by that of car users of 0.09. The elasticity estimates for each of the user groups examined were within a close range of each other. This demonstrates that that a 1% increase in wait time saved is equally likely to impact upon all users in a similar manner.

The cost elasticities for the internet demonstrate that rail users were estimated to have the lowest cost coefficient, indicating an increase in cost does not impact upon rail users as much as bus and car users. The base model 3 elasticity of result demonstrates that for a 1% increase in cost would result in a 0.21% decrease in the likelihood respondents would choose to access transport information using the internet. Of the public transport user

groups at this stage, rail users were found to have the lowest negative elasticity of -0.17 compared to an elasticity of -0.18 for bus users. Given the similarity in these estimates it is fair to say an increase in the cost of using the internet is likely to impact upon both user groups equally.

The wait-time saved elasticity estimates for the SMS option for stage three were found to be positive (see Table 8-6). Bus users were found to have the highest positive elasticity of 0.28, indicating that for a 1% increase in wait-time saved the probability that bus users will choose SMS will increase by 0.28% (see Table 8-6). Rail users were found to be more likely to choose SMS than car users if there is a 1% increase in wait-time saved. As with the wait-time saved option at all three stages bus users were again found to have the highest elasticity estimates. This demonstrates that as wait-time decreases, the probability that bus users will choose SMS to receive real-time information increases. Therefore, it can be said that bus users derive a higher benefit from a decreased wait-time than any of the other user groups.

The cost coefficients for SMS demonstrate that the base model 3 estimates of -0.27, indicates that for a 1% increase in cost, the probability that respondents will choose SMS falls by 0.27% (see Table 8-6). An increase in cost by 1% was found to have the least impact on bus users, followed by rail and car users, with estimated elasticities of -0.19, -0.24 and -0.27 respectively. An increase in the cost of SMS is therefore least likely to impact upon bus users. This result demonstrates that bus users derive a greater benefit from SMS as the estimated elasticity was lowest for this group.

The wait-time saved elasticity estimates for call centre were estimated to be positive for each of the models estimated. The bus user elasticity estimate of 0.23 indicates that a 1% increase in wait-time saved would result in an increase of 0.23% in the probability that bus users will choose to access transport information from a call centre. Rail users were found to have a higher elasticity value of 0.18 compared to 0.15 for car users. These results once again show that bus users derive a higher benefit from real-time information compared to rail and car users.

The cost elasticity for call centre for base model 3 was estimated at -0.31, which indicates that a 1% increase in cost would result in a 0.31% decrease in the probability that respondents will choose to access transport information from a call centre. Bus users were

found to have the lowest elasticity estimate of -0.25 followed by rail (-0.28) and car users (-0.34), indicating that an increase in cost is less of a deterrent to public transport users. This result once again indicates that bus users are the least likely to choose an alternative method of obtaining real-time information if there is an increase in the cost of a call centre. This suggests that bus users are more willing to accept an increase in the cost of obtaining information from a call centre relative to rail and car users.

Table 8-6 Elasticities of choice-stage three

Coefficient		Base Model 3	Base Model 3 BUS	Base Model 3 RAIL	Base Model 3 CAR
Internet	Wait-time saved	0.10	0.12	0.10	0.09
	Cost	-0.21	-0.18	-0.17	-0.21
SMS	Wait-time saved	0.13	0.28	0.23	0.04
	Cost	-0.27	-0.19	-0.24	-0.27
Call Centre	Wait-time saved	0.19	0.23	0.18	0.15
	Cost	-0.31	-0.25	-0.28	-0.34

8.4 WILLINGNESS TO PAY

The willingness to pay for real-time public transport information is reported in this section. The outputs of discrete choice models are often used to determine the amount of money individuals are willing to forfeit in order to obtain some benefit from the undertaking of some specific action or task (Hensher et al, 2005). The purpose of estimating these values for this study is to place a monetary value on the benefit respondents derive from the real-time public transport information.

Willingness to pay amounts are calculated by dividing the variable of interest by a cost variable in order to derive a value which represents the amount respondents would be willing to pay for the variable of interest. Equation 8-1 calculates the willingness to pay for an individual i for attribute a in relation to attribute b. See section 3.2 for a detailed explanation of the concept of willingness to pay. The willingness to pay amounts presented in the sections below refer to willingness to pay for SMS - per message received, passenger information display – per trip, internet – per trip and call centre – per call.

Equation 8-2

$$WTP(i) = \frac{\beta_{ia}}{\beta_{ib}}$$

8.4.1 Willingness to pay – stage one

Table 8-7 presents the willingness to pay for the internet; SMS and call centre at stage one. Willingness to pay amounts are calculated from the coefficients estimated in Base Model 1, Base Model 1 BUS, Base Model 1 RAIL and Base Model 1 CAR. Firstly, comparing the different user groups, bus users were found to have the highest willingness to pay amounts, followed then by rail and car users. Respondents were found to have the highest willingness to pay amounts for SMS followed then by the internet and call centre (see Table 8-7). The results for this stage show that the bus user group have the highest willingness to pay amount for SMS of 36c per message.

As bus users were found to be willing to pay the most for the provision of real-time information it is fair to say that this user group derive the greatest benefit from this information. This finding demonstrates that bus users require more information on their trip to work as they were found to be willing to pay the most for such information. The willingness to pay amounts for rail users intuitively was found to be higher than that of car users, indicating that rail users place a higher benefit on real-time public transport information. A comparison between rail and bus users shows that bus users derive a higher benefit from real-time information. This finding may be attributable to the perceived reliability of a rail service schedule compared to that of a bus schedule.

Of the three methods of receiving real-time information at the pre-trip planning stage from home to work, respondents, regardless of user group were found to be willing to pay the most for obtaining public transport information via SMS. This result suggests that the first stage respondents derive the most benefit from using an SMS to access real-time public transport information. Of the remaining information provision options bus users demonstrate a higher willingness to pay for the internet compared to a call centre. In contrast, rail users and car users were found to be willing to pay more for using a call centre compared to the internet. Therefore rail and car users perceive using a call centre to be more beneficial than using the internet.

Table 8-7 Willingness to pay – stage one

Variables traded off	Option	Base Model 1	Base Model 1 BUS	Base Model 1 RAIL	Base Model 1 CAR
Information/ cost	Internet	22c	26c	14c	7c
	SMS	28c	36c	28c	17c
	Call centre	10c	23c	17c	8c

8.4.2 Willingness to pay – stage two

The willingness to pay amounts for the real-time information options considered at stage two are reported in Table 8-8. As with the first stage, bus users were found to be willing to pay more for real-time public transport information, followed by rail users and car users. At this stage passenger information displays were found to yield the highest willingness to pay amounts, with bus users willing to pay 32c per trip, rail users 27c and car users 11c per trip (see Table 8-8). SMS users were found to have the second highest willingness to pay amounts, followed by call centre users. As with the first stage, car users were found to have the lowest willingness to pay amounts.

As with the willingness to pay estimates for stage one bus users were found to be willing to pay the most for real-time information at the second stage. Rail users estimates were found to be second highest followed by the car user results. The higher result for bus users at this stage as with the first stage demonstrates that bus users derive a greater benefit from real-time public transport information. As with the first stage the higher willingness to pay amounts found for bus users could be related to the perceived lack of reliability in the bus schedule. A further reason for these findings is that in Dublin the information provided at bus stops has traditionally been quite poor. This was indicated by respondents in section 5.5 in chapter 5, where 64% of bus users indicated that the quality of maps provided was poor or very poor and 49% said the quality of bus time tables was poor or very poor. Therefore, it is fair to say that this is a contributory factor to bus users being willing to pay more for real-time information at this stage.

Rail users willingness to pay estimates were found to be second highest followed by car users. These findings follow a similar pattern to that found at the first stage. These findings make intuitive sense as rail users can be said to derive a greater benefit from real-time information given the potential higher frequency of use compared to car users.

At this second stage respondents were found to be willing to pay the most to receive real-time information from a passenger information display. The estimates demonstrate that

while respondents are waiting at their bus stop/train station, they would derive the greatest benefit from using a passenger information display. This finding was expected as the use of a passenger information display is the most convenient and efficient way of delivering real-time information to passengers while they wait for their vehicle to arrive. The willingness to pay estimates for SMS was found to be the second highest at this stage followed by those for using a call centre. The convenience of accessing real-time information may be a factor in the results found at this stage, as the respondents are under time constraints and logically wish to minimise their time waiting at their stop/station. This consideration may influence the benefits derived from an SMS compared to a call centre, as it is fair to say accessing real-time information from a call centre is more time consuming than from an SMS.

Table 8-8 Willingness to pay – stage two

Variables traded off	Option	Base Model 2	Base Model 2 BUS	Base Model 2 RAIL	Base Model 2 CAR
Information / cost	PID	22c	32c	27c	11c
	SMS	20c	25c	22c	9c
	Call centre	16c	21c	18c	8c

8.4.3 Willingness to Pay – stage three

The willingness to pay amounts estimated from the results from stage three are presented in Table 8-9. The results show that as with the first two stages, bus users are willing to pay more than the other two user groups for real-time public transport information. Rail users were found to have the second highest willingness to pay amounts followed by car users. Respondents were found to have the highest willingness to pay amounts for SMS, with bus users willing to pay 34c and rail and car users willing to pay 28c and 18c respectively.

The willingness to pay estimates at this stage demonstrates that bus users were found to be willing to pay the most for real-time information. This result, as with the findings for stages one and two previously, demonstrates that bus users derive the greatest benefit from real-time public transport information. The same pattern is repeated with the other user groups at stage three, with rail users found to be willing to pay more than car users for real-time information. The results at this stage demonstrate once again that if respondents were to take a public transport trip, those who currently use public transport were found to be willing to pay the most for real-time information.

The estimates for each of the different real-time information options at this stage shows that respondents were willing to pay the most for receiving real-time information via an SMS. This finding is similar to that reported at the first stage, demonstrating that the pre-trip planning stage, whether it is planning from home to work or vice versa, that respondents indicated that they would derive the greatest benefit from using an SMS at these stages. The willingness to pay amounts for a call centre was found to be higher than the estimates for using the internet at stage three. One possible reason for this is that individuals at this stage have access to a work phone and may use this phone to make a call to a call centre, therefore at no cost to the respondent.

Table 8-9 Willingness to pay – stage three

Variables traded off	Option	Base Model 3	Base Model 3 BUS	Base Model 3 RAIL	Base Model 3 CAR
Information / cost	Internet	13c	15c	12c	7c
	SMS	25c	34c	28c	18c
	Call centre	21c	26c	23c	7c

8.4.4 Comparison of willingness to pay across all three stages

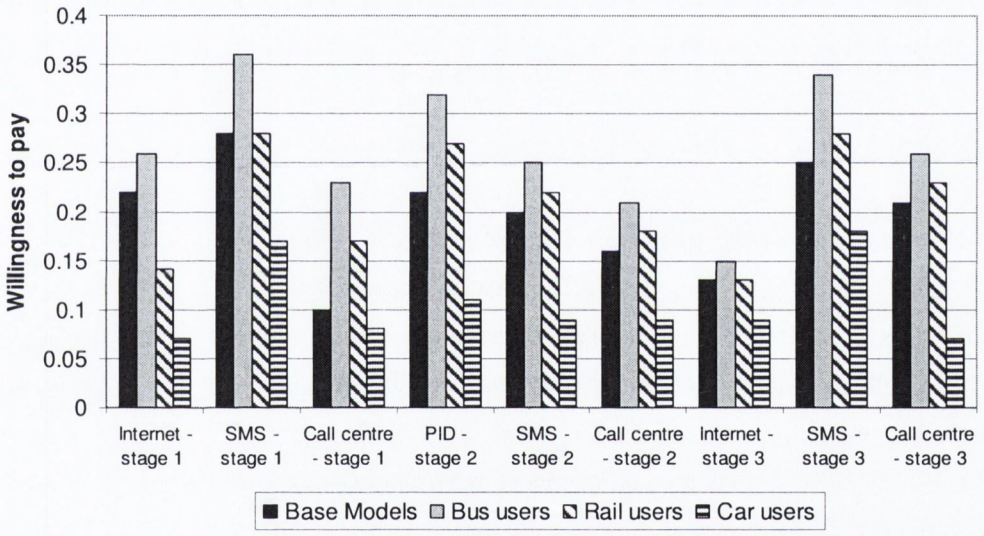
The results from tables 8-7, 8-8 and 8-9 are presented in Figure 8-1. The results show that bus users have the highest willingness to pay values across all stages and for all methods of information provision. The results also show that at stages one and three, SMS has the highest results and passenger information display having the highest results at stage two.

The willingness to pay estimates across all three stages clearly show that bus users are willing to pay the most for the provision of real-time information at each of the stages examined. Of the three trip planning stages examined, the highest willingness to pay amounts were found for using an SMS at stage one followed by using SMS to obtain public transport information at stage three, followed by using a passenger information display at the second stage. These findings show that respondents are willing to pay more for their information before setting out to meet their public transport service. It is at these pre-trip planning stages when this information can be said to be at its most beneficial, in that they can schedule their departure from home/work to minimise their wait time at their stop/station.

The willingness to pay values for information provision via SMS and a call centre at the second stage was found to be less than the corresponding estimates for these options at stages one and three. This finding demonstrates that while waiting at their stop/station, the

benefit derived from real-time information drops and respondents at this stage derive the most benefit from a passenger information display. As mentioned above, this may be due to the diminished benefit of wait-time saving, or that at this stage respondents derive the most benefit from a passenger information display. One could argue both sides of this finding, that the passenger information display willingness to pay amounts was greater than the SMS and call centre estimates, but on the other hand, that the willingness to pay amounts for passenger information display was less than the SMS amounts estimated at stages one and three. However, this may be an unfair comparison as the passenger information display option was only offered to respondents at stage two. Given that the overall willingness to pay results at stage two were generally lower, it is fair to conclude that at this stage respondents were willing to pay less for real-time information.

Figure 8-1 Comparison of willingness to pay amounts across all stages



8.5 TESTS OF THE INDEPENDENCE FROM IRRELEVANT ALTERNATIVES (IIA) ASSUMPTION

One of the fundamental assumptions of the MNL approach is the property of independence from irrelevant alternatives (IIA) (see section 3.8 for a discussion of this property). Essentially this property states that the ratio of probabilities of any two alternatives is independent of the presence or absence of a third alternative. To put this property in the context of this study, the ratio of probabilities at stage one for choice between the internet and a call centre is the same regardless of whether the SMS option is introduced or not.

There are several tests to ascertain if the IIA property holds. The most commonly applied test is that by Small & Hsiao (1985). The basic premise of this test is that if the IIA property holds then the log-likelihood of the restricted choice set (e.g. the internet and call centre choice at stage one) is not statistically different to log-likelihood of the IIA for the full choice set (see section 3.2 for a description of this test). The hypothesis of the test stipulates that if the hypothesis is accepted, there is a violation of the IIA property, and if rejected there is no violation of the IIA property. As the IIA property is an underlining assumption of MNL modelling it is important that this property is not violated.

The results of the Small-Hsiao test for stage one is presented in Table 8-10. The test was run on the model specification for base model 1. The first test was estimated omitting the SMS variable; this resulted in 14 degrees of freedom, with a critical value of 23.69. The estimated test statistic value of 84.22 rejects the null hypothesis (see Table 8-10). The second test omitted the call centre variable, which results in 18 degrees of freedom and a critical value of 28.87. The test value estimated that when the call centre option is omitted was 50.67, which again means the null hypothesis can be rejected.

As the Small-Hsiao test rejected the null hypothesis it is fair to say that the IIA property is not violated. This implies that at this first stage, the probability of a respondent choosing one alternative, for example SMS, is not affected by the absence or presence of any of the other alternatives. Another implication of the non-violation of the IIA property is that alternative model structures can be examined such as nested models.

In table 8-10, $LL^{B'}(\beta^{AB'})$ is the likelihood function of the model estimated with all three alternatives included. $LL^{B'}(\beta^{B'})$ represents the likelihood of the restricted choice set, in the example of test 1 in table 8-10, the choice set without the SMS alternative. This notation is also used in tables 8-11 and 8-12.

Table 8-10 The Small-Hsiao test of the IIA for Base Model 1

Statistic	Test 1: SMS alternative omitted	Test 2: Call centre alternative omitted
$LL^{B'}(\beta^{AB'})$ (full choice set)	-1580.99	-1643.54
$LL^{B'}(\beta^{B'})$ (restricted choice set)	-1538.88	-1618.21
Test statistic value	84.22	50.67
Degrees of freedom	14	18
Critical value of χ^2	23.69	28.87
	Reject null hypothesis	Reject null hypothesis

Table 8-11 details the IIA test results for the models estimated at stage two. The third Small-Hsiao test omits the SMS alternative, resulting in 16 degrees of freedom, and a critical value of 26.30. The test statistic produces a value of 61.77 which means that the null hypothesis can be rejected. The fourth test omits the call centre variable among the choice set at stage two. The critical value with 16 degrees of freedom produces a value of 26.30. The test statistic value of 81.5 rejects the null hypothesis (see Table 8-11). The rejection of the null hypothesis for both of the tests conducted demonstrates that there is no IIA violation in the model results from stage two. The rejection of the null hypothesis at this stage demonstrates that the probability of choosing a particular real-time information option is the same regardless if the choice set is restricted or unrestricted.

Table 8-11 The Small-Hsiao test of the IIA for Base Model 2

Statistic	Test 3: SMS alternative omitted	Test 4: Call centre alternative omitted
$LL^{B'}(\beta^{AB'})$ (full choice set)	-1432.118	-1387.341
$LL^{B'}(\beta^{B'})$ (restricted choice set)	-1401.234	-1346.591
Test statistic value	61.77	81.5
Degrees of freedom	16	16
Critical value of X^2	26.30	26.30
	Reject null hypothesis	Reject null hypothesis

The results of the Small-Hsiao tests conducted on the base model 3 specification are presented in Table 8-12. The fifth test omits the internet option from the model specification of base model 3. The estimated test statistic of 70.73 is greater than the critical value of 26.30, which therefore rejects the null hypothesis (see Table 8-12). The final Small-Hsiao conducted omits the call centre option from the results at stage 3. The null hypothesis is rejected as the estimated test statistic of 39.53 is greater than the critical value of 26.30 (seeTable 8-12). As with the first two stages, the results from the Small-Hsiao test demonstrate that there is no violation of the IIA property at stage three. As there is no violation of the IIA property, alternative model specifications can be applied to the results from stage three.

Table 8-12 The Small-Hsiao test of the IIA for base model 3

Statistic	Test 5: Internet alternative omitted	Test 6: Call centre alternative omitted
$LL^{B'}(\beta^{AB'})$ (full choice set)	-1445.234	-1340.798
$LL^{B'}(\beta^{B'})$ (restricted choice set)	-1409.871	-1321.034
Test statistic value	70.73	39.528
Degrees of freedom	16	16
Critical value of X^2	26.30	26.30
	Reject null hypothesis	Reject null hypothesis

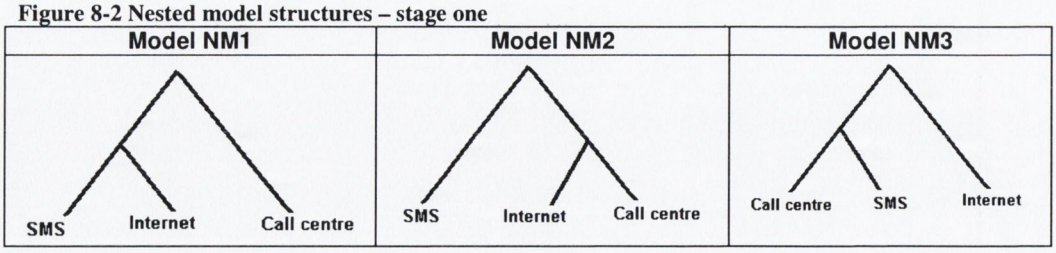
8.6 NESTED MNL MODELS

The models in the previous section demonstrated that there was no violation of the IIA assumption; therefore alternative model structures may be estimated. This section presents the results of the nested multinomial logit models (NMNL). A detailed description of this modelling approach may be found in section 3.2. The aim of this section is to ascertain the level of correlation among the unobserved parts of the utility alternatives in the nested models presented in this section. This correlation is measured using the LOGSUM statistic. This test produces values between 0 and 1, and the closer the values are to 1, the greater the independence between alternatives, and therefore less correlation in the model. Improvements in the model specification in this section are measured by comparing the $\rho^2(0)$ and $\rho^2(c)$ values from the MNL models to the NMNL.

8.6.1 Nested models – stage one

This section presents the nested models from the stage one model. Three nested models have been defined in this section (see Figure 8-2). The first nested model 1 (NM1) combines the alternatives SMS and the internet in one limb, and call centre in the other. The second nested model isolates SMS on one limb and combines the Internet and call centre on the other (see model NM2 in Figure 8-2). The third nested structure model NM3 has the internet on one branch, and call centre and SMS on the other (see Figure 8-2). The purpose of these different nested structures is to ascertain which structure provides the best model results. Therefore three nested structures are tested in this section to determine which produces the best model results.

Figure 8-2 Nested model structures – stage one



The key statistic to be examined in the nested models is the LOGSUM statistic. The nested model results in Table 8-13 show that the MN1 nest structure produced the highest LOGSUM value of 0.804, compared to 0.697 and 0.787 in structures NM2 and NM3

respectively. The value range for the LOGSUM statistic ranges between 0 and 1, the higher the value the greater the degree of independence between choices. In the range of values presented above, 0.804 for MN1 can be said to have the greatest degree of independence. Each of the LOGSUM variables was found to be significant at the 99% confidence level. These values demonstrate that nested structure NM1 produces the best results as there is the least correlation within this structure.

One of the purposes of nesting MNL models is to produce an improved model performance, which as before is measured by improvements in the $\rho^2(0)$ and $\rho^2(c)$ values. The $\rho^2(0)$ and $\rho^2(c)$ values estimated in model NM1 were 0.260 and 0.237, 0.241 and 0.203 for model NM2 and 0.254 and 0.211 for model NM3. In Table 8-13 the $\rho^2(0)$ and $\rho^2(c)$ values of the nested models NM1, NM2 and NM3 do not produce improved $\rho^2(0)$ and $\rho^2(c)$ values compared to those estimated in Base Model 1 of 0.268 and 0.239. Based upon the failure of the nested models to produce an improved model performance the estimates from base model 1 are demonstrated to be the best model specification for stage one.

The estimates presented in Table 8-13 for wait-time saved, cost and information for each of the information options considered at this stage were found to have results consistent with that of all the other models estimated for stage one presented in this thesis. The estimated coefficients for the explanatory variables such as CAR, BUS and WAIT and so on, were all found to be significant and consistent with those estimated in Base Model 1.

Table 8-13 Nested model results – stage one

Variables		Base model 1	MN1	MN2	MN3
		Stage One			
Internet	Wait-time saved	-0.040 (-5.6)**	-0.025 (-6.0)**	-0.120 (-7.2)**	-0.233 (-4.2)**
	Cost	-0.041 (-5.5)**	-0.074 (-2.3)*	-0.039 (-4.2)**	-0.117 (-2.4)**
	Information	-0.852 (-3.1)**	-0.621 (-5.9)**	-0.784 (-4.8)**	-1.029 (-2.8)**
SMS	Wait-time saved	-0.042 (-5.4)**	-0.031 (-2.3)*	-0.104 (-7.4)**	-0.121 (-4.1)**
	Cost	-0.030 (-12.9)**	-0.047 (-8.7)**	-0.089 (-7.2)**	-0.087 (-9.1)**
	Information	-1.597 (-10.4)**	-0.828 (-11.3)**	-1.024 (-11.7)**	-0.891 (-12.1)**
Call centre	Wait-time saved	-0.032(-4.9)**	-0.054(-1.9)*	-0.107(-2.7)**	-0.128 (-2.4)**
	Cost	-0.039 (-9.2)**	-0.074 (-7.7)**	-0.029 (-8.1)**	-0.078 (-7.1)**
	Information	-0.377 (-2.5)*	-0.408 (-2.9)**	-0.287 (-1.9)*	-0.281 (-1.9)*
CAR (1)		-0.276 (-6.3)**	-0.187 (-5.2)**	-0.317 (-5.9)**	-0.338 (-7.8)**
BUS (2)		0.243 (3.7)**	0.098 (2.1)*	0.411 (2.4)**	0.412 (4.5)**
WAIT (2)		0.066 (2.2)*	0.104 (1.9)*	0.069 (2.7)**	0.117 (1.9)*
PTTIME (3)		0.167 (2.7)**	0.209 (2.5)*	0.441 (8.0)**	0.158 (3.1)**
GENDER (3)		0.161 (3.5)**	0.157 (2.5)**	0.321 (1.9)*	0.144 (2.8)**
AGE (1)		-0.284 (-2.9)**	-0.187 (-3.1)**	-0.309 (-3.7)**	-0.207 (-3.7)**
INCOME (2)		0.082 (6.0)**	0.110 (4.7)**	0.198 (4.1)**	0.134 (5.4)**
CARAV (3)		-0.011 (-3.0)**	-0.054 (-3.2)**	-0.501 (-2.8)**	-0.217 (-4.0)**
ZONE (2)		0.050 (3.3)**	0.074 (2.4)*	0.241 (2.7)**	0.231 (2.8)**
DEPT (1)		0.245 (2.0)*	0.471 (3.9)*	0.326 (6.1)*	0.130 (4.7)*
FRUST (1)		0.068 (6.2)**	0.087 (2.7)**	0.212 (4.4)**	0.174 (3.1)**
CONVN1 (2)		0.041 (4.6)**	0.061 (3.6)**	0.119 (2.9)**	0.251 (4.4)**
PERSEP (2)		-0.097 (-2.5)*	-0.121 (-3.8)*	-0.170 (-1.9)*	-0.184 (-3.4)*
USE1 (2)		-0.034 (-2.6)**	-0.409 (-1.9)*	-0.211 (-4.7)**	-0.289 (-1.9**
LOGSUM			0.804 (2.6)**	0.697 (4.1)**	0.787 (3.2)**
N		1980	1980	1980	1980
$\rho^2(0)$		0.268	0.260	0.241	0.254
$\rho^2(c)$		0.239	0.237	0.203	0.211

(1) Internet (2) SMS (3) Call centre

* Significant at the 95% confidence level

** Significant at the 99% confidence level

8.6.2 Nested models – stage two

Three nested structures were tested with the model results for stage two, 1) with passenger information display on one limb and SMS and call centre on the other (NM4), 2) SMS on one limb and passenger information display and call centre on the other (NM5), and 3) Call centre on one limb and SMS and passenger information display on the other (NM6) (see Figure 8-3).

Figure 8-3 Nested model structures – stage two

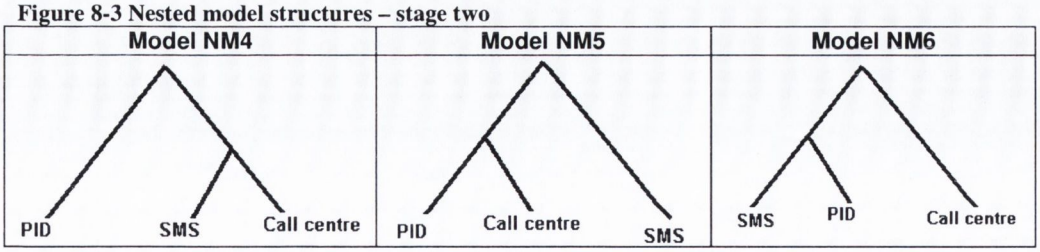


Table 8-14 presents the results of the nested model structures examined at stage two. The results show that NM6 produces the highest LOGSUM value of 0.914. Structure NM4 produced a LOGSUM value of 0.812, and NM5 a value of 0.749. As the LOGSUM statistic has a range of between 0 and 1, and the closer to 1 the estimated coefficient is the greater the independence between choices, model NM6 can be said to produce the least correlation among alternatives. .

The $\rho^2(0)$ and $\rho^2(c)$ values estimated for the nested models presented in Table 8-14 were as follows; 0.241 and 0.204 for model NM4, 0.224 and 0.217 for model NM5 and 0.249 and 0.209 for model NM6. The Base Model 2 estimates of 0.259 and 0.219 for the $\rho^2(0)$ and $\rho^2(c)$ values respectively in Table 8-14 were not improved upon in any of the nested model specifications. Therefore it can be concluded that the MNL specification produced the best model results based upon an examination of the $\rho^2(0)$ and $\rho^2(c)$ values. The estimated coefficients for wait-time saved, cost and information in the nested models were all found to be significant and to have negative coefficients similar to those estimated in Base Model 2.

The estimated coefficients for the explanatory variables presented in Table 8-14 for models NM4, NM5 and NM6, were all found to be significant and to have the same coefficient signs as those estimated in Base Model 2. This demonstrates that the nested models did produce the results found in the MNL models such as Base Model 2, however, the lack of improvement in the $\rho^2(0)$ and $\rho^2(c)$ values in the nested models, indicates that Base Model 2 is a better model specification.

Table 8-14 Nested model results – stage two

Variables		Base model 2	NM4	NM5	NM6
		Stage Two			
SMS	Wait-time saved	-0.032(-4.3)**	-0.121 (-4.7)**	-0.045 (-1.9)*	-0.701(-2.4)**
	Cost	-0.044 (-6.1)**	-0.081 (-2.1)*	-0.124 (-5.3)**	-0.214 (-4.4)**
	Information	-1.079 (-7.3)**	-1.112 (-4.1)**	-0.981 (-5.2)**	-1.191 (-2.8)**
Call centre	Wait-time saved	-0.017 (-2.6)**	-0.051 (-3.3)**	-0.041 (-5.2)**	-0.124 (-1.9)*
	Cost	-0.038 (-7.6)**	-0.127 (-6.4)**	-0.108 (-3.1)**	-0.142 (-4.1)**
	Information	-1.110 (-7.2)**	-0.891 (-4.3)**	-1.089 (-2.0)*	-1.019 (-4.3)**
PID	Wait-time saved	-0.043 (-7.1)**	-0.214 (-3.2)**	-0.121 (-6.2)**	-0.081 (-3.8)**
	Cost	-0.034 (-9.6)**	-0.120 (-2.4)**	-0.117 (-1.9)*	-0.034 (-9.6)**
	Information	-1.200 (-7.8)**	-0.914 (-9.1)**	-0.781 (-6.0)**	-1.221 (-8.1)**
CAR (2)		-0.328 (-2.0)*	-0.147 (-3.7)**	-0.298 (-4.1)**	-0.145 (-5.1)**
BUS (1)		0.152 (2.9)**	0.087 (2.1)*	0.078 (1.9)*	0.092 (3.6)**
WAIT (1)		0.112 (4.1)**	0.517 (3.7)**	0.417 (5.2)**	0.068 (2.7)**
PTTIME (3)		0.233 (3.1)**	0.098 (2.1)*	0.310 (2.8)**	0.178 (4.5)**
GENDER (2)		-0.265 (-1.9)*	-0.312 (-2.7)**	-0.167 (-2.4)*	-0.301 (-2.7)*
AGE (2)		-0.183 (-2.1)*	-0.417 (-3.7)**	-0.183 (-2.1)*	-0.271 (-2.7)*
INCOME (3)		0.254 (2.0)*	0.317 (4.2)*	0.470 (3.1)**	0.147 (2.8)*
CARAV (1)		-0.011 (-2.1)*	-0.207 (-3.8)*	-0.089 (-2.7)**	-0.174 (-3.7)**
ZONE (1)		0.405 (4.0)**	0.311 (5.2)**	0.214 (5.7)**	0.547 (4.8)**
CONMOB (3)		0.149 (2.5)*	0.214 (3.7)**	0.781 (4.7)*	0.617 (2.9)**
DEPT (3)		0.316 (2.8)**	0.471 (1.9)*	0.117 (1.9)*	0.019 (3.4)**
FRUST (2)		0.049 (2.6)**	0.715 (4.6)**	0.214 (2.9)**	0.152 (1.9)*
CONVN2 (1)		0.019 (3.0)**	0.022 (2.1)*	0.051 (3.1)**	0.471 (7.8)**
PERSEP (1)		-0.021 (-3.9)**	-0.127 (-1.9)*	-0.067 (-2.5)*	-0.327 (-4.7)**
USE2 (1)		-0.054 (-3.1)**	-0.450 (-1.9)**	-0.109 (-3.7)**	-0.631 (-4.5)**
LOGSUM			0.812 (3.2)**	0.749 (4.1)**	0.914 (2.7)**
N		1980	1980	1980	1980
$\rho^2(0)$		0.259	0.241	0.224	0.249
$\rho^2(c)$		0.219	0.204	0.217	0.209

(1) SMS (2) Call Centre (3) PID
* Significant at the 95% confidence level
** Significant at the 99% confidence level

8.6.3 Nested models – stage three

The nested structures examined at stage three are presented in Figure 8-4. The first structure NM7, nests SMS and the internet on one limb and call centre on the other limb. The second nest NM8 isolates SMS on one limb and combines the internet and call centre on the other. The final structure nests call centre and SMS together on one limb, and the internet on the other.

Figure 8-4 Nested model structures – stage three

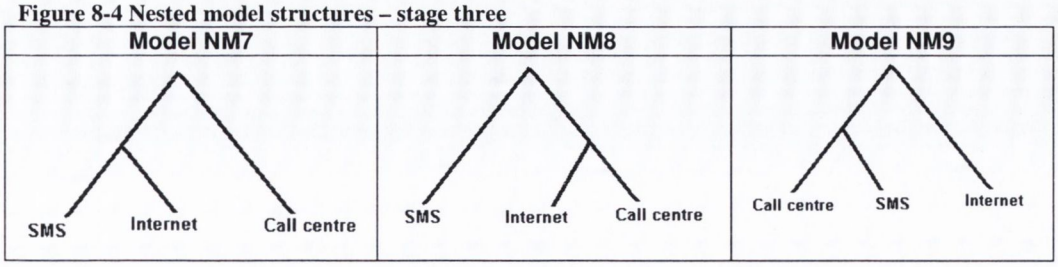


Table 8-15 presents the results of the model structures presented in Figure 8-4. The estimated LOGSUM values of 0.784, 0.842 and 0.697 for NM7, NM8 and NM9 respectively demonstrate that there is little correlation among the choice sets examined at this stage. The model specified in NM8 was found to have the least correlation, as this result was the one found to be closest to 1. Therefore, when comparing the different nested model structures, grouping the internet and call centre options on one limb and SMS on the other limb produces the best model specification at this third stage.

As with the previous two stages the nested model specifications did not produce an improved model performance. The $\rho^2(0)$ and $\rho^2(c)$ values estimated for model NM7 were 0.274 and 0.258, the model NM8 values were 0.287 and 0.247 and 0.281 and 0.241. A comparison between the $\rho^2(0)$ and $\rho^2(c)$ values estimated by the nested models NM7, NM8 and NM9 with the values estimated in Base Model 3 ($\rho^2(0)$ and $\rho^2(c)$ values of 0.296 and 0.267) demonstrates that the base model produces a better model specification due to the higher $\rho^2(0)$ and $\rho^2(c)$ values. Based upon the higher $\rho^2(0)$ and $\rho^2(c)$ values, it is concluded that the MNL model estimates in Base Model 3 provide a better model specification for the results at stage three (see Table 8-15).

The coefficients estimated by the nested models for wait-time saved, cost and information for the different options examined at stage three were all found to be significant and to have the same coefficient signs as those estimated in base model 3 (see Table 8-15). This consistency in the estimates between the Base Model and the nested models is also found in the coefficient values for the explanatory variables examined at this third stage.

Table 8-15 Nested model results – stage three

Variables		Base model 3	NM7	NM8	NM9
		Stage Three			
Internet	Wait-time saved	-0.022 (-3.5)**	-0.051 (-1.9)*	-0.035 (-4.0)**	-0.074 (-6.7)**
	Cost	-0.011 (-13.6)**	-0.024 (-9.4)**	-0.056 (-8.4)**	-0.024 (-14.0)**
	Information	-0.814 (-7.6)**	-0.641 (-4.2)**	-0.927 (-8.1)**	-1.027 (-8.1)**
SMS	Wait-time saved	-0.024 (-3.4)**	-0.107 (-2.1)*	-0.081 (-5.2)**	-0.041 (-7.2)**
	Cost	-0.044 (-7.6)**	-0.039 (-8.1)**	-0.051 (-2.8)**	-0.107 (-5.1)**
	Information	-1.311 (-7.2)**	-0.874 (-7.9)**	-1.027 (-3.3)**	-1.403 (-5.9)**
Call Centre	Wait-time saved	-0.020 (-8.3)**	-0.018 (-5.7)**	-0.054 (-6.7)**	-0.141 (-7.0)**
	Cost	-0.037 (-8.7)**	-0.051 (-2.7)**	-0.118 (-4.2)**	-0.071 (-6.2)**
	Information	-0.782 (-7.9)**	-0.941 (-6.2)**	-0.803 (-5.1)**	-1.147 (-5.4)**
CAR (2)		-0.147 (-2.4)*	-0.215 (-3.1)**	-0.098 (-1.9)*	-0.117 (-2.7)**
BUS (1)		0.315 (7.0)**	0.178 (5.1)**	0.724 (4.5)**	0.465 (6.1)**
GENDER (3)		-0.162 (-5.4)**	-0.078 (-1.9)*	-0.289 (-4.7)**	-0.178 (-2.1)*
AGE (2)		-0.267 (9.3)**	-0.451 (7.4)**	-0.148 (4.2)**	-0.647 (7.8)**
INCOME (2)		0.173 (5.2)**	0.210 (1.9)*	0.218 (4.6)**	0.314 (3.7)**
CARAV (1)		-0.144 (-2.1)*	-0.478 (-3.4)*	-0.478 (-4.8)**	-0.541 (-2.7)**
ZONE (2)		0.477 (2.9)**	0.609 (4.1)**	0.381 (3.4)**	0.618 (5.2)**
CONMOB (3)		0.033 (2.1)*	0.171 (4.8)**	0.271 (5.7)**	0.719 (4.6)**
FIXW (2)		-0.175 (-4.0)**	-0.209 (-5.7)**	-0.414 (-6.9)**	-0.521 (-7.8)**
FRUST (1,2)		0.010 (2.6)**	0.147 (1.9)*	0.081 (1.9)*	0.198 (4.2)**
CONVN1 (1,2)		0.024 (9.0)**	0.417 (8.1)**	0.187 (4.9)**	0.247 (1.9)*
PERSEP (3)		-0.018 (-3.8)**	-0.081 (-2.7)**	-0.107 (-7.1)**	-0.087 (-5.2)**
USE3 (2)		-0.036 (-2.0)*	-0.118 (-4.1)**	-0.054 (-2.7)**	-0.132 (-7.0)**
LOGSUM			0.784 (2.8)**	0.842 (2.7)**	0.697 (3.10**
N		1980	1980	1980	1980
$\rho^2(0)$		0.296	0.274	0.287	0.281
$\rho^2(c)$		0.267	0.258	0.247	0.241

(1) Internet (2) SMS (3) Call centre
* Significant at the 95% confidence level
** Significant at the 99% confidence level

8.7 SUMMARY

The purpose of this chapter is to combine the results from chapters 6 and 7 and produce behavioural outputs from the utility estimates. The behavioural outputs that can be produced from discrete choice models are willingness to pay/marginal rates of substitution and elasticity estimates, these are presented in this chapter.

In order to produce elasticity and willingness to pay amounts for the different modes of transport used, segmented models were produced and presented in this chapter. The utility coefficients produced for stage one demonstrates that bus users derive the highest benefit from real-time public transport information at this stage, followed by rail and car users

respectively. The utility derived at this stage was highest from SMS, followed by the internet and call centre.

At the second stage respondents' utility was found to be highest for passenger information display followed by SMS and call centre. As with the fist stage the model estimates demonstrated that bus users were found to derive the highest utility from real-time public transport information, followed by rail and car users. Finally at the third stage, utility was found to be highest from SMS, followed by call centre and the internet. Bus users were again found to derive the greatest benefit from real-time transport information.

The direct elasticity of choice estimates produced results similar to that of the utility coefficients. The findings show that bus users had the highest positive wait-time saved and lowest negative cost elasticities. This demonstrates that bus users derive a greater benefit from real-time public transport information compared to the other user groups.

A comparison of the elasticity estimates among the choices made at each stage demonstrates that at the first stage users derive the most benefit from SMS. At stage two, the elasticity estimates show that respondents derive the most benefit from passenger information displays. As with the first stage the elasticity estimates show that respondents obtain the greatest benefit from SMS at the third stage.

The final behavioural output to be examined in this chapter was the willingness to pay for real-time public transport information. With willingness to pay estimates as with the utility and elasticity estimates bus users were found to yield the greatest benefit from real-time transport information, as they were found to be willing to pay the most for this information. At the first stage respondents were found to be willing to pay the most for SMS, followed by the internet and a call centre. At the second stage the highest willingness to pay amounts were found for passenger information display. At stage two the second highest willingness to pay amounts were found for SMS with call centre estimated to have the lowest values. The willingness to pay amounts for stage three demonstrated that respondents' values were highest for SMS, followed by call centre and the internet.

The tests for violations of the IIA property demonstrated that this property holds allowing nested model structures to be examined. The nested model structures estimated

demonstrated that for each of the stages examined there was no correlation among the unobserved components of utility for each of the models examined. However the nested models produced did not improve on the model performance.

9 CONCLUSIONS

9.1 INTRODUCTION

The main objective of this research was to examine what types of real-time public transport information individuals require over three stages of a public transport trip. Preferences for such information have been examined using a stated choice approach, utilising discrete models to measure these preferences, the results of which are presented in this thesis. This chapter concludes the thesis by addressing the main findings of the research, the impacts and the limitations of this research and areas for further research.

9.2 RESPONDENTS REQUIREMENTS FOR REAL-TIME PUBLIC TRANSPORT INFORMATION

The initial research objective in the introduction chapter asked *when presented with an option between several methods of obtaining real-time public transport information, which option do individuals derive the greatest benefit from?* In each of the models presented in chapters 6, 7 and 8 this has been the primary task of the research.

The answers to the first research objective are complemented with the outcomes of the second research objective, which examined how the *choice of real-time public transport information option differed across the three different stages of a public transport trip examined.*

The findings for the first stage of a respondent's trip, when at home planning a public transport trip to get to work, demonstrate that respondents derive the greatest benefit from using an SMS. This conclusion was reached having examined the MNL model estimates, the elasticity of choice results and the willingness to pay amounts estimated for the results at the first stage. Based upon the model results, respondents were found to derive a greater benefit from the internet compared to a call centre.

The results at the first stage demonstrate that convenience and ease of access play a part in demanding real-time public transport information. The SMS option would be considered to be the quickest and most convenient for accessing information. It can be concluded that

while planning a trip from home, this is one of the key considerations individuals have when choosing how to obtain public transport information.

Whilst waiting at their bus stop/train station, at the second stage, respondents were found to derive the greatest benefit from using a passenger information display. The willingness to pay, the elasticity and the MNL models all demonstrated that respondents were the most likely to choose a passenger information display at the second stage to obtain real-time public transport information. The model estimates and the willingness to pay amounts found that SMS was respondents' second choice for receiving real-time public transport information, followed by the call centre option. The preferences for real-time information at the second stage demonstrate that respondents at this stage, as with the first stage indicated that the more convenient options of passenger information display and SMS have a higher preference rating with respondents.

The preferences for accessing real-time information at the final stage, when respondents were on their return trip from work to home, follow a similar pattern to the preferences displayed at the first stage. Respondents were found to yield the most utility at this stage from accessing real-time public transport information via an SMS, followed by using a call centre and finally the internet. As with the two previous stages, the option that individuals were found to derive the most benefit from, would be generally considered to be the most convenient and efficient method of receiving real-time public transport information.

9.3 Respondent Characteristics that Impact Upon the Utility Derived from Real-Time Information

The final research question which is addressed in this thesis addresses *what factors impact upon the choice of real-time public transport information option.* This research question has been used in this thesis to build a profile of the type of individual and in what situation he/she would use real-time public transport information.

As one might expect, those respondents who currently use public transport were found to derive a greater benefit from real-time public transport information, specifically bus users were found to be willing to pay the most for real-time public transport information followed by rail and car users. The higher utility derived by bus users was found at all

three of the stages examined in this thesis. This higher preference may be attributed to the perceived lack of certainty and the poor at-stop information indicated by respondents.

Several aspects of public transport trips, such as multi-stage trips, wait time and distance were also found to impact upon the utility derived from real-time public transport information. The model estimates found that those respondents that took more than one mode of public transport were found to derive a higher utility from real-time public transport information. This finding would seem to make intuitive sense as those individuals taking more than one mode of public transport would need to have information on all modes used in the one trip. The findings related to the distance travelled by public transport demonstrated that as the distance travelled increased, so too did the utility derived from real-time public transport information.

The reported wait-time at public transport stop/station was found to impact upon the utility derived from real-time public transport information. The model estimates demonstrated that as the reported wait-time increases, so too does the benefit derived from real-time information.

The estimates for gender demonstrated that at the first stage males were found to derive a higher benefit from real-time public transport information at the first stage. At stages two and three females were found to derive a higher utility compared to males at these stages from accessing real-time public transport information. The age of a respondent was another variable examined for a significant impact upon utility. The results at all three stages found that younger respondents were more likely to derive a higher utility from real-time information. Income was found to have a positive effect on utility, demonstrating that as income increases so too does the utility derived from real-time information.

Location variables were examined to ascertain what impact the geographical location of the respondent has upon the utility derived from real-time information. The results demonstrate that as the distance travelled increases, so too does the utility derived from real-time information. The proximity of the respondents to high quality public transport such as heavy/light rail and bus corridors were also examined to determine if individuals who reside close to a one of these modes derived the same utility as those who do not. The model estimates found that respondents who do not live near a heavy/light rail station were more likely to derive a higher utility from real-time information, at each of the stages

examined. Those respondents living in close proximity to a bus corridor at the first stage were found to derive a greater benefit from real-time information than those who do not. However, at the second stage those respondents who live near a high quality bus corridor were found to derive a lower utility than those who do not live close to such a service.

These findings demonstrate that while waiting at a bus stop/ rail station respondents who live close to a high frequency service derive a less utility than those who live close to a low frequency service. Therefore, it can be concluded that respondents who use a low frequency public transport service derive a higher utility from real-time information. This set of findings provides an interesting insight as to how bus users view the need for real-time public transport information. The results in this thesis would seem to suggest that when bus users who use a service that has access to a priority corridor and is a high frequency service, they do not demand real-time information as much as those individuals who use a service without these attributes. This finding indicates that investment in real-time information displays at stops/stations should be focused on lower frequency routes with no access to priority corridors to maximise the benefit of such services.

Work schedules and departure times to work were also examined to ascertain if they impact upon the likelihood that respondents would derive utility from real-time public transport information. The findings demonstrate that individuals who have a flexible start time, and depart later to work are more likely to derive a greater utility from real-time information. These results indicate that individuals that have a flexible departure time from home, and therefore have less routine in their journey derive a higher utility from real-time information. This finding would seem to make intuitive sense as individuals have less regularity in their trip to work and require more information on their public transport trip.

The impacts of perceptions and attitudes to public transport have been examined in this thesis. Frustration with public transport was measured by asking respondents several questions on aspects of a public transport service which may cause frustration. These aspects were summed into a single variable to provide an indication of overall frustration with public transport. The model estimates found for each of the stages examined that as frustration with public transport increases so too does the utility derived from real-time public transport information. Levels of frustration with public transport would be expected to reduce with the use of real-time information, as the uncertainty of arrival time would be

reduced. This finding would seem to make intuitive sense. Therefore, it can be concluded that as frustration with public transport increases, so too does the benefit derived from real-time public transport information.

Convenience levels with using the various methods of accessing real-time information such as a public transport web-site, SMS, a passenger information display and a call centre were measured to ascertain levels of convenience impact upon the utility derived from real-time information. The findings show that those individuals, who find it convenient to access real-time public transport information using the different methods examined in this thesis, were more likely to derive a greater benefit from real-time public transport information.

9.4 Impact of the Research

The research presented in this thesis contributes to the field of research conducted upon the uses and benefits of real-time public transport information in several ways. The analysis of the preferences between real-time public transport information options is one of the main contributions to knowledge achieved by this thesis. Such an analysis has not been completed using a stated preference approach to evaluate preferences between real-time information options. The evaluation of preferences for real-time information across different stages of a public transport further strengthens this contribution to knowledge. By conducting an analysis between options and across stages of a public transport trip, this research provides a detailed account of the method individuals require to receive public transport information across their journey to and from work. This then provides a profile of the information required at each stage, and the likely demand for such information.

The analysis of the preferences for real-time information is supplemented by examining how a number of other factors ranging from socio-economic to attitudes to public transport, impact upon the choices between real-time information options. The analysis of these factors enhances the analysis between choices and identifies the types of individuals and the factors which impact upon their choice of real-time information option. The findings from examining which factors impact upon the choice and the benefit derived from real-time information option, adds to the field of research conducted to date on examining what influences the use of real-time public transport information.

The results presented in this thesis also have very practical policy implications, as one of the main focuses of the findings is to provide economic valuation of this information in the form of willingness to pay amounts. These amounts demonstrate the economic benefits which could be accrued by implementing a system of real-time public transport information. The findings also demonstrate where such information systems could yield the most benefit among users, for example less frequent bus service users were found to benefit more from real-time information. As the results presented focus upon the choice between options of real-time information options, policymakers could use the findings to inform investment priorities in real-time information, based upon the benefits derived from such systems.

9.5 Critical Assessment

Although there are many areas in this thesis which have added to the body of research conducted on the uses and benefits of real-time public transport information, there are a number of limitations to the research which have been summarised below.

The use of the internet as a tool to collect survey responses' inevitably leads to the argument of bias in the data collected, as not all members of the population have access to the internet. As discussed in chapter 3, there were several reasons for choosing the internet as the means of collecting survey responses, which varied from time and resource considerations to targeting a population of interest. While these considerations have been justified in the thesis, some may argue that the sample collected for this research is not representative of the population.

The scenarios examined focused upon ascertaining respondents public transport information requirements travelling to work on a daily basis. The absence of other types of trips such as recreation, shopping and leisure trips can be seen as a limitation of the research in that individuals may have different real-time public transport information requirements, dependant upon their trip purpose.

Finally, the approach used to evaluate the use of real-time public transport information in this thesis has been the stated preference approach. Many have criticised this approach as it examines what individuals say they will do as opposed to what they actually do. However, given that the real-time public transport information options available in Dublin

at the time of this study did not include those examined in the stated choice scenarios; the stated preference approach was deemed to be the most suitable method of examining preferences for these real-time information options. This conclusion was drawn from the many examples in the literature where stated preference methods have been used to evaluate many hypothetical transport scenarios such as new modes of transport, congestion charging and real-time public transport information, to mention a few examples.

9.6 AREAS FOR FURTHER RESEARCH

Possible areas for further research could focus on sampling different sections of the population and changing the scenarios presented to respondents. The approach applied in this thesis could be used to target subsections of the population which may be of particular interest to transport planners. Such subsections could include the physically impaired, the elderly, disadvantaged groups and individuals living in rural or remote areas. Using any of these subsections to model the perceptions and the willingness to pay for real-time public transport information would provide detailed insights as to what specific information these groups require.

An examination of how visitors to a city perceive the quality of public transport information available, and its resulting impact upon them using public transport during their stay would also be another interesting area for further research. Such a study could show how accessible the city is for those who are not familiar with the public transport network.

Changing the scenarios examined would be another area for further research. One such scenario could examine the impact of non-work trips on the demand for public transport information. Examining trips which are not taken as frequently, where the respondent may not be familiar with the public transport service and this service may not be as frequent, could produce different results compared to the ones presented in this thesis.

REFERENCES

Abdel-Aty, M. A. (2001) Using ordered probit modelling to study the effect of AITS on transit ridership. *Transportation Research Part C 9* pp 256-277.

Abdel-Aty, M., Abdalla. M. F. (2004) Modelling drivers' diversion from normal routes under AITS using generalized estimating equations and binomial probit link function. *Transportation 31* (3), pp 327-348.

Accent Marketing. (1995a) Uxbridge Road Countdown Report, London Transport Buses.

Accent Marketing. (1995b) Nag's Head Countdown Phase I Bus User Fieldwork, London Transport Buses.

Accent Marketing. (1996) Nag's Head Countdown, London Transport Buses.

Adelaide Metro. (2004a) [online], Available from: www.adelaidemetro.com.au/cgi-bin/Press.pl?unique_id=PR4071f65fd52f [Accessed: 19th March 2004].

Adelaide Metro (2004b) [on-line], Available from: http://www.adelaidemetro.com.au/guides/adfree.html [Accessed: 19th March 2004]

Al-Deek. H. M., A. J. Khattak., and P. Thananjeyan. (1998) A combined traveller behaviour and system performance model with advanced traveller information systems. *Transportation Research Part A,* Vol 32, No. 7, pp 479-493.

Anderson. S.E. and B. M. Gansnder. (1995) Using e-mail surveys and computer monitored data for studying computer mediated communication systems, *Social Science Computer Review*, Vol 13, pp 313-346.

Aventze, T.A., H. J. P. Timmermans. (2005) Representing mental maps and cognitive learning in micro-simulation models of activity-travel choice dynamics. *Transportation*, 32 (4) pp 321 – 340.

Bateman, I (2002) *Economic valuation with stated preference techniques: a manual.* Great Britain. Dept. for Transport.

Beirão. G. and J. A. Sarsfield Cabral. (2007) Understanding attitudes towards public transport and private car: A qualitative study. *Transportation Policy* [IN PRESS].

Baker. M. J. (1995) *Research for Marketing.* London: Macmillan.

Ben-Akiva, M and S. R. Lerman. (1985) *Discrete Choice Analysis: Theory and Application to Travel Demand*, MIT Press, USA.

Ben-Akiva, M and M. Bierlaire (1999) Discrete choice methods and their applications to short-term travel decisions, in R.Hall(ed.), *Handbook of Transportation Science, International Series in Operations Research and Management Science*, Vol. 23, Kluwer

Berfot. J.L and C. R. McClure. (1996) Electronic surveys: methodological impacts for using the world wide wed to collect survey data, *ASIS'96 Proceedings of the 59th ASIS Annual Meeting*, pp 173-185.

Baltes, M. (2003) Statistical Estimation of the Importance Placed on Specific Elements of Bus Rapid Transit by Customers. *82nd Annual Meeting Transportation Research Board. (CD-ROM), Washington, D.C.*

Bogers. E. A.I. A., F. Viti and S. P. Hoogendoorn. (2004) Joint Modelling of AITS, Habit and Learning Impacts on Route Choice by Laboratory Simulator Experiments. *84th Annual Meeting of the Transportation Research Board, (CD-ROM),* Washington, D.C.

Brazell, J. and J. Louviere. (1997) Respondents' help, learning and fatigue. *INFORMS Marketing Science Conference 1997*, University of California at Berkeley.

Brennan. M and J. Hoek. (1992) The Behaviour of Respondents, Non-respondents, and Refuses Across. *The Public Opinion Quarterly*, Vol. 56, No. 4 pp. 530-535.

Brown. S. (1987) Drop and Collect Surveys: A neglected research technique? *Marketing Intelligence and Planning*, 5(1), pp 19-23.

Buntine. C. K. Clean. (2003) Personal Mobility Services: A Transit Enhancements Alternative to the private automobile travel, *82nd Annual Meeting of the Transportation Research Board. (CD-ROM)*, Washington, D.C.

BVG, Berlin (2004) [online], Available from: www.bvg.de/plan/faq-sms.pdf [Accessed: 19th March 2004].

Carson, R. T., R, C, Mitchell, W. Hanemann, M. Kopp, J. Raymond, S. Presser, and P. A. Ruud (2004) Contingent Valuation and Lost Passive Use: Damages from the Exxon Valdez. *Discussion Paper 94-18, Resources for the Future*, Washington, DC.

Caulfield, B., and M. M. O'Mahony. (2003) Evaluating the success of Quality Bus Corridors in Dublin using an automatic License Plate Recognition System. *Transportation Research Record*, 1887, pp 195-204

Caulfield, B. and M. M. O'Mahony. (2004) The provision of on-street passenger information via real-time passenger information: a case study of Dublin. *International Road Transport Information and Control IEEE*, London

Caulfield, B, M.M. O'Mahony. (2007a) An examination of the public transport information requirements of users. *IEEE Transactions on Intelligent Transport Systems*, Vol. 8, No. 1.

Caulfield, B, M.M. O'Mahony. (2007b) The Impact of Trip Characteristics on the Willingness to Pay for Real-time Transit Information, [SUBMITTED TO] *The 87th Meeting of the Transportation Research Board*, Washington, D.C.

Caulfield, B., and M.M. O'Mahony. (2007c) The impact of geographic location on the utility derived from real-time public transport information, *10th International Conference on Competition and Ownership in Land Passenger Transport*, Hamilton Island, Australia.

Central Statistics Office. (2007) [online], Available from: http://www.cso.ie/pressreleases/prelcen02pser.html [Accessed 11th Febuary 2007].

Cervero. R. (2003) City CarShare First year travel demand impacts. *82nd Annual Meeting of the Transportation Research Board, (CD-ROM),* Washington, D.C.

Chatterjee, K. and M. McDonald. (2004) Effectiveness of Using Variable Message Signs to Disseminate Dynamic Traffic Information: Evidence from Field Trials in European Cities. *Transport Reviews*, Vol. 24, No. 5, pp 559-585.

Chorus. C. G., E.J.E. Molin, T.A. Arentze, S. P. Hoogendoorn, H. J. P. Timmermans and B. Van Wee. (2007) Validation of a multimodal travel simulator with travel information provision. *Transportation Research Part C* 15, pp 191-207.

Church, A. H. (1984) Estimating the effect of incentives on mail survey response rates: A meta analysis. *Public Opinion Quarterly*, Vol 57, pp 62-79.

Claycomb. C., S.S. Porter and C. L. Martin. (2000) Riding the Wave: Response Rates and the Effects of Time Intervals between Successive Mail Survey Follow-up Efforts. *Journal of Business Research*, Volume 48, Issue 2, Pages 157-162.

Cochran, W. G. (1977) *Sampling Techniques*, 3rd Edition, Wiley Series in Probability and Mathematical Statistics, Wiley & Sons.

CODE. (2000) Guidelines for Implementing Real-Time Information Projects for City-wide Public Transport, Prepared by the CODE Task Force formed after the first 'Traveller Inter-modality' CODE Workshop.

Commission for Communications Regulation. (2006) Quarterly Report July - September 2006, Commission for Communications Regulation. Dublin, Ireland.

Dessouky, M. M., R. Hall, L Zhang and A. Singh (2003) Real-Time Control of Buses for Schedule Coordination at a Terminal, Transportation Research, Part A: Policy and Practice , 37; 145-164.

de Leeuw, E. and M. Collins. (1997) Data collection methods and survey quality: An overview, in L.Lyberg, P.Biemer and M.Colins (eds) *Survey Measurement and Process Quality*, New York: Wiley, pp. 199-220.

DeSalle, B. R. and A. P. Tarko. (2003) Quality of Highway Safety Information Collection with an Internet-Based Survey Tool. *82nd Annual Meeting of the Transportation Research Board, (CD-DOM),* Washington D.C.

Dillman, D.A. (2000) *Mail and Internet surveys: the tailored design methods.* Second edition. New York: John Wiley & Sons

Dublin Bus (2003) [online], Available from: http://www.dublinbus.ie/projects/real_time_passenger_information_system.asp [Accessed: 20th May 2003].

Dublin Bus. (2004) [online], Available from: www.dublinbus.ie/home/bus_text.asp [Accessed: 20th March 2004].

Dublin Bus. (2006) Dublin Bus Annual Accounts 2005, Dublin Bus.

Dublin Bus. (2007) [online], Available from: http://www.dublinbus.ie/home/bus_text.asp [Accessed: 14th May 2007].

Dublin Transportation Office. (2001) A Platform for Change, Dublin.

Dublin Transportation Office. (2002) QBC Report to QBC Committee/ Steering Committee, Dublin, Ireland.

Dublin Transportation Office. (2004) Report to the DTO Real Time Public Transport Information Committee: A Strategy for Integrated Public Transport Information, including Real Time, in the Greater Dublin Area, Dublin Transportation Office.

Dziekan. K. and K. Kottenhoff. (2007) Dynamic at-stop real-time information displays for public transport: effects on customers. *Transportation Research Part A*, Volume 41, Issue 6, pp. 489-501.

Eisinger. R. A., W.P. Janicki, R.L. Stevenson and W.L. Thompson. (1974) Increasing Returns in International Mail Surveys. *The Public Opinion Quarterly*, Vol. 38, No. 1., pp. 124-130.

Emmerink . R. H. M., P. Nijkamp., P. Rietveld and J. N. Van Ommeren. (1996) Variable Message Signs and Radio Traffic Information: An Integrated Empirical Analysis of Drivers' Route Choice Behaviour. *Transport Research Part A* No. 2 pp 135-153.

Englisher, L., R. Juster., S. Bergman., and A. Willson. (1997) Promoting advanced traveller information systems among cellular and land-line phone users. *Transportation Research Record,* 1588. pp 63-69.

Farag. S., Dijst. M. and M. Lanzendof. (2003) Exploring the use of e-shopping and its impacts on personal travel behaviour in the Netherlands. *82nd Annual Meeting of the Transportation Research Board, (CD-ROM)*, Washington, D.C.

Fayish. A. C. and P.P. Jovanis. (2004) Usability study of state wide web-based roadway weather information systems. *83rd Annual Meeting of the Transportation Research Board, (CD-ROM),* Washington, D.C.

Fox. C.M., K. L. Robinson, and D. Boardley. (1998) Cost effectiveness of follow-up strategies in improving the response rate of mail surveys. *Industrial Marketing Management,* 27(2), pp 127-133.

Fujii, S, and R. Kitamura. (2003) What does one-month free bus ticket do to habitual drivers? *Transportation* 30 pp 81-95.

Gardner, B. and C. Abraham. (2007) What drives car use? A grounded theory analysis of commuters' reasons for driving. *Transportation Research Part F*, pp 187-200.

Geweke. S. and D. Zumkeller. (2006) A simulation game to explore the effects of information on traveller behaviour. *85th Annual Meeting of the Transportation Research Board, (CD-ROM),* Washington, D.C.

Gothenburg Traffic Information Centre. (2002) Effects of real-time information in Gothenburg, 19th GoTiC Report, Gothenburg, Sweden.

Goulias. K. G., K. Tae-Gyu., and O. Pribyl. (2004) A Longitudinal Analysis of Awareness and Use for Advanced Traveller Information System. *Intelligent Transportation Systems*, 8:3-17.

Grotenhuis, J.W., B. W. Wiegmans, and P, Rietveld. (2007) Desired quality of integrated multimodal travel information in public transport: Customer needs for time and effort savings. *Transport Policy*, Vol 14, Issue 1, pp 27-38.

Hague Consulting Group (2004) Alogit Users Guide, Version 3.2.

Hall. L. and S. Bowling, and J. C. Asher. (2000) ARTIMIS Telephone Travel Information Service: Current use patterns and user satisfaction. *Transportation Research Record.* No. 1739, pp 9-14.

Hato, E., Y. Asakura, M. Kashiwadani, and S. Katsuki. (2000) The Simulation study of Information Strategies using the computer data collection on drivers' response to AITS. *Fifth International Conference on Urban Transport and the Environment for the 21st Century.*

Hato, E. M. Taniguchi, Y. Sugie., M. Kuwahara and H. Morita. (1999) Incorporating an information acquisition process into a route choice model with multiple information sources. *Transport Research Part C*, pp 109-129.

Hayslett. M.M and B. M, Wildermuth. (2004) The Relative effectiveness of web-based versus paper surveys. *Library and Information Science Research* 26, pp73-95.

Hendricks. S. J. (2004) Results of the 2003 TMA Survey. *83rd Annual Meeting of the Transportation Research Board, (CD-ROM),* Washington, D.C.

Hensher, D. A., J. M. Rose, and W. H. Greene. (2005) *Applied Choice: A Primer.* Cambridge University Press, New York.

Horst, D. E. and D. Ettema (2004) Modelling departure time choice in the context of activity scheduling behaviour. *Transportation Research Record*, No 1893, pp39-46

Hickman, M. D. and N. H. M. Wilson. (1995) Passenger Travel time and path choice implications of real-time transit information. *Transportation Research Part C* No.4 pp 211-226.

Hickman, M. (2003) Robust Passenger Planning Using Transit AVL Data. *82nd Annual Meeting Transportation Research Board, (CD-ROM),* Washington, D.C.

Hine, J. and J. Scott. (2000) Seamless travel: users' views of the public transport journey and interchange. *Transport Policy,* Vol 7, pp 217-226.

Humphreys. I. and S. Ison. (2003) Ground Access Strategies: Lessons from UK Airports. *82nd Annual Meeting of the Transportation Research Board, (CD-ROM),* Washington, D.C.

Iragüen, P and J. D. Ortúzar. (2004) Willingness-to-pay for reducing fatal accident risk in urban areas: an Internet-based Web page stated preference survey. *Accident Analysis & Prevention*, Volume 36, Issue 4, pp 513-524.

Irish Rail. (2004) [online], Available from: www.irishrail.ie/dart/news_centre/general_news.asp?action=view&news_id=117 [Accessed: 19th March 2004].

Irish Rail. (2006) Irish Rail Annual Accounts - 2005, Dublin, Ireland.

Irish Rail. (2007) [online], Available from: http://www.iarnrodeireann.ie/news_centre/general_news.asp?action=view&news_id=71 [Accessed: 11th May 2007].

James. J.M and R. Bolstein. (1990) The Effect of Monetary Incentives and Follow-Up Mailings on the Response Rate and Response Quality in Mail Surveys. *The Public Opinion Quarterly,* Vol. 54, No. 3., pp. 346-361.

James. J.M and R. Bolstein. (1992) Large Monetary Incentives and Their Effect on Mail Survey Response Rates. *The Public Opinion Quarterly*, Vol. 56, No. 4, pp 442-453.

Johnson R.F. and W.H. Desvouges (1997) Estimating stated preferences with rated-pair data: environmental, health, and employment effects of energy programs, *Journal of Environmental Economics and Management* 34, pp. 79–99.

Kenyon. S. and G. Lyons. (2003) The Value of integrated multimodal traveller information and its potential contribution to modal change. *Transportation Research Part F6,* pp 1-21.

Khattak, A. J., F. S. Koppelman, and J. L. Schofer. (1993) Stated Preference for investigating commuters' diversion propensity. *Transportation 20 (2),* pp 107-127.

Khattak, A., A. Polydoropoulou., and M. Ben-Akiva. (1996) Modeling Revealed and Stated Pretrip Travel Responses to Advanced Traveller Information Systems. *Transportation Research Record*, No. 1537, pp 46-54.

Khattak. A. J., Y. Yim., and L. S. Prokopy. (2003) Willingness to pay for travel information. *Transport Research Part C* 11, pp 137 – 159.

Killi, M and H. Samstad. (2003) Travellers' valuation of traffic information based on work journeys, Norwegin Institute of Transport Economics.

Kinnear, T.C. and J. R. Taylor. (1991) *Marketing Research: An applied approach* (4th ed) New York: McGraw-Hill.

Krann, M., H. Mahmassani, and N. Huynh. (1999) Interactive survey approach to study traveller responses to ATIS for shopping trips. *78th Annual Meeting of the Transportation Research Board, (CD-ROM),* Washington, D.C.

Kronborg, P. A. Lindkvist, and E. Schelin. (2002) Fungera transportinformatik I prakitken? 14 fallstudier I syfte att undvika misstaf I framtiden (No. 2002:18) TFK Stockhlom

Lancashire County Council .(2004) [online], Available from: http://www.lancashire.gov.uk/environment/traveline/index.asp [Accessed 12th March 2004].

Lehtonen, M. R, Kulmala. (2001) The Benefits of a Pilot Implementation of Public Transport Signal Priorities and Real-Time Passenger Information, VTT Department of Transport.

Levinson, H., S. Zimmerman, J. Clinger and J. Gast. (2003) Bus Rapid Transit, Synthesis of Case Studies. *82nd Annual Meeting of the Transportation Research Board, (CD-ROM),* Washington D.C.

Liping Fu, L. Quing, and P. Calamai (2003) A Real-Time Optimization Model for Scheduling of Transit Operations. *82nd Annual Meeting of the Transportation Research Board, (CD-ROM),* Washington D.C.

Lo. H. K. and W. Y. Szeto. (2004) Modelling advanced traveller information services: static versus dynamic paradigms. *Transportation Research Part B.* pp 495-515.

Lotan. T. (1997) Effects of familiarity on route choice behaviour in the presence of information. *Transportation Research Part C,* Vol 5, No. 3/4. pp 225-243.

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

Liu, P., R.D. Cashin. And J. X. Chen (2000) Developing the advance public transportation systems technologies in Los Angeles: A summary and analysis. *Journal of Advanced Public Transportation,* Vol 36, No. 1.

Maged D., R. Hall, L. Zhang, and A. Singh. (2003) Real Time Control of buses for schedule co-ordination at a terminal, *Transportation Research Part A,* Volume 37, Issue 2, pp 145-164.

Mahmassani, H. S., N. Huynh., K. Srinivasan, and M, Kraan. (2001) Trip maker choice behaviour for shopping trips under real-time information: Model formulation and results of stated-preference internet-based interactive experiments, *80th Annual Meeting of the Transportation Research Board, (CD-ROM),* Washington, D.C.

Marca, J. E. (2003) The Design and implementation of an on-line travel and activity survey. *82nd Annual Meeting of the Transportation Research Board, (CD-ROM),* Washington, D.C.

Mason R. D., D. A. Lind and W. G. Marchal (2000) *Statistical Techniques in Business and Economics*, 10th edition, McGraw-Hill International Edition.

Metlink, Melbourne. (2004) [online], Available from: www.metlinkmelbourne.com.au/timetables/sms_timetables.php [Accessed: 19th March 2004].

Mitretek Systems. (2001) Intelligent Transport Systems Benefits, 2001 Update, United States Department of Transportation.

Mittlehammer, R. C., G. G. Judge, and D. J. Miller. (2001) Econometric Foundations, Cambridge University Press, Cambridge, United Kingdom.

Moiln, E. J.E. and H. J. P. Timmermans. (2006) Traveller expectations and willingness to pay for Web-enabled public transport services. *Transportation Research Part C* 14, pp 57-67.

Molin, E. and H. Timmermans. (2002) Travellers' Stated Choices for Public Transport Information Systems on the Internet. *81st Annual Meeting of the Transportation Research Board, (CD-ROM),* Washington, D.C.

Moiln. E. and C. Chorus. (2004) Willingness to Pay for personalised dynamic public transport systems. *83rd Annual Meeting of the Transportation Research Board, (CD-ROM),* Washington, D.C.

Molin, E., C. Chorus. and R. van Sloten. (2007) The Need for Advanced Public Transport Information Services when Making Transfers. *86th Annual Meeting of the Transportation Research Board, (CD-ROM),* Washington, D.C.

Muni, San Francisco. (2004) [on-line] http://www.sfmuni.com/contact/phone.htm.

MVV, Munich. (2004) [online], Available from: www.mvv-muenchen.de/de/home/fahrgastinformation/efa/efa-services/wap/sms/index.html#4 [Accessed: 19th March 2004].

Newell, G.F. (1974) Control of Pairing of vehicles on a public transport route, two vehicles one control point., *Transportation Sicence*, Vol 8, No3.

Nijkamp, P., G. Pepping, D. Banister. (1996) Telematics and Transport Behaviour, Chapter 7: Public Transport Information Systems: An English Case Study. Springer, Heidelburg.

Nottingham County Council, (2004) [online], Available from: www.itsnottingham.info/ttptnews.htm#text [Accessed 20th March 2004].

Pattison, T and C. Bushell. (2002) Jane's Urban Transport Systems, Mary Webb and Jackie Clarke.

Peng. Z. and O. Jan. (1999) Assessing Means of Transit Information Delivery for Advanced Public Transportation Systems. *Transportation Research Record*, No. 1666, pp 92-100.

Peirce, S. and J. Lappin. (2004) Why don't people use advanced traveller information? Evidence from the Seattle area. *84th Annual Meeting of the Transportation Research Board, (CD-CROM),* Washington, D.C.

Polak, J., P. and P. Jones. (1993) The acquisition of pre-trip information: a stated preference approach. *Transportation 20*, pp 179-198.

Polydoropoulou, A., D. Gopinath and M. Ben-Akiva. (1997) Willingness to pay for advanced traveller information systems: SmarTraveler case study. *Transportation Research Record*, Vol. 1588, pp 1-9.

Pudney, S. (1989) *Modelling Individual Choice, The Econometrics of Corners, Kinks and Holes*, Basil Blackwell Ltd.

Railway Procurement Agency. (2006) Railway Procurement Agency Annual Accounts 2005, Dublin, Ireland.

Raub. T. (2003) Towards a better understanding of traveller information. *82nd Annual Meeting of the Transportation Research Board, (CD-ROM),* Washington, D.C.

Rideline, Auckland. (2004) [online], Available from: www.lgnz.co.nz/news/pr1080523799.html [Accessed: 19th March 2004].

RMTV Frankfurt. (2004) [online], Available from: http://www.rmv.de/coremedia/generator/RMV/NeuImRMVGebiet/inhalt=en.htm [Accessed: 19th March 2004].

Schafer, D.R and D.A. Dillman. (1998) The Development of a Standard E-mail Methodology: Results of an Experiment. *The Public Opinion Quarterly*, Vol. 62, No. 3, pp. 378-397.

Schlich, R., W. H. Axhausen. (2003) Habitual travel behaviour: evidence from a six-week travel diary. *Transportation 30*, pp 13-36.

Schweiger, C.L. (2003) Customer and media reactions to real-time bus arrival information systems, *Transportation Research Board,* No. 48, Washington, D.C.

SL Transport, Stockholm. (2004) [online], Available from: http://www.sl.se [Accessed: 19th March 2004].

Small, K.A. and C. Hsiao. (1985) Multinomial Logit specification tests. *International Economic Review,* 26, pp 619–627.

Smith, V.K. and W.H. Desvouges (1987) An empirical analysis of the economic value of risk changes. *Journal of Political Economy*, 95(1), pp 89-114.

Steer Davis Gleave. (1996) Bus Passenger Preferences, for London Buses, Steer Davis Gleave, London.

Stinson, M. A. and C. R. Bhat. (2004) An Analysis of the Frequency of Bicycle Commuting Using and Internet-Based Survey. *83rd Annual Meeting of the Transportation Research Board, (CD-ROM),* Washington, D.C.

Stradling, S, J, Anable, and M. Carreno. (2007) Performance, importance and user disgruntlement: A six-step method for measuring satisfaction with travel modes. *Transportation Research Part A,* Vol 41, Issue 1, pp 98-106.

Swait, J., and J. Louviere. (1993) The role of the scale parameter in the estimation and use of multinomial logit models. *Journal of Marketing Research* 30: pp 305-14.

Tam, M. L and W. H. Lam. (2005) Modelling the market penetration of personal public transport information systems in Hong Kong, *Journal of Intelligent Transportation Systems,* 9 (2): pp 81-89.

Turnquist, M. A. (1978) A model for investigating the effects of service frequency and reliably ob bus passenger waiting times. *Transportation Research Record No.* 663, pp 108-119.

Transit Cooperative Research Program (1997) AVL Systems for Bus Transit, A Synthesis of Transit Practice. *Transportation Research Board, National Research Council*, Washington, D.C.

Transport for London. (2004a) [online], Available from: http://alerts.tfl.gov.uk/ [Accessed 20th March 2004].

Transport for London. (2004b) [online], Available from: http://www.tfl.gov.uk/tfl/ftt_tic_products.shtml [Accessed 21st May 2004].

Train, K, Discrete Choice Methods with Simulation, Cambridge University Press, 2003

Van der Horst. R. S. N. and D. Ettema. (2005) Use of travel information and effects on mode choice for recreational trips. *84th Annual Meeting of the Transportation Research Board, (CD-ROM),* Washington, D.C.

Västtrafik. (2003) [online], Available from: http://www.vasttrafik.se/eng/internet.aspx?desktop=3&language=1053&menu=1 [Accessed: 11th November 2003].

VL, Vienna. (2003) [online], Available from: http://www.wienerlinien.at/wl/wlinien/jsp/content/item_detail.jsp?BV_Session [Accessed: 11th November 2003].

Wafaa, S and S, Farrell. (2005) Implications of congestion charging for departure time choice: Work and non-work schedule flexibility. *Transportation Research Part A,* Vol 39, Issues 7-9.

Wall, G. and M. McDonald. (2007) Improving bus service quality and information in Winchester. *Transport Policy*, Vol 14, Issue 2 , pp 165-179.

Wardman, M. J. Hine., and S. Stradling. (2001) Interchange and travel choice. Vol 1. For the Scottish Executive Central Research Unit.

Wardman. P. (1994) Passenger Information at Bus Stops, report on monitoring studies of route 18 demonstration, London Transport Planning.

Warman, P. (2003) Measured Impacts of Real-time control and information systems for bus services, Transport Direct, Department for Transport.

Warriner. K., J.Goyder, H. Gjertsen, P.H. and K. McSpurren. (1996) Charities, No; Lotteries, No; Cash, Yes; Main Effects and Interactions in a Canadian Incentives Experiment. *The Public Opinion Quarterly*, Vol. 60, No. 4, pp. 542-562.

Watters, P. M. M. O'Mahony and B. Caulfield. (2006) Response to cash outs for work place parking and work place parking charges, *Transport Policy, Volume 13, Issue 6, November 2006, Pages 503-510.*

Weisberg, H. F., J.A. Krosnick. and B. D. Bowen. (1996) *An Introduction to Survey Research, Polling, and Data Analysis,* Third Edition, Sage Publications.

Wells, K., H. Lomimer, D. Kosiki, and C. Pansing. (2004) Assessing telecommuting supportive policy in Minnesota: Implications for travel behaviour, quality of life and organisational performance. *83rd Annual Meeting of the Transportation Research Board, (CD-ROM),* Washington D.C.

Witt, K. J. (1998) Best practices in interviewing via the internet, *Proceedings of Sawthooth Software Conference, Sawthooth Software, Inc, Sequim*, Washington, pp 15-37.

Whelan, G.A, J. P. Toner, P. J. Mackie, and J. M. Preston. (2002) Value for Public Support of the Bus Industry, Report to the Commission for Integrated Transport, London, England.

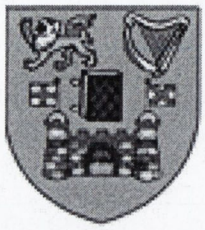
Wolinetz, L., A. J. Khattak. and Y. B. Yim. (2001) Why will some individuals pay for travel information when it can be free? Analysis of a Bay Area Traveler Survey. *Transport Research Record No.* 1759, pp 9-18.

Yim. Y, A. J. Khattak, and J. Raw. (2003) Traveller Response to New Dynamic Information Sources: Analysing Corridor and Area-wide Behavioural Surveys. *81st Annual Meeting of the Transportation Research Board, (CD-ROM),* Washington, D.C.

YTV Helsinki. (2004) [online], Available from: http://www.hel.fi/HKL/index_e.html [Accessed: 19th March 2004].

Zhang. L and D. Levinson. (2006) Determinants of Route Choice and the Value of Traveller Time Information: A Field Experiment. *85th Annual Meeting of the Transportation Research Board, (CD-ROM),* Washington, D.C.

APPENDIX 1: MAIN SURVEY



The Centre for Transport Research

The Department of Civil, Structural and Environmental Engineering

Trinity College Dublin

Passenger Information Survey

This is an important opportunity to put your views forward on public transport in Dublin, **whatever mode of transport you currently use.** Please answer the following questions and the survey will be collected in due course.

To show our appreciation, upon receipt of your completed questionnaire your contact details will be entered into a PRIZE DRAW, for one of three €50 gift vouchers for Arnotts.

With thanks in anticipation of your assistance

If you have any questions relating to this survey please contact
Brian Caulfield, (01) 6082537 or email: caulfieb@tcd.ie.

The Centre for Transport Research
The Department of Civil, Structural and Environmental Engineering
Trinity College Dublin
Dublin 2

Instructions for filling out this questionnaire

- We expect that this survey will take about 15 minutes to complete.
- There are no right or wrong answers so please express your own opinion, but it is important for the research that you fill out all of the survey.
- Partially completed surveys cannot be used, and they will not be entered into the prize draw.

Section One: Your trip to work

1.1 Please write the name of the company you currently work for _____

And the location _____

1.2 How often would you use each of the following modes of transport for your journey to and from work?

Please tick ✓the appropriate boxes

Mode of transport	Choice
Walk	☐
Cycle	☐
Car (Drive)	☐
Car (Passenger)	☐
Bus	☐
Luas	☐
DART	☐
Arrow	☐
Taxi	☐
Any other rail	☐

If you NEVER use public transport to get to work please skip to Question 1.5

1.3 If you use public transport, do you on average use more than one mode (for example Bus and Luas) to complete your journey to and from work each day?

☐Yes ☐No

If yes please indicate which modes you use in combination

Please tick ✓the appropriate boxes

Combinations of transport	Choice
Bus and Bus	☐
Bus and Luas	☐
DART and Bus	☐
DART and Luas	☐

1.4 When using public transport please indicate how long <u>on average</u> the following take;

Walking time to the stop/station from your home	minutes
Waiting time at your stop/station	minutes
Time spent on bus or train	minutes
Walking time from stop/station to your place of work	minutes

If you never use a car to get to work please skip to Question 1.6

1.5 When driving to work please indicate how long <u>on average</u> the following take;

Time spent driving to work	minutes
Time spent looking for parking	minutes
Walk time from your car to your place of work	minutes

1.6 Which of the following best describes your hours of work?

Please tick ✓the appropriate box

☐ Regular set hours
☐ Flexitime
☐ Shift work
☐ No set working hours

1.7 My usual start and finish times are;

Start time _____
Finish time _____

1.8 Which of the following Dublin areas is your home located in?

Please tick ✓the appropriate box

Area	Location of Home	Area	Location of Home
Dublin 1	☐	Dublin 14	☐
Dublin 2	☐	Dublin 15	☐
Dublin 3	☐	Dublin 16	☐
Dublin 4	☐	Dublin 17	☐
Dublin 5	☐	Dublin 18	☐
Dublin 6	☐	Dublin 20	☐
Dublin 6w	☐	Dublin 22	☐
Dublin 7	☐	Dublin 24	☐
Dublin 8	☐	Co. Dublin	☐
Dublin 9	☐	Kildare	☐
Dublin 10	☐	Meath	☐
Dublin 11	☐	Wicklow	☐
Dublin 12	☐	Louth	☐
Dublin 13	☐	Other	☐

1.9 Do you live within 15-minute walk of any of the following public transport services?

Please ✓ all that apply	Yes	No
A Quality Bus Corridor (Bus Lane) stop	☐	☐
Luas Sandyford-St Stephens Green line	☐	☐
Luas Tallaght-Connolly Station line	☐	☐
DART station	☐	☐
Other Rail station	☐	☐

Section Two: Your views on public transport information

2.1 Please rate the quality of the following sources of public transport information currently available in Dublin

	Quality of Information				
Please ✓ all that apply	**Very good**	**Good**	**Average**	**Poor**	**Very Poor**
Maps provided at bus stops/train stations	☐	☐	☐	☐	☐
Timetables provided at bus stops/train stations	☐	☐	☐	☐	☐
Public transport websites	☐	☐	☐	☐	☐
The availability of information on the cost of your trip	☐	☐	☐	☐	☐
Availability of real-time information on your trip	☐	☐	☐	☐	☐
Information on amount of time your trip is likely to take	☐	☐	☐	☐	☐

2.2 Please rate the following aspects of public transport usage which cause you the most frustration

	Using Public Transport Information		
Please ✓ all that apply	**Very frustrating**	**No opinion**	**Not frustrating**
Uncertainty as to **when** my bus/train will arrive	☐	☐	☐
Not knowing **if** my bus/train has already passed	☐	☐	☐
The service provided is not flexible enough	☐	☐	☐
Missing services due to uncertainty of departure time	☐	☐	☐

Section Three: Passenger Information Scenarios

This section of the survey seeks your opinion on several different options for providing public transport information.

The following options are described in this section.

Options	Features
Public transport web site	↳Can provide the following - Time tables - Real-time location of buses/trains - Journey Planners - Email alerts and text on disruptions
Passenger Information Displays	↳Can display the following - Estimated arrival time of your service - News on disruptions to the service - Details of connecting services
Text Messages	↳Can display the following - Real-time information on the location of you servic - Details of connecting service - News on disruptions to your service
Call Centre	↳ Can provide the following - Details on the location of your service - Journey planners - Information on all modes and routes - News on disruptions to the service

Note of caution
The situations described in this section may appear to be similar. However they are all different and we ask you to take your time when considering which option to choose.

Part One: Pre-trip planning for you home to Work

In this section we ask you to imagine yourself at home planning your journey to work. Given this situation which of the following, the Internet, a text message or calling a call centre, would you use to receive public transport information.

INSTRUCTIONS
For each of the situations 1,2 and 3 described below, please choose between options A, B or C, ticking the appropriate box which indicates your preferred method of information delivery.
PLEASE ANSWER ALL THREE SITUATIONS

Situation One: Please consider the following options A-C below, and based upon the information provided choose your preferred method of receiving public transport information.

	Option A	**Option B**	**Option C**
	Internet site	**Text message**	**Call centre**
Information given	Real-time information provided	No real-time information provided	Real-time information provided
Time Saved	5% decrease in wait time at stop/station	10% decrease in wait time at stop/station	10% decrease in wait time at stop/station
Cost	2 minutes to turn on computer and access the information	15c per message	8c per call
Please tick one	☐	☐	☐

Situation Two: Please consider the following options A-C below, and based upon the information provided choose your preferred method of receiving public transport information.

	Option A	**Option B**	**Option C**
	Internet site	**Text message**	**Call centre**
Information given	Real-time information provided	No real-time information provided	Real-time information provided
Time Saved	5% decrease in wait time at stop/station	10% decrease in wait time at stop/station	10% decrease in wait time at stop/station
Cost	4 minutes to turn on computer and access the information	30c per message	40c per call
Please tick one	☐	☐	☐

Situation Three: Please consider the following options A-C below, and based upon the information provided, choose your preferred method of receiving public transport information.

	Option A	**Option B**	**Option C**
	Internet site	**Text message**	**Call centre**
Information given	Real-time information provided	No real-time information provided	Real-time information provided
Time Saved	5% decrease in wait time at stop/station	10% decrease in wait time at stop/station	10% decrease in wait time at stop/station
Cost	10 minutes to turn on computer and access the information	Free message	Free call
Please tick one	☐	☐	☐

Situation Four: **Please consider the following options A-C below, and based upon the information provided, choose your preferred method of receiving public transport information.**

	Option A	**Option B**	**Option C**
	Internet site	**Text message**	**Call centre**
Information given	Real-time information provided	No real-time information provided	Real-time information provided
Time Saved	10% decrease in wait time at stop/station	15% decrease in wait time at stop/station	15% decrease in wait time at stop/station
Cost	2 minutes to turn on computer and access the information	15c per message	8c per call
Please tick one	☐	☐	☐

Part Two: Information At-Stop/Station

In this section we ask you to imagine yourself at your bus/train stop waiting for your bus/train to go to work. Given this situation which of the following, information display, a text message or calling a call centre, would you use to receive public transport information.

INSTRUCTIONS:
For each of the situations 1,2 and 3 described below, please choose between options A, B or C, ticking the appropriate box which indicates your preferred method of information delivery.
PLEASE ANSWER ALL THREE SITUATIONS

Situation One: Please consider the following options A-C below, and based upon the information provided choose your preferred method of receiving public transport information.

	Option A	**Option B**	**Option C**
	Information display at stop/station	**Text message**	**Call centre**
Information given	Real-time information provided	No real-time information provided	Real-time information provided
Time Saved	5% decrease in wait time at stop/station	10% decrease in wait time at stop/station	10% decrease in wait time at stop/station
Cost	1c per trip added to the price of your bus or train ticket	15c per message	8c per call
Please tick one	☐	☐	☐

Situation Two: Please consider the following options A-C below, and based upon the information provided, choose your preferred method of receiving public transport information.

	Option A	**Option B**	**Option C**
	Information display at stop/station	**Text message**	**Call centre**
Information given	Real-time information provided	No real-time information provided	Real-time information provided
Time Saved	5% decrease in wait time at stop/station	10% decrease in wait time at stop/station	10% decrease in wait time at stop/station
Cost	15c per added to the price of your bus or train ticket	30c per message	8c per call
Please tick one	☐	☐	☐

Situation Three: Please consider the following options A-C below, and based upon the information provided, choose your preferred method of receiving public transport information.

	Option A	**Option B**	**Option C**
	Information display at stop/station	**Text message**	**Call centre**
Information given	Real-time information provided	No real-time information provided	Real-time information provided
Time Saved	5% decrease in wait time at stop/station	10% decrease in wait time at stop/station	10% decrease in wait time at stop/station
Cost	38c per added to the price of your bus or train ticket	Free message	Free call
Please tick one	☐	☐	☐

Situation Four: **Please consider the following options A-C below, and based upon the information provided, choose your preferred method of receiving public transport information.**

	Option A	**Option B**	**Option C**
	Information display at stop/station	**Text message**	**Call centre**
Information given	Real-time information provided	No real-time information provided	Real-time information provided
Time Saved	10% decrease in wait time at stop/station	15% decrease in wait time at stop/station	15% decrease in wait time at stop/station
Cost	1c per added to the price of your bus or train ticket	15c per message	8c per call
Pleas tick one	☐	☐	☐

Part Three: Pre-trip planning from Work to Home

In this section we ask you to think of yourself at work, planning your journey home. Given this situation, which of the following, the Internet, a text message or calling a call centre, would you use to receive public transport information.

INSTRUCTIONS:
For each of the situations 1,2 and 3 described below, please choose between options A, B or C, ticking the appropriate box which indicates your preferred method of information delivery.
PLEASE ANSWER ALL THREE SITUATIONS

Situation One: Please consider the following options A-C below, and based upon the information provided, choose your preferred method of receiving public transport information.

	Option A Internet site	Option B Text message	Option C Call centre
Information given	Real-time information provided	No real-time information provided	Real-time information provided
Time Saved	5% decrease in wait time at stop/station	10% decrease in wait time at stop/station	10% decrease in wait time at stop/station
Cost	Instant connection to the data - is this a cost?	15c per message	8c per call
Please tick one	☐	☐	☐

Situation Two: Please consider the following options A-C below, and based upon the information provided, choose your preferred method of receiving public transport information.

	Option A Internet site	Option B Text message	Option C Call centre
Information given	Real-time information provided	No real-time information provided	Real-time information provided
Time Saved	5% decrease in wait time at stop/station	10% decrease in wait time at stop/station	10% decrease in wait time at stop/station
Cost	1 minute to turn on computer and access the information	30c per message	40c per call
Please tick one	☐	☐	☐

Situation Three: Please consider the following options A-C below, and based upon the information provided, choose your preferred method of receiving public transport information.

	Option A Internet site	Option B Text message	Option C Call centre
Information given	Real-time information provided	No real-time information provided	Real-time information provided
Time Saved	5% decrease in wait time at stop/station	10% decrease in wait time at stop/station	10% decrease in wait time at stop/station
Cost	2 minutes to turn on computer and access the information	Free message	Free call
Please tick one	☐	☐	☐

Situation Four: **Please consider the following options A-C below, and based upon the information provided, choose your preferred method of receiving public transport information.**

	Option A	**Option B**	**Option C**
	Internet site	**Text message**	**Call centre**
Information given	Real-time information provided	No real-time information provided	Real-time information provided
Time Saved	10% decrease in wait time at stop/station	10% decrease in wait time at stop/station	15% decrease in wait time at stop/station
Cost	Instant connection to the information	15c per message	8c per call
Please tick one	☐	☐	☐

Section Four: Changes to your perception of public transport

4.1 Please rate how convenient you consider the following technologies as a means of accessing public transport information.

Please ✓ all that apply	Convenient	No opinion	Inconvenient
Method of Information Provision	☐	☐	☐
The Internet	☐	☐	☐
Mobile Phone (Text)	☐	☐	☐
Call Centre	☐	☐	☐
Passenger Information Display	☐	☐	☐

4.2 If accessing public transport information over the various stages of your journey to and from work, please indicate from the options below at which stage you are most likely to seek to access information.

Please ✓ all that apply	Regularly (more than 3 times a week)	Sometimes (1-3 times a week)	Seldom (less than once a week)	Never
At home planning your trip to work	☐	☐	☐	☐
At your bus stop/train station	☐	☐	☐	☐
On board your bus/train	☐	☐	☐	☐
At work planning your trip home	☐	☐	☐	☐

Section Six: About Yourself

5.1 Gender: ☐ Male ☐ Female

5.2 Age: ☐ under 24 ☐ 24 to 34 ☐ 35 to 44 ☐ 45 to 54 ☐ 55 or over

5.3 Total household annual income (before tax and PRSI)

☐ Less than €10,000 per annum
☐ €10,000 to €19,000 per annum
☐ €20,000 to €30,000 per annum
☐ €30,000 to €40,000 per annum
☐ €40,000 to €50,000 per annum
☐ €50,000 to €60,000 per annum
☐ €60,000 to €80,000 per annum
☐ €80,000 to €100,000 per annum
☐ €100,000 to €120,000 per annum
☐ €120,000 to €140,000 per annum
€140,000 or more per annum
☐ I do not wish to answer

5.4 Number of cars in the household?

☐ No car ☐ 1 car ☐ 2 cars ☐ 3 or more cars

5.5 Do currently own a mobile phone?

☐ Yes ☐ No

If yes, is it a pay monthly or a pay-as-you-go?
☐ Pay Monthly ☐ Pay-as-you-go

5.6 Where do you usually have Internet access? (You may tick more than one)

☐ Home ☐ Work ☐ Internet Café ☐ I don't have access ☐ Mobile Phone (WAP)

5.7 If you have the Internet at home do you have a broadband connection?

☐ Yes ☐ No

5.8 At work do you have free access to a telephone?

☐ Yes and I have unlimited use
☐ Yes and but have to use it in moderation
☐ Yes but for business purposes only
☐ I have no access

5.9 At work do you have free access to the internet?

☐ Yes and I have unlimited use
☐ Yes and but have to use it in moderation
☐ Yes but for business purposes only
☐ I have no access

If you have any comments please write them in the space provided below.

Comments:

APPENDIX II: ALTERNATIVE MODEL SPECIFICATIONS

The models presented in this appendix refer to the models not presented in chapters 6 and 7. The coefficients presented are those deemed not to be as significant in terms of the $\rho^2(0)$ $\rho^2(c)$ values. The models presented in the chapters are represented in the tables below in bold text.

Chapter 6 – Models representing trip characteristics

Table	Model	Variable	Coefficient value	T-value	$\rho^2(0)$ value	$\rho^2(c)$ value
6-1	M6-4	WALKCY(1)	-0.014	-1.9	0.202	0.187
6-1	**M6-4**	**WALKCY(2)**	**-0.150**	**-2.5**	**0.230**	**0.201**
6-1	M6-4	WALKCY(3)	-0.101	-2.1	0.200	0.180
6-1	**M6-5**	**BUS(1)**	**0.390**	**3.2**	**0.218**	**0.209**
6-1	M6-5	BUS(2)	0.124	2.1	0.201	0.182
6-1	M6-5	BUS(3)	0.105	1.9	0.211	0.201
6-1	M6-6	RAIL(1)	0.103	1.9	0.212	0.200
6-1	**M6-6**	**RAIL(2)**	**0.122**	**2.3**	**0.220**	**0.206**
6-1	M6-6	RAIL(3)	0.017	1.8	0.201	0.184
6-1	M6-7	CAR(1)	-0.218	-2.1	0.211	0.201
6-1	M6-7	CAR(2)	-0.183	-2.0	0.204	0.179
6-1	**M6-7**	**CAR(3)**	**-0.309**	**-3.6**	**0.227**	**0.210**
6-2	M6-8	WALKCY(4)	-0.211	-1.9	0.204	0.195
6-2	M6-8	WALKCY(2)	-0.107	-1.8	0.207	0.193
6-2	**M6-8**	**WALKCY(3)**	**-0.240**	**-2.0**	**0.231**	**0.202**
6-2	M6-9	BUS(4)	0.019	1.8	0.201	0.180
6-2	**M6-9**	**BUS(2)**	**0.173**	**2.0**	**0.209**	**0.201**
6-2	M6-9	BUS(3)	0.162	1.9	0.201	0.194
6-2	**M6-10**	**RAIL(4)**	**0.168**	**4.5**	**0.203**	**0.197**
6-2	M6-10	RAIL(2)	0.097	2.3	0.201	0.190
6-2	M6-10	RAIL(3)	0.108	2.9	0.197	0.184
6-2	M6-11	CAR(4)	-0.020	-2.5	0.215	0.201
6-2	M6-11	CAR(2)	-0.009	-2.1	0.201	0.194
6-2	M6-11	CAR(3)	-0.017	-2.4	0.209	0.200
6-3	M6-12	WALKCY(1)	-0.201	-2.9	0.210	0.201
6-3	**M6-12**	**WALKCY(2)**	**-0.223**	**-3.3**	**0.214**	**0.205**
6-3	M6-12	WALKCY(3)	-0.198	-2.1	0.209	0.197
6-3	**M6-13**	**BUS(1)**	**0.132**	**1.9**	**0.233**	**0.209**
6-3	M6-13	BUS(2)	0.105	1.8	0.211	0.198
6-3	M6-13	BUS(3)	0.109	1.9	0.209	0.197
6-3	M6-14	RAIL(1)	0.098	2.1	0.204	0.198
6-3	**M6-14**	**RAIL(2)**	**0.192**	**2.8**	**0.210**	**0.201**
6-3	M6-14	RAIL(3)	0.145	2.4	0.208	0.190
6-3	M6-15	CAR(1)	-0.171	-1.8	0.200	0.194
6-3	**M6-15**	**CAR(2)**	**-0.188**	**-1.9**	**0.212**	**0.203**
6-3	M6-15	CAR(3)	-0.147	-1.9	0.204	0.197
6-4	**M6-16**	**MULTI(1)**	**0.248**	**2.3**	**0.212**	**0.201**
6-4	M6-16	MULTI(2)	0.154	1.9	0.204	0.191
6-4	M6-16	MULTI(3)	0.208	2.1	0.207	0.199
6-4	**M6-17**	**MULTI(4)**	**0.139**	**2.0**	**0.209**	**0.201**
6-4	M6-17	MULTI(2)	0.102	2.0	0.201	0.190
6-4	M6-17	MULTI(3)	0.098	1.9	0.198	0.179
6-4	M6-18	MULTI(1)	0.317	2.0	0.208	0.200
6-4	**M6-18**	**MULTI(2)**	**0.460**	**2.2**	**0.216**	**0.203**
6-4	M6-18	MULTI(3)	0.414	2.1	0.204	0.193
6-5	M6-19	WALKSTOP (1)	0.091	3.0	0.201	0.194
6-5	**M6-19**	**WALKSTOP (2)**	**0.128**	**3.2**	**0.211**	**0.207**

6-5	M6-19	WALKSTOP (3)	0.107	2.7	0.207	0.200
6-5	M6-20	WAIT(1)	0.211	1.8	0.197	0.180
6-5	**M6-20**	**WAIT(2)**	**0.316**	**1.9**	**0.208**	**0.201**
6-5	M6-20	WAIT(3)	0.310	1.9	0.204	0.199
6-5	M6-21	PTTIME(1)	0.241	2.0	0.207	0.194
6-5	**M6-21**	**PTTIME(2)**	**0.364**	**2.6**	**0.210**	**0.200**
6-5	M6-21	PTTIME(3)	0.301	2.4	0.201	0.189
6-5	**M6-22**	**WAIT(4)**	**0.419**	**3.1**	**0.209**	**0.197**
6-5	M6-22	WAIT(2)	0.315	2.9	0.201	0.196
6-5	M6-22	WAIT(3)	0.351	2.4	0.204	0.192
6-5	**M6-23**	**PTTIME (4)**	**0.824**	**2.7**	**0.241**	**0.213**
6-5	M6-23	PTTIME (2)	0.641	2.1	0.221	0.201
6-5	M6-23	PTTIME (3)	0.810	2.2	0.214	0.217
6-5	M6-24	WAIT(1)	0.091	1.8	0.201	0.187
6-5	**M6-24**	**WAIT(2)**	**0.104**	**1.9**	**0.214**	**0.209**
6-5	M6-24	WAIT(3)	0.081	1.9	0.207	0.199
6-5	M6-25	PTTIME(1)	0.187	4.1	0.211	0.187
6-5	**M6-25**	**PTTIME(2)**	**0.196**	**5.5**	**0.213**	**0.199**
6-5	M6-25	PTTIME(3)	0.180	2.9	0.201	0.198

(1) Internet (2) SMS (3) Call centre (4) PID

Chapter 6 – Models representing socio-economic characteristics

Table	Model	Variable	Coefficient value	T-value	$\rho^2(0)$ value	$\rho^2(c)$ value
6-9	M6-29	GENDER(1)	0.181	2.4	0.230	0.202
6-9	**M6-29**	**GENDER(2)**	**0.197**	**2.9**	**0.235**	**0.208**
6-9	M6-29	GENDER(3)	0.177	2.5	0.229	0.201
6-9	M6-30	GENDER(4)	**-0.116**	**-2.0**	**0.211**	**0.203**
6-9	M6-30	GENDER(2)	-0.097	-1.8	0.208	0.196
6-9	M6-30	GENDER(3)	-0.111	-2.0	0.210	0.200
6-9	M6-31	GENDER(1)	-0.249	-3.0	0.209	0.201
6-9	**M6-31**	**GENDER(2)**	**-0.363**	**-3.7**	**0.217**	**0.210**
6-9	M6-31	GENDER(3)	-0.231	-2.8	0.211	0.201
6-10	M6-32	AGE(1)	-0.703	-1.8	0.201	0.190
6-10	**M6-32**	**AGE(2)**	**-0.503**	**-2.3**	**0.212**	**0.205**
6-10	M6-32	AGE(3)	-0.438	-2.1	0.209	0.201
6-10	**M6-33**	**AGE(4)**	**-0.182**	**-4.1**	**0.209**	**0.204**
6-10	M6-33	AGE(2)	-0.098	-3.9	0.201	0.197
6-10	M6-33	AGE(3)	-0.111	-2.9	0.207	0.200
6-10	M6-34	AGE(1)	-0.098	-2.0	0.210	0.201
6-10	**M6-34**	**AGE(2)**	**-0.114**	**-2.1**	**0.217**	**0.209**
6-10	M6-34	AGE(3)	-0.111	-2.1	0.201	0.192
6-11	M6-35	INCOME(1)	0.340	2.8	0.231	0.208
6-11	**M6-35**	**INCOME(2)**	**0.411**	**3.9**	**0.236**	**0.210**
6-11	M6-35	INCOME(3)	0.238	2.9	0.214	0.209
6-11	**M6-36**	**INCOME(4)**	**0.103**	**4.5**	**0.212**	**0.205**
6-11	M6-36	INCOME(2)	0.092	3.6	0.209	0.201
6-11	M6-36	INCOME(3)	0.101	2.7	0.201	0.192
6-11	M6-37	INCOME(1)	0.097	4.3	0.209	0.201
6-11	**M6-37**	**INCOME(2)**	**0.110**	**5.0**	**0.217**	**0.211**
6-11	M6-37	INCOME(3)	0.107	3.1	0.201	0.194
6-12	M6-38	CARAV(1)	-0.514	-2.0	0.211	0.201
6-12	**M6-38**	**CARAV(2)**	**-0.685**	**-2.2**	**0.212**	**0.203**
6-12	M6-38	CARAV(3)	-0.419	-2.1	0.210	0.200
6-12	**M6-39**	**CARAV(4)**	**-0.319**	**-5.1**	**0.211**	**0.202**
6-12	M6-39	CARAV(2)	-0.291	-3.9	0.209	0.194
6-12	M6-39	CARAV(3)	-0.301	-4.3	0.203	0.198
6-12	M6-40	CARAV(1)	-0.290	-2.9	0.208	0.201
6-12	M6-40	CARAV(2)	**-0.319**	**-3.4**	**0.218**	**0.210**
6-12	M6-40	CARAV(3)	-0.301	-2.8	0.201	0.190

(1) Internet (2) SMS (3) Call centre (4) PID

Chapter 6 – Models representing location characteristics

Table	Model	Variable	Coefficient value	T-value	$\rho^2(0)$ value	$\rho^2(c)$ value
6-16	M6-44	HQBUS(1)	0.091	1.9	0.221	0.202
6-16	**M6-44**	**HQBUS(2)**	**0.161**	**2.0**	**0.232**	**0.221**
6-16	M6-44	HQBUS(3)	0.159	2.0	0.230	0.209
6-16	M6-45	HQRAIL(1)	-0.211	-2.5	0.207	0.200
6-16	**M6-45**	**HQRAIL(2)**	**-0.283**	**-2.7**	**0.224**	**0.213**
6-16	M6-45	HQRAIL(3)	-0198	-1.9	0.221	0.209
6-16	**M6-46**	**HQBUS(4)**	**-0.155**	**-1.9**	**0.213**	**0.206**
6-16	M6-46	HQBUS(2)	-0.099	-1.8	0.209	0.201
6-16	M6-46	HQBUS(3)	-0.123	-1.9	0.210	0.200
6-16	**M6-47**	**HQRAIL(4)**	**-0.107**	**-2.1**	**0.220**	**0.211**
6-16	M6-47	HQRAIL(2)	-0.092	-2.0	0.219	0.201
6-16	M6-47	HQRAIL(3)	-0.101	-1.9	0.210	0.203
6-17	M6-48	ZONE(1)	0.209	2.3	0.209	0.201
6-17	**M6-48**	**ZONE(2)**	**0.304**	**2.6**	**0.219**	**0.205**
6-17	M6-48	ZONE(3)	0.289	2.1	0.203	0.197
6-17	**M6-49**	**ZONE(4)**	**0.667**	**2.1**	**0.217**	**0.209**
6-17	M6-49	ZONE(2)	0.457	1.8	0.208	0.193
6-17	M6-49	ZONE(3)	0.568	2.0	0.211	0.200
6-17	M6-50	ZONE(1)	0.111	3.1	0.209	0.201
6-17	**M6-50**	**ZONE(2)**	**0.120**	**3.7**	**0.224**	**0.211**
6-17	M6-50	ZONE(3)	0.106	2.6	0.206	0.197

(1) Internet (2) SMS (3) Call centre (4) PID

Chapter 6 – Models representing access to technology characteristics

Table	Model	Variable	Coefficient value	T-value	$\rho^2(0)$ value	$\rho^2(c)$ value
6-20	M6-53	CONMOB(1)	0.119	2.0	0.209	0.200
6-20	**M6-53**	**CONMOB(2)**	**0.213**	**2.1**	**0.214**	**0.209**
6-20	M6-53	CONMOB(3)	0.210	1.9	0.207	0.201
6-20	**M6-54**	**BBNET(1)**	**0.183**	**2.0**	**0.219**	**0.206**
6-20	M6-54	BBNET(2)	0.099	1.9	0.211	0.200
6-20	M6-54	BBNET(3)	0.109	2.0	0.201	0.193
6-20	**M6-55**	**CONMOB(4)**	**O.661**	**2.5**	**0.215**	**0.207**
6-20	M6-55	CONMOB(2)	0.509	2.3	0.209	0.204
6-20	M6-55	CONMOB(3)	0.456	2.0	0.203	0.194
6-20	M6-56	CONMOB(1)	0.217	2.1	0.209	0.200
6-20	**M6-56**	**CONMOB(2)**	**0.234**	**2.2**	**0.222**	**0.207**
6-20	M6-56	CONMOB(3)	0.230	2.0	0.209	0.201
6-20	M6-57	PWORK(1)	0.106	1.9	0.211	0.205
6-20	M6-57	PWORK(2)	0.119	2.0	0.210	0.200
6-20	**M6-57**	**PWORK(3)**	**0.140**	**2.2**	**0.216**	**0.208**
6-20	**M6-58**	**NETWEK(1)**	**0.138**	**1.9**	**0.223**	**0.217**
6-20	M6-58	NETWEK(2)	0.122	1.8	0.214	0.201
6-20	M6-58	NETWEK(3)	0.134	1.9	0.209	0.198

(1) Internet (2) SMS (3) Call centre (4) PID

Chapter 6 – Models representing work pattern characteristics

Table	Model	Variable	Coefficient value	T-value	ρ^2(0) value	ρ^2(c) value
6-23	M6-61	DEPT(1)	0.378	2.2	0.210	0.201
6-23	**M6-61**	**DEPT(2)**	**0.440**	**2.6**	**0.216**	**0.209**
6-23	M6-61	DEPT(3)	0.234	2.1	0.209	0.200
6-23	M6-62	FIXW(1)	-0.303	-2.2	0.209	0.201
6-23	**M6-62**	**FIXW(2)**	**-0.312**	**-3.0**	**0.220**	**0.214**
6-23	M6-62	FIXW(3)	-0.298	-2.1	0.201	0.190
6-23	**M6-63**	**DEPT(4)**	**0.140**	**4.3**	**0.218**	**0.210**
6-23	M6-63	DEPT(2)	0.103	3.3	0.216	0.209
6-23	M6-63	DEPT(3)	0.091	3.2	0.209	0.200
6-23	**M6-64**	**FIXW(4)**	**-0.146**	**-2.1**	**0.211**	**0.204**
6-23	M6-64	FIXW(2)	-0.119	-2.0	0.209	0.201
6-23	M6-64	FIXW(3)	-0.098	-1.9	0.203	0.198
6-23	**M6-65**	**FIXW(1)**	**-0.121**	**-2.6**	**0.225**	**0.217**
6-23	M6-65	FIXW(2)	-0.129	-2.0	0.210	0.214
6-23	M6-65	FIXW(3)	-0.104	-1.9	0.209	0.200

(1) Internet (2) SMS (3) Call centre (4) PID

Chapter 7 – Models

Table	Model	Variable	Coefficient value	T-value	ρ^2(0) value	ρ^2(c) value
7-1	M7-2	FRUST(1)	0.107	2.0	0.241	0.210
7-1	**M7-2**	**FRUST(2)**	**0.124**	**2.1**	**0.263**	**0.237**
7-1	M7-2	FRUST(3)	0.110	1.9	0.214	0.201
7-2	**M7-2**	**FRUST(4)**	**0.174**	**2.0**	**0.267**	**0.220**
7-2	M7-2	FRUST(2)	0.098	1.8	0.219	0.200
7-2	M7-2	FRUST(3)	0.109	1.9	0.241	0.205
7-3	**M7-6**	**FRUST(1)**	**0.120**	**7.0**	**0.297**	**0.250**
7-3	M7-6	FRUST(2)	0.107	4.5	0.241	0.207
7-3	M7-6	FRUST(3)	0.114	3.1	0.271	0.211
7-6	M7-8	CONVN1(1)	0.108	2.1	0.247	0.212
7-6	**M7-8**	**CONVN1(2)**	**0.133**	**2.8**	**0.258**	**0.240**
7-6	M7-8	CONVN1(3)	0.127	2.4	0.233	0.213
7-7	**M7-10**	**CONVN2(4)**	**0.111**	**2.3**	**0.267**	**0.221**
7-7	M7-10	CONVN2(2)	0.078	1.9	0.211	0.197
7-7	M7-10	CONVN2(3)	0.104	2.2	0.241	0.217
7-8	M7-12	CONVN1(1)	0.114	6.1	0.247	0.215
7-8	**M7-12**	**CONVN1(2)**	**0.125**	**7.1**	**0.289**	**0.259**
7-8	M7-12	CONVN1(3)	0.107	5.4	0.239	0.209
7-9	M7-14	PERSEP(1)	-0.117	-2.9	0.234	0.214
7-9	**M7-14**	**PERSEP(2)**	**-0.137**	**-4.0**	**0.255**	**0.231**
7-9	M7-14	PERSEP(3)	-0.107	-3.1	0.241	0.221
7-10	**M7-16**	**PERSEP(4)**	**-0.106**	**-2.5**	**0.260**	**0.218**
7-10	M7-16	PERSEP(2)	-0.098	-2.0	0.245	0.204
7-10	M7-16	PERSEP(3)	-0.101	-2.1	0.231	0.200
7-11	M7-18	PERSEP(1)	-0.112	-4.0	0.271	0.257
7-11	M7-18	PERSEP(2)	-0.119	-4.8	0.224	0.211
7-11	**M7-18**	**PERSEP(3)**	**-0.154**	**-5.1**	**0.294**	**0.264**