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***Impacts of Telecommuting, and Related Aspects of Intelligent
Transportation Systems on Residential Location Choice:
A Combined Revealed and Stated Preference Approach***

By

Mohammad R. Tayyaran, M.Eng.

Carleton University, 1994

*A thesis submitted to the
Faculty of Graduate Studies and Research
in Partial Fulfilment of the Requirements
for the Degree of
Doctor of Philosophy*

Department of Civil and Environmental Engineering

Carleton University

Ottawa, Ontario

July 2000

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ABSTRACT

Telecommuting and Intelligent Transportation Systems (ITS) have already demonstrated transportation-related benefits such as reduced vehicle kilometres of travel, and reduction of fuel consumption and emissions. However, the long-term effects of ITS and telecommuting on land use are subject to uncertainty. Considering the relationship between land use and transportation, the question is what will be the impacts of telecommuting and ITS on urban development pattern, which in turn will effect travel demand structure. The purpose of this study was to investigate the impacts of telecommuting and ITS on land use patterns, specifically on households' residential location choice decisions. To study these effects, discrete choice analysis within the well-developed random utility theory framework was adopted. Within this framework, combined revealed preference (RP) and stated preference (SP) logit analysis was performed to estimate the parameters of the utility function. Using the sequential maximum likelihood estimation procedure, taste parameters of the combined RP and SP multinomial logit model were obtained. Statistical inferences on the estimated parameters were made and measures of goodness-of-fit were also calculated and discussed.

The main conclusion of this research was that telecommuting and ITS measures were found to be highly significant factors in the residential choice model. The effects of these measures were in the direction of supporting the decentralization of land use pattern.

The SP model provided useful information on tradeoffs among attributes. It also produced more robust parameter estimates than the RP model due to wider range of attributes in the SP data as well as the well-designed SP matrix. The combined model

produced a much better data fit than the RP and SP models, separately. This indicates that the combined model was a stronger model than either of those models alone.

Also, the comparison of telecommuters and non-telecommuters in terms of their residential location behaviour showed that the coefficient of telecommuting factor was much larger for the former group than the latter. In addition, the magnitude of this factor was higher in the second- and third-tier locations than in the central city. This further reinforced the perspective that urban areas would experience sub-urbanization trend as a result of telecommuting.

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*To the memory of my late father-in-law,
Dr. Ahmad Tafazzoli,
who was a great scholar and researcher,
But above all, a true human being.*

TABLE OF CONTENTS

ABSTRACT	iii
ACKNOWLEDGMENTS	v
TABLE OF CONTENTS.....	vii
LIST OF TABLES	x
LIST OF FIGURES.....	xi
LIST OF APPENDICES	xii
LIST OF SYMBOLS AND ACRONYMS	xiii
CHAPTER I: INTRODUCTION	1
1.1. OVERVIEW	1
1.2. TELECOMMUTING	3
1.3. INTELLIGENT TRANSPORTATION SYSTEMS (ITS)	7
1.4. INFORMATION TECHNOLOGY AND FUTURE OF CITIES	11
1.5. ADVANCES IN TELECOMMUNICATIONS TECHNOLOGY	16
1.5.1. Devices	17
1.5.2. Databases.....	18
1.5.3. Telecommunications Networks.....	19
1.5.4. The Software	22
1.6. THESIS ORGANIZATION	24
CHAPTER II: RESIDENTIAL LOCATION THEORY AND STATED PREFERENCE APPROACH	26
2.1. INTRODUCTION	26
2.2. LOCATION THEORIES AND RESIDENTIAL LOCATION CHOICE	27
2.3. QUALITATIVE VS. QUANTITATIVE RESEARCH STUDIES	30
2.3.1. Focus Groups.....	31
2.3.2. Delphi Approach	32
2.4. STATED PREFERENCE VS. REVEALED PREFERENCE APPROACH	33
2.5. CONJOINT PARADIGMS	34
2.5.1. Ranking Responses	35
2.5.2. Rating Responses	35
2.5.3. Choice Responses.....	36
2.6. HOUSING LOCATION BEHAVIOUR USING SP TECHNIQUES	37
2.7. TELECOMMUNICATIONS AND OFFICE LOCATION	38

CHAPTER III: RESEARCH FRAMEWORK	40
3.1. RATIONALE FOR THE RESEARCH.....	40
3.2. RESEARCH GOALS AND OBJECTIVES	41
3.3. SCOPE OF THE STUDY	42
3.4. RESEARCH FRAMEWORK.....	42
3.5. COMBINING REVEALED AND STATED PREFERENCE DATA	43
3.5.1. Estimation Method	47
3.6. DECISION MAKING PROCESS	48
3.7. ANALYSIS TOOL	50
3.7.1. Multinomial and Conditional Logit: LOGIT	51
CHAPTER IV: DISCRETE CHOICE ANALYSIS.....	53
4.1. OVERVIEW	53
4.2. DISCRETE CHOICE MODELS DEVELOPMENT	53
4.3. LOGIT MODEL.....	55
4.4. PROPERTIES OF THE LOGIT MODELS	56
4.4.1. Independence From Irrelevant Alternatives (IIA).....	57
4.4.2. Elasticities of Logit	58
4.5. THE LOGIT MODEL ESTIMATION METHODS.....	58
4.6. MEASURES OF GOODNESS-OF-FIT	60
4.6.1. Likelihood Ratio Test.....	60
4.6.2. The Overall Test of Fit.....	61
4.6.3. Rho-Squared Index.....	62
4.6.4. The Asymptotic t Test.....	63
4.6.5. Variable Sign (Informal)	64
4.7. AGGREGATE FORECASTING	64
CHAPTER V: SURVEY DESIGN AND ANALYSIS— THE PILOT STUDY	66
5.1. INTRODUCTION	66
5.2. PILOT SURVEY	67
5.3. ALTERNATIVES DEFINITION	67
5.4. ATTRIBUTES AND THEIR LEVELS.....	70
5.5. EXPERIMENTAL DESIGN	72
5.6. SAMPLING PROCESS	74
5.7. PILOT SURVEY ADMINISTRATION – SECOND SURVEY	74
5.8. ESTIMATION WITH RP DATA	78
5.9. ESTIMATION WITH SP DATA	79
CHAPTER VI: SURVEY DESIGN AND IMPLEMENTATION—THE FINAL STUDY	84
6.1. INTRODUCTION	84
6.2. ALTERNATIVES DEFINITION	84
6.3. ATTRIBUTES AND THEIR LEVELS	84
6.4. EXPERIMENTAL DESIGN	86
6.5. SAMPLING PROCESS	96

6.5.1. Private Sector	96
6.5.2. Public Sector	98
6.6. SAMPLE SIZE	99
6.7. ADMINISTRATION OF THE FINAL SURVEY	101
6.8. PRELIMINARY ANALYSIS	103
6.9. ANALYSIS OF INDIVIDUAL CHARACTERISTICS	108
6.9.1. Gender	109
6.9.2. Job Category.....	112
6.9.3. Effect of Age	115
6.10. CONCLUDING REMARKS	118
CHAPTER VII: DISCRETE CHOICE ANALYSIS OF THE FINAL SURVEY .	120
7.1. INTRODUCTION	120
7.2. ESTIMATION WITH RP DATA FOR THE WHOLE SAMPLE	120
7.2.1. Goodness-of-fit Measures	122
7.2.2. Validation	123
7.2.3. Discussion of the Results	125
7.3. ESTIMATION WITH SP DATA FOR THE WHOLE SAMPLE	128
7.3.1. Goodness-of-fit Measures	132
7.3.2. Discussion of the Results	132
7.3.3. Final Reduced SP Model.....	136
7.3.3.1. <i>Goodness-of-fit Measures</i>	140
7.3.3.2. <i>Validation</i>	142
7.3.3.3. <i>Discussion of the Results</i>	143
7.3.3.4. <i>Estimating Consistent Standard Errors Using Jackknife Procedure</i>	155
7.4. COMBINED RP AND SP DATA ESTIMATION	158
7.4.1. Goodness-of-fit Measures	164
7.4.2. Validation	164
7.4.3. Discussion of the Results	166
7.5. COMPARING THE BEHAVIOUR OF TELECOMMUTERS VS. NON-TELECOMMUTERS	168
7.5.1. The SP Model of NTCers vs. TCers	169
7.5.1.1. <i>Goodness-of-fit Measures</i>	172
7.5.1.2. <i>Discussion of the Results</i>	172
7.6. AGGREGATE FORECASTING	175
CHAPTER VIII: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS	181
8.1. SUMMARY.....	181
8.2. CONCLUSIONS	182
8.2.1. General Conclusions	182
8.2.2. Conclusions Relating to SP Design and Pooled RP+SP Model.....	185
8.2.3. Conclusions Relating to Other Statistical Aspects of the Research	186
8.3. RECOMMENDATIONS FOR FURTHER STUDY	189
REFERENCES	191

LIST OF TABLES

Table 5.1. List of Attributes and Their Levels for the SP Experiment (Pilot Survey)	73
Table 5.2. Estimation Results With RP Data (Pilot Survey)	80
Table 5.3. Estimation Results With SP Data (Pilot Survey)	82
Table 6.1. List of Attributes and Their Levels for the SP Experiment (Final Survey)	85
Table 6.2. Three-Level Interactions and Their Generalized Interactions for Alt. A	89
Table 6.3. Three-Level Interactions and Their Generalized Interactions for Alt. B	89
Table 6.4. Three-Level Interactions and Their Generalized Interactions for Alt. C	89
Table 6.5. SP Treatment Combinations (Final Survey)	94
Table 6.6. Descriptive Sample Characteristics	105
Table 6.7. Contingency Table for Testing the Effects of Gender on Telecommuting	110
Table 6.8. Contingency Table for Comparing Observed and Expected Frequencies	111
Table 6.9. Computation of the χ^2 -test Statistic For the Effects of Gender	112
Table 6.10. Job Category of Respondents	113
Table 6.11. Contingency Table for Comparing Observed and Expected Frequencies ...	115
Table 6.12. Computation of the χ^2 -test Statistic for the Effects of Job Category	116
Table 6.13. Analysis of Variance Summary Table	117
Table 6.14. Analysis-of-Variance Table for the Effects of Age	118
Table 7.1. Estimation With RP Data For the Whole Sample	122
Table 7.2. Macro Validation for the RP Data	124
Table 7.3. Micro Validation for the RP Data	125
Table 7.4. Correlation Matrix for the RP Data	126
Table 7.5. Base SP Model for The Whole Sample (Full Model)	130
Table 7.6. 3-level Attributes and their Equivalent Orthogonal Polynomial Codes	132
Table 7.7. Final SP Model for the Whole Sample Without Restriction	139
Table 7.8. Final SP Model for the Whole Sample With Restriction on TSQ	141
Table 7.9. Macro Validation for the Final Reduced SP Model	142
Table 7.10. Micro Validation for the Final Reduced SP Model	143
Table 7.11. Corrected t-Statistic of Final SP Model Based on Jackknife Procedure	159
Table 7.12. Final Reduced SP Model With Re-Coded Data for the Whole Sample	161
Table 7.13. RP Model For the Whole Sample With W^{RP} Included as a Variable	162
Table 7.14. Estimation Results with Combined RP and SP Data for the Whole Sample	163
Table 7.15. Macro Validation for the Final Joint Model	165
Table 7.16. Micro Validation for the Final Joint Model	165
Table 7.17. The SP Main-Effect Model for the Telecommuting Group	170
Table 7.18. Reduced SP Model of Non-Telecommuters	171
Table 7.19. The SP Model of Non-Telecommuters Vs. Telecommuters	173
Table 7.20. Predicted Probabilities With respect to Change in Various Factors	176

LIST OF FIGURES

Figure 3.1. Research Framework	44
Figure 3.2. Conceptual Structure of Consumer Behaviour Process	49
Figure 5.1. Schematic Diagram of Housing Location Alternatives	69
Figure 5.2. Modal Split to Work (Pilot Survey).....	77
Figure 6.1. Modal Split to Work (Final Survey)	106
Figure 6.2. Average Ranking of Various Residential Factors.....	107
Figure 7.1. TCA-DLA Interaction: Marginal Plot of Delay.....	137
Figure 7.2. TCA-DLA Interaction: Marginal Plot of Telecommuting.....	137
Figure 7.3. TC-DL Interaction: Marginal Plot of Delay	147
Figure 7.4. TC-DL Interaction: Marginal Plot of Telecommuting	147
Figure 7.5. TC-HC Interaction: Marginal Plot of Housing Cost.....	148
Figure 7.6. TC-HC Interaction: Marginal Plot of Telecommuting	148
Figure 7.7. TC-RM Interaction: Marginal Plot of Number of Rooms	150
Figure 7.8. TC-RM Interaction: Marginal Plot of Telecommuting.....	150
Figure 7.9. TC-RM Interaction: Marginal Plot of Number of Rooms	151
Figure 7.10. TC-RM Interaction: Marginal Plot of Number of Rooms	151
Figure 7.11. TC-TW Interaction: Marginal Plot of Travel Time to Work.....	153
Figure 7.12. TC-TW Interaction: Marginal Plot of Telecommuting.....	153
Figure 7.13. TC-RC Interaction: Marginal Plot of Recreational Opportunities.....	154
Figure 7.14. TC-RC Interaction: Marginal Plot of Telecommuting.....	154
Figure 7.15. DL-RM Interaction: Marginal Plot of Number of Rooms	156
Figure 7.16. DL-RM Interaction: Marginal Plot of Delay	156

LIST OF APPENDICES

Appendix A.1. Sample Pilot Survey	204
Appendix A.2. Correlation Matrix of the SP Experimental Design.....	213
Appendix A.3. Sample Final Survey.....	228
Appendix B.1. RP Model Source Code and Output.....	245
Appendix B.2. Base SP Model Source Code and Output	252
Appendix B.3. Final SP Model Source Code and Output.....	259
Appendix B.4. Source Code for the Jackknife Procedure.....	268
Appendix B.5. Combined RP+SP Model Source Code and Output	272
Appendix B.6. Source Code and Output for Comparing TCers and NTCers	284

LIST OF SYMBOLS AND ACRONYMS

α, β, γ	Vector of unknown parameters in the logit model.
μ	Scaling parameter
v	Random error component in the RP model
ε	Random error component in the SP model
$L(\beta)$	Value of the log likelihood function at its maximum
$L(0)$	Value of the log likelihood function when all parameters are zero
$L(C)$	Value of the log likelihood function when only alternative-specific constant is included
$L(\beta_R)$	Value of the log likelihood function for the restricted model
$L(\beta_{UR})$	Value of the log likelihood function for the unrestricted model
U_{im}	Utility of Alternative i for individual m
V_{im}	Systematic component of the utility of Alternative i for individual m
ATIS	Advanced Traveller Information Systems
ATMS	Advanced Traffic Management Systems
AVCS	Advanced Vehicle Control Systems
ITS	Intelligent Transportation Systems
IIA	Independence from Irrelevant Alternatives
IID	Independently and Identically Distributed
LR	Likelihood Ratio
MLE	Maximum Likelihood Estimation
MNL	Multinomial Logit
NTCers	Non-telecommuters
RP	Revealed Preference
SP	Stated Preference
TCers	Telecommuters
TDM	Travel Demand Management
TSP	Times Series Processor
TC	Telecommuting level
DL	Travel time delay
HC	Monthly housing cost
RM	Number of rooms
TW	Travel time to work
TS	Travel time to school
RC	Recreational opportunities

CHAPTER I: INTRODUCTION

1.1. OVERVIEW

Historically, transportation infrastructure and information technologies have had close positive relationship. With the invention of rail transport, communication technologies such as telegraph and later telephone were advanced to manage and monitor the trains across their rail networks (Graham and Marvin, 1996). Rail transport also allowed urban areas to expand along streetcar lines radiating from the central city (Meyer & Miller, 1984). The second major 'spatial technology' in 1920s, namely the automobile, allowed even more freedom for urban growth, thus resulting in what today is known as urban sprawl. In most cities in the United States as well as in other developed and developing countries, urban growth has occurred in the form of low density bedroom suburbs located at the urban fringe, and in some cases even lower density developments emanating from these suburbs (Hanson, 1992; Meyer & Miller, 1984).

Telecommunications technology has advanced even more drastically in the last decade. On the transmission side, the traditional copper and coaxial cable links are being replaced by optic fibre, wireless, and microwave systems. This, in turn, has resulted in the information to be carried in 'real time' rather than delayed. Also, telecommunications themselves are moving from analogue to digital. As a result, the previously separate areas of telecommunications, computing, and media technologies are now converging around a core group of digitalized technologies called 'telematics' (Graham and Marvin, 1996).

Due to such rapid advancements in telematics more and more information (i.e., voice, data, image, video) are being carried through the connection links.

In recent years and in the context of contemporary city, application of informatics technologies such as Intelligent Transportation Systems (ITS), and their specialized use in electronic road pricing have been developed for enhancing the efficiencies of the existing surface transportation system. Therefore, it is reasonable to expect that, in the light of the transportation-land use interaction theory, the information technology revolution will also impact the management and provision of not only urban transportation network but also urban land use patterns.

More specifically, this research work is focused on two of the telecommunications-related technologies: telecommuting and ITS. Telecommuting is a term coined by Nilles et al (1976) and it refers to the use of telecommunications technology to partially or completely replace daily trips to and from the workplace. Although availability and use of a computer is not a prerequisite for telecommuting, most of the tasks carried by telecommuters today are done by the use of computers and access to information technologies. The second technological phenomenon is ITS. According to ITS Canada "ITS technologies include micro-electronics, mobile communications, computer informatics and other advanced technologies, to improve mobility, safety and security, and productivity in the transportation sector, in association with other measures, to reduce energy consumption, improve air quality and enhance transportation accessibility". The most significant aspect of ITS which makes it distinct from any other transportation improvement strategies is the use of information technologies to help the components of surface transportation work together as an integral system (Shladover, 1993).

These two phenomena are chosen because they seem to have attracted most interest with regard to their impacts on travel behaviour and land use patterns.

Considering the relationship between land use and transportation, the question is what will be the effects of telecommuting and ITS on urban development pattern which in turn have effects on travel demand pattern. These two new technological innovations will have some short- and long-term implications for travel behaviour and land use patterns.

As shall be discussed in the following sections, the long-term effects of ITS and telecommuting are subject to uncertainty. Different studies have speculated different hypotheses about their impacts on the resulting land use patterns and in particular on households' residential location decisions.

It is the purpose of this research to provide an insight into the effects of telecommuting and ITS on residential location behaviour. More specifically, it is the intent of this research to develop a model of residential location choice by combining the revealed and stated preference data sources and incorporating the ITS and telecommuting measures.

1.2. TELECOMMUTING

While the subject of the substitution of telecommunications vs. physical transport has been of interest since early 1940s, telecommuting was never pursued seriously due to technology limitations and the prevailing lifestyle at the time (Oberlander cited in Khan, 1976a). The interest in the use of telecommunications as a substitute for travel was renewed in the 1970s (Khan, 1976a). In the 1990s developments in computer and telecommunications technology as well as concerns over traffic congestion, energy consumption, and air pollution resulted in considerable interest in telecommuting. At

present telecommuting is widely recognized as a transportation demand management (TDM) strategy due to its potential to relieve traffic congestion, conserve fuel, reduce greenhouse gases and improve air quality in urban areas (Transportation Climate Change Table, 1999; Statistics Canada, 1995; Matthes cited in Gupta et al, 1995). Telecommuting offers many benefits for individual workers as well. These include greater productivity, less stress, more flexibility to balance work with family commitments, greater job satisfaction, and lower costs of travel, clothing, and childcare ((Bélanger, 1999; Statistics Canada, 1995; Humble et al, 1995; Tung and Turban, 1996).

A distinction should be made between short- and long-term effects of telecommuting. In the short-run it is expected that telecommuting will result in a reduction in the number of peak-hour trips due to fewer commutes. For instance, the Regional Municipality of Ottawa-Carleton in Ontario, Canada has included telecommuting as a transportation demand management measure in its transportation master plan. They expect that this measure alone would reduce peak hour work trips by 7% (Institute of Transportation Engineers [ITE], 1996).

A simulation study by Gordon and Van Arsdale (1986) indicated that transportation and air quality improvements resulted from a scenario of telecommuting in the form of a mix of work-at-home and work-at-telecenter. Nilles et al (1976) studied the tradeoffs between transportation and telecommunications through a case study of an insurance firm in California. The results suggested higher productivity by telecommuters. It was also found that the firm would relocate to the outskirts of the city due to cost-savings accrued from cheaper rental space.

However, the interaction between transportation and information technology (IT) in

general, and telecommuting in particular, is complex and not necessarily completely beneficial. Nevertheless, empirical evidence from several studies has demonstrated transportation benefits such as reduced vehicle kilometres of travel, and fuel consumption and emissions on telecommuting days (Mokhtarian et al, 1995; Henderson et al, 1996; Henderson and Mokhtarian, 1996; Balepur et al, 1998; Moss and Carey, 1994; Irwin, 1994; Weiner, 1994; Pendayala et al, 1991; Hamer et al, 1991, 1992). In Sydney, Australia it was estimated that if 10 percent of workers telecommute one day a week the annual cost of congestion delay would be reduced by up to 38 percent depending how the telecommuting days are distributed over a 5-day week (Luk, 1994). A similar study in the U.S. has found that with 10%-20% level of telecommuting as much as \$23 billion would be saved in energy, transportation, and environment costs (Humble et al, 1995).

Despite the fact that interest in telecommuting is growing and that its potential effectiveness as a transportation control measure have been reported, estimating current levels of telecommuting has remained a challenge. The reason has been attributed in most part to the lack of telecommuting-related questions in transportation surveys as well as a lack of consistent definitions of working at home. This makes forecasting future levels of telecommuting even more difficult and more uncertain. For example, a study by the Transportation Research Institute (cited in Nilles, 1991) in 1991 forecasted that by 2002 as many as 50 million workers in the U.S. would be telecommuters. In contrast, the U.S. Department of Transportation forecast for 2002 was between 4 to 8 million telecommuters (Handy and Mokhtarian, 1996b). This number was estimated between 7.5 and 15 millions teleworkers in the study by Hopkins et al (1994). According to a survey

by FIND/SVP, there were approximately 11 millions telecommuters in the U.S. in 1997 (Meyer, 1998). In Canada, a recent Gallop poll estimated that approximately 2.2 million Canadians work at home some of the time, whereas the 1991 Census estimated this number to be around 1.1 million (Gurstein, 1994). The existence of such wide range is attributed to disparate definitions of working at home. As such, in recent years there have been a number of research efforts to model and forecast the adoption of telecommuting (Bernardino et al, 1993; Mokhtarian and Salomon, 1994, 1995, 1997; Handy and Mokhtarian, 1996a,b).

A telework symposium was recently held in Toronto to promote awareness of and education about telecommuting. There were mixed feelings about the spatial impacts of telework in that they ranged from no or minimal relocation impacts to high relocation impacts in terms of moving towards suburban and rural areas. In this symposium, results of a national study funded by Canada Mortgage and Housing Corporation (CMHC) were presented that aimed at providing some insight into factors that affect telework and home-based employment. Some of their important findings as they relate to this research were as follows (Gurstein, 1994):

- 80% of respondents were very satisfied with working at home;
- The majority of teleworkers lived in single-family detached homes in suburban areas;
- About 20% of teleworkers had moved or were planning to move outside the city.

However, no model was developed to analyse the acquired information.

Long-term effects due to adoption of telecommuting are also expected. Level of automobile ownership may be reduced. Of great importance, are the land use impacts of

telecommuting. A thorough literature review about the impacts of information technology on urban form and structure is presented in Section 1.4 since both telecommuting and ITS are subsets of information technology.

1.3. INTELLIGENT TRANSPORTATION SYSTEMS (ITS)

Although ITS is a new concept and is still in its experimental stages in North America, similar technologies have been in use in Europe (e.g., PROMETHEUS and DRIVE) and Japan (i.e., AMTICS) for many years, dedicated to improving the transportation system for motorists and alleviating traffic problems.

ITS is comprised of a broad range of diverse technologies and systems that although each of which has some specific tasks and activities to do, they work together as an integrated system. Describing very briefly, the existing ITS capabilities are bundled under the following seven user service categories (Transport Canada, 1999):

1. Travel and Transportation Management – includes functions such as en-route driver information, route guidance, traffic control, incident management, traveller services information.
2. Travel Demand Management – includes demand management operations, pre-trip travel information, and ride matching and reservation functions.
3. Public Transportation operations – this service bundle consists of public transportation management, en-route transit information, personalized public transit, and public travel security.
4. Electronic Payment – includes functions in the area of electronic payment services such as electronic toll collection (ETC) and electronic parking payment.

5. Commercial Vehicle Operations – includes services such as commercial vehicle electronic clearance, automated roadside safety inspections, on-board safety monitoring, hazardous material incident response, and freight mobility.
6. Emergency Management – this user service bundle includes emergency notification and personal security, and emergency vehicle management.
7. Advanced Vehicle Control and Safety Systems – includes the following functions: longitudinal and lateral collision avoidance, intersection collision avoidance, safety readiness, pre-crash restraint deployment, and automated highway system.

ITS can be applied to all modes of surface transportation such as private cars, vans, trucks, and transit buses. Therefore, by using any combination of above technologies, ITS will be able to improve mobility, safety, and productivity in the transportation sector according to service function and user needs (Diebold Institute, 1995; Whelan, 1995). Currently, there are more than 400 ITS projects underway throughout the United States and Puerto Rico, where the objective of each project is to provide a safer, more efficient transport system (Levy, 1997).

According to a recent study by Statistics Canada, nationwide, drivers spent an average of 58 minutes each workday in 1998 commuting to and from work. This excluded side trips such as picking up their children, which added 37 minutes to their commute time (Beauchesne, 2000). However, for Ottawa and other mid-size cities such as Calgary and Edmonton, commute time was reduced from an average of 61 minutes in 1988 to 57 minutes in 1998. According to the same study, which was part of the 1998 nationwide survey of more than 10,000 Canadians aged 15 and over, there were other factors that contributed to traffic congestion. These included road construction, bad weather, and

traffic collisions (Beauchesne, 2000). In fact, this is exactly where the chief benefits of ITS lie: to reduce travel times and delays due to such non-recurrent events.

It is highly likely that such a new technology with such a powerful ability to enhance the system operations will have some potential implications for both individuals and society as a whole. As is the case with telecommuting, these effects can be classified into short-term and long-term ones.

In the short-run, the pilot projects in the U.S. have shown very little ambiguity in terms of the resulting benefits. For instance, the INFORM Project, a precursor to an all-comprehensive ITS, devised in Long Island, New York States, has resulted in 300,000 vehicle hours of savings per year and 3-8% increase in average speeds (Transportation Research Board, 1993). In another study, GAO (1991) has synthesized the major research studies published over the last decade. All these studies have resulted in transportation benefits, especially in the area of congestion reduction. Most of these projects have shown that economic, safety and air quality benefits are also possible.

The long-term effects of ITS are, however, not so clear as are its short-term effects. ITS is different from other technological advancements in that it is promising to increase the system's capacity substantially by making a much more efficient and smoothly operated system, without any physical (or very little, if any) expansion to the existing system.

The historical development of American cities has served as evidence that, in the long run, transportation improvements (mainly for motorists) have caused urban areas to expand in the direction of these improvements. In the case of ITS, it has been speculated that such transportation improvements may cause new land development further away from existing ones. ITS is capable of reducing travel times between an origin and a

destination (e.g., by increasing travel speeds or optimisation of traffic signals that minimizes delays for motorists) as well as increasing the travel time reliability by means of providing real-time information to motorists. This capability may encourage individuals to move their residential location further away where housing is more abundant and cheaper without having to spend more time travelling, thus contributing to the urban sprawl problem and consumption of more transportation services. The smoother traffic operations provided by ITS may also bring about the latent (or induced) demand. That is, due to a more efficient system, people who had already foregone their trips (because of a congested and costly system, for example) may now make those trips, leading to consumption of more transportation services, thereby offsetting the benefits that are accrued.

These issues have been dealt with and discussed only qualitatively in the papers such as those by Shladover (1993) and Ostria and Lawrence (1994) mainly due to lack of enough data, as claimed by the authors, and by Mokhtarian (1993) who also believes that the contribution of ITS to decentralization might be much larger than that of telecommuting because ITS will most likely ultimately be available to every one all the time. Therefore, there is a definite research need in this area and as mentioned earlier this research intends to shed some lights on this issue. More on the long-term effects of information technology on urban area is said in the following section.

It is important to note here that only related aspects of ITS will be assumed to be available. These include Advanced Traveller Information Systems (ATIS) and Advanced Transportation Management Systems (ATMS). It is reasonable to assume that the above features will be more readily available for any urban area than other aspects of ITS (such

as AVCS and Electronic Toll Collection).

1.4. INFORMATION TECHNOLOGY AND FUTURE OF CITIES

Cities, especially in industrialized and developed countries, are transforming and shifting from a manufacturing-dominated society to an information-based one as a result of growing use and significance of telecommunications.

Urban areas are dominant focal point of population, economy, and communication in western societies including Canada. While urban nodes occupy only 3 percent of landmass in Canada, they accommodate over 76 percent of the population and 80 percent of economic activity (Simmons, 1991). As such, the move toward information-based societies, along with the revolution in communications (and transportation) is expected to have profound impacts on urban form.

There are a number of perspectives on the relationship between technology and society in general, and that of telecommunications and city as its subset. Some studies suggest that the revolution of information technology and decentralized nature of information will cause more and more people and businesses to move to city outskirts to form societies like 'edge cities' (Garreau, 1991) and 'telecities' (Fathy, 1991). These studies contend that dense cities no longer provide cost-saving advantages they once did. This perspective also suggests what is called 'technological determinism'. That is, new telecommunications technologies are seen directly to cause urban change, in a cause and effect manner (Graham and Marvin, 1996). It argues that new information technologies provide greater accessibility for the society by substituting communication for transportation, and movement of goods and services with the transmission of information.

This view is also supported by the works of Williams (1982) and Webber (1963).

In his study of impacts of telecommunications on metropolitan areas, Dakin (1973) made a number of important conclusions that are quoted here:

“... Evidence accumulates that future growth of metros will increasingly involve diffusion of population through their greater regions. Telecommunications and computer technology will not only be used to make this possible but will play the key role in maintaining and enhancing the present level of transactions in metros and spreading that level across their regions. A more balanced symbiosis between urban and non-urban areas will be required.”

He further suggested that teleconferencing would emerge as a likely very important element in future metropolitan planning, including the possibility of reconciling some administrative conflicts as well as that of increased scope of public participation.

Although the use of telecommunications will substitute for travel in many instances, the interaction between telecommunications and transportation is more complex. It has been recognized by many studies that telecommunications can also generate and induce new demands for travel. While substitution effects may occur these are likely to take place in the context of an overall increase in all forms of communication, including personal travel, in which telecommunications may take a larger share (Khan, 1976b; Salomon, 1986; Mokhtarian, 1990; Graham, 1997; Gasper and Glaeser, 1998). Research shows that telecommunications may also alter the trip purpose but not necessarily the frequency (Mokhtarian and Salomon, 1994). Thus, telecommuting and ITS might be a quick fix to urban congestion problems only in the short run. By the same token, the environmental benefits accrued from telecommuting and ITS may not be as high as it is expected to be;

people who avoided using their cars due to congestion will now start doing so because telecommuting has lessened congestion, therefore offsetting reductions in fuel use and emissions (Graham and Marvin, 1996).

In recent years there has been much speculation and debate about the future of cities and the role of advanced information technologies. Unfortunately, most of these debates tend to rely more on speculation, or unjustified assumptions about how telecommunication impact cities rather than on empirical analysis of city-telecommunications relations. This has created the field for extremes of optimism and pessimism about the impacts of telecommunications on both urban function and urban structure (Graham and Marvin, 1996).

In terms of urban function and form, on the one hand, there are technological determinists and futurists who think of telecommunications as a quick-fix solution to the social, economic, and political problems of the society. On the other hand, there are anti-utopians who view telecommunications as the means for increased polarization and depression of urban areas. As far as the urban form is concerned, futurists like Toffler (1981), who coined the term 'electronic cottage', Naisbitt (1995), and Eubanks (1994) believe that improved information technology will dissolve cities. The basic idea as described by Gasper and Glaeser (1998) is that the ongoing advancements in telecommunications create a 'space-less world' where everybody lives in electronic cottages and teleconference or telecommute. One of the main reasons for these arguments is that they rely on the questionable assumption that (although not unreasonable *a priori*) telecommunications has substitution effects on face-to-face interactions and on the

transportation of goods and people. If telecommunications were to substitute for face-to-face meetings, improvements in telecommunications technology should reduce the number of face-to-face contacts. However, studies from France (Graham and Marvin, 1996), Japan and the U.S. (Gasper and Glaeser, 1998), and the U.K. and Australia (Wigan, 1985) show a strong positive relationship between telecommunications technology usage and passenger transport.

As for the urban structure, there are also various opposing views. One view suggests the spatial dispersion of cities due to telecommunications revolution (Toffler, 1981; Alber, 1975; Schuler, 1992). These studies argue that because “the cost of distance” is diminishing through advanced telecommunications, travel time no longer acts as a binding constraint. This will result in further dispersal. This logic is largely based on the sub-urbanization pattern experienced with the previous ‘spatial technology’, namely, the automobile. The automobile provided people with the mobility to move out of central cities, a pattern which was followed by the sub-urbanization of retail, employment and leisure activities. With the advent of telematics it is expected this trend will be reinforced but in a modern telecommunications-based society. Edge cities (Garreau, 1991), the ‘wired city’ (Dutton et al, 1987), the telecity (Fathy, 1991), the electronic cottage (Toffler, 1981) are but a few notions developed in recent years to describe various forms of future cities. A study by Lund and Mokhtarian (1994) developed a single partial equilibrium model based on Alonso's (1964) model of residential location, which states that households will find a location that minimizes their commuting and housing costs. The model showed that the introduction of telecommuting would cause a relocation further away from city centre whose extent depends only upon the level of

telecommuting and the rate of change in land price as one moves away from city centre. Hopkins et al (1994) and Bernardino et al (1993) have also suspected that telecommuting might encourage people to move further to urban fringe and/or rural areas because of less need for everyday travel, thus contributing to the imbalance among jobs, housing and transportation patterns. In terms of energy consumption and air quality, this eventual relocation may or may not offset the telecommuting benefits, since emission characteristics depend on the vehicle efficiency and its operation cycles which are not linearly related to VKT (Hopkins et al, 1994).

Another viewpoint on urban structure is that telecommunications will have minimal impacts on the existing locational patterns (Nijkamp and Salomon, 1989; Salomon, 1986, 1996; Gottmann, 1977). These studies believe that although information technologies will be adopted and applied in remote regions, the overall pattern of activities will not change significantly from what they are today. A study by Nilles (1991) investigated the relationship (if any) between telecommuting and urban sprawl. He hypothesized that telecommuting can be structured based on nearby telework centres so that it does not influence housing location decisions that result in urban sprawl (by producing net long term increases in travel). From an analysis of 2-year data from the California Telecommuting Pilot Project, Nilles found that there was no significant difference between the telecommuters and the control group (i.e., non-telecommuters) with respect to their residential move patterns, thus supporting his hypothesis. The results, however, are supportive for the short period of two years observations, which means that it is quite conceivable that the hypothesis may be rejected in the future. Mokhtarian (1993) in a discussion paper about land use implications of telecommuting technologies suggests that

any negative relocation impacts of telecommuting may be small and that many factors are involved in location decision with telecommuting being only a facilitator in this decision. On par with the 'minimal impact' viewpoint, some studies have supported the notion that telecommunications technology is neutral, meaning that either concentration or dispersion may happen depending on the city's existing economic profile and its socio-political characteristics (Webber, 1963; Graham, 1997; Blais, 1994, 1998; Webber, and Manderville cited in Young, 1990). These studies argue that the dispersion theory is based on the following assumptions that are often simplistic and implicit (Salomon, 1996):

- Telecommunications substitutes transportation;
- Information substitutes material good;
- Telecommunications systems are ubiquitous;
- Dispersal is constrained by congestion and travel cost.

What can be concluded from these studies is that one should avoid speculating on extremism such as 'death of distance' proposed by Cairncross (1997). Information technology is just a tool, albeit very powerful, to conduct economic activities in a faster and more efficient manner. There is little doubt that the information revolution will have profound impacts on cities. The question that has not been answered is that what type of impact it would be. The reason is in part due to relative infancy of the telecommunications advances as well as lack of empirical analysis.

1.5. ADVANCES IN TELECOMMUNICATIONS TECHNOLOGY

One of the main reasons that telecommuting was not accepted widely in the 1970s was

the technological limitation both in the computer hardware and software, and in the telecommunications industry. Today, however, the revolution in information technology that has occurred over the past decade has paved the way to support telecommuting (as well as ITS) more than ever before.

In telecommuting practice, more often than not, information has to be exchanged between the telecommuter and the main office. The information could be in the form of graphic, data, video, or sound. When all or some of these information types are incorporated together through a common channel, most often a computer, it is called multimedia (Merakovsky, 1994). The information structure has to support telecommuting to make it a successful practice. In recent years there have been numerous advances in areas of devices, databases, telecommunications networks, and software, which are the major infrastructure categories required to support telecommuting. Each of these categories is described briefly below.

1.5.1. Devices

The devices that can be used to support telecommuters include telephone, copier/fax machines, computer (portable or otherwise), personal digital assistant (PDA), printer, cellular phone, etc. Of the above equipments PDAs are being viewed as a major technological breakthrough. They are most suitable for travelling telecommuters. According to Henning (1993):

“... PDAs are handheld pen computers which represent the convergence of three different product classes: (a) electronic reference devices, (b) communicators, and (c) computers.”

They have a number of advantages over traditional portable personal computers. PDAs (Tung and Turban, 1996):

- Are smaller than portable PCs and can be easily carried anywhere;
- Cost less than laptops and notebooks;
- Are easier to use than portable PCs;
- Provide easy access to e-mail, fax, and paging services.

In essence, PDA acts as an input device. The user can write on it or make sketches and annotations using the special pen that comes with it. The resulting data can then be transferred to a computer. To quote Tung and Turban (1996):

“... When a user brings a PDA from the road into an office or home, the PDA will log on to the PC, download from the PC any e-mail, exchange new files, and update any files. In this manner it will function as a briefcase that packs itself with those needed items from the employee’s desktop PC.”

1.5.2. Databases

Telecommuters often need to access their corporate database and/or create their own database. This can be achieved with the innovative client/server approach. In client/server architecture the computing task is split efficiently between the server, which can be a corporation’s mainframe or minicomputer, and the client, which may include telecommuter’s notebook, microcomputer, or PDA (Pliskin, 1998).

The databases can be kept on the telecommuter’s hard disk, or CD-ROM that can hold the entire Encyclopaedia Britannica on one disk. More recently, double-sided Digital Video Disks (DVDs) have been introduced to the market that can hold 17 gigabytes of

data- roughly equivalent of four movies of 135 minutes each (Baal-Schem and Shinar, 1998).

1.5.3. Telecommunications Networks

Telecommunications networks are needed to provide access between a telecommuter's and other remote computers. There have been a number of technological advances in recent years. One of them is the development of faster modems. Nortel Networks has developed a modem that can transmit data at an incredible speed of one million bits per second (1 Mbps) downstream (i.e., to user's computer) that is roughly 30 times faster than today's standard 28 Kbps modems, and a speed of 120Kbps upstream (i.e., from user's computer) (Bell Canada, 2000; Bagnall, 1998). Moreover, it is capable of handling voice and data at the same time, which means one can surf the web while conducting a telephone conversation.

Another technology from phone companies is Digital Subscriber Loop (DSL). DSL is a circuit that connects a user's premise to the telephone central office. It allows speeds of up to 1.5 Mbps downstream and 176 Kbps upstream. DSL acts basically as a personal internal LAN (it is discussed in more detail below) that routes data stream around old, slow telephone switches (Piskurich, 1997).

More recently, cable modems have been developed. It is offered through the cable companies and uses the current cable TV lines at home to provide remote access. They provide download speeds of up to 6Mbps, roughly 100 times faster than current computer modems (Piskurich, 1997).

The computers are also connected to other computers using Local Area Networks

(LANs). This system interconnects computers within a building complex in order to enable workers to share resources such as printers and hard disks as well as to exchange e-mail, share database, transfer files, and virtually any other data and information that can be accessed while sitting at a computer terminal at the main office (Tung and Turban, 1996). Of above applications, e-mail was the major force behind the growth of LANs. In the U.K. alone, the network technology has been installed at a rate of 1500 LANs per month (Murphy, 1993). LANs were originally developed to connect a set of computers that reside in the same building. However, with the recent advances in wireless technology and local area digital technology, remote workers are able to access LAN resources. The wireless LAN market in the U.S. is expected to grow four-fold from about \$200 million in 1997 to \$800 million by the year 2000 (Wireless LANs, 1998). It is also possible to create a Wide Area Network (WAN) by connecting a LAN in one office to another LAN located either at telecommuter's house, a telecenter, or another office branch.

Integrated Service Digital Network (ISDN) is another technology that has been used as a major support of telecommuting. ISDN provides high-speed digital transmission to the home over a special line (Sprey, 1997). An ISDN line, which can be either leased or used as a dial-up service, is 10 to 100 times faster than existing analogue telephone lines. It also makes desktop videoconferencing (which will be described later) a feasible and affordable option (Tung and Turban, 1996).

Perhaps one of the most dramatic advances in telecommunications technology in recent years is the development of optical fibres. One of the major problems with any of the above-mentioned technologies is the bandwidth restriction. Bandwidth is the maximum

amount of data that can travel a communication path in a given time and is measured in seconds (Adler, 2000). In analogy to transportation system, if one thinks of communication path as a highway, bandwidth is the available capacity of the highway. When a signal is to be transmitted, the channel must provide enough bandwidth (capacity) to capture all the information being sent (Adler, 2000). The developments in optical fibre cables allow for the transfer of large amounts of information. In theory, each fibre can transmit 10 million phone calls or their equivalent in teleconferences or files (Baal-Schem and Shinar, 1998). Research and development in fibre-optic technology is ongoing. Nortel Networks recently introduced a new fibre optic technology- OPTera 1600G. It carries a beam of light containing 160 colour streams, which will increase by 640 times the Internet's backbone speed and capacity to carry multimedia information to consumers and businesses (Nortel Boasts Internet, 1999). As an example of its capabilities, a single strand of optical fibre can transport the entire four million book collection of the U.S. Library of Congress from Washington to Los Angeles in just seconds (Nortel Boasts Internet, 1999). Although this technology is currently being developed and tested for corporate business, in the near future the optical fibre cables will be available to residential homes to replace the existing twisted-pair or coaxial wiring.

It should be mentioned that telecommunications is the backbone of all ITS applications as well. Many of the technologies described above, in one-way or another, are used in all seven major ITS user services (described in Section 1.3) to transmit information between two or more sources. For example, fibre optics and ISDN lines are used in Advanced Traveller information System (ATIS) to support provision of travel information. Telecommunications systems also enable electronic toll collection systems and assist in

the location and identification of commercial vehicles and buses. They provide the critical link among the elements of physical networks, vehicles and users that traverse the network, and the operators and managers of the network (Adler, 2000).

1.5.4. The Software

To perform the telecommuting tasks a variety of software can be used by utilizing the infrastructure described above. Videoconferencing and groupware tools are two of the most advanced software products used by workers and telecommuters. These are described below.

Videoconferencing

A broad definition of videoconferencing is real-time communication between two or more remote locations engaging in face-to-face interaction (Sprey, 1997). Videoconferencing can be done from either a conference room specifically set for this purpose, or from the person's desktop that uses a personal computer equipped for multimedia communication (Merakovsky, 1994). Basic equipment includes monitor, camera, microphone, speakers, and CODEC (which stands for Coder/Decoder, and is used to compress and decompress video signals). When more than two locations are involved, a video bridge is used to provide interaction among all sites (Sprey, 1997). In previous years, room-based videoconferencing was more widely used than desktop-based due to the system cost. However, over the past few years, the development of semiconductor chip sets (i.e., video CODECs) has made it possible for CODECs to be installed on PCs as a PC card to make them affordable (Merakovsky, 1994). In desktop

videoconferencing, participants sit at their own desks and call up other participants using their personal computer through digital telephone lines (i.e., ISDN) to share audio and visual information. The relatively new desktop system is typically used in conjunction with software tools such as electronic white boards (which are used for modifying data files) or other shared applications. As such, desktop systems are more intimate, collaborative, and interactive than the room-based videoconferencing (Sprey, 1997).

The ability to access and modify data files provides more flexibility than face-to-face meeting. Therefore, multimedia videoconferencing is seen by many as a technology to remove the necessity of travel for in-person meetings and to increase workers productivity (Merakovsky, 1994).

The growth in sales of videoconferencing in the U.S. has been phenomenal as it rose from \$660 million in 1993 to (expected) \$10.8 billion in 1997. Several videoconferencing products are being marketed by companies like Picture Tel (PCS 1000), Fujitsu (Desktop Conferencing), and Creative Technology (Share Vision PC3000) (Tung and Turban, 1996).

Groupware Tools

Groupware tools are those that allow multiple users to share information. Lotus Notes is one of the most advanced groupware tools in the market that may influence telecommuting strongly due to its capabilities. To quote Tung and Turban (1996):

“... Lotus Notes is a robust, secure application development environment through which developers can quickly create cross-platform client-server applications that have an immediate impact on the efficiency of business processes. [Lotus Notes] is a

Windows-base software that acts as a group communications environment that let users access and create shared information. It provides a workgroup e-mail, distributed databases, bulletin boards, text editor, document management and form generator, workflow capabilities and various applications development tools, all integrated into an environment with a graphical menu-based user interface. Lotus Notes is used for many applications including fostering the virtual cooperation and similar inter-company alliances.”

1.6. THESIS ORGANIZATION

The thesis is presented in the following format. Chapter 2 provides a review of residential location theory and residential choice models. With the background presented in Chapters 1 and 2, the research objectives, research framework and methodology is explained in Chapter 3.

Chapter 4 explains in detail the logit analysis within the context of discrete choice and random utility theory framework. It includes properties of logit models, the estimation method, and measures of goodness-of-fit of the model. The issue of aggregate forecasting is also discussed.

Chapter 5 explains the survey design, implementation, and analysis for the pilot study. These include various aspects of experimental design such as definition of alternatives or choices, definition of attributes and their levels, and sampling process.

In Chapter 6, the issues of survey design and implementation are revisited, but in the context of the final survey. Also, descriptive analyses of factors related to telecommuting are presented.

In Chapter 7, discrete choice analysis of the final survey is presented in detail. This includes logit estimation with revealed preference (RP) data, stated preference (SP) data, and combined RP and SP data. The models' results are also discussed in full length. Aggregate forecasts of future market shares for the available residential location alternatives are also presented.

Finally, Chapter 8 includes a summary of the thesis, and conclusions. In addition, extensions and recommendations for further study are made.

CHAPTER II: RESIDENTIAL LOCATION THEORY AND STATED PREFERENCE APPROACH

2.1. INTRODUCTION

As mentioned earlier, this research is focused on the impacts of ITS and telecommuting, among other factors, on residential location choice. Thus, before formulating the research framework and methodology, a review of residential location theory is necessary. This review is presented in this chapter. It also explains various methodologies and techniques used to develop empirical housing location models.

Before proceeding to the next sections, a short note is in order. Although much of the literature in this research is related to the U.S. cases, most of the differences between the U.S. and Canada are often explained by a moderate time lag rather than by significant differences in spatial structure (Gordon and Richardson, 1997). A study by Goldberg and Mercer (cited in Gordon and Richardson, 1997) also shows that although Canadian metropolitan areas have higher central city densities, both countries' cities are decentralizing at the same rate. Urbanization in Canada has been under transformation since 1921. At that time, just over 4.2 million or 48 percent of Canadians lived in urban areas. By 1986, the number rose to 19.4 million persons or over 76 percent of the nation's population. Of these, 15.2 million or almost 60 percent lived in census metropolitan areas (Bourne, 1991). In terms of intra-urban form and development, since 1981 urban areas in Canada have been experiencing continued decentralization toward outer suburbs and urban fringe areas, with central city population remaining stable to modest growth,

a trend that is similar to those of U.S. cities (Bourne, 1991).

2.2. LOCATION THEORIES AND RESIDENTIAL LOCATION CHOICE

Location theory generally deals with the issue of how various land uses compete for space in a region (Steiner, 1994). It has its roots as early as the 19th century when Ricardo (cited in Deakin, 1991) observed that land, labour and capital are the primary inputs of production and that location of land determines, in parts, its use. Since then many researchers have attempted to develop mathematical models for different land uses including residential use.

Residential location theories can be divided into three broad categories: hedonic pricing models, urban economic models, and discrete choice models. The first group of models focuses on factors that affect housing value through multiple regression of key attributes of housing and neighbourhoods (Steiner, 1994). In terms of the second category, one of the most prominent theories of urban growth is the bid-rent theory introduced by Alonso (1964), which focuses on economic factors in explaining urban spatial structure. This theory, which may be categorized as a deterministic approach in its application to residential location and housing demand, is based on marginal utility theory and had other followers like Muth (1969) and Goldberg and Chinloy (1984). Although very popular, this theory has some theoretical and empirical shortcomings. One major restriction of this theory is that it is based on the concept of a monocentric city with a Central Business District (CBD) in the centre and housing units arranged around it (Anas, 1982). Another one is that it does not consider the leisure time budget, which is a major factor in residential location choice. The problems with the deterministic approach made

urban planners and economists depart from it and develop other formulations, one of them being the development of discrete choice analysis in the context of random utility theory, of which the logit and probit models are the most popular ones. The probabilistic concept of this approach enables us to take into account explicitly the variations in taste and preference of individuals in choosing their housing location as well as socio-economic differences in the population. However, a weak point in this theory, as claimed by Matsuura & Numada (1992) is that the mutual relationship among the factors constituting the theory are not clear and accurate, because each attribute in the theory is assumed to be a random variable.

Discrete choice models have had extensive transportation applications particularly for the choice of travel modes (e.g., Domencich & McFadden, 1975; Richards & Ben-Akiva, 1975; Ben-Akiva, 1973). However, due to its nature, discrete choice analysis can and has been applied to numerous fields including urban planning, telecommunications, operations research, market research and public policy. More will be said about stochastic disaggregate models in Chapter IV.

Residential choice models have been used for almost two decades. These models focus on trade-offs among various factors that influence residential choice. Most of these studies developed logit models in one form or another. Some developed simple multinomial logit (MNL) model (Pollakowski, 1982; Friedman, 1981; Quigley, 1976) while others developed joint logit model of residential location and mode to work (Lerman, 1976; Anas, 1981, 1982; Horowitz, 1986). Also, nested logit models were developed to explain households' residential location decisions (Weisbrod et al, 1980; Quigley, 1985; Ben-Akiva & dePalma, 1986; Kim, 1991). Most of these studies have

included in their utility model, in addition to housing price and transportation accessibility measures, socio-economic factors such as age, income, family size, auto ownership level, etc., as well as level of public services such as property tax rate, per pupil school expenditures, etc. A list of various attributes influencing the housing choice is provided by Hunt et al (1994) along with their relevant source references.

One recent study by Matsuura and Numada (1992) has attempted, under the deterministic approach, to examine the effects of a change in travel speed to and from work on the residential location and housing size of households. The factors they considered in their model were: travel impedance (consisting of line haul travel time, access and egress times, and travel distance), income, housing price, and per capita leisure time budget. The model showed, theoretically and empirically, that an increase in travel speed would produce a proportionate shift in residential location, but just a minor effect on housing size. The model, however, does not consider most of the above-mentioned socio-economic factors. It is important to note that although transportation variables (e.g., time and cost) do matter in the residential location decisions, recent models have shown that these are no more critical to location decision than other factors such as housing type, neighbourhood quality as well as life-cycle of the households (Deakin, 1991; Lerman, 1976; Weisbrod, 1978; Weisbrod et al, 1980). More recently, the regional planning agency in Los Angeles County sponsored a study to examine the impacts of a \$78.3 billion rail-transit investment plan on land use patterns in that county. The program planners expected that this massive program would increase the transit share from 4.5% to 19% by the year 2010. However, using a transportation-forecasting model, the study group estimated that only 7 to 10 percent of the commuters would use transit (Giuliano,

1995). This is the same case as in 1977 when the studies of the BART rail system in San Francisco found that its impacts on residential location pattern was over-estimated (Metropolitan Transportation Commission cited in Weisbrod et al, 1980). Another survey was conducted in Orange County, California in 1994 to examine the attitudes about living in planned communities at the southeast of the county. The study provided evidence that outdoor amenities, housing and public school quality were far more important than commuting considerations in residential location choices for these people (Giuliano, 1995). These studies support the fact that there is a trade-off between transportation measures and other factors in residential location decisions.

2.3. QUALITATIVE VS. QUANTITATIVE RESEARCH STUDIES

In the market research industry, there are two major categories of research studies: qualitative and quantitative studies, each of which has different sub-classes of research approach.

The quantitative research is primarily conducted for the purpose of obtaining empirical evaluations of behaviour, attitudes, or performance (Greenbaum, 1988). The major types of quantitative research are behavioural and attitudinal surveys. The qualitative research, on the other hand, is used for exploratory purposes in situations where not enough is known about a marketing problem (Aaker & Day, 1990).

Focus groups and Delphi are the most frequently used methods of qualitative research. They are briefly explained in the following sections along with reasons why they were not used in this research. Section 2.4 explains the Stated Preference and Revealed Preference approach in the class of quantitative research studies, which was used for the

purpose of this research.

2.3.1. Focus Groups

To quote Krueger (1988): "... A focus group can be defined as a carefully planned discussion designed to obtain perceptions on a defined area of interest in a permissive, unthreatening environment". The size of the group ranges from as low as four to twelve people representing the general public, led by a skilled moderator. This technique has been mostly used in studies of consumer products, but it can also be used for many other situations. The main objective of a focus group is to discuss the issues and factors that influence the participants' choices on the defined area of interest (which in the case of this research, would be the residential location choice). However, in the case of this research, studies of this kind have been carried out for almost two decades now, and many of the important factors affecting households' decision have been identified (Hunt et al, 1994). Furthermore, although focus group approach is very useful for exploratory purposes, it is not an easy technique to employ. It requires planning the agenda, recruitment of participants, and effective moderation to name a few (Aaker & Day, 1990). For large focus groups, logistics is an important concern as well. Moreover, the purpose of this research is to carry out a quantitative research into the impacts of telecommuting and ITS, among other factors, on residential location choice behaviour. Therefore, although this technique is useful and valuable supplement to quantitative research, considering its administrative and logistics problems, it was not considered in this research. This, in no way compromised the quality and usefulness of this research study.

2.3.2. Delphi Approach

The Delphi technique is basically used for forecasting purposes. In the Delphi approach, a group of experts in the specific subject gather and reach a consensus on a forecast (Aaker & Day, 1990). This approach is comprised of a series of questionnaires known as "rounds". In each round, input from the group members is gathered, analysed, and fed back to participants by the moderator for the next round. The process continues until there is a convergence in response- usually after three or four iterations (Porter et al, 1991). As with any other survey method, there are some advantages and disadvantages associated with this approach. The main advantage is that the amount of information available to the group is at least as great as that available to any of the group member, which would lead to a better forecast than that of any one of the participants (Martino, 1983). On the other hand, one of the disadvantages of a Delphi is that there is a social pressure that the group exerts on its members- that is, the pressure to agree with the majority although the individual believes that the majority is wrong (Martino, 1983). Another disadvantage is that most often than not reaching consensus becomes a goal in itself with a greater importance than obtaining a well thought-out forecast.

There is also a question of "accuracy" of the forecast produced by the Delphi group. To quote Martino (1983): "...Delphi is based solely on expert opinions. The accuracy of the forecasts is only as good as the opinions that go into the forecasts". In general, there is a lot of work required for conducting a Delphi survey (Porter et al, 1991). Although most appropriate for normative forecasts, considering the aforementioned disadvantages of this approach, its administrative and logistics problems, and the fact that this technique falls into the class of qualitative methods, it was not used as the forecasting tool in this

research. Moreover, the main objectives of this research are to identify telecommuting- and ITS-related factors and their relative importance in residential location decisions. The residential model then can be used to forecast aggregate demand for various residential alternatives- a task that is the main objective of a Delphi.

2.4. STATED PREFERENCE VS. REVEALED PREFERENCE APPROACH

All the literature reviewed so far used the revealed preference (RP) approach in studying housing location behaviour. Choice models based on revealed (or observed) behaviour are calibrated to actual data, and therefore they have a high degree of reliability. Revealed preference data, however, suffer from a number of perspectives (Kroes & Sheldon, 1988):

- Correlation exists among some of the attributes (e.g., time and cost), and thereby trade-offs among these attributes may not be clearly observable;
- There is a limited range of attributes;
- Some choice alternatives, characteristics, and/or services may not exist.

From the viewpoint of this research, the last-mentioned shortcoming of RP data has a strong bearing on this research. Telecommuting and ITS are innovative technologies whose effects on residential location are not conclusive, on the basis of what has been studied so far, simply because there is not enough observed data for them. Therefore to investigate their impacts on residential choice, one must consider another refined method. Stated preference (SP) approach is a technique that was developed to overcome the above problems with RP data. In this method, individuals are presented with hypothetical alternatives and asked to indicate their preferences towards the choices offered (Hunt et

al, 1994; Pearmain et al, 1991). In this technique, the researcher has complete control over the factors that influence the choice. Therefore, SP models can be designed to reduce or eliminate the interdependency among attributes, can provide respondents with broader ranges of choice attributes, and can include policies and alternatives that are completely new (Louviere et al, 1981).

Before continuing with this subject, it is important to introduce different terminologies for SP techniques. The most widely used SP techniques are referred to as "conjoint analysis" (Pearmain et al, 1991). To quote Louviere (1988):

"...The term conjoint analysis means decomposition into part-worth utilities or values of a set of individual evaluations of, or discrete choice from, a designed set of multi-attribute alternatives."

In travel behaviour research, the terms conjoint analysis, 'direct utility assessment' (Kocur et al, 1982), 'functional measurement', 'stated preference analysis', and 'trade-off analysis' are used interchangeably. Louviere (1988) recommends the term conjoint analysis that is well known in marketing research and other social science disciplines. In any case, all these nomenclatures refer to a single general approach, which uses experimental design procedures to elicit information about respondents' preferences in a set of transport (or housing location, in our case) options to estimate their utility functions (Kroes & Sheldon, 1988).

2.5. CONJOINT PARADIGMS

There are a number of conjoint paradigms for measuring the individual utility. A brief overview of them is presented below.

2.5.1. Ranking Responses

This type of conjoint analysis is based on the axiomatic theory called conjoint measurement, which was first developed in the applied psychology field by Krantz and Tversky (cited in Louviere, 1988a). In this approach, all the options are presented to the respondent at once and then s/he is required to rank these hypothetical alternatives in order of her/his preference, thereby implying a hierarchy of utility values (Pearmain et al, 1991). The main attraction of this technique is that all options are presented together but this also limits the number of options that can be evaluated without causing fatigue in the respondent. Furthermore, the data provided in this approach represent *judgment* by the respondent and not necessarily their choice in real life (Ortúzar and Willumsen, 1994).

2.5.2. Rating Responses

This technique is related to the Information Integration Theory (IIT) and Social Judgment Theory. In conjoint analysis, the use of IIT models to estimate the vector of coefficients of utility function is also called functional measurement (Louviere, 1988a). In this method, the respondent is asked to score or rate each alternative on some type of scale- e.g. stating satisfaction, likelihood of use, or a numerical scale (Bradley & Kroes, 1990). The responses might then be handled using normal arithmetic operations such as calculating averages or ratios. However, it has been shown that responses are correlated with the scales used and labels attached to them. Therefore, there is no evidence that the ratings can be usefully elicited and translated into cardinal scales of this type (Ortúzar and Willumsen, 1994).

2.5.3. Choice Responses

In choice experiments respondents are being presented with a pair or group of options, and are asked to simply select their most preferred option. This method has advantage over ranking or rating approach because it corresponds more closely to the kind of choices they encounter in real life (Pearmain et al, 1991). In other words, the information provided by ranking or rating methods indicate "judgment" by individuals and thus are not realistic in terms of people's actual choice behaviour. Those methods, however, provide very rich response data.

Each of these three methods, then, has its own strengths and weaknesses, and there is no consensus in the literature for the use of one method over the other (Louviere, 1988a; Pearmain et al, 1991; Bradley & Daly, 1993). However, a few literature items prefer the method of SP choice to other methods on the grounds that it is easiest to complete and the best understood by respondents (Hensher et al, 1988). Moreover, recently Ben-Akiva et al (1992) investigated the reliability of SP ranking data. They found that there were significant differences among response data for different ranks. Their empirical results also showed that the reliability increased with increasing rank.

Therefore, **the method of 'SP choice' will be used in this study as opposed to 'SP ranking' or 'SP rating'**, especially because in recent years the 'SP choice' has been shown to be the trend (Bradley & Daly, 1993) as well as the fact that it is the only way one can combine RP and SP data (Hensher, 1994).

2.6. HOUSING LOCATION BEHAVIOUR USING SP TECHNIQUES

The weaknesses associated with RP data encouraged researchers to divert to conjoint analysis in studies of housing preferences, in one form or the other. These studies successfully provided insight into the influences of factors affecting residential choice behaviour of individuals (Louviere, 1979; Timmermans, 1984; Joseph et al, 1989; Hunt et al, 1994).

Although a powerful method, the SP data suffer from a serious flaw. The principal weakness is the fact that respondents are stating what they would do given the hypothetical choices, which implies that in reality they may not necessarily do what they say. Therefore, the reliability of SP data is uncertain. This is a problem that is not very serious with RP data because those models are calibrated against actual behaviour not the intended ones. The reliability of SP data is manifested in two different ways: "validity" and "stability" (Ben-Akiva & Morikawa, 1990a). Lack of validity indicates a discrepancy between actual and stated behaviour and it relates to a bias in SP data. Lack of stability corresponds to the magnitude of random error or noise in the SP data and it often depends on the quality of survey and experimental design (Ben-Akiva & Morikawa, 1990a). Thus, on one hand, the RP data have high degree of reliability but cannot represent the trade-offs among factors due to multicollinearity among explanatory variables. On the other hand, SP data can provide rich information on various options and the trade-offs that exist among variables but the responses are highly subjective and may differ from the actual choice. Therefore, combining RP and SP data seems to be an appealing way to overcome the shortcomings of each data type and to take advantage of their strengths. In fact, Morikawa (1989) formulated the combination of different data sources. As such, RP

and SP data compliment each other. The mixed estimation has some statistical issues associated with it and recent developments in combined analysis of RP and SP data have addressed most of them (Ben-Akiva & Morikawa, 1990a,b; Morikawa, 1994; Pearmain et al, 1991; Bradley & Kroes, 1990). More about the mixed estimation method is explained in the next chapter.

2.7. TELECOMMUNICATIONS AND OFFICE LOCATION

Although beyond the scope of this research work, it is worth noting here that telecommunications technology is also expected to have impacts on firms location decisions as indicated in Section 1.4.

Traditionally, important factors in firm location decisions include land cost and availability, transportation accessibility to costumers and suppliers, labour availability, wages, taxes, and measures of agglomeration economies and quality of life (Hansen, 1987; Shukla & Waddell, 1991). However, a number of research works has shown that the ability to transfer information using communications channels is becoming increasingly an important factor in firms' relocation decisions by creating significant increased flexibility in the location of office activity (Kellerman, 1984; Goddard and Pye, 1977; James et al, 1979; Nicol, 1985). In addition, Kumar (1990) showed that advances in telecommunications technology would tend to cause a dispersal of information-based firms into different parts of a city and shift urban areas toward multi-centric ones. The same study found a decline in average daily work trips for telecommuters suggesting a substitution effect of telecommunications.

From a firm's perspective, advances in telecommunications technology will be beneficial

as it allows the firm to, for example, create satellite offices in either rural areas or even in other countries where real estate and labour costs are cheap. Some examples of companies that are freeing up their floors of expensive office space are as follows:

- Currently the entire air ticketing operation of American Airlines is being processed in Barbados, which is known as the 'offshore information capital of the world', at a fraction of cost of renting office space in New York City (Humble et al, 1995).
- At IBM's new regional office in Cranford, New Jersey, there are only 220 desks for the 650 sales and services staff. Telecommuting arrangements have been made for these employees to share the office desks, thereby saving company substantial office space (Baal-Schem and Shinar, 1998).
- By providing its southeast sales staff with laptop computers, AT&T was able to reduce its overhead costs by 50 percent and cut office space dramatically from 12 floors to 2.5 floors (Pratt, 1997).

CHAPTER III: RESEARCH FRAMEWORK

3.1. RATIONALE FOR THE RESEARCH

With advanced transportation systems being implemented in Europe and Japan, and being under final experimental stages in the U.S. and parts of Canada, it is expected that these systems will be in full operation in the near future. Telecommuting is also gaining popularity in recent years and with overcoming some behavioural and technological problems, it is also highly likely that many organizations and their employees in the near future adopt this technology to replace some work trips. What remains to be examined is their effects on residential location patterns in the long run. The literature review revealed that there is mixed evidence regarding these impacts, thereby making it worthwhile to probe this area of work. None of the previous studies of residential location choice have investigated such impacts of telecommuting and ITS. To investigate these impacts, it is the intent of this research to develop a model of residential location in light of the ITS and telecommuting.

However, the important point is to understand how the attributes of telecommuting and ITS will be introduced and measured in this analysis. To answer this, one should find out in what ways these technologies will affect people. In other words, how individuals will perceive these technologies.

For telecommuting, as the literature suggests, the relevant characteristic will be savings in travel time and money due to less need for daily work trips plus other social conveniences (e.g., comfort of being at home, flexible hours, control over work).

For the ITS case, the most prominent characteristics, as perceived by people, could be:

- Shorter travel times for motorists and transit users through ATMS and ATIS technologies.
- More reliable (or less variable) travel times. Because of the real-time information provided by ITS (as well as a historic database constructed in this way over time which will be fed back to the system), commuters and other travellers will be much more certain about the roadway and traffic conditions ahead of them. Reduction in travel time variability might be the most important aspect of ITS from the user point of view. This variability will have two dimensions: magnitude and frequency (e.g. 5 minutes a day, 10 minutes a week, etc.) (Senna, 1994).

3.2. RESEARCH GOALS AND OBJECTIVES

Based on the foregoing, the main goal of this research is to examine the trade-offs that households make when deciding where to live, with a focus on the significance of telecommuting and ITS. Accordingly, the main objectives of this research are to:

- Develop a residential discrete choice model;
- Quantify impacts of telecommuting and related aspects of ITS measures on residential choice;
- Identify the important transportation-related factors, among other things, on residential location choice behaviour;

- Compare the behaviour of telecommuters and non-telecommuters with respect to their residential location choice; and
- Estimate aggregate demand for various residential choices within the study area.

3.3. SCOPE OF THE STUDY

The literature review presented in Chapter 1, revealed that long-term effects of both telecommuting and ITS, as subsets of information technologies, on urban land use patterns are subject to uncertainties. Cities are basically made up of business and residential entities. Although incorporating both elements will ideally provide for a thorough investigation of such potential impacts, such undertaking is beyond the scope of this research work due to financial, data requirement, and time constraints of this research thesis. Instead, the focus is on the residential side only. This, by no means indicates that telecommunications technology does not have any impact on business location choice.

The information required for the development of the empirical residential models was obtained through an attitudinal survey. The Ottawa-Carleton Region was selected as the case study. The sample included the employees of all organizations within the Region whose job description was deemed suitable for telecommuting (for more details please refer to Section 6.5.).

3.4. RESEARCH FRAMEWORK

Based on the overview, presented in Chapter 2, on residential location theory, discrete choice analysis within the random utility theory was adopted to study the effects of telecommuting and ITS on individuals' housing location decisions. The residential model

provides information regarding the trade-offs among various factors that affect housing choice behaviour, and in particular, the relative weights of telecommuting and ITS in the decision process. The deterministic utility function is additive and linear in parameters. The vectors of explanatory variables may consist of generic variables (e.g. travel time and cost); socio-economic variables (e.g. age, income, education, etc.) that may be represented by dummy variables; and alternative-specific constants.

Combined RP and SP logit analysis was used to estimate the parameters of the utility function through an attitudinal survey of people, which is explained in detail in Chapters 5 and 6. The combined estimation procedure is explained in Section 3.6. The research framework is shown in Figure 3.1.

As such, the original contributions of this research in expanding the present state of knowledge are as follows:

- Exploring telecommuting and ITS measures in the study of residential location choice;
- Use of combined RP and SP data in residential location choice;

3.5. COMBINING REVEALED AND STATED PREFERENCE DATA

As mentioned in Section 2.6, the reliability of SP data is uncertain. This is a problem that is not very serious with RP data because those models are calibrated against actual behaviour not the intended ones. Therefore, combining RP and SP data is an effective way to overcome the shortcomings of each data type and to take advantage of their strengths.

Figure 3.1. Research Framework

Joint estimation of SP and RP data can provide estimates of parameters that are efficient and are corrected for bias of the SP data. It also provides estimation of trade-offs among attributes and the effects of new services that are not identifiable from RP data (Morikawa, 1994). The theoretical framework for integrating RP and SP data was first developed by Morikawa (1989) and Ben-Akiva and Morikawa (1990a,b) and is based on utility maximization theory. This methodology is well suited for this research as well. To explain briefly, assume there are two different data sources (Ortúzar and Willumsen, 1994):

- The RP data that constitute the primary data set, since these data represent actual choice behaviour; and
- The SP data that constitute the secondary data set and represents stated intentions.

Then the utility expressions are defined as follows (Ben-Akiva & Morikawa, 1990a):

RP model:

$$\begin{aligned} U_i^{RP} &= \beta'x^{RP} + \alpha'y^{RP} + \varepsilon \\ &= V_i^{RP} + \varepsilon \end{aligned} \quad (3.1)$$

SP model:

$$\begin{aligned} U_i^{SP} &= \beta'x^{SP} + \gamma'z^{SP} + v \\ &= V_i^{SP} + v \end{aligned} \quad (3.2)$$

$$\text{Var}(\varepsilon) = \mu^2 \text{Var}(v) \quad (3.3)$$

where:

U_i = utility of alternative i (to individual n)

V_i = systematic component of U_i

$\mathbf{x}^{RP}, \mathbf{x}^{SP}$ = a vector of observed variables common to RP and SP data

$\mathbf{y}^{RP}, \mathbf{z}^{SP}$ = vectors of observed variables specific to one data type or the other

α, β, γ = vector of unknown parameters

ε, v = random error components associated with RP and SP data, respectively

μ = the scaling parameter.

Since the effects of unobserved factors may well be different between revealed and stated preferences, there is no reason to believe that ε and v have identical distributions (although one may assume that they are independently distributed with zero mean).

Introduction of scale parameter, μ , reflects the fact that the level of noise between the two data types (which is represented by their variances, ε and v) is different (Ben-Akiva & Morikawa, 1990a; Hensher, 1994). Moreover, there are two fundamental assumptions implied by the above equations. First, existence of variables $\mathbf{x}$ with coefficient vector β in RP and SP models indicates that the trade-off relationship among major attributes is the same in both actual behaviour and SP tasks. Secondly, it is assumed that RP and SP data are statistically independent. To quote Morikawa (1994):

"...it is assumed that the random component of the utility of an alternative of an individual in the SP model is independently distributed from that of any alternative for the same individual in the RP model".

By introducing the scale factor μ , ε and μv are identically (i.e., Gumbel distribution) and independently distributed (iid) not only within each type of data, but also across them, thus enabling one to combine the two data types and jointly estimate them. In this case, the SP model of Eq. (3.2), for the purpose of estimation, will be multiplied by μ :

$$\mu U_i^{SP} = \mu \beta' x^{SP} + \mu \gamma' z + \mu v \quad (3.4)$$

3.5.1. Estimation Method

The unknown parameters α, β, γ , and μ can be estimated either by (a) joint maximum likelihood (MLE), using RP and SP data simultaneously, or (b) sequential MLE, using RP and SP data in sequence (Ortúzar and Willumsen, 1994). Estimators obtained by either method are consistent. Joint estimation method produces more efficient estimators (i.e., the least variance) than the sequential method but requires programming the joint likelihood function in a general MLE program, whereas one can use ordinary logit or probit estimation software in the sequential method.

Steps involved in the sequential method are as follows (quoted from Ben-Akiva & Morikawa, 1990a):

1. Estimate the SP model of Equation (3.4) from SP data to obtain $\hat{\mu}\beta$ and $\hat{\mu}\gamma$. Define

$$W^{RP} = \mu \beta' x^{RP} \text{ and form the estimated value } \hat{W}^{RP} = \hat{\mu}\beta' x^{RP}.$$

2. Estimate the following RP model with the estimated value $\hat{W}^{RP}$ included as a variable to obtain $\hat{\lambda}$ and $\hat{\alpha}$:

$$U^{RP} = \lambda \hat{W}^{RP} + \alpha' y^{RP} + \varepsilon$$

where $\lambda = 1/\mu$. Calculate $\hat{\mu} = 1/\hat{\lambda}$, $\hat{\beta} = \hat{\mu}\beta/\hat{\mu}$, and $\hat{\gamma} = \hat{\mu}\gamma/\hat{\mu}$. The following additional step can be taken to improve the accuracy of $\hat{\alpha}$, $\hat{\beta}$, and $\hat{\gamma}$:

3. Multiply x^{SP} and z^{SP} by $\hat{\mu}$ to obtain a modified SP data set. Pool the RP data and the modified SP data and then estimate the two models jointly to obtain $\hat{\alpha}$, $\hat{\beta}$, and $\hat{\gamma}$:

3.6. DECISION MAKING PROCESS

Like travel behaviour, residential location behaviour is a complex subject area and one can only provide a basic conceptualization of the processes that takes place. Such conceptualization is presented in Figure 3.2. This conceptual decision making process can be applied to people's behaviour in different contexts such as a decision to buy a product, to choose a particular mode of travel, or to choose where to live.

According to this structure and in the context of housing location choice, as consumers learn about the available set of residential alternatives, their attributes and attribute levels, as well as their own socio-economic characteristics, they form perceptions (or beliefs) about those options. Eventually, the individual has enough information to form a utility function for valuing and trading off various residential location attributes (Hensher et al, 1999). Once the consumer has valued various attributes possessed by residential alternatives, s/he is able to compare alternatives to form overall preferences for available set of housing location alternatives. Depending on the individual's budget constraints or other external considerations, s/he decides whether to choose, wait, or never choose. If the decision is to choose, then the individual chooses from among the two or more available sets of alternatives (Louviere, 1988b; Hensher et al, 1999).

In this diagram, a distinction is made between the observable (or external) and unobservable (or internal) elements. The former affect market behaviour, whereas the latter reflect individuals' understanding of their options and influence their choice decision (Pearmain et al, 1991).

Figure 3.2. Conceptual Structure of Consumer Behaviour Process
(Adapted from Pearmain et al, 1991)

3.7. ANALYSIS TOOL

To estimate the parameters of SP and/or RP data the Time Series Processor (TSP) software developed by TSP International was used. TSP is a general-purpose computer program for econometric and statistical data processing on any computer platform including microcomputers (TSP International, 1995). The program can be used for many tasks including:

- Applied econometrics;
- Sales forecasting;
- Cost analysis and forecasting;
- Monte Carlo simulation;

In addition to standard econometric techniques such as ordinary and weighted least squares, two-stage least squares, and limited information maximum likelihood (LIML), TSP is also capable of performing advanced econometric techniques including nonlinear least squares, three-stage least squares, full information maximum likelihood (FIML), and estimation of models with qualitative dependent variables. With respect to the latter option, it can perform Tobit, Probit, and Logit analysis.

The basic data object within TSP is the series. Each series has a name and operations on the series can be performed just by mentioning its name. Panel and cross-section data sets can be handled by TSP as easily as time series (TSP International, 1995). In some cases it has handled as much as one million observations or more.

Since all the analyses in this research were done using logit formulation, the LOGIT function in TSP is explained briefly below.

3.7.1. Multinomial and Conditional Logit: LOGIT

LOGIT command is used to estimate a conditional logit, multinomial logit, or both. In conditional logit the explanatory variables in the model vary across alternatives (choices) for each observation. In multinomial logit the explanatory variables are the same across all choices for each observation (i.e., they are characteristics of the chooser). Mixed logit contains both data types. For the conditional logit the regressors change across the choices and a single coefficient is estimated for each set of regressors. For multinomial logit a separate coefficient for each regressor is estimated for all but one of the choices. In this case, the coefficients are normalized by setting the coefficients for the lowest choice to zero (TSP International, 1996).

The general form of the LOGIT command is as follows:

LOGIT (COND, NCHOICE=*n*) Dependent variable Conditional variables | multinomial variable;

For example,

LOGIT (COND, NCHOICE=3) Y A B | C D;

Y takes on values 1,2, and 3. TSP looks for the conditional variables A1, A2, A3, and B1, B2, B3 corresponding to the 3 choices. C and D are multinomial variables (e.g., C can be alternative-specific constant and D number of automobiles in the household). The coefficients A, B, C2, C3, D2, and D3 would be estimated, with C1 and D1 normalized to zero (TSP International, 1996).

When there are two alternatives, the parameter estimates for probit and logit are comparable in a sense that the coefficients estimated by probit model are larger by a

factor of $\pi/\sqrt{3}$ due to the larger standard deviation of disturbance terms in logit analysis (Ben-Akiva and Lerman, 1985).

TSP uses the maximum likelihood (ML) technique to estimate the logit parameters. TSP maximizes the log of the likelihood function with respect to the parameters in the model, using the data in the current sample. The function ML also exists in TSP. It is a general-purpose maximum likelihood estimation procedure. It can be used to estimate the parameters of any identified model for which one can write the logarithm of the likelihood function in a TSP equation (using FRML command) such as logit, probit, or tobit models. If one is performing a standard discrete choice estimation in TSP, the existing LOGIT, PROBIT, and TOBIT functions are more efficient (in terms of computer CPU time), more resistant to numerical problems, and often have better starting values than the general ML function (TSP International, 1996). However, if one needs, for example, to impose (linear) restrictions on some of the parameters, then the ML command along with other appropriate ones (such as FRML, EQSUB, and ANALYZ) should be used. In this research both approaches were used.

CHAPTER IV: DISCRETE CHOICE ANALYSIS

4.1. OVERVIEW

In general, many urban policy issues are concerned with the behaviour of a large group of people or a specific market segment in the society (e.g., market demand for transit system). However, this aggregate behaviour is in essence the result of individual decisions. Thus the modelling of individual behaviour is at the core of all predictive models of aggregate behaviour (Ben-Akiva and Lerman, 1985). As all the data analysis in this thesis will be based on the discrete choice theory, the purpose of this chapter is to describe principles of random utility theory upon which discrete choice models (also called disaggregate demand models) are developed.

4.2. DISCRETE CHOICE MODELS DEVELOPMENT

A discrete (or qualitative) choice situation, described by discrete choice models, is defined as one in which a decision maker is faced with a choice from a set of mutually exclusive and collectively exhaustive alternatives, with the number of alternatives being finite (Train, 1986). The discrete choice analysis uses the principle of utility maximization. That is, briefly speaking, a decision maker when faced with a set of alternatives chooses the one with the highest perceived utility.

The model consists of a set of utility functions with some observable independent variables and unknown parameters, which is calibrated by means of a sample of observed choices made by decision makers when faced with the choice situation (Ben-Akiva & Lerman, 1985). It is important to note that an individual is always assumed to choose an alternative with the highest utility. Therefore her/his choice is deterministic: s/he either chooses alternative i or not. However, from the viewpoint of an analyst who is trying to model or predict the choice of this individual, the utility function is not deterministic, but rather is probabilistic, simply because the analyst is not able to observe all the relevant factors that affected the individual's choice. Therefore, an individual's utility is treated as random (by the analyst). From this perspective, the choice probability of alternative i , P_{im} , is equal to the probability that the utility of alternative i , U_{im} is higher than that of any other alternative, given the observed components of utility for each alternative (Ben-Akiva & Lerman, 1985; Train, 1986). This can be written as follows:

$$P_{im} = Pr[U_{im} > U_{jm}, \forall j \in C_m, i \neq j] \quad (4.1)$$

where C_m is the set of feasible alternatives faced by individual m .

This utility function can be divided into two additive parts as follows:

$$U_{im} = V_{im} + e_{im}$$

The same is true for any other alternative j ; that is $U_{jm} = V_{jm} + e_{jm}$

Here, V is called the systematic component of the utility of i or j , and is assumed to be deterministic (i.e., non-random). The second term, e_{im} , is the random part and is called disturbance or random component.

V_{im} (or V_{jm}) is a function of a vector of attributes x which includes characteristics of the alternative that are observed by the researcher, and those of the decision maker m (Train,

1986). In most practical cases, the functional form for V is chosen to be additive and *linear in parameters*. So, defining $\beta=[\beta_1,\beta_2,...,\beta_K]'$ as the vector of K unknown parameters:

$$V_{im}=\beta_1x_{im1}+\beta_2x_{im2}+...+\beta_Kx_{imK}, \text{ and}$$

$$V_{jm}=\beta_1x_{jm1}+\beta_2x_{jm2}+...+\beta_Kx_{jmK}.$$

Recalling Eq. (4.1), we can re-write it as follows:

$$\begin{aligned} P_{im} &= Pr[(V_{im} + e_{im}) > (V_{jm} + e_{jm})] \\ &= Pr[(e_{jm} - e_{im}) < (V_{im} - V_{jm})] \end{aligned}$$

The last assumption required to make the random utility theory operational, is that of the disturbance terms. Making different assumptions about the distribution of the random parts leads to different formulations for the P_{im} . If one assumes that the disturbance terms follow Gumbel (or double exponential) distribution, then the well-known *logit* model is developed. The following sections describe the logit formulation and some of its important characteristics.

4.3. LOGIT MODEL

The binary logit model arises from the assumption that e_{im} and e_{jm} are identically and independently distributed (iid) with Gumbel distribution (it is also called logistics or double exponential distribution). In this case the density function for e_{im} is:

$$f(e_{im}) = \exp(-e_{im}).\exp(-\exp(-e_{im}))$$

and its cumulative distribution is:

$$F(e_{im}) = \exp(-\exp(-e_{im})).$$

With this assumption, the choice of alternative i , is given by:

$$P_{im} = \frac{e^{V_{im}}}{e^{V_{im}} + e^{V_{jm}}} \quad (4.2)$$

which is called binary logit model. The model is easily extended to the case where there are more than two alternatives. The resulting model is called multinomial logit (MNL) model and is expressed as follows:

$$P_{im} = \frac{e^{V_{im}}}{\sum_{j=1}^{J_m} e^{V_{jm}}} \quad (4.3)$$

where J_m is the full choice set faced by individual m .

The main advantage of this model over the probit model is its closed form which makes it much more convenient analytically.

4.4. PROPERTIES OF THE LOGIT MODELS

Logit models have some desirable properties, which make them widely used. A strong aspect of logit model is that it is robust and tractable. With respect to the former, the formulation allows the model to adapt to changes in variable data and relevant policy variables. With respect to tractability, the model only requires very basic calculations and therefore can be applied to very large choice problems without undue computational burden (Travel Model Improvement Program [TMIP], 1997). Also, based on Eq. 4.3, given above, it can be seen that the probability of choosing a particular alternative depends on the deterministic components of all other available alternatives. The alternative with the highest utility is then selected. Also, the probability of selecting a particular alternative increases when the deterministic component of that alternative

increases. By the same token, the probability decreases with a decrease in the deterministic component.

In addition to the above properties, there are two very important properties of the logit models, namely the ‘independence from irrelevant alternatives’, or IIA, and the elasticities of the model variables, which deserve noting. These are explained below.

4.4.1. Independence From Irrelevant Alternatives (IIA)

One of the most significant properties of logit models is the IIA property. The IIA property states that the ratio of the choice probabilities for two alternatives does not depend on any other alternatives (Train, 1986). In other words, this odds ratio depends only on the observed characteristics of those two alternatives. This can be easily shown as follows:

$$\frac{P_{im}}{P_{km}} = \frac{\frac{e^{V_{im}}}{\sum e^{V_{jn}}}}{\frac{e^{V_{km}}}{\sum e^{V_{jn}}}} = \frac{e^{V_{im}}}{e^{V_{km}}} = e^{V_{im} - V_{km}} \quad (4.4)$$

This property could be considered an advantage of the model as it allows the analyst to treat new alternatives quite neatly. However, it requires that the iid assumption of error terms in the MNL model to hold true. On the other hand, the IIA property is perceived as a disadvantage if the alternatives are correlated in their unobserved characteristics or if they have different variance in their error terms (Ortúzar and Willumsen, 1994). In this case, the IIA property can lead to somewhat odd and erroneous predictions (the *red bus/blue bus paradox* is the famous example). One remedial measure in cases where some of the alternatives are suspected to have shared, unobserved effects is to use 'nested logit' structure. In nested logit the *similar* alternatives are grouped into a lower nest. This eliminates the

problem of correlation because the logit probabilities are based on differences in alternatives utilities, therefore any shared (common) effects will cancel in the subtraction (Mannering and Mokhtarian, 1995). It should be noted here that the IIA property does not apply to the population as a whole; rather, it applies to each homogenous group within the population (Ben-Akiva and Lerman, 1985).

4.4.2. Elasticities of Logit

Another useful property of logit is that it is possible to derive fairly simple equations for the direct and cross-elasticities of the model. For example, the direct elasticity, that is, the percentage change in the probability of an individual choosing alternative i with respect to a marginal change in a given attribute x_{imk} is simply given by (Ortúzar and Willumsen, 1994):

$$E_{x_{imk}}^{p_m(i)} = [1 - p_m(i)] \beta_k x_{imk} \quad (4.5)$$

and the cross-elasticity (i.e., the percentage change in the probability of an individual choosing alternative i with respect to a marginal change in an attribute of alternative j , x_{jmk}) is also simply given by:

$$E_{x_{jmk}}^{p_m(i)} = -p_m(j) \beta_k x_{jmk} \quad \text{for } j \neq i \quad (4.6)$$

It can be seen from Eq. 4.6 that the cross-elasticities of any alternative i with respect to the attribute x_{jmk} of alternative j are equal and independent from alternative i . This result is also due to the IIA property.

4.5. THE LOGIT MODEL ESTIMATION METHODS

There are two most widely used methods to estimates the parameters of the MNL model.

These are:

- Least square (LS) method; and
- Maximum likelihood (ML) method.

In the least square approach, the choices are transformed into log odds format and the model is estimated using the (generalized) least square technique. For example, for the binary logit model, the logit model is written in the following form:

$$\text{Log}\left[\frac{p_m(i)}{p_m(j)}\right] = \beta'x_m \quad (4.7)$$

One natural problem with applying this approach is that for any individual, $p_m(i)$ is of course not observed. One remedy is to divide the sample into homogenous subgroups and use the 'share of each group' choosing each alternative as estimates of the choice probabilities. In spite of this, there are other problems with this method, and as a result it is not widely used in demand analysis (for more details please see Ben-Akiva and Lerman, 1985).

On the other hand, the ML procedure is normally used for parameter estimation. The ML method produces estimates of the parameters, which will generate the observed sample based on the idea that although a sample could most often originate from several populations, a particular sample has a higher probability of having been drawn from a certain population than from the others (Ortúzar and Willumsen, 1994). As such, the ML procedure tries to maximize the likelihood function (or more precisely, its logarithm, $L(\beta)$) with respect to vector of parameters β through an iterative procedure. For the MNL model the function is well behaved, so the process converges quickly and always to a unique maximum. The ML estimates are, in general, consistent, asymptotically efficient,

and asymptotically normal. Thus, it is the most widely used estimation approach. The TSP software also uses the ML method for estimation of logit coefficients.

4.6. MEASURES OF GOODNESS-OF-FIT

As with any other stochastic model, there are a number of statistical measures for testing how well the logit model fits into the observed data. These measures include:

- Likelihood ratio test
- The overall test of fit
- Rho-square index
- Asymptotic t test
- Variable signs (informal)

Each of these tests is explained below.

4.6.1. Likelihood Ratio Test

A formal hypothesis of test of goodness-of-fit is the likelihood ratio (LR) statistic. In general, it is written as follows:

$$-2[L(\beta_R) - L(\beta_U)] \quad (4.8)$$

where:

β_R = the estimated coefficients of the restricted model;

β_U = the estimated coefficients of the unrestricted model.

This statistic is χ^2 distributed with $(K_U - K_R)$ degrees of freedom, where K_U and K_R are the number of coefficients estimated for the unrestricted and restricted models, respectively

(Ben-Akiva & Lerman, 1985). This test is most useful when the model under the null hypothesis is obtained by imposing two or more linear restrictions on the more general unrestricted model. Some important examples of this test statistic are for testing attribute genericity and sample homogeneity (Ortúzar and Willumsen, 1994). To perform the test, the estimation program is first run for the unrestricted model to produce the log-likelihood at convergence $L(\beta_U)$. Then the linear restrictions are imposed and the model is run again to obtain the new log-likelihood at convergence $L(\beta_R)$. The above χ^2 test statistic is then formed. The rejection of the null hypothesis implies that the restricted model is erroneous (Ortúzar and Willumsen, 1994).

4.6.2. The Overall Test of Fit

A special case of LR test is to examine the null hypothesis that all the estimated coefficients are jointly zero. The test statistic of Eq. 4.8 is then written as follows:

$$-2[L(0) - L(\beta)] \quad (4.9)$$

and is χ^2 distributed with K degree of freedom, where K is the total number of estimated parameters. However, the test is not very useful because almost always we can reject the null hypothesis at very low level of significance (Ben-Akiva & Lerman, 1985). A more informative test is to verify whether all variables, except the alternative-specific constants, are jointly zero. The LR statistic is then written as follows:

$$-2[L(C) - L(\beta)] \quad (4.10)$$

where, $L(C)$ is the log-likelihood at convergence when only the alternative-specific constants are included in the model. The statistic has K-J+1 degrees of freedom, where J is the total number of alternatives in the universal choice set. In general, an extra run is

required to calculate $L(C)$, except where all individuals face the same choice set, in which case it can be obtained from the following formula:

$$L(C) = \sum_{i=1}^J N_i \ln\left(\frac{N_i}{N}\right) \quad (4.11)$$

where N_i is the number of individuals choosing alternative i . The notional relation between the values of log-likelihood functions is as follows:

$$L(0) < L(C) < L(\beta) \quad (4.12)$$

4.6.3. Rho-Squared Index

In addition to the likelihood ratio test, researchers have made a number of proposals for defining a measure analogous to R^2 used in regression analysis. One suggested measure, although not universally accepted, is the likelihood ratio index, ρ^2 :

$$\rho^2 = 1 - \frac{L(\beta)}{L(0)} \quad (4.13)$$

Rho-squared measures the proportion of the initial log likelihood value explained by the model. The measure is between 0 and 1. If all the model coefficients are zero, then $L(0) = L(\beta)$, and therefore ρ^2 is equal to zero. However, there is no way that ρ^2 will be 1 although we can come close (Judge *et al*, 1985). Unfortunately, values between zero and one have no obvious intuitive meaning. In fact, there is no test statistic in logit or probit models comparable to R^2 in conventional regression. The reason is (Greene, 1990):

“...The maximum likelihood estimator is *not* chosen in order to maximize a fitting criterion based on predicting of y , as it is in the classical regression (which maximizes R^2). It is chosen to maximize the joint density of the observed dependent variable. It remains an interesting question for researcher whether fitting y well or obtaining good parameter estimates is a preferable

estimation criterion.”ⁱ

Tardiff (1976) also showed that the ρ^2 obtained from Eq. 4.13 does not satisfy the zero lower bound. To alleviate this problem he proposed the use of $L(C)$ instead of $L(0)$ in Equation 4.13. Thus, he defined adjusted rho-square, ρ_c^2 as follows:

$$\rho_c^2 = 1 - \frac{L(\beta)}{L(C)} \quad (4.14)$$

The modified ρ_c^2 has the properties of a zero to one range, comparability across models calibrated with different samples, as well as a direct relationship to the χ^2 statistic defined in Equation 4.10 (Tardiff, 1976).

As with the R^2 in regression analysis, the value of ρ_c^2 will always increase (or at least stays the same) whenever a new variable is added to the utility function. To compensate for this, the adjusted rho-bar-squared, $\bar{\rho}_c^2$, is always used:

$$\bar{\rho}_c^2 = 1 - \frac{L(\beta) - K}{L(C)} \quad (4.15)$$

4.6.4. The Asymptotic t Test

The asymptotic t test is primarily used to test whether a specific parameter is statistically different from a known value, often zero. It is used in the same way as the regression, except that for nonlinear models such as logit and probit it is valid only asymptotically—that is, it is valid only for large samples (Ben-Akiva & Lerman, 1985). The t -statistic is calculated by dividing the value of the parameters by its standard deviation. If the t value is large enough (typically larger than 1.96 for 95% confidence level), the null hypothesis

ⁱ y is a choice indicator, which is equal to 1 if U^{RP} (or U^{SP}) > 0 and is 0 otherwise.

of $\beta_k=0$ is rejected and the k^{th} variable is retained in the model. The current practice recommends to include the highly relevant or policy variables (such as time and cost) with a correct sign even if it fails any significance test (typically with a t value of greater than 1 or less than -1). The reason, indicated in Ortúzar and Willumsen (1994), is that the estimated coefficient is the best approximation for its true value; lack of significance may just be due to lack of enough data or lack of enough variability of the attribute in the sample.

4.6.5. Variable Sign (Informal)

The most basic test of the model estimation output is the examination of sign of the estimated coefficients. Usually one has a priori expectations with respect to the sign and magnitude of a coefficient based on theory, experience, and judgment. As mentioned in the previous section, the important policy variables with correct sign are kept in the model even if they fail the statistical significance test. Retaining other types of variables in the model that are not so crucial for policy evaluation (e.g., gender) and have correct sign, depends on their significance level and the usual practice is to leave them out if they are not significant at 80% level (Ortúzar and Willumsen, 1994). Finally, if these types of variables have wrong sign they are always rejected.

4.7. AGGREGATE FORECASTING

The disaggregate demand models deal with predicting *individual* behaviour. They are superior to aggregate demand models with respect to flexibility, accuracy, and cost (Ben-Akiva & Lerman, 1985). However, in making planning and investment decisions the

individual behaviour is of little use. In case of disaggregate random utility models (i.e., logit and probit) the aggregation problem is how to obtain from data at the individual level, *aggregate demand* such as market share of different modes, flows on links, and so on (Ortúzar and Willumsen, 1994). The most widely used procedure for making aggregate forecast with disaggregate models is the 'sample enumeration' method. . This method uses a random sample of the population as 'representative' of the entire population. The predicted market share for alternative i , $\hat{S}_i$, is used as an estimator for true share of i (Ben-Akiva & Lerman, 1985):

$$\hat{S}(i) = \frac{1}{N} \sum_{i=1}^N P(i) = \frac{1}{N} \sum_{i=1}^N \frac{e^{v_i}}{\sum_j e^{v_j}} \quad (4.15)$$

where:

N = number of individuals in the sample

$P(i)$ = probability that individual n chooses alternative i

CHAPTER V: SURVEY DESIGN AND ANALYSIS— THE PILOT STUDY

5.1. INTRODUCTION

To study the impacts of ITS and telecommuting, a survey questionnaire was designed. In this regard, there were a number of issues to be addressed. Almost all SP techniques use experimental designs for creating hypothetical choice situations that are presented to respondents. The main purpose of the experimental design is to maintain the "orthogonality" between the alternatives. That is, to define the combinations of all levels of all variables in the experiment to ensure that they are varied independently (i.e., completely uncorrelated) from one another (Kroes & Sheldon, 1988). Therefore, the issues to be addressed in the design of the experiment in this research were as follows:

- Defining the alternatives;
- Defining the variables (or attributes) of interest and their values (or levels);
- Statistical design;
- Sampling issues including choice of sample units, sampling method, and sampling size; and
- Presentation of the survey instrument questionnaire.

In this chapter each of these issues are discussed in detail in the context of the pilot survey. In the next chapter, some of these issues are revisited, as required, and are dealt with in the context of the final survey.

5.2. PILOT SURVEY

The main objective of a pilot survey is to identify and correct any deficiencies in the questionnaire draft. These deficiencies could include long questions, missing important variable(s), ambiguous questions, illogical flow of questionnaire, etc. (Aaker & Day, 1990). It is also used for preliminary analysis of variables as well as to indicate some practical management issues such as likely response rate that will be achieved in the final survey (Pearmain et al, 1991). Therefore, at least one pilot study is essential.

Two pilot surveys were carried out in this research before the final survey was administered. In the first pilot, staff and faculty at Carleton University were selected randomly and 17 questionnaires were returned. The main purpose of this pilot was to identify unclear or confusing words, and to obtain an estimate of the length of the survey. No analysis was done on the data. The pilot survey consisted of three sections. Section one was an introduction letter about the purpose of the survey. Section two sought to obtain background information about the respondents' household in terms of their housing, work trip, and socio-economic characteristics. Section three presented the respondents with the SP experiment on the housing location choice (the SP experiment is discussed in detail in the following sections). Based on the feedbacks from respondents some questions were modified, added, or deleted from the survey for the next round of pilot study. The survey format was also changed to make it more appealing and easier to follow by respondents. This served the basis for the second pilot survey.

5.3. ALTERNATIVES DEFINITION

The intent of this research was to find out whether adopting telecommuting by

individuals and deployment of ITS would result in any change in their housing location decision. To do so, the Regional Municipality of Ottawa-Carleton (RMOC) was chosen as the case study. There are a number of reasons for this selection. First, is of course, the convenience. Secondly, it is a fact that Ottawa-Carleton Region is the focal point of information technology-related employment (which is the best suited sector for adoption of telecommuting), not only in Ontario but also in Canada. Moreover, the bulk of other service jobs as well as government jobs are also concentrated in this region.

Based on the Official Plan of the RMOC, most of the future development in the region will be concentrated inside the Green Belt. However, any additional future growth in the Region is to be accommodated in three satellite cities namely Kanata Urban Centre, Nepean & Gloucester Urban Centre, and Orleans Urban Centre, located in some distance in the west, south, and east of Ottawa, respectively (RMOC, 1997). Moreover, it is highly likely that any growth beyond those predicted by the Official Plan will be located in second-tier satellite cities in the longer term. In other words, the Plan does not permit sprawl to happen in the future; rather any growth in population, housing, and business will have to happen inside the Green Belt as well as in the satellite nodes located on the well-defined transportation axes. Thus, for the purpose of this research, three location alternatives were defined as follows:

Alt. A - Central area of the Region inside the Green Belt consisting of Cities of Ottawa, Vanier, Nepean, Gloucester, Village of Rockcliffe, and City of Hull.

Alt. B - First-tier satellite nodes including Cities of Kanata, Aylmer, Gatineau, and Townships of Cumberland (i.e., Orleans), Barrhaven, and Chelsea.

Alt. C - Second-tier satellite nodes such as Buckingham and Rockland in east, Rideau and Osgoode in south, West Carleton and Goulbourn in west, and Clarence and Val-des-mont in north.

Figure 5.1 shows a schematic diagram of location of these alternatives in the Region. These alternatives were the same for both the pilot studies and the final survey.

5.4. ATTRIBUTES AND THEIR LEVELS

In a conjoint analysis, one would like to relate a series of independent variables to some dependent variable such as mode choice, or in our case, to housing location choice. Each of these attributes will have two or more levels, as designated by the experimental plan (Kocur et al, 1982). Also, to have an orthogonal design, one should consider all possible combinations of these independent variables. Therefore, for example, if one is examining respondents' preferences for three attributes of a public transit system (say, fare, travel time, and comfort level), each with two levels, there will be eight options overall ($2 \times 2 \times 2 = 2^3 = 8$) for the respondent to evaluate (e.g., rating on numerical scale). The experimental design presented in this example is referred to as 'full factorial' design because every possible combination of variables is used (Pearmain et al, 1991). In general, if a, b, and c are different number of levels and there are x a-level, y b-level, and z c-level attributes, the full factorial experimental design will contain $a^x \cdot b^y \cdot c^z$ options (Kocur et al, 1982). It can be seen that the number of options will grow drastically with an increase in the number of variables and/or levels. A high number of options, in turn, will increase the likelihood that respondents experience 'fatigue' in evaluating the alternatives presented to them, and subsequently increasing the response error (Pearmain et al, 1991). In fact, the

literature suggests that the number of options be limited to a range of 9 to 16 (Kroes & Sheldon, 1988). It is mainly for this reason that one cannot incorporate all possible factors influencing the choice, especially for a complex decision of residential location choice. Moreover, the primary interest of this research was to investigate the transportation level of service variables on housing choice, and in particular, the influences of telecommuting and ITS. Accordingly, based on the available literature, the following attributes were considered for the SP part of the second pilot survey:

- Housing cost- representing monthly rent for rental units and monthly mortgage (including tax) for homeowners;
- Housing floor area- representing the size of a dwelling unit;
- Door-to-door one-way travel time to work;
- Door-to-door one-way travel time to school (for households with school-age children);
- Availability of outdoor recreational opportunities- representing how readily available and close-by are outdoor amenities such as parks, lakes, golf course, etc.

Furthermore, the following variables were considered as measures of telecommuting and ITS:

- Magnitude and frequency of travel time variability to work- representing the impact of ITS and;
- Level of telecommuting per week- representing the impact of telecommute.

In terms of the specification of the magnitude of attributes, the rule of thumb is that the attribute levels should both be within the range currently experienced by respondent and appear plausible (Hensher, 1994).

As for the number of levels, the more the number of levels are, the more the complexity of the design will be. For some attributes of particular interest, more than two levels are suggested (Pearmain et al, 1991; Hensher, 1994). This is particularly important because it allows examining the 'non-linear' effect of an attribute on a response. For example, it is plausible to suspect that the impact of having a 5-minutes travel time variability will be different from that of a 20-minute variability. The attributes and their levels used for the second pilot survey are listed in Table 5.1.

5.5. EXPERIMENTAL DESIGN

Having identified the attributes and their levels and magnitude, the attribute levels are combined into an experiment. The mix of attribute levels describes an alternative. The alternatives can be abstract, in which the attribute mix is not defined say for a particular mode (e.g., travel time and cost); or it can be mode-specific attribute mix (e.g., travel time and cost by bus) (Hensher, 1994). In this research the latter one is the case.

In Section 5.4, it was noted that in practice it is not possible to evaluate full factorial designs. To make such evaluation manageable, a '*fractional factorial design*' is constructed. Such an experiment reduces the number of options to a manageable size albeit at the expense of losing some statistical efficiency.

In this type of design one should assume that some interactions among variables are negligible, which is often a very reasonable assumption for a large proportion of interactions, especially three-way interactions and more (Pearmain et al, 1991). In fact, Louviere (1988b) states that main effects account for 80% or more of variability in response data, and two-way interactions account for 3% to 6% of such variations.

Attributes Description	Level
Travel time to work	-50% 0% +50%
Travel time to school	20 min. 40 min. 60 min.
Monthly housing cost	\$500 \$700 \$1000 \$1300
Housing size (m ² or ft ²)	-20% 0% +20%
Frequency of telecommuting per week	0 day 1 day 2 days 3-4 days
Travel time variability	5 min. 10 min. 20 min. 30 min.
Frequency of travel time variability	Once a month Once a week Twice a week
Availability of outdoor recreational opportunities	Poor Good Excellent

Table 5.1. List of Attributes and Their Levels for the SP Experiment (Pilot Survey)

However, if interactions are statistically significant, a fractional design will cause their effects to be loaded onto the main effects, thus yielding biased results. This is referred to as

'*confounding*' interaction effects with main effects (Hensher, 1994). The fractional factorial designs are listed in standard tables in Hahn and Shapiro (1966) and in Kocur et al (1982). These plans reflect the power of various designs in estimating interaction effects.

In this experiment, a full factorial design will have $(3^5 \times 4^3)^3$ possible combinations. An orthogonal fractional design can be selected to vary all attribute levels simultaneously. However, the problem here is that even an orthogonal main effect design will still result in a large number of options to be evaluated by respondents. Alternatively, one can follow the approach suggested by Louviere et al (1981). That is, first, all possible combinations of options (i.e., $3^{15} \times 4^9$) were generated. Then, for each respondent, a fixed number of these options (in a range of 9 to 16 options) was drawn randomly from the whole set. The respondent will then state her/his choice for either of alternatives A, B, or C for each choice set. This method ensures the orthogonality of design and was also used by Hunt et al (1994) in their study of housing preference for the city of Calgary, Canada, and by Adamowicz et al (1994).

5.6. SAMPLING PROCESS

For the second pilot survey, faculty and staff from Carleton University and the University of Ottawa were sampled. The procedure is explained below. It was in the final survey that respondents were randomly selected from private and public sectors. The sampling process for the final survey is explained in detail in Section 6.5.

5.7. PILOT SURVEY ADMINISTRATION – SECOND SURVEY

The focus of the second pilot was on the SP task in addition to further identifying

ambiguous questions. It aimed to measure statistical importance of attributes of housing location. The survey contained three parts. Part (1) was the introduction letter which explained the purpose of survey and also described briefly the concepts of telecommuting and ITS to ensure that respondents had an understanding of these technologies. Part (2) contained some background questions about the respondent's housing, work trip, and demographic characteristics. Finally, part (3) contained ten choice scenarios. For each scenario, the three alternatives were characterized by a combination of attributes. Each respondent was asked to evaluate the alternatives and then to choose one and only one alternative as his/her preferred choice. The sample questionnaire is presented in Appendix A.1. As explained earlier, each scenario was different from another scenario randomly, in terms of the combination of the levels of its attributes. As for travel time to work variable, the idea of travel time and its variability was presented to respondents through a concept suggested by Jackson and Jucker (1981). That is, for travel time, a term named 'usual time' was used which is defined as 'the approximate time it takes most of the time'. This is nothing but the mode of the travel time distribution. For travel time variability, the term 'possible delays' was used which meant delays that occur due to accidents, road repairs, unexpected congestion, etc (Senna, 1994).

To better meet the objectives of the pilot survey and to obtain feedback about the survey quality, the questionnaire included the following additional questions (Kocur et al, 1982):

- Are the instructions clear?
- Is the experiment too lengthy or too complicated? How so?
- Do the attribute levels in the survey Table seem reasonable?
- Are any of the questions ambiguous? Which ones?

- Are there any factors other than those mentioned in here that you think are important in your decision for the housing location choice?

During the months of June and July 1997, a survey of faculty and staff at Carleton University and University of Ottawa was carried out. Respondents were selected randomly from the Staff Directory at the respective universities and were contacted via e-mail. The purpose and description of the study was explained in this e-mail and they were asked whether they would be willing to participate in the survey. As a result, a total of 209 survey questionnaires were sent out, 177 to Carleton University employees and 32 surveys to those at the University of Ottawa. Out of these, 127 questionnaires were returned. Three of the returned surveys were largely blank and were discarded from further analysis. Another 16 surveys were usable for the RP part only (due to incomplete answers in the SP part), thus producing an effective response rate of 59%, which was considered excellent given the length and complexity of the task involved.

For this sample 78% of respondents were living in the central area of the region (i.e., Alt. A), compared to 11% who were living in Alt. B and Alt. C each. As for classification, 48% of the sample was male and 82% were homeowners.

The average household size was 2.5 persons. 31% of respondents had children age 16 and under in the household.

On average, respondent households had 1.45 vehicles, and 0.8 vehicles per licensed driver. The average distance from respondents' residence to work was 13.2 km, with an average one-way commute time of 22.5 minutes (for motorized modes). Figure 5.2 shows modal split to work for the sample and for the Ottawa-Carleton region, which was based

on the 1995 O-D survey.

Figure 5.2. Modal Split to Work (Pilot Survey)

On average, respondent households have been living in their residence for 7.8 years. The modal household income category was \$100,000 and above (33%), followed by categories of \$75,001-\$100,000 (28%) and \$50,001-75,000 (22%).

Having a large number of faculty members as respondents along with 63% of sample being dual-earner households, led to the above income distribution.

About 30% of respondents stated they were telecommuting. On average, they were telecommuting 1.9 days a week (either the whole day or part thereof) for roughly 4 years.

Of the remaining 70% who were not telecommuting, 75% stated that they would telecommute if they were given the opportunity to do so.

5.8. ESTIMATION WITH RP DATA

The pilot survey asked about current location of respondents' residence along with other housing and travel information such as housing size, monthly housing cost, travel time and mode to work.

The RP model included the following variables:

- Two alternative-specific constants;
- Housing cost (\$/month);
- Housing size (ft²);
- One-way travel time to work (min.);
- Vehicle/licensed driver ratio (specific to Alt. B and C).

To estimate parameters of variables in a logit model's utility function, which are choice specific, one has to know their values for *rejected* alternatives in addition to those of the chosen alternative. The information available from the survey provides only the characteristics of the housing occupied by the respondent's household in its chosen community. Information on the housing bundles and their prices in other communities is not available. Therefore, to obtain such information, Census data were obtained from Statistics Canada. It was assumed that in each community families with similar characteristics in terms of income, family size, and housing type (single detached/semi detached vs. low-rise/high-rise apartment) would spend similar amount on housing in terms of both cost and size.

The 1991 Census provided information on housing consumption for the whole population. A customized cross-tabulation was run by Statistics Canada which provided information on housing cost, number of bedrooms and number of rooms by income,

family size, and housing type categories for each municipality in the study area.

As explained in Section 5.3, each residential location alternative defined in this study consists of a number of municipalities or townships. To estimate rejected values for housing cost and housing size variables, first three townships/municipalities were selected randomly within each rejected alternative. Then, based on socio-economic status of the respondent (i.e., income level, household size, and housing type s/he is living in at), the average of the housing cost and housing size variables for the three communities were calculated and substituted in the utility function.

The estimation results are shown in Table 5.2. It can be seen that the housing cost coefficient has the wrong sign and it is not significant. All other coefficients have the expected signs although those of housing size and travel time variables are statistically significant at slightly less than 10% significance level.

5.9. ESTIMATION WITH SP DATA

The SP experiment was designed to collect information on residential location choice behaviour by presenting to respondents hypothetical choice scenarios described by a set of explanatory variables. As indicated earlier, there may be a bias in SP data toward the residential location actually chosen which reflects inertia effect, justification of past behaviour, or the effect of variables that are not included in the model (Ben-Akiva & Morikawa, 1990a). A variable that indicates the actual choice was included in the model to estimate such inertia effect. As a household lives in a particular location for a long period of time, it is possible that it develops some form of attachment to that place. As defined below, the inertia variable captures this effect by measuring the duration of stay

of a household in its current residence.

Variable	Parameter Estimate	Standard Error	t-statistics
Alt. B constant	-3.174	0.771	-4.11
Alt. C constant	-2.678	0.912	-2.94
Housing cost	0.000803	0.000742	1.08
Housing size	0.000646	0.000495	1.31
Travel time	-0.0379	0.0235	-1.62
Veh/driver (specific to Alt. B and C)	2.069	0.760	2.72
Summary Statistics:			
N=124 L(0)=-136.23 L(C)=-85.64 L(B)=-78.45 $\rho_c^2=0.084$ $\bar{\rho}_c^2 = 0.013$			
-2[L(0)-L(B)]=115.6 $\rho^2=0.420$ $\bar{\rho}^2 = 0.380$			
-2[L(C)-L(B)]=14.39			

Table 5.2. Estimation Results With RP Data (Pilot Survey)

Accordingly, the following explanatory variables were present in the pilot SP model:

- housing cost (\$/month);
- housing size (ft²)
- one-way travel time to work (min.)
- one-way travel time to school for households with school-age children (min.)
- availability of outdoor recreational activities (3 levels: Excellent, Good, Poor)
- telecommuting measures: travel time x number of telecommuting days per week
- ITS measure: travel time variability = delay (min.) x no. of occurrences per week
- travel mode dummy (specific to Alt. A) = 1 if the respondent walks/cycles to work; 0 otherwise
- inertia (specific to Alt. A) = duration of stay in current residence (in years) if Alt.

A was actually chosen; 0 otherwise

- inertia (specific to Alt. B) = duration of stay in current residence (in years) if Alt.

B was actually chosen; 0 otherwise

The estimated coefficients are shown in Table 5.3. The coefficients of all variables have the expected signs and are statistically significant at 95% confidence level. The Alt. A- and Alt. B-specific constant are both positive but very close. However, the presence of inertia dummy variables cause these constants to get larger and more distinguished from each other as a household stays longer in its residence. This implies that there is inertia effect of the actual choice in the SP experiment.

The coefficient of telecommuting measures have positive signs, indicating that by telecommuting the respondent's desire (utility) for residential locations which are farther to his/her workplace (i.e., longer travel times) increases as well, which in turn translates to higher utility values for housing locations in Alt. C. The estimated coefficient of travel time variability factor is negative as expected. It indicates that everything else being equal, people would choose residential location along transportation systems, which provide them with more reliable travel times to work. This suggests that if ITS is applied to any part of the region which would reduce the variability of people's daily commute trips, the probability of choosing housing in that region would increase.

Variable	Parameter Estimate	Standard Error	t-statistics
Alt. A constant	0.335	0.129	2.59
Alt. B constant	0.311	0.106	2.94
Housing cost	-0.00148	0.000156	-9.51
Housing size	0.000677	0.000167	4.05
Travel time to work	-0.0283	0.0055	-5.09
Travel time to school	-0.0254	0.0051	-5.03
Travel mode dummy (specific to Alt. A): (=1 if non-motorized; =0 else)	1.142	0.182	6.27
Outdoor recreational activity dummy: =1 if excellent; =0.5 if good	1.039	0.123	8.43
Travel time variability (delay $\times$ frequency)	-0.00195	0.00066	-2.95
Level of telecommuting $\times$ travel time:			
1- or 3-days/week	0.00825	0.00424	1.94
2-days/week	0.0215	0.00469	4.58
Inertia (specific to Alt. A)	0.187	0.0287	6.50
Inertia ² (specific to Alt. A)	-0.00489	0.0011	-4.46
Inertia (specific to Alt. B)	0.157	0.051	3.07
Inertia ² (specific to Alt. B)	-0.00678	0.0028	-2.40
Summary Statistics:			
N=1080 L(0)=-1186.5 L(C)=-1069.67 L(B)=-873.3 $\rho_c^2=0.183$ $\bar{\rho}_c^2=0.169$			
-2[L(0)-L(B)]=626.4 $\rho^2=0.264$ $\bar{\rho}^2=0.251$			
-2[L(C)-L(B)]=392.74			

Table 5.3. Estimation Results With SP Data (Pilot Survey)

The SP model, however, had a number of flaws in it and was not used for forecasting or hypothesis testing. These include:

1. Interactions of the ITS and telecommuting attributes with other attributes was not estimable due to the structure of the experimental design.
2. The observations made on the scenarios are scattered all over the respondents' response surface, which translates into large variance of observations.
3. Not all attributes were equally spaced. Although it is not a requirement for

qualitative attributes, it is for quantitative ones. With quantitative data, if one wants to estimate their linear and quadratic effects the levels should be evenly spaced to produce a statistically optimal estimate; that is, an estimate with the smallest variance.

4. Although not a requirement, in a design with a large number of attributes it is better to use same number of levels for all attributes. This design is called a 'symmetrical factorial' design. In terms of the data analysis, there is no difference between a symmetrical and asymmetrical design. From an experimental design viewpoint, however, a symmetrical design is easier to construct, especially when selected number of interactions are to be estimated, which is the case in this research.

All the above issues were resolved and addressed in the final survey. The only use of the SP analysis at this stage was to see if the variables included in the SP experiment were highly statistically significant. Thus, no further step was taken to combine the RP and SP data.

CHAPTER VI: SURVEY DESIGN AND IMPLEMENTATION—THE FINAL STUDY

6.1. INTRODUCTION

The results of the two pilot surveys helped to further refine the final questionnaire in terms of wording, format, and layout. The results of the SP analysis of the second pilot survey presented in Chapter V showed that, although statistically flawed, all selected variables were in fact important and there was a trade-off among them.

The rest of this chapter explains in detail the steps taken in the final survey's experimental design, sampling issues, survey administration, and estimation procedure. It discusses the same issues as in Chapter V, but in the context of the final survey.

6.2. ALTERNATIVES DEFINITION

The definition of alternatives and their description was the same as in the pilot survey, but with improved explanations and graphical details.

6.3. ATTRIBUTES AND THEIR LEVELS

To avoid problems outlined in the pilot survey, and to make the experimental design more manageable in size, it was decided to have seven attributes at three levels each for each of the alternatives A, B, and C. The attributes and their levels are presented in Table 6.1.

Attribute (abbr.)	Alt. A	Alt. B	Alt. C
Level of Tele-Commuting (TC) (days/week)	None 1 day a week 2 days a week	None 1 day a wee 2 days a we	None 1 day a week 2 days a week
Travel Delays (DL)	No delay at all 10 min. once a week 10 min. twice a week	No delay at all 10 min. once a week 10 min. twice a week	No delay at all 10 min. once a week 10 min. twice a week
Monthly Housing Cost (HC)	no change +\$150 +\$300	no change +\$150 +\$300	-\$300 -\$150 no change
Number of Rooms (RM)	-1 no change +1	-1 no change +1	no change +1 +2
Travel Time to Work (one way) (TW)	no change +5 min +10 min	no change +10 min. +20 min.	no change +10 min. +20 min.
Travel Time to School (one way) (TS)	10 20 30	10 20 30	10 20 30
Access to Outdoor Recreational Opportunities (RC)	poor good excellent	poor good excellent	poor good excellent

Table 6.1. List of Attributes and Their Levels for the SP Experiment (Final Survey)

There are a number of differences between this table and Table 5.1 that was used for the pilot survey.

- For the final survey, number of rooms replaced the area of house as a measure of housing size. The reason was the difficulty many of the respondents had in the pilot survey in knowing their housing size in either ft² or m² terms. Thus, it was difficult for them to perceive the effects of a $\pm 20\%$ change in housing size.

- All attributes are at three levels each.
- The values of levels are alternative-specific for three of the variables namely monthly housing cost, number of rooms in the house, and one-way travel time to work. One of the reasons households move to urban fringe areas is because of less expensive and more spacious housing bundle available in those areas. As such, the magnitude of the levels were set more attractive in Alt. C compared to those of Alt. A and B to observe whether those factors would influence a respondent's choice toward Alt. C.
- Finally, all attributes are evenly spaced to produce efficient estimates.

6.4. EXPERIMENTAL DESIGN

With the background presented in Section 5.5, a full factorial design for the final survey would include $(3^7)^3=3^{21}$ profiles, which is prohibitively large. The fractional factorial designs available in the literature are available for up to 3^{10} to 3^{12} , at the maximum. Moreover, as the number of attributes grows beyond seven or eight, the available plans become basically main effects plans only, with some of them allowing the estimation of one or two interactions at most. This research is trying to find out if the adoption of telecommuting and deployment of ITS would influence people's choice of residential location. This impact, if any, could be not only due to the societal and economic benefits of telecommuting and ITS, but also due the fact that they might interact with housing price, housing size, and commute time. Therefore, the experimental design in this research had to be able, at the very least, to measure the interactions of telecommuting and ITS with other variables.

A fractional factorial design was developed with help of one of the most renowned statisticians in the field of SP design, Dr. Donald Andersonⁱⁱ. This design calls for three alternative-specific models each with seven three-level attributes and a total of 11 interactions (i.e., telecommuting factor with six other variables + ITS factor with five remaining variables) to be estimated. Each individual attribute has two degrees of freedom to be estimated: one is the linear (L) and the other one is quadratic (Q) component. Each of the interactions has the potential for four degrees of freedom to be estimated: LxL, LxQ, QxL, and QxQ. Thus, each alternative-specific model has potential for estimating 1 intercept + 14 linear and quadratic main effects + 44 combination of quadratic and linear interactions totalling 59 parameters not counting any cross effects. Since the attributes are quantitative, it would be reasonable to estimate only the linear by linear interactions, which leaves only 26 parameters (1+14+11) to be estimated per alternative.

The factorial design for this research was more complex than conventional designs due to the requirements for interactions estimability. The design used in this research contains 3^4 (=81) profiles (or scenarios)ⁱⁱⁱ. The experimental design procedure, which is explained below briefly, was carried out from 4 factors at three levels each and all of their generalized interaction. If we name the factors as a , b , c , and d , there are two degrees of freedom (d.f) associated with each attribute. The interaction between a and b has 4 d.f, and these can be expressed as two independent 3-level variables usually denoted as ab and ab^2 . Hence, the two-factor interactions in this case would be: ab , ab^2 , ac , ac^2 , ad , ad^2 ,

ⁱⁱ Dr. Anderson is the president of StatDesign in Denver, Colorado, U.S.A

ⁱⁱⁱ The following explanation is based on the outlined design procedure provided by Dr. Anderson. The author greatly appreciates his contribution in the design of this experiment.

$bc, bc^2, bd, bd^2, cd, cd^2$. Likewise, the three-factor interaction between a, b , and c (and similarly for other three-factor combinations) has $2 \times 2 \times 2 = 8$ d.f. These 8 d.f. can be represented as abc, abc^2, ab^2c , and ab^2c^2 . The four-factor interaction has $2 \times 2 \times 2 \times 2 = 16$ d.f, and they are represented as $abcd, abcd^2, abc^2d, ab^2cd, abc^2d^2, ab^2cd^2, ab^2c^2d, ab^2c^2d^2$. In total, there are 40 of these independent 2 d.f factorial effects; in effect, a 3^{40} ‘main effect’ design. For three level factorial designs, whenever any two such main effects are selected, two additional ‘generalized interactions’ can be computed. In general, if X and Y are two independent effects, the two generalized interactions are XY and XY^2 (Montgomery, 1997). As an example, suppose we have two ‘main effects’ abc^2 and bcd . The generalized interactions of these two factors are:

$$(abc^2)(bcd) = ab^2c^3d = ab^2d \text{ (reduced to modulus 3); and}$$

$$(abc^2)(bcd)^2 = ab^3c^4d^2 = acd^2 \text{ (reduced to modulus 3)}$$

The final design was made by trial and error using these factorial effects and their generalized interactions subject to the following rules:

1. None of the ‘main effects’ in Alt. A, Alt. B, and Alt. C will be the same to ensure perfect main effect balance and orthogonality within and between alternatives.
2. The generalized interactions of variables 1 and 2 with other effects within each alternative will be distinct to ensure estimability and perfect orthogonality within each alternative for all main effects and interactions within each alternative.

Tables 6.2, 6.3, and 6.4 show the seven 3-level effects that were selected and put in each of Alt. A, B, and C, respectively, along with their generalized interactions.

Three-level Main Effect Factors	Generalized Interactions	
	Interactions with a	Interactions with b
a		
b	ab, ab^2	
abc	ab^2c^2, bc	ab^2c, ac
abd^2	ab^2d, bd^2	ab^2d^2, ad^2
$abcd$	$ab^2c^2d^2, bcd$	ab^2cd, acd
$abcd^2$	ab^2c^2d, bcd^2	ab^2c^2, acd^2
abc^2d	ab^2cd^2, bc^2d	ab^2c^2d, ac^2d

Table 6.2. Three-Level Interactions and Their Generalized Interactions for Alt. A

Three-level Main Effect Factors	Generalized Interactions	
	Interactions with c	Interactions with d
c		
d	cd, cd^2	
abc^2	ab, abc	abc^2d, abc^2d^2
acd	ac^2d, ad	acd^2, ac
bcd	bc^2d, bd	bcd^2, bc
ab^2cd	ab^2c^2d, ab^2d	ab^2cd^2, ab^2c
ab^2c^2d	ab^2d, ab^2cd	$ab^2c^2d^2, ab^2c^2$

Table 6.3. Three-Level Interactions and Their Generalized Interactions for Alt. B

Three-level Main Effect Factors	Generalized Interactions	
	Interactions with ac	Interactions with bd
ac		
bd	$abcd, ab^2cd^2$	
ac^2	a, c	$abc^2d, ab^2c^2d^2$
bd^2	$abcd^2, ab^2cd$	b, d
bc	abc^2, ab^2	bc^2d^2, cd^2
bc^2	ab, ab^2c^2	bcd^2, cd
abc^2d^2	ab^2d, bcd^2	ab^2c^2, ac^2d

Table 6.4. Three-Level Interactions and Their Generalized Interactions for Alt. C

It can be seen that within Tables 6.2 and 6.3 none of the interactions appears twice. This indicates that the second condition mentioned above is satisfied. In Table 6.4 there are two pairs of generalized interactions in common. Since only the Linear x Linear component of the interaction is required (i.e., one d.f out of the four for interactions), it was checked that these two LxL effects were estimable. They are not perfectly orthogonal, however they are estimable with only small correlations.

In practice it is impossible to present such a large number of profiles to a respondent. Thus, the profiles were separated into 'blocks'. In general, the object of blocking is to reduce the number of treatments into manageable size, as well as to reduce the error variance by placing experimental units that are as similar as possible, with respect to the dependent variable, in a given block (Kirk, 1995). Obviously the block size is smaller than the number of treatment combinations (i.e., scenarios). For 3-level attributes, a 3^k factorial design may be confounded in 3^p block, where $p < k$. Thus, the designs may be confounded in three blocks, nine blocks, and so on (Montgomery, 1997). With blocking, however, one or more higher order interactions will be confounded with blocks.

In the case of this research, the 81 treatment combinations were separated into $3^2=9$ blocks of size 9 each. This design is shown in Table 6.5. For the purpose of this research, in order to create the blocks, an additional 9-level variable was constructed so that it was not aliased with any main effects in any of the three alternatives^{iv}. This guaranteed that each person saw each level of every attribute in all three alternatives exactly three times. The design is an orthogonal main effects design for the $3 \times 7 = 21$ main effects attributes plus permitting the desired interactions to be estimated. The main effects are orthogonal

^{iv} Based on personal communication with Dr. Anderson.

both within and between alternatives. The design assumes that cross effects (i.e., between alternatives) are negligible, as it is almost always the case. This design has two main advantages over the one used in the pilot survey. Firstly, one is able to estimate interactions of telecommuting and ITS measures with other variables. This was not possible in the former approach. Secondly, with 81 scenarios each for Alternatives A, B, and C, there are 81 observations on the response surface. Since there are a large number of replications per scenario, the variance of observations is substantially reduced^v. In the former design there were 1090 scenarios presented in total (109 respondents with 10 scenarios each). The 1090 observations were scattered all over the respondents' response surface, which has a much larger variance than the latter design where 3456 observations are positioned at 81 points from an orthogonal factorial design.

^v As will be discussed later, there were 385 SP observations, which translate to approximately 43 responses per scenario version.

Alternative A							Alternative B							Alternative C							
A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	Block No.
0	0	2	0	0	2	1	1	1	2	2	2	2	2	1	1	2	2	1	2	1	1
2	2	2	1	1	2	0	2	2	0	1	1	0	2	1	1	0	0	1	0	0	1
1	1	1	2	2	1	0	1	1	0	2	2	0	1	2	2	0	0	2	0	0	1
1	1	2	2	2	2	2	0	0	1	0	0	1	2	1	1	1	1	1	1	2	1
2	2	0	1	1	0	2	1	1	1	2	2	1	0	0	0	1	1	0	1	2	1
0	0	1	0	0	1	2	2	2	1	1	1	1	1	2	2	1	1	2	1	2	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1	1	0	2	2	0	1	2	2	2	1	1	2	0	0	0	2	2	0	2	1	1
2	2	1	1	1	1	1	0	0	2	0	0	2	1	2	2	2	2	2	2	1	1
2	1	2	0	0	2	1	1	1	1	0	1	0	2	0	2	1	0	2	0	1	2
0	2	1	2	2	1	0	1	1	2	0	1	1	1	1	0	2	1	0	1	0	2
1	0	2	1	1	2	0	2	2	2	2	0	1	2	0	2	2	1	2	1	0	2
1	0	0	1	1	0	2	1	1	0	0	1	2	0	2	1	0	2	1	2	2	2
0	2	0	2	2	0	1	2	2	1	2	0	0	0	2	1	1	0	1	0	1	2
0	2	2	2	2	2	2	0	0	0	1	2	2	2	0	2	0	2	2	2	2	2
1	0	1	1	1	1	1	0	0	1	1	2	0	1	1	0	1	0	0	0	1	2
2	1	1	0	0	1	2	2	2	0	2	0	2	1	1	0	0	2	0	2	2	2
2	1	0	0	0	0	0	0	0	2	1	2	1	0	2	1	2	1	1	1	0	2
2	0	2	2	2	2	2	0	0	2	2	1	0	2	2	0	2	0	0	0	2	3
0	1	0	1	1	0	2	1	1	2	1	0	0	0	1	2	2	0	2	0	2	3
1	2	2	0	0	2	1	1	1	0	1	0	1	2	2	0	0	1	0	1	1	3
1	2	1	0	0	1	2	2	2	2	0	2	0	1	0	1	2	0	1	0	2	3
2	0	1	2	2	1	0	1	1	1	1	0	2	1	0	1	1	2	1	2	0	3
0	1	1	1	1	1	1	0	0	0	2	1	1	1	0	1	0	1	1	1	1	3
2	0	0	2	2	0	1	2	2	0	0	2	1	0	1	2	0	1	2	1	1	3
0	1	2	1	1	2	0	2	2	1	0	2	2	2	2	0	1	2	0	2	0	3
1	2	0	0	0	0	0	0	0	1	2	1	2	0	1	2	1	2	2	2	0	3
2	2	0	2	0	2	1	0	2	1	2	2	1	1	2	1	2	0	2	2	2	4
0	0	0	1	2	2	2	2	1	0	0	0	0	1	2	1	1	2	2	1	0	4
1	1	0	0	1	2	0	1	0	2	1	1	2	1	2	1	0	1	2	0	1	4
2	2	2	2	0	1	2	1	0	0	1	1	0	0	0	2	1	2	0	1	0	4
0	0	1	1	2	0	1	1	0	1	1	1	1	2	1	0	2	0	1	2	2	4
1	1	2	0	1	1	1	2	1	1	0	0	1	0	0	2	2	0	0	2	2	4

Alternative A							Alternative B							Alternative C							
A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	Block No.
1	1	1	0	1	0	2	0	2	0	2	2	0	2	1	0	1	2	1	1	0	4
0	0	2	1	2	1	0	0	2	2	2	2	2	0	0	2	0	1	0	0	1	4
2	2	1	2	0	0	0	2	1	2	0	0	2	2	1	0	0	1	1	0	1	4
1	0	1	2	0	0	0	2	1	1	1	2	0	2	0	1	2	2	2	1	1	5
1	0	2	2	0	1	2	1	0	2	2	0	1	0	2	0	0	0	1	2	0	5
1	0	0	2	0	2	1	0	2	0	0	1	2	1	1	2	1	1	0	0	2	5
2	1	0	1	2	2	2	2	1	2	1	2	1	1	1	2	0	0	0	2	0	5
2	1	2	1	2	1	0	0	2	1	0	1	0	0	2	0	2	2	1	1	1	5
0	2	0	0	1	2	0	1	0	1	2	0	0	1	1	2	2	2	0	1	1	5
0	2	1	0	1	0	2	0	2	2	0	1	1	2	0	1	0	0	2	2	0	5
2	1	1	1	2	0	1	1	0	0	2	0	2	2	0	1	1	1	2	0	2	5
0	2	2	0	1	1	1	2	1	0	1	2	2	0	2	0	1	1	1	0	2	5
0	1	0	2	0	2	1	0	2	2	1	0	0	1	0	0	0	2	1	1	2	6
1	2	1	1	2	0	1	1	0	2	0	2	0	2	2	2	0	2	0	1	2	6
0	1	2	2	0	1	2	1	0	1	0	2	2	0	1	1	2	1	2	0	0	6
0	1	1	2	0	0	0	2	1	0	2	1	1	2	2	2	1	0	0	2	1	6
2	0	1	0	1	0	2	0	2	1	1	0	2	2	2	2	1	0	0	0	0	6
1	2	2	1	2	1	0	0	2	0	1	0	1	0	1	1	1	0	2	2	1	6
2	0	2	0	1	1	1	2	1	2	2	1	0	0	1	1	0	2	2	1	2	6
2	0	0	0	1	2	0	1	0	0	0	2	1	1	0	0	1	0	1	2	1	6
1	2	0	1	2	2	2	2	1	1	2	1	2	1	0	0	2	1	1	0	0	6
1	1	1	1	0	2	1	2	0	0	2	2	0	0	0	1	2	1	0	2	0	7
0	0	1	2	1	2	0	0	1	1	1	1	1	0	0	1	0	2	0	0	2	7
2	2	2	0	2	0	1	0	1	0	1	1	0	1	2	0	2	1	2	2	0	7
0	0	2	2	1	0	2	2	0	2	2	2	2	1	2	0	1	0	2	1	1	7
1	1	2	1	0	0	0	1	2	1	0	0	1	1	2	0	0	2	2	0	2	7
2	2	0	0	2	1	0	2	0	1	2	2	1	2	1	2	0	2	1	0	2	7
0	0	0	2	1	1	1	1	2	0	0	0	0	2	1	2	2	1	1	2	0	7
1	1	0	1	0	1	2	0	1	2	1	1	2	2	1	2	1	0	1	1	1	7
2	2	1	0	2	2	2	2	2	0	0	2	0	0	0	1	1	0	0	1	1	7
2	1	0	2	1	1	1	1	2	2	1	2	1	2	0	0	1	2	2	0	0	8
2	1	2	2	1	0	2	2	0	1	0	1	0	1	1	0	1	0	2	1	1	8

Alternative A							Alternative B							Alternative C							
A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	Block No.
2	1	1	2	1	2	0	0	1	0	2	0	2	0	2	2	2	0	1	1	2	8
0	2	0	1	0	1	2	0	1	1	2	0	0	2	0	0	0	1	2	2	1	8
0	2	1	1	0	2	1	2	0	2	0	1	1	0	2	2	1	2	1	0	0	8
1	0	2	0	2	0	1	0	1	2	2	0	1	1	1	1	1	2	0	0	0	8
1	0	0	0	2	1	0	2	0	0	0	1	2	2	0	0	2	0	2	1	2	8
1	0	1	0	2	2	2	1	2	1	1	2	0	0	2	2	0	1	1	2	1	8
0	2	2	1	0	0	0	1	2	0	1	2	2	1	1	1	2	0	0	1	2	8
0	1	0	0	2	1	0	2	0	2	1	0	0	2	2	1	1	1	0	2	2	9
0	1	1	0	2	2	2	1	2	0	2	1	1	0	1	0	2	2	2	0	1	9
0	1	2	0	2	0	1	0	1	1	0	2	2	1	0	2	0	0	1	1	0	9
2	0	0	1	0	1	2	0	1	0	0	2	1	2	2	1	2	2	0	0	1	9
2	0	2	1	0	0	0	1	2	2	2	1	0	1	0	2	1	1	1	2	2	9
1	2	0	2	1	1	1	1	2	1	2	1	2	2	2	1	0	0	0	1	0	9
1	2	2	2	1	0	2	2	0	0	1	0	1	1	0	2	2	2	1	0	1	9
2	0	1	1	0	2	1	2	0	1	1	0	2	0	1	0	0	0	2	1	0	9
1	2	1	2	1	2	0	0	1	2	0	2	0	0	1	0	1	1	2	2	2	9

Notes:

Numbers 0,1, and 2 indicate low, middle, and high levels of each attribute, respectively.
Letters A through G indicate first through seventh attributes, respectively.

Table 6.5. SP Treatment Combinations (Final Survey)

As was shown in Table 6.4, the only problem with this design was that two pairs of generalized interactions were not perfectly orthogonal. The correlation matrix, presented in Appendix A.2, shows that the correlation is about 0.25 and the following correlation structure existed in the correlation matrix^{vi}:

Within alternative A: A.D was correlated with B.E by about 0.25.

A.E was correlated with B.D by about 0.25.

^{vi} In the following discussion, the capital letters A, B, C represent variables; whereas italic letters *A*, *B*, *C* represent the three alternatives.

The same correlation structure existed for Alt. *B*.

Within alternative *C*: A.F was correlated with B.G by about 0.25.

A.G was correlated with B.F by about 0.25.

In the design, 'A' represents the telecommuting variable and 'B' represents travel time variability (i.e., measure of ITS) attribute. To reduce the correlation problem the following was done:

As can be seen from the above correlation structure, the third variable, named C, did not participate in the interaction effects correlations. Therefore, it was assigned to the most important attribute, namely housing cost. The selection of this variable was based on the results of the SP analysis in the pilot survey as well as the literature on housing location choice (e.g., Hunt et al, 1994; Quigley, 1985). At the same time, one less important variable (other than telecommuting and ITS) was assigned to one of the variables that was participating in the interaction-effect correlation. Since variables D and E are observed in both Alt. *A* and Alt. *B*, it was reasonable to assign either of these to the less important variable. As such, D was arbitrarily assigned to the 'number of rooms' variable, and E was assigned to the 'travel-time-to-work' variable. The idea here was that if one could statistically justify that either of these variables did not have a statistically significant interaction with either the first variable (i.e., telecommuting) or the second variable (i.e., travel time variability), then the correlation problem for Alt. *A* and *B* would be resolved. As will be seen later in the analysis section, this condition was satisfied.

6.5. SAMPLING PROCESS

When telecommuting was starting to gain acceptance in the U.S. and elsewhere it was thought that telecommuters would have two characteristics in common: they were information workers and that telecommuting had to be full-time. Today, however, evidence from operational experiences both in public and private sectors shows that those assumptions need not hold (Mokhtarian, 1991; Hopkins et al, 1994). Empirical evidence shows that in addition to high-tech industry employees, telecommuting is adopted by industries such as finance, consulting services, education and research, insurance, and retail (Mokhtarian, 1992). Research also shows that both public and private sectors adopt telecommuting successfully and there is no reason to believe that one sector will have a higher proportion of telecommuters than the other (Mokhtarian, 1992; Moss and Carey, 1994). As such, it was decided to select samples from both sectors. The sampling process for each sector is explained below.

6.5.1. Private Sector

For the private sector, the sample was selected from two sources:

1. 'The Ottawa Technology Business Guide' by the Ottawa-Carleton Economic Development Corporation [OCEDC] (1997); and
2. 'Ottawa Business Contacts' by Kantraco Ltd. (1995).

The first publication contained listings of private organizations in the Ottawa-Carleton Region in sectors such as computer hardware and software, consulting services, defence, energy, environment, telecommunications, and transportation. For each organization in the list, the directory provided information on its location, number of employees, present

sector and present market, and brief description of the type of its business activity.

The second publication contained listings of almost all businesses in the region. For each business in the list, the directory contained information on its address, contact name, and telephone and/or fax number. Although this directory contained most of the businesses in the region, it was decided to use it as the supplementary source of selecting the sample. The main reason was that, after examining a few of the listings randomly, it was found out that the information provided was out-dated. For example, either the address was changed, or the company did not exist any more, or the phone number was not in service any more. In addition, many of the jobs listed were obviously not suitable for telecommuting.

The combined advanced technology and service sectors comprised about 47% of total employment in Ottawa-Carleton in 1996 (OCEDC, 1998). As these industry sectors were among the most appropriate sectors for telecommuting as well as the fact that the first publication mentioned earlier was the only most comprehensive business directory for the service and high-technology sectors, the OCEDC (1997) was used as the primary source for drawing random samples. The latter publication, 'Ottawa Business Contacts', was used as the supplementary source to contact organizations in the finance, insurance, and consulting sectors, which were not listed in the former source (for the consulting services, the listing was more comprehensive in the latter than the former publication).

The sampling procedure from the OCEDC source was as follows:

1. Industry sectors not suitable for telecommuting were crossed off from the Ottawa Business Directory. These included chemical; biochemistry, medical, and pharmaceutical laboratories; and subassemblies and components.

2. The remaining companies were numbered sequentially starting with number 1. It should be mentioned that companies were listed in alphabetical order in the Directory.
3. Every 10th company was marked and contacted by phone and/or e-mail. The purpose of the study was explained during the conversation. The correspondence asked the company's president (or CEO or public relations director, as appropriate) to authorize the distribution of the survey among the company's employees.

Thus the sampling method was a simple random sampling.

For the second publication, the available companies were also numbered sequentially, and every 10th business was contacted as described in step 3 above.

6.5.2. Public Sector

The sampling strategy for the public sector was completely different. Currently, there are a few public sector organizations in the Region who permit telecommuting by some of their employees. These include Statistics Canada, Transport Canada, Treasury Board of Canada, National Bank, Industry Canada, and the Regional Municipality of Ottawa-Carleton. All of these organizations were contacted for participation in the survey. Although this approach did not provide us with a true random sample of all public agencies in the Region, it could be considered a quasi-random sampling, since the employees within each of these organizations were surveyed randomly. Moreover, this approach provided the basis to compare travel and residential behaviour between telecommuters and non-telecommuters. Of the above organizations, three agreed to

participate. They were: Statistics Canada, the National Bank, and the Regional Municipality of Ottawa-Carleton. Within these agencies only those divisions where a telecommuting program was in effect participated in the survey.

6.6. SAMPLE SIZE

The size of the sample depends on (1) the desired level of statistical accuracy and confidence interval needed, and (2) the expected response rate (Kocur et al, 1982). In terms of accuracy, one should specify the level of accuracy and of confidence interval needed for the sample. In dealing with categorical variables, the sample proportion, $\hat{p}$, is an estimator of population proportion p . Analogous to the sampling distribution of the mean for numerical variables, the confidence interval for the sample proportion is defined as:

$$\hat{p} \pm Z_{\alpha/2} \sqrt{\frac{\hat{p}(1-\hat{p})}{n}} \quad (6.1)$$

Where:

$\hat{p}$ = Sample proportion possessing a specific characteristic; and

$Z_{\alpha/2}$ = number of standard errors of the standard normal curve at the significance level α .

The term $\sqrt{\frac{\hat{p}(1-\hat{p})}{n}}$ is in fact the standard error of the sample proportion $\hat{p}$. From the

above equation it can be seen that the sample size required for a specific sampling error, e , is (Berenson and Levine, 1996):

$$n = \frac{Z_{\alpha/2}^2 \hat{p}(1-\hat{p})}{e^2} \quad (6.2)$$

Thus, if for example, one wants the 'error in the estimate' to be 0.05 (i.e., $e=0.05$), a

sample size of nearly 400 is required for a 95% confidence level^{vii}.

When there are two sample proportions involved the confidence interval becomes:

$$\hat{p}_1 - \hat{p}_2 \pm Z_{\alpha/2} \sqrt{\frac{\hat{p}_1(1-\hat{p}_1)}{n_1} + \frac{\hat{p}_2(1-\hat{p}_2)}{n_2}} \quad (6.3)$$

Where subscripts 1 and 2 correspond to samples 1 and 2, respectively.

In this case, if for example, one wants to be able to detect a difference of 0.1 between $\hat{p}_1$ and $\hat{p}_2$, a sample size of nearly 200 for each sample, or a total of 400 is required. For a difference of 0.05 the size increases to almost 800 per sample or 1600 in total.

With this background in mind, the experimental design in here consists of seven attributes each at three levels in each of the three alternatives. Hence, the number of degrees of freedom for the main effects is $(2 \times 7) \times 3 = 42$. There are also 11 two-factor interactions in each of the three alternatives. Since we are considering only the LxL effects, the number of degrees of freedom is $(11 \times 1) \times 3 = 33$. Thus, in total there are $42 + 33 = 75$ attribute parameters to be estimated for each alternative. In general, one needs enough sensitivity in the experiment to detect 'changes in proportions' (i.e., share of each of Alt. A, B, and C) over the range of the 75 parameters. Therefore, the sample size equation for the difference of proportions needs to be considered 75 times. For this case, in particular, where the data are of multinomial type, it is not simple to estimate the sample size accurately. At an absolute minimum, however, 30 respondents per scenario version or at least $9 \times 30 = 270$ respondents are required^{viii}.

^{vii} When there is no information available on σ , a conservative estimation will be obtained by setting $p=0.5$ which maximizes σ and subsequently the required sample size. So, for $Z=1.96$, $p=0.5$, and $e=0.05$, $n=384$.

^{viii} Personal communication with Dr. D. Anderson.

6.7. ADMINISTRATION OF THE FINAL SURVEY

As with previous pilot surveys, the final questionnaire contained three parts. A sample questionnaire is attached in Appendix A.3. Part one was an introduction letter outlining the purpose of the survey plus explanations about telecommuting and ITS. Part two contained questions about the respondent's housing choice, travel behaviour, employment, and demographic information. Part three contained the stated preference task and provided respondents with nine hypothetical scenarios. They were asked to choose one alternative from the choice set. Based on the feedback from the second pilot survey, Part 3 started out with a one-page introduction explaining the nature of the task and what was required of the respondents. After the introduction page, the questionnaire also provided them with a complete example scenario to show them how to respond. All the terminologies used in the scenarios were defined clearly as well. They were asked to assume that their entire family was moving to a new place in the region. Within this context, their task was to evaluate each given scenario and choose either Alt. A, B, C, or 'None'. The 'None' alternative was added to the choice set to ensure that if any respondent did not like the combination of factors for all the given alternatives, s/he would not be 'forced' to choose any of the alternatives (Ortúzar and Willumsen, 1994). Thus, the 'None' choice meant that either the respondent would not move or that s/he would not live in any of the presented alternatives.

The final survey was carried out between August 1998 and February 1999. During this period the selected organizations were contacted using the sampling procedure described in Section 6.5.

Private Sector— The process of contacting sampled companies was very time-

consuming and cumbersome. More than 100 companies were contacted by various means such as phone, fax, e-mail, and personal visit. In total only 25 companies initially agreed to participate. Of these, 3 declined to proceed with the survey, after reviewing the questionnaire due to reasons such as heavy workload and/or lengthiness of the survey. For the companies that participated, the number of employees ranged from 5 to 110. These companies were within the following sectors: high technology such as web design, software development, telecommunications; consulting services; finance; and research and education.

The questionnaires were delivered in person to each company. For larger size companies, a separate cover letter from the company's authoritative person was attached to the survey asking for the employees' cooperation. The whole package was then distributed among workers through their reception desk or the organization's internal mail system, as appropriate. After completing the survey, respondents returned it in the supplied return envelope to the reception desk or to the designated person within the organization. The surveys were collected back in about two to three weeks later.

The response rate varied from 20% to 100%. In total 550 survey questionnaires were sent out. A total of 215 questionnaires were returned. Three of these were largely blank and were discarded from the further analysis thus yielding an effective response rate of 39%, which was considered very high given that the survey took an average of 30 minutes to fill out. In passing note, out of the 212 usable surveys, 2 of them were usable for the RP analysis only (due to incomplete answers in the SP part) and 6 of them were usable for SP analysis only due to large number of unanswered questionnaires in the RP section.

Public Sector—Within this sector, only a handful of agencies had a telecommuting

program. After an exhaustive search and several contacts with these agencies, three agreed to participate. They were Statistics Canada, the National Bank, and the Regional Municipality of Ottawa-Carleton. After coordination with the authorities in these agencies the survey was delivered in person to their respective liaison people. A cover letter from these agencies was added to the survey.

For the RMOC, 400 surveys were sent out and 95, all of them usable, were collected back. For the other two agencies it was not possible to collect the completed surveys personally. As such, a postage-paid return envelope was enclosed with the survey package and completed questionnaires were returned directly by mail. In addition, due to existing regulations in Statistics Canada, a French version of the survey was also enclosed. In total, 202 and 100 survey questionnaires were sent out to Statistics Canada and the National Bank, respectively. For the former, 58 surveys were returned, where 2 of them were blank, and another 2 were usable for the RP analysis only. For the latter, 27 surveys were returned with one survey being usable for the RP analysis only.

Thus, for the public sector, 178 usable surveys were returned producing an effective response rate of 25%, which was lower than that of the private sector.

All in all, out of 1252 total surveys which were sent out, a total of 390 usable questionnaires were returned yielding an overall response rate of 31% (384 surveys were usable for RP analysis and 385 surveys were usable for SP analysis).

6.8. PRELIMINARY ANALYSIS

For the sample in the final survey 58% of respondents were living in the central area of the region (i.e., Alt. A), compared to 25% and 17% who were living in Alt. B and Alt. C,

respectively. The sample consisted of 54% male and 75% were homeowners.

The average housing cost was \$1019 per month with an average of 7.1 rooms. On average, respondent households have been living in their current residence for 6.3 years. The average household size was 3.0 persons and 44% of respondents had children age 16 and under in the household.

On average, respondent households had 1.48 vehicles, and 0.74 vehicles per licensed driver. The average distance from respondents' residence to work was 19 km, with an average one-way commute time of 29 minutes.

The modal household income category was \$100,000 and above (30%), followed by categories of \$75,001-\$100,000 (27%) and \$50,001-75,000 (24%). The median income range was \$75,001-\$100,000. Having 67% of sample being dual-earner households as well as being in the service and hi-tech sectors, has led to the above income distribution.

About 25% of respondents stated they were telecommuting. On average, they were telecommuting 11 hours per week for roughly 3 years. Of the remaining 75% who were not telecommuting, 69% stated that they would either definitely or probably telecommute if they were given the opportunity to do so. This shows the interest among respondents in adopting telecommuting. However, it does not necessarily imply that they would telecommute if they had the opportunity. Table 6.6 provides more detailed descriptive information about telecommuters, non-telecommuters, and for the whole sample.

Figure 6.1 shows modal split to work for the sample and for the Ottawa-Carleton region, which was based on the 1995 O-D survey.

Attribute	Non-Telecommuters	Telecommuters	Total
<u>Housing Information:</u>			
Location choice:			
Alt. A:	60%	53%	58%
Alt. B:	25%	24%	25%
Alt. C:	15%	23%	17%
Tenure type:	Own	87%	75%
	Rent	13%	25%
Average housing cost (\$/month)	\$993	\$1094	\$1019
Average number of rooms	7.0	7.5	7.1
Average length of residence (year)	6.0	7.2	6.3
<u>Travel-to-work Information:</u>			
Mode of travel:			
Automobile	64%	62%	63%
Public transit	24%	32%	26%
Walk/cycle	12%	6%	11%
Average one-way commute length (km)	18.6 km	21.0 km	19 km
Average one-way commute time (min)	28 min.	32 min.	29 min.
<u>Demographic Information:</u>			
Average age	38.9	42.7	39.8
Gender:	Male 162 (56%)	45 (46%)	207 (54%)
	Female 125 (44%)	52 (54%)	177 (46%)
Household size	2.93	3.04	2.96
Presence of children under 16 (percent)	42%	49%	44%
Average vehicles per driver	0.75	0.72	0.74
Median Income	\$75K-\$100K	\$75K-\$100K	\$75-\$100K
Percentage of Dual-earner families	64%	74%	67%
<u>Telecommuting Information:</u>			
Telecommuting adoption	287 (75%)	97 (25%)	
• Average number of hours per week	N/A	11 hrs	
• Average duration of participation (yr)	N/A	2.9 years	
• Ever contemplated moving or actually moved because of telecommuting	N/A	13%	
Suitability of job for telecommuting			
• YES (%)	46%	N/A	
• Not Sure (%)	17%	N/A	
Whether or not telecommute if given the opportunity			
• Definitely or probably YES (%)	69%	N/A	
• Not sure (%)	15%	N/A	
• Definitely or probably NOT (%)	16%	N/A	

Table 6.6. Descriptive Sample Characteristics

It can be seen that modal share for telecommuters and non-telecommuters is roughly the same in terms of automobile but telecommuters use public transit more than their counterparts whereas the reverse is true with respect to the walk/cycle model. Also, the sample as a whole, uses public transit more than the transit market share for the Region.

Figure 6.1. Modal Split to Work (Final Survey)

At the end of the RP part in the survey, respondents were also asked to rank the seven given residential location choice-related factors in terms of their importance to them. They were asked to do so by giving a rank of 1 to the most important factor and a rank of 7 to the least important one. Figure 6.2 shows the average ranking score for each factor. It should be mentioned that only about 80% of the sample responded correctly to this question. Most of the remaining sample performed a rating exercise on the factors.

Figure 6.2. Average Ranking of Various Residential Factors

As it can be seen there is very little difference between the telecommuters and non-telecommuters with respect to their rankings of factors. Housing cost had the highest rank as expected, whereas the telecommuting factor got the lowest ranking. However, the average ranking for the latter factor was a little higher for telecommuters than the other group suggesting that actual experience with telecommuting might have caused the wider difference. It should be born in mind, however, that the graph only depicts the level of importance but it does not imply that telecommuting does not play any role in housing choice decision. As will be shown in the next chapter, telecommuting, among other factors, showed to be a significant parameter.

To see whether the adoption of telecommuting had any impact on the respondents' choice of housing location, telecommuters were asked if they ever contemplated moving or actually moved because telecommuting gave them freedom to live where they want. Only 13% of the respondents said they either moved or contemplated moving as a result of telecommuting.

6.9. ANALYSIS OF INDIVIDUAL CHARACTERISTICS

Although it was not the objective of this research to identify factors (related to the characteristics of individuals) that might influence the individual's propensity to telecommute, it is worthwhile to statistically check on these factors since some of the data have already been collected in this survey. This analysis is presented in this section. The discrete choice analysis is discussed in the next chapter.

Based on the obtained data, one can try to identify whether three factors namely age, gender, and job category have any impact on the telecommuting adoption. Literature suggests that the age of individual does not affect one's propensity to telecommute, whereas gender affects such propensity (Olson and Primps, 1984). As for the job category, although it is expected that job type differs between telecommuters and non-telecommuters, since the sample selected for this analysis was based on the premise of their suitability for telecommuting, therefore it is expected that it wouldn't affect individual's propensity to telecommute. Thus, similar to analysis done by Bélanger (1999) one may present these expectations in the hypothesis form listed below:

- ***H1***: There will be a significant difference between telecommuters and non-telecommuters with respect to gender.

- **H2:** There will be no significant difference between telecommuters and non-telecommuters with respect to job category.
- **H3:** There will be no significant difference between telecommuters and non-telecommuters with respect to age.

Each of these hypotheses is tested below.

6.9.1. Gender

As can be seen from Table 6.7 the proportion of females in the sample is 46% whereas this proportion in the telecommuters group is 54%. Under the null hypothesis that there is no difference in the two groups proportions of males and females, the test statistic given below follows approximately a χ^2 distribution:

$$\chi^2 = \sum_{\text{all cells}} \frac{(f_o - f_e)^2}{f_e} \quad (6.4)$$

where:

f_o is the *observed frequency* or actual tally in a particular cell of the contingency table;

and

f_e is the *expected frequency* or what one would expect to find in a particular cell if the null hypothesis is true.

To compute f_e the use is made of another statistic, given by the symbol $\bar{p}$:

$$\bar{p} = \frac{(X_1 + X_2)}{(n_1 + n_2)} = \frac{X}{n} \quad (6.5)$$

where:

X_1 and X_2 are the number of successes in samples 1 and 2, respectively;

n_1 and n_2 are the sample sizes for groups 1 and 2, respectively;

X is the total number of successes for the whole sample; and

n is the total sample size.

GENDER	GROUP		TOTAL
	Telecommuters	Non-Telecommuters	
Male	45	162	207
Female	52	125	177
Total	97	287	384

Table 6.7. Contingency Table for Testing the Effects of Gender on Telecommuting

$\bar{p}$ represents the overall or average proportion of males (or females) for the two groups combined. It is based on the premise that if the null hypothesis is true and proportions of males and females is equal for each population, then the sample proportions computed from the two groups should differ from each other only by chance, since they would each be providing an estimate of the common population parameter, p (Berenson and Levine, 1996). In such a situation, $\bar{p}$ is pooling the two separate estimates into one overall or average estimate of the population parameter, p , and thus would provide more information than any two separate estimates.

To obtain the expected frequency, f_e , for each cell pertaining to male respondents, the sample size (or column total) for telecommuters was multiplied by $\bar{p}$.

By the same token, the expected frequency for cells pertaining to female respondents (that is, the second row in Table 6.7), the sample size (or column total) for the non-

telecommuters group was multiplied by $1 - \bar{p}$.

The test-statistic given in Eq. 6.4 has degrees of freedom equal to the number of rows in the contingency table minus one times the number of columns in the table minus one:

$$\text{degrees of freedom [d.f.]} = (r-1)(c-1)$$

where r = number of rows in the table

c = number of columns in the table

For the 2x2 contingency Table 6.8, there is one degree of freedom: $\text{d.f.} = (2-1)(2-1) = 1$

GENDER	Telecommuters		Non-Telecommuters		TOTAL
	Observed	Expected	Observed	Expected	
Male	45	52.4	162	155	207
Female	52	44.6	125	132	177
Total	97	97	287	287	384

Table 6.8. Contingency Table for Comparing Observed and Expected Frequencies

Referring to Eq. 6.4 if the null hypothesis were true, the calculated χ^2 should be sufficiently close to zero since the squared difference between the observed frequency in each cell and the expected one would be very small. The closeness to zero is decided by comparing the calculated χ^2 to the critical χ^2 at the desired level of significance α , χ^2_{α} . That is, the decision rule is to reject H_0 if: $\chi^2 > \chi^2_{\alpha}$.

For the case at hand, the pooled proportion of males in the sample is:

$$\bar{p} = \frac{(45 + 162)}{(97 + 287)} = \frac{207}{384} = 0.54$$

Therefore, the proportion of females in the sample is $1 - 0.54 = 0.46$. Multiplying these two

proportions by the sample size used for the telecommuters' group gives the number of people expected to adopt telecommuting. In a similar manner, multiplying the two respective proportions by the sample size used for the non-telecommuters' group gives the number of people expected not to telecommute. Table 6.8 shows these expected frequencies.

To test the null hypothesis of equal proportion of males and females; that is, $H_0: p_1=p_2$, the data from Table 6.8 are used to calculate the χ^2 -test statistic given by Eq. 6.4. The calculations are presented in Table 6.9.

f_o	f_e	(f_o-f_e)	$(f_o-f_e)^2$	$(f_o-f_e)^2/f_e$
45	52.4	-7.4	54.8	1.05
162	155	7	49	0.32
52	44.6	7.4	54.8	1.23
125	132	7	49	0.37
				2.97

Table 6.9. Computation of the χ^2 -test Statistic For the Effects of Gender

As it can be seen from Table 6.9, the resulting chi-square statistic was 2.97. This value is less than the critical value of 3.84 at $\alpha=0.05$ significance level. Therefore, we cannot reject the null hypothesis and it can be concluded that gender did not have an impact on the adoption of telecommuting by workers. If a 10 percent significance level were chosen, the corresponding χ^2 would be 2.706, which would reverse the conclusion.

6.9.2. Job Category

As discussed in Chapter 1, some researchers believe that not all jobs are suitable for

telecommuting. To investigate whether job category had any impact on adoption of telecommuting, respondents were asked to identify their current job types. Since the sample of firms was originally selected based on the proposition that their line of work is suitable for telecommuting, it was expected that there should not be any difference between the telecommuters and non-telecommuters with respect to their job type. The job categories presented to respondents were adopted based on an earlier study by KPMG (1997). Table 6.10 shows these job categories for the sample and the breakdown of respondents per category. From the Table, it is seen that the largest group of workers among respondent was by far the professional/technical people. These generally included jobs such as engineers, analysts, computer programmers, etc.

Job Category	Non-		Total	Percent
	Telecommuters	Telecommuters		
Professional/Technical	68	167	235	61.2
Sales/Marketing	0	12	12	3.1
Finance/Accounting	5	18	23	6.0
Clerical/Administrative	9	46	55	14.3
Management/Executive	12	34	46	12.0
Other	3	10	13	3.4
Sum=	97	287	384	100

Table 6.10. Job Category of Respondents

To test whether job categories were different between telecommuters and non-telecommuters, the χ^2 -test statistic, explained in previous section was used again. The test explained in the previous section can be extended to the general case where there are m groups to be compared. In this case, the same χ^2 -test statistic in Eq. 6.4 is used to test the

null hypothesis of no difference in the proportions among the m populations:

$$H_0: p_1 = p_2 = \dots = p_m$$

against the alternative that not all the m population proportions are equal:

$$H_1: \text{Not all } p_i \text{ are equal (where } i=1, 2, \dots, m)$$

The difference between this case and the previous case is that the number of degrees of freedom in here is:

$$\text{d.f.} = (2-1)(m-1) = m-1$$

As with the previous case, if the null hypothesis were true, the calculated χ^2 should be sufficiently close to zero since the squared difference between the observed frequency in each cell and the expected one would be very small. The closeness to zero is decided by comparing the calculated χ^2 to the critical χ^2 at the desired level of significance α , χ^2_{α} . That is, the decision rule is to reject H_0 if: $\chi^2 > \chi^2_{\alpha, (m-1)}$.

Under the null hypothesis of no differences between telecommuters and non-telecommuters with respect to job categories, we can use Eq. 6.5 to calculate an estimate of the common parameter p , the population proportion of telecommuters. That is, $\bar{p}$, the overall or average proportion of telecommuters taken over all six job categories, is calculated as

$$\begin{aligned} \bar{p} &= \frac{(X_1 + X_2 + \dots + X_m)}{(n_1 + n_2 + \dots + n_m)} = \frac{X}{n} \\ &= \frac{(68 + 0 + 5 + 9 + 12 + 3)}{(235 + 12 + 23 + 55 + 46 + 13)} = \frac{97}{384} = 0.25 \end{aligned}$$

The estimated proportion of non-telecommuters in the population is the complement,

$1 - \bar{p}$, or 0.75. Multiplying these two proportions by the sample size used obtained for

each job category results in the expected frequencies of telecommuters and non-telecommuters. These are shown in Table 6.11.

JOB CATEGORY	Telecommuters		Non-Telecommuters		TOTAL
	Observed	Expected	Observed	Expected	
Professional/Technical	68	59.4	167	175.6	235
Sales/Marketing	0	3.0	12	9.0	12
Finance/Accounting	5	5.8	18	17.2	23
Clerical/Administrative	9	13.9	46	41.1	55
Management/Executive	12	11.6	34	34.4	46
Other	3	3.3	10	9.7	13
Total	97	97	287	287	384

Table 6.11. Contingency Table for Comparing Observed and Expected Frequencies

To test the null hypothesis of equality of proportions the data from Table 6.11 are used to calculate the χ^2 -test statistic given by Eq. 6.4. The calculations are presented in Table 6.12. If a 0.05 significance level is chosen, the critical value of the χ^2 -test statistic with $(2-1)(6-1)=5$ degrees of freedom is 11.071. Since the calculated χ^2 is less than the critical one, we cannot reject the null hypothesis meaning that there is no significant difference between telecommuters and non-telecommuters with respect to their job category.

6.9.3. Effect of Age

In order to investigate whether average age of individuals had any effect on the choice of telecommuting when it was available to employees, 'one-way ANOVA' test was performed.

f_o	f_e	$(f_o - f_e)$	$(f_o - f_e)^2$	$(f_o - f_e)^2 / f_e$
68	59.362	8.638	74.615	1.257
0	3.0313	-3.031	9.1885	3.0313
5	5.8099	-0.81	0.6559	0.1129
9	13.893	-4.893	23.944	1.7234
12	11.62	0.3802	0.1446	0.0124
3	3.2839	-0.284	0.0806	0.0245
167	175.64	-8.638	74.615	0.4248
12	8.9688	3.0313	9.1885	1.0245
18	17.19	0.8099	0.6559	0.0382
46	41.107	4.8932	23.944	0.5825
34	34.38	-0.38	0.1446	0.0042
10	9.7161	0.2839	0.0806	0.0083
				8.2439

Table 6.12. Computation of the χ^2 -test Statistic for the Effects of Job Category

In general, the ANOVA test objective is to analyse differences among the c group means through an analysis of variation in the data, both among and within the given number of groups (Berenson and Levine, 1996). In ANOVA the total variation in the outcome measurements (sum of squares total, or SST) is subdivided into two components. One that is attributed to the differences among the c groups (i.e., sum of squared among, or SSA) and one that is due to chance or attributable to inherent variation within the c groups (i.e., sum of squares within, or SSW). The results of the ANOVA procedure are usually displayed in a Table format as shown in Table 6.13.

Source	Degrees of freedom	Sum of Squares	Mean Square (Variance)	F
Among groups	$c-1$	$SSA = \sum_{j=1}^c n_j (\bar{X}_j - \bar{\bar{X}})^2$	$MSA = \frac{SSA}{c-1}$	$F = \frac{MSA}{MSW}$
Within groups	$n-c$	$SSW = \sum_{j=1}^c \sum_{i=1}^{n_j} (X_{ij} - \bar{X}_j)^2$	$MSW = \frac{SSW}{n-c}$	
Total	$n-1$	$SST = \sum_{j=1}^c \sum_{i=1}^{n_j} (X_{ij} - \bar{\bar{X}})^2$		

Table 6.13. Analysis of Variance Summary Table
(Berenson and Levine, 1996)

Where:

X_{ij} is the i th observation in group or level j

$\bar{X}_j$ is the sample mean of group j

$\bar{\bar{X}}$ is the grand or overall mean

n_j is the number of observations in group j

n is the total number of observations in all groups combined ($n = n_1 + n_2 + \dots + n_c$)

c is the number of groups or levels of the factor of interest.

If the null hypothesis of no real differences in the c group means is true, all three mean square terms—MSA, MSW, and MST—provide unbiased estimate of the variance σ^2 inherent in the data. Thus, to test the null hypothesis:

$$H_0: \mu_1 = \mu_2 = \dots = \mu_c$$

we compute the test statistic F , calculated as the ratio of MSA to MSW. This ratio follows an F-distribution with $c-1$ and $n-c$ degrees of freedom. The null hypothesis may be rejected at a given significance level α if the calculated F statistic above exceeds the upper-tailed critical value $F_{crit(c-1, n-c)}$ from the F-distribution. That is, the decision rule is:

Reject H_0 if $F_{calculated} > F_{crit(c-1, n-c)}$, Otherwise do not reject H_0

The average age for the whole sample in this research was 39.9 years. This figure for the telecommuters and non-telecommuters was 42.7 and 38.9, respectively^{ix}.

The objective was to test whether the average age between the two groups of telecommuters and non-telecommuters was equal. Table 6.14 shows the summary of ANOVA calculations.

Source	Degrees of freedom	Sum of Squares	Mean Square (Variance)	F
Among groups	2-1=1	1035	1035	10.33
Within groups	382-2=380	38065	100.2	
Total	382-1=381	39100		

Table 6.14. Analysis-of-Variance Table for the Effects of Age

Since the calculated F is greater than $F_{crit(1,380)}=3.84$ at 5% significance level, we may reject the null hypothesis and conclude that the average age of telecommuters is higher than that of non-telecommuters.

6.10. CONCLUDING REMARKS

The experimental design developed for the final survey is an orthogonal main effect design both within and between alternatives. It also enables us to estimate interactions of telecommuting and ITS measures with other variables. Moreover, since there are a large number of replications per scenario, the variance of observations is substantially reduced.

^{ix} Two of the respondents in the non-telecommuters group refused to provide their age. Therefore, the ANOVA test was done based on the sample size of 382.

The results of χ^2 analysis revealed that there is no significant difference between telecommuters and non-telecommuters with respect to gender and job category. However, the results of the ANOVA analysis showed that there is significant difference between the two groups with respect to age.

CHAPTER VII: DISCRETE CHOICE ANALYSIS OF THE FINAL SURVEY

7.1. INTRODUCTION

This chapter explains the logit analysis in the context of the research framework. Unknown parameters α , β , γ and the scale parameter μ were estimated by the sequential ML estimation method using the RP and SP data in sequence (for more detail please see Section 3.5). The advantage of using sequential method over the joint ML method is that ordinary logit (or probit) estimation software can be used to estimate the unknown parameters. Moreover, research shows that the parameter estimates from the joint and sequential ML are very close (Ortúzar and Willumsen, 1994). The Times Series Processor (TSP) was used to estimate the coefficients. The following sections explain in detail the estimation procedures.

7.2. ESTIMATION WITH RP DATA FOR THE WHOLE SAMPLE

The RP model in the final survey was tested with various variables thought to have an impact on residential location choice. After running various models the final model included the following variables:

- Monthly housing cost;
- Number of rooms;
- Travel time to work;

- Vehicle/licensed driver ratio (specific to Alt. B and C)
- School dummy =1 if there are school-age child(ren) in the household; 0 otherwise (specific to Alt. B and C);
- Mode of travel dummy (specific to Alt. A) =1 if the person takes non-motorized mode to go to work; 0 otherwise;
- Telecommuting dummy (specific to Alt. C) =1 if the person telecommutes; 0 otherwise
- Single earner dummy =1 for Alt. i if there is one breadwinner in the family and s/he works within that alternative; 0 otherwise;
- Dual earner dummy =1 if there are dual earner in the family and both work in the same city; 0 otherwise
- Two alternative-specific constants;

To estimate parameters of variables in logit Eq. 3.1 which are choice-specific, one has to know their values for rejected alternatives in addition to those of chosen alternative. The same procedure explained in Section 5.8 was employed to arrive at the required rejected values. The estimation result for the RP model is shown in Table 7.1. The source code and computer output are also shown in Appendix B.1. It should be noted here that for the purpose of model estimation, the observed data on housing cost, number of rooms, and travel time to work variables were centred around their mean value. While this data transformation has no effect on the final results (compared to the case where the original data are used to estimate the model) it minimizes the correlation between the intercept and other variables, and provides more stable variance estimates of the parameters.

Variable	Parameter Estimate	Standard Error	t-statistics
Housing cost	-0.0010	0.0004	-2.3211
Number of Rooms	0.2016	0.0635	3.1733
Travel time to work	-0.0090	0.0119	-0.7556
Vehicle/driver (specific to Alt. B and C)	0.8780	0.3877	2.2647
Mode of travel dummy (specific to Alt. A)	1.0716	0.2768	3.8708
Single-earner dummy	0.7224	0.2564	2.8177
Double-earner dummy	0.3558	0.2337	1.5225
School dummy (specific to Alt. B and C)	0.8034	0.2328	3.4517
Telecommuting dummy (specific to Alt. C)	0.5819	0.3062	1.9002
Alt. A specific constant	1.7582	0.4234	4.1523
Alt. B specific constant	0.5296	0.1910	2.7727
Summary Statistics:			
N=384 L(0)=-421.87 L(C)=-368.49 L(B)=-326.06 $\rho_c^2=0.115$ $\bar{\rho}_c^2=0.085$			
-2[L(0)-L(B)]=191.6 $\rho^2=0.227$ $\bar{\rho}^2=0.201$			
-2[L(C)-L(B)]=84.9			

Table 7.1. Estimation With RP Data For the Whole Sample

Although all the coefficients in the model have the correct sign, that of travel time is not statistically significant

7.2.1. Goodness-of-fit Measures

The values of likelihood ratios $-2[L(0)-L(\beta)]$ and $-2[L(C)-L(\beta)]$ are 191.6 and 84.9, respectively. These values are greater than the critical $\chi^2_{11,0.01}=26.75$ at 1% significance level. Therefore, we can reject the hypotheses that all parameters are jointly zero, and all parameters except the intercept are jointly zero, respectively.

As for the rho-squared index, as explained in Section 4.5.3, it measures the proportion of

the initial log likelihood value explained by the model. It is most useful in comparing two different specifications developed on the exact same data (Ben-Akiva & Lerman, 1985). For the RP model above, ρ_c^2 and $\bar{\rho}_c^2$ are 0.115 and 0.085 respectively. If one wishes to find out how high the independent variables convey explanatory power of the model, the ρ^2 value for this model (which is calculated to be 0.227 based on Eq. 4.10) can be compared to that for the 'market share' model, that is, one with only alternative-specific constant variables. In the market share model, the choice probability for each alternative will simply equal the aggregate share of the alternative in the sample. The market share model produces a ρ^2 value of 0.126 (or 12.6%). This suggests that other variables in the RP model explain only an additional 10.1% of information. However, when the RP model was re-estimated with constant terms constrained to be zero, it resulted in a ρ^2 of 0.203. This indicates that the other variables convey almost the full explanatory power of the model (Mokhtarian and Salomon, 1995). As such, the implication of this comparison is that constant terms play a role, although not as important as the independent variables, in conveying the choice information.

7.2.2. Validation

To see how well the RP model would predict the choices two validation approaches were taken: Macro validation, and Micro validation.

In the macro validation, the choices predicted by the model were calculated and compared with the actual residential location choices. That is, the utility of each alternative was calculated and the corresponding choice probability was obtained. It was assumed that the individuals selected the alternative with highest utility (i.e., highest

choice probability). Then, for the whole sample, the total number of choices for each of the alternatives was counted. As such, the macro validation provided an indication of the overall predictability of the model. The results of the macro validation are presented in Table 7.2.

Alternative	Number of observed choices	Number of predicted choices	Error	Overall Predictability
Alt. A	224	309	+85	78%
Alt. B	96	62	-34	
Alt. C	64	13	-51	
Total	384	384	0	

Table 7.2. Macro Validation for the RP Data

From Table 7.2 it can be seen that the model underestimates the choices for Alt. B and C while it overestimates that of Alternative A. One reason might be the much higher proportion of the sample choosing Alt. A than the other two alternatives. The model overestimates 85 choices for Alt. A while it underestimates those of alternatives B and C by 34 and 51, respectively. As a result, the overall predictability of the model is approximately 78%.

In micro validation, the choices calculated by the model are compared against the actual choice for each individual. This would give an indication of the predicting capability of the model at individual (i.e., micro) level. The results of micro validation are shown in Table 7.3 below.

From Table 7.3 it is observed that the model does not do a good job in estimating choices

for alternative C. However, although the percent correct values are not very high, the number of correctly predicted choices is proportional to the observed ones. The overall percent correct predictability is 59%, which is in fact the weighted average of all three choices.

Alternative	Number of Observed Choices	Number of Choices Predicted Correctly	Percent Correct
Alt. A	224	199	86%
Alt. B	96	21	24%
Alt. C	64	5	3%
Total	384	225	59%

Table 7.3. Micro Validation for the RP Data

It should be mentioned, however, that Ben-Akiva and Lerman (1985) argue against the use of “% right” statistic due to the insensitivity of the “% right” as well as its potential for completely misleading indications. For the model evaluation they prefer the use of the log likelihood value, $L(\beta)$, or transforms of it, such as ρ^2 and $\bar{\rho}^2$. These “% right” values are reported here since they are often reported in the modelling of transport demand.

7.2.3. Discussion of the Results

From Table 7.1 it can be seen that all variables have correct signs. Each of the coefficients is discussed below.

In general, housing cost is a key policy variable and by far the most important factor in

people's housing choice decisions. In the RP model the housing cost variable has negative sign as expected. Although it is significant at 95% level, its t-value is not as high as it was expected to be. The main reason is perhaps the relatively high correlation that exists between the housing cost and housing size, measured by the number of rooms. The correlation matrix is shown in Table 7.4. It can be seen that the two variables are correlated by as much as about 0.7 in Alternative B.

The number of rooms coefficient has positive sign as expected. That is, the higher the number of rooms, the higher the utility of the housing would be for any given alternative. Although the travel time variable has the correct sign it did not produce a statistically significant estimate. This is not an uncommon phenomenon in model estimation with RP data. Often it is in part due to limited variability observed in some of the variables, and as was shown in Table 7.4, strong correlation that might exist among some of the variables.

	Choice	HC1	HC2	HC3	RM1	RM2	RM3	TW1	TW2	TW2
Choice	1.00									
HC1	0.19	1.00								
HC2	0.13	0.54	1.00							
HC3	0.04	0.43	0.46	1.00						
RM1	0.15	0.64	0.52	0.46	1.00					
RM2	0.17	0.54	0.70	0.49	0.56	1.00				
RM3	0.20	0.45	0.48	0.64	0.48	0.56	1.00			
TW1	0.00	0.02	-0.01	0.02	0.00	-0.03	0.03	1.00		
TW2	0.05	0.07	0.05	0.11	0.07	0.06	0.09	0.18	1.00	
TW3	-0.05	0.12	0.09	0.11	0.12	0.10	0.12	0.02	0.14	1.00

Table 7.4. Correlation Matrix for the RP Data

In general, it is always desirable to have as low correlation among independent variables as possible. The literature shows that a correlation value greater than 0.8 indicates that a

particular effect has been accounted for twice in the model and therefore one of the two should be removed from the model (RMOC; 1998). In other words, it indicates that multicollinearity between independent variables exists. The correlation matrix in Table 7.4 shows that there is no double-counting problem here although the correlation is relatively high. As will be shown in later sections, when the RP data is combined with SP data, this problem is alleviated significantly.

The number of autos per licensed driver ratio is positive indicating that households with higher auto ownership rate have higher probability of living further away from central area of the region.

The effect of mode of travel is such that people who take non-motorized modes of travel (i.e., a value of 1) to work have preference for living in Alternative A. This is due to the fact that the distance between work and home is generally shorter in Alternative A than the other two alternatives.

The *Single-earner* dummy is positive, as one would expect. It takes a value of 1 for alternative i if there is only one working person in the household and the respondent's workplace is also located within that alternative, otherwise it is zero. In other words, there is a higher probability of living and working in the same alternative for single earner families.

The *dual-earner dummy* sign is also positive. This dummy variable takes a value of 1 if there are two working members in the family and that both work within the same alternative, otherwise it is zero. Thus, its positive sign is in line with expectation indicating that if both household heads work in the same region the probability of choosing that alternative as their residential location increases.

The school dummy variable (specific to Alternatives B and C) has a positive sign indicating that families with school-age child(ren) prefer housing locations further away from Alternative A. This reinforces the observed trend in North American cities that middle-age families prefer housing in suburban areas.

The telecommuting dummy variable also has a positive sign indicating that if a person telecommutes the utility of housing location in Alternative C increases relative to those of Alternative B and C. Thus, it is supporting some studies, which contend that adoption of telecommuting may cause people to live further away from the city centre.

Lastly, the constant terms for Alternatives B and C are both negative and significant. It indicates that for these two alternatives the mean of unobserved effects is negative. In other words, some effects exist that were not captured by the model that favour the choice for Alternative A.

7.3. ESTIMATION WITH SP DATA FOR THE WHOLE SAMPLE

The SP experiment was designed to collect information on residential location choice behaviour by presenting to respondents hypothetical choice scenarios described by a set of explanatory variables. There may be a bias in SP data toward the residential location actually chosen which reflects inertia effect, justification of past behaviour, or the effect of variables that are not included in the model (Ben-Akiva & Morikawa, 1990a). A variable that indicated the actual choice was included in the model to estimate such inertia effect. As a household lives in a particular location for long period of time, it is possible that it develops some form of attachment to that place. The inertia variable captured this effect by being defined as duration of stay in respondent's current residence

(in years) if any of the Alt. A, B, or C was actually chosen; 0 otherwise.

As discussed in Section 6.4 there were 26 parameters to be estimated for each alternative, totalling 78 parameters. In addition to these parameters inertia variables and their quadratic components were also included in the model to capture the bias effects. As such, the variables included in the SP model are as follows.

- Number of telecommuting days per week (denoted by **TC**);
- Level of travel time delay for work trips (denoted by **DL**);
- Monthly Housing cost (denoted by **HC**);
- Number of rooms (denoted by **RM**);
- One-way travel time to work (denoted by **TW**);
- One-way travel time to school for child(ren) (denoted by **TS**);
- Availability of outdoor recreational opportunities (denoted by **RC**) ;
- Inertia (specific to Alt. A) = duration of stay in current residence (in years) if Alt. A was actually chosen; 0 otherwise (denoted by **IA**);
- Inertia (specific to Alt. B) = duration of stay in current residence (in years) if Alt. B was actually chosen; 0 otherwise (denoted by **IB**);
- Inertia (specific to Alt. C) = duration of stay in current residence (in years) if Alt. C was actually chosen; 0 otherwise (denoted by **IC**);

Considering the inertia variables and their quadratics the base SP model estimated 84 parameters in total for the whole sample. The estimated coefficients are shown in Table 7.5. The source code and computer output are presented in Appendix B.2.

Parameter	Estimate	Std. Error	t-statistic	Parameter	Estimate	Std. Error	t-statistic	Parameter	Estimate	Std. Error	t-statistic
TCA	0.1260	0.0564	2.2346	TCHCA	-0.1744	0.0699	-2.4965	DLRCA	-0.0774	0.0710	-1.0908
TCB	0.2637	0.0750	3.5144	TCHCB	-0.0656	0.0853	-0.7688	DLRCB	0.1003	0.0856	1.1721
TCC	0.2946	0.0501	5.8843	TCHCC	-0.0032	0.0613	-0.0521	DLRCC	-0.0783	0.0606	-1.2913
DLA	-0.0901	0.0559	-1.6138	TCRMA	0.1602	0.0732	2.1881	TCQA	-0.0364	0.0322	-1.1298
DLB	-0.1050	0.0738	-1.4219	TCRMB	-0.0273	0.0904	-0.3019	TCQB	-0.0639	0.0367	-1.7424
DLC	-0.1022	0.0470	-2.1753	TCRMC	0.0650	0.0626	1.0383	TCQC	-0.0144	0.0271	-0.5332
HCA	-0.5741	0.0578	-9.9339	TCTWA	-0.1912	0.0703	-2.7208	DLQA	0.0114	0.0326	0.3494
HCB	-0.6280	0.0694	-9.0534	TCTWB	0.0759	0.0892	0.8505	DLQB	-0.0263	0.0374	-0.7048
HCC	-0.1873	0.0462	-4.0518	TCTWC	0.1915	0.0620	3.0881	DLQC	0.0100	0.0268	0.3733
RMA	0.2265	0.0577	3.9280	TCTSA	-0.0897	0.1133	-0.7914	HCQA	-0.0128	0.0318	-0.4037
RMB	0.3743	0.0709	5.2780	TCTSB	0.0272	0.1189	0.2283	HCQB	-0.0227	0.0385	-0.5888
RMC	0.0627	0.0469	1.3378	TCTSC	0.0589	0.0902	0.6533	HCQC	0.0335	0.0268	1.2501
TWA	-0.0537	0.0570	-0.9429	TCRCA	0.1223	0.0729	1.6779	RMQA	-0.0734	0.0315	-2.3318
TWB	-0.2508	0.0676	-3.7115	TCRCB	0.1398	0.0879	1.5900	RMQB	-0.0789	0.0368	-2.1430
TWC	-0.3443	0.0494	-6.9665	TCRCC	0.0523	0.0609	0.8596	RMQC	0.0004	0.0270	0.0134
TSA	-0.2971	0.0904	-3.2858	DLHCA	-0.0259	0.0714	-0.3634	TWQA	-0.0238	0.0315	-0.7555
TSB	-0.2374	0.0933	-2.5440	DLHCB	0.1147	0.0848	1.3529	TWQB	-0.0171	0.0371	-0.4603
TSC	-0.2172	0.0701	-3.0992	DLHCC	-0.0225	0.0628	-0.3585	TWQC	-0.0346	0.0267	-1.2924
RCA	0.3108	0.0560	5.5492	DLRMA	0.1691	0.0719	2.3512	TSQA	-0.2179	0.0355	-6.1374
RCB	0.3625	0.0692	5.2351	DLRMB	0.2357	0.0892	2.6420	TSQB	-0.0087	0.0378	-0.2312
RCC	0.3966	0.0480	8.2697	DLRMC	0.0838	0.0611	1.3726	TSQC	-0.0626	0.0288	-2.1729
IA	0.1241	0.0183	6.7927	DLTWA	-0.1318	0.0716	-1.8410	RCQA	-0.0730	0.0311	-2.3462
IB	0.0400	0.0243	1.6439	DLTWB	-0.0403	0.0864	-0.4666	RCQB	-0.1073	0.0368	-2.9147
IC	0.2386	0.0263	9.0731	DLTWC	0.1333	0.0584	2.2839	RCQC	-0.0517	0.0267	-1.9396
TCDLA	-0.0458	0.0702	-0.6524	DLTSA	-0.0791	0.1098	-0.7202	IAQ	-0.0044	0.0009	-4.9214
TCDLB	-0.2429	0.0844	-2.8776	DLTSB	0.0285	0.1194	0.2384	IBQ	-0.0010	0.0011	-0.8899
TCDLC	-0.0654	0.0609	-1.0749	DLTSC	0.0885	0.0868	1.0185	ICQ	-0.0097	0.0014	-7.0931
								C1	-0.7101	0.0834	-8.5173
								C2	-0.7989	0.0840	-9.5069
								C3	0.1924	0.0592	3.2517
Summary Statistics:											
N=3465			L(0)=-4803.5	L(C)=-4620.9			L(β)=-4146.90	$\rho_c^2=0.103$			$\bar{\rho}_c^2=0.084$
								$-2[L(0)-L(β)]=1313.2$			$-2[L(C)-L(β)]=948.0$

Table 7.5. Base SP Model for The Whole Sample (Full Model)

The following is a description of how to read the models' output variables:

For main effect variables:

These are three-letter words. The first two letters denote the variable. The last letter denotes whether it is for Alt. A, B, or C.

E.g., HCA: HC denotes the variable HC (housing cost). Letter A indicates that the estimated coefficient is for Alt. A.

For quadratic variables:

A letter Q is added to the main effect variable to denote that it is a quadratic component.

E.g., HCQA: Means housing cost quadratic component for Alt. A.

For interaction variables:

These are five-letter words. The first two letters denotes the first variable. The third and fourth letters indicate second variable and the last letter denotes whether it is estimated for Alt. A, B, or C.

E.g., TCRMB. It indicates interaction between variable TC (telecommuting) and variable RM (number of rooms) for Alt. B.

An important note is worth mentioning here. For the estimation purposes, the actual levels of attributes, shown in Table 6.1, were replaced by '*orthogonal polynomial design codes*' to estimate the model coefficients. The orthogonal polynomial codes for 3-level attributes are shown in Table 7.6. These codes can be thought of as a different set of dummy codes. Unlike regular (0,1) dummy variables, the vectors of orthogonal polynomial codes are exactly orthogonal to one another and to all estimable interactions if the original design matrix is orthogonal (Louviere, 1988b). Their use in this research is most appropriate since not only linear main effects are present but also are quadratic and

interaction terms.

Levels	Polynomial Codes	
	Linear	Quadratic
0	-1	+1
1	0	-2
2	+1	+1

Table 7.6. 3-level Attributes and their Equivalent Orthogonal Polynomial Codes

The base SP model presented in Table 7.5 served as the reference to modify the model by removing the insignificant parameters plus other modifications as required, in order to arrive at the final SP model specification. First the model output is discussed in terms of its goodness-of-fit measures and then the procedure for developing the final model is described.

7.3.1. Goodness-of-fit Measures

The values of likelihood ratios $-2[L(\mathbf{0})-L(\beta)]$ and $-2[L(C)-L(\beta)]$ are both highly significant rejecting the null hypotheses that all parameters are jointly zero, and all parameters except the intercept are jointly zero, respectively.

For this model, ρ_c^2 and $\bar{\rho}_c^2$ are 0.103 and 0.084 respectively. The low values are very typical of SP models and do not imply a weak model.

7.3.2. Discussion of the Results

In terms of the coefficients, all the main effect parameters have correct sign although two

of them are not highly statistically significant. The travel time variable in Alt. A (TWA) was based on the incremental change of 5 minutes of travel time whereas for the other two alternatives it was based on the incremental change of 10 minutes. The 5-minute change may have been perceived to be insignificant by respondents resulting insignificant coefficient in the model. As for the RMC variable (i.e., number of rooms specific to Alt. C), its magnitude is smaller than those of Alt. A and B indicating that it is not as crucial to respondent in Alt. C. One reason might be that for some respondents housing bundle is, in general, perceived to be larger in Alt. C than the other two alternatives, prompting them to assign less weight to it. Another reason could be that more rooms in Alternative C may not have necessarily meant better because the respondent didn't think s/he needed bigger housing.

Many of the quadratic components as well as interaction effects have come out to be insignificant, as expected.

A note is in order with regard to the magnitude of the quadratic and interaction parameters. The general rule is that if the utility function is to be monotonic with respect to any given variable, then the condition for the monotonicity is that^x:

For quadratic variables: $|b_2| \leq |b_1|/6$

where:

$|b_1|$ is the (absolute) coefficient of the linear effect; and

$|b_2|$ is the (absolute) coefficient of the quadratic effect

For interaction effect: The parameter estimate for the interaction effect to be less than (in absolute terms) either of the two main effects.

^x Based on personal communication with Dr. Anderson, President, StatDesign, Colorado, U.S.A.

In general, whether in the context of residential location choice or mode choice, variables such as cost and time have been shown to be monotonic. That is, as the travel time and cost increase, the utility decreases. In this case, it is reasonable to assume that variables HC, TW, TS, DL, and RC to be monotonic. For the variables TC and RM, however, this may not be the case. In terms of TC variable, one expects that the utility will increase as the person starts to telecommute *up to a certain point* due to positive factors such as flexibility and convenience. However, as the number of telecommuting days increases beyond that point, say for example to five days a week, the utility might in fact decrease due to some negative factors such as sense of isolation and lack of interaction. In terms of the housing size, represented in the model by the number of rooms, as it increases from 0 up to a certain point the utility increases, but beyond that level, any increase in the number of rooms may in fact decrease the utility function simply because the house would be '*too large*' for that household to maintain.

Having said this, therefore, for the TC and RM variables the conditions mentioned above regarding the magnitudes of quadratic and interaction effects need not hold.

To better appreciate how the interaction effects work, it is best to plot their marginal effects on the utility function. Since the number of interactions in the base SP model are too many to be displayed here, the following sample calculation is presented to demonstrate how the marginal interaction effects were plotted. In section 7.3.3.3 all the significant interactions in the final reduced SP model are discussed and their respective marginal plots are presented as well.

Let us say that we want to plot the marginal effect of TCDLA (i.e., the interaction between telecommuting variable and the delay variable for Alt. A) on the utility function

of Alternative A. The marginal utility for Alt. A is written as follows:

$$U_A = b_0 + b_1*TC_A + b_2*DL_A + b_{12}*TC*DL_A + b_{11}*TCQA + b_{22}*DLQA$$

$$= -0.71 + 0.126*TC_A - 0.09*DL_A - 0.046*(TC_A*DL_A) - 0.036*TCQA + 0.011*DLQA$$

The marginal plot for DL is obtained by substituting each level of TC in the above equation. Since there are three levels of TC, there would be three (linear) equations as a result. For each level of the TC attribute the equivalent orthogonal codes, as shown in Table 7.6, is used:

TC level 0: $U_A = -0.71 + 0.126(-1) - 0.09DL_A - 0.046(-1)(DL_A) - 0.036(1) + 0.011DLQA$

$$= -0.87 - 0.044DL_A + 0.011DLQA$$

TC level 1: $U_A = -0.71 + 0.126(0) - 0.09DL_A - 0.046(0)(DL_A) - 0.036(-2) + 0.011DLQA$

$$= -0.64 - 0.09DL_A + 0.011DLQA$$

TC level 2: $U_A = -0.71 + 0.126(1) - 0.09DL_A - 0.046(1)(DL_A) - 0.036(1) + 0.011DLQA$

$$= -0.62 - 0.136DL_A + 0.011DLQA$$

Then, by substituting the three levels of DL_A variable in each of the above equations, three data points are obtained for each equation, which are then connected to each other by straight lines, thereby producing Figure 7.1. That is, we have the following data matrix:

	TC level 0	TC level 1	TC level 2
DL level 0:	-0.817	-0.536	-0.473
DL level 1:	-0.895	-0.660	-0.643
DL level 2:	-0.905	-0.716	-0.745

The same approach is taken to plot marginal utility of the TC variable that is shown in

Figure 7.2. The 3x3 data point matrix for the marginal plot of telecommuting will be the transpose of the above one.

7.3.3. *Final Reduced SP Model*

Considering the above discussion, the following modifications were made to the base SP model of Table 7.5 to arrive at the final SP model for the whole sample:

- DLQs, HCQs, TCTs, IBQ and DLHCs were all removed because they were not statistically significant at 95% level;
- Forced $TCB=TCC$, $TWB=TwC$, $TCTWB=TCTWC$, $TSA=TSB=TSC$, and $RMQA=RMQB$ because they are similar in the base SP model;
- Forced DL variable to be generic (to balance it with others and to make it more interpretable);
- Forced the RC variable to be generic. Also forced its quadratics to be generic.
- In the base SP model DLTWA and DLTWC were too large as well as being erratic. If one ran a generic model, the resulting DLTW coefficient would not be significant. So, to make the model a feasible one, the DLTWs variables were removed altogether.
- Forced $RMQA=RMQB$ (the new variable called RMQAB) because they were similar.
- Also, forced TCDLs, TCHCs, and TCRMs interactions to be generic. This was done to balance out the effects of some of the alt-specific interactions that were too large in some instances in the base SP model.
- Since the TS variable was forced to be generic, its quadratic component was also set to be generic to make the variable interpretable.

Figure 7.1. TCA-DLA Interaction: Marginal Plot of Delay

Figure 7.2. TCA-DLA Interaction: Marginal Plot of Telecommuting

- The interaction variable TCTWA (as compared to the TCTWB and TCTWC interactions) was erratic. We were not able to explain it. Therefore, it was decided to drop this variable to keep the model as a feasible one.

As a result, the base SP model was run again with the above modifications to develop the final SP model as presented in Table 7.7. Appendix B.3 shows the source code and computer output.

To test whether the above restrictions were statistically justified, the likelihood ratio test, as explained in Section 4.5.1 was performed. In this case the test statistic is calculated as:

$$-2[L(\beta_R)-L(\beta_{UR})]=-2[(-4185.57)-(-4146.90)]= 77.34$$

It is χ^2 distributed with $(84-32)=52$ degrees of freedom under the null hypothesis of no difference between the two models. Since $77.34 < \chi^2_{52,0.01} \approx 82$ at 1% significance level, the null hypothesis holds and therefore the linear restriction imposed on the model were correct. In other words, the final model conveyed essentially the same information as the base model.

Variable	Parameter Estimate	Standard Error	t-statistics
Telecommuting level (TC)			
Alt. A:	0.1514	0.0532	2.8439
Alt. B and C:	0.2778	0.0377	7.3613
Delay (DL)	-0.1111	0.0305	-3.6469
Housing cost (HC)			
Alt. A:	-0.5634	0.0549	-10.2692
Alt. B:	-0.6266	0.0647	-9.6782
Alt. C:	-0.2034	0.0459	-4.4289
Number of Rooms (RM)			
Alt. A:	0.2213	0.0546	4.0536
Alt. B:	0.3415	0.0654	5.2212
Alt. C:	0.0648	0.0457	1.4183
Travel time to work (TW)			
Alt. A:	-0.0484	0.0526	-0.9202
Alt. B and C:	-0.3026	0.0379	-7.9879
Travel time to school (TS)	-0.2480	0.0468	-5.3018
Recreational opportunity (RC)	0.3653	0.0314	11.6468
Inertia effect (IE)			
Alt. A:	0.1203	0.0179	6.7349
Alt. B:	0.0214	0.0106	2.0215
Alt. C:	0.2388	0.0260	9.1968
TC*DL	-0.0843	0.0385	-2.1886
TC*HC	-0.0550	0.0377	-1.4602
TC*RM	0.0748	0.0381	1.9632
TC*TW (specific to Alt. B and C)	0.1525	0.0473	3.2208
TC*RC	0.0803	0.0389	2.0613
DL*RM			
Alt. A:	0.1990	0.0671	2.9644
Alt. B:	0.2204	0.0802	2.7490
Alt. C:	0.0613	0.0566	1.0838
Number of Rooms Quad (RMQ)			
Alt. A and B:	-0.0678	0.0231	-2.9334
Travel time to school Quad (TSQ)	-0.0920	0.0221	-4.1633
Recreational opportunity Quad (RCQ)	-0.0727	0.0174	-4.1875
Inertia effect Quad (IEQ)			
Alt. A:	-0.0040	0.0009	-4.6293
Alt. C:	-0.0097	0.0014	-7.1126
Alt. A specific constant	-0.5531	0.0717	-7.7184
Alt. B specific constant	-0.8505	0.0707	-12.0246
Alt. C specific constant	0.1646	0.0545	3.0191
Summary Statistics:			
N=3465 L(0)=-4803.5 L(C)=-4620.9 L(B)=-4185.57 $\rho_c^2=0.094$ $\bar{\rho}_c^2=0.087$			
-2[L(0)-L(B)]=1235.9 $\rho^2=0.129$ $\bar{\rho}^2=0.122$			
-2[L(C)-L(B)]=870.7			

Table 7.7. Final SP Model for the Whole Sample Without Restriction

Before discussing the model of Table 7.7 there was one final modification to be made to the model. If one looks at the coefficient of the TSQ in the model and compare it to the linear effect TS, it can be seen that the TSQ coefficient did not meet the $|b_2| \leq |b_1|/6$ criterion outlined earlier. Since it was expected that the utility function would be monotonic with respect to the TS variable the final model was re-run imposing the restriction that $TSQ \leq TS/6$. With this restriction the logit model was run again. The model output is presented in Appendix B.3. The final SP model with the imposed restriction is shown in Table 7.8. The coefficients between the two models do not differ much from each other except, of course, for the coefficients of the TS and TSQ variables. The model output is discussed below.

7.3.3.1. Goodness-of-fit Measures

The values of likelihood ratios $-2[L(0)-L(\beta)]$ and $-2[L(C)-L(\beta)]$ are 1230.9 and 865.8, respectively. These are much higher than the critical $\chi^2_{32,0.01} \approx 56$ at 1% significance level. Therefore, we can reject the null hypotheses that all parameters are jointly zero, and all parameters except the intercept are jointly zero, respectively.

For this model, ρ_c^2 and $\bar{\rho}_c^2$ are 0.094 and 0.087 respectively. The low values are very typical of SP models and do not imply a weak model.

Variable	Parameter Estimate	Standard Error	t-statistics
Telecommuting level (TC)			
Alt. A:	0.1491	0.0532	2.8017
Alt. B and C:	0.2777	0.0377	7.3599
Delay (DL)	-0.1124	0.0305	-3.6911
Housing cost (HC)			
Alt. A:	-0.5659	0.0549	-10.3162
Alt. B:	-0.6264	0.0647	-9.6756
Alt. C:	-0.2049	0.0459	-4.4624
Number of Rooms (RM)			
Alt. A:	0.2240	0.0546	4.1046
Alt. B:	0.3440	0.0654	5.2573
Alt. C:	0.0632	0.0456	1.3837
Travel time to work (TW)			
Alt. A:	-0.0539	0.0526	-1.0262
Alt. B and C:	-0.3029	0.0379	-7.9958
Travel time to school (TS)	-0.2760	0.0446	-6.1936
Recreational opportunity (RC)	0.3640	0.0314	11.6099
Inertia effect (IE)			
Alt. A:	0.1199	0.0178	6.7180
Alt. B:	0.0213	0.0106	2.0119
Alt. C:	0.2362	0.0259	9.1103
TC*DL	-0.0831	0.0385	-2.1584
TC*HC	-0.0531	0.0377	-1.4091
TC*RM	0.0761	0.0381	1.9979
TC*TW (specific to Alt. B and C)	0.1540	0.0474	3.2503
TC*RC	0.0836	0.0389	2.1477
DL*RM			
Alt. A:	0.1980	0.0671	2.9491
Alt. B:	0.2236	0.0802	2.7867
Alt. C:	0.0595	0.0565	1.0520
Number of Rooms Quad (RMQ)			
Alt. A and B:	-0.0684	0.0231	-2.9609
Travel time to school Quad (TSQ)	-0.0460	0.0074	-6.1936
Recreational opportunity Quad (RCQ)	-0.0708	0.0173	-4.0914
Inertia effect Quad (IEQ)			
Alt. A:	-0.0040	0.0009	-4.5988
Alt. C:	-0.0095	0.0014	-7.0306
Alt. A specific constant	-0.5018	0.0677	-7.4069
Alt. B specific constant	-0.8006	0.0670	-11.9445
Alt. C specific constant	0.2169	0.0491	4.4151
Summary Statistics:			
N=3465 L(0)=-4803.5 L(C)=-4620.9 L(B)=-4188.02 $\rho_c^2=0.094$ $\bar{\rho}_c^2 = 0.087$			
-2[L(0)-L(B)]=1230.9 $\rho^2=0.128$ $\bar{\rho}^2 = 0.121$			
-2[L(C)-L(B)]=865.8			

Table 7.8. Final SP Model for the Whole Sample With Restriction on TSQ

7.3.3.2. Validation

Although in the SP experiments respondents express their ‘stated intentions’ and not their ‘actual decision’ it would be useful to test the model’s predictability both at macro and micro level similar to what was done for the RP model. This is due to the fact that the SP experiment in this survey was presented in the context of stated ‘choice’. As such, the validation procedure in here implies that respondents’ stated choice is the same as their actual choice.

The results of the macro validation are presented in Table 7.9.

Alternative	Number of observed choices	Number of predicted choices	Error	Overall Predictability
None	839	308	-531	77%
Alt. A	801	794	-7	
Alt. B	517	272	-245	
Alt. C	1308	2091	+783	
Total	3465	3465	0	

Table 7.9. Macro Validation for the Final Reduced SP Model

From Table 7.9 it can be seen that the model overestimates the choices for Alt. C while it underestimates those of other alternatives.

The results of micro validation are shown in Table 7.10 below.

From Table 7.10 it is observed that the model does not do a good job in estimating choices for the ‘None’ alternative and Alt. B, while it is relatively good for the other two.

Alternative	Number of Observed Choices	Number of Choices Predicted Correctly	Percent Correct
None	839	114	14%
Alt. A	801	343	43%
Alt. B	517	110	21%
Alt. C	1308	1007	77%
Total	3465	1574	45%

Table 7.10. Micro Validation for the Final Reduced SP Model

However, although the percent correct values are not very high, the number of correctly predicted choices is proportional to the observed ones. The overall percent correct predictability is 45%.

As mentioned earlier, it should be stressed here that the ‘percent right’ statistic reported in these tables should not be relied upon and used rigorously, as they are not considered to be robust measures of goodness-of-fit by researchers (Ben-Akiva and Lerman, 1985).

7.3.3.3. Discussion of the Results

In terms of the coefficients, all the main effect parameters have the correct sign although two of them namely travel time to work specific to Alt. A and number of rooms specific to Alt. C are not highly statistically significant, as was the case in the base SP model of Table 7.5. However, these two variables were retained in the model because as discussed in Section 4.5.5, the estimated coefficient for each variable is the best approximation for its true value (lack of significance may just be due to lack of enough data or lack of

enough variability of the attribute in the sample).

The telecommuting variable is significant and has positive sign implying that the utility of any given alternative increases with increase in the level of telecommuting. Moreover, its magnitude is almost twice as high for alternatives B and C than in Alternative A. In other words, being able to telecommute is viewed more and highly positively in distant suburbia than in central city leading to higher probabilities of residential choice in those areas.

The estimated coefficient of the travel time variability factor is negative as expected. It indicates that everything else being equal, people would choose residential location along transportation systems that provide them with more reliable travel times to work. This suggests that if ITS is applied to any part of the region which would reduce the variability of people's daily commute trips, the probability of choosing housing in that area would increase.

The inertia variables are all statistically significant. The inertia dummies captured the preference bias towards the housing location actually chosen, therefore producing positive coefficients as expected. This indicates that their inclusion in the model was appropriate. The inertia dummies are affecting the choice in the following manner: For Alt. A, every additional year of living in that alternative creates an alternative-specific constant of $-0.55 + 0.12 * 1 - 0.004 * (1)^2 = -0.434$ in magnitude. This compares to -0.83 and $+0.39$ for Alt. B and C, respectively. As the households live longer in their current residence the difference among the alternatives becomes more prominent. For example, for ten years duration of living, the alternative-specific constants become 0.25 , -0.65 , and 1.58 for Alt. A, B, and C, respectively. The difference between the highest and lowest

number was 1.01(i.e., 0.39-(-0.83)) for the case of one year residence while this difference is 2.22 (i.e., 0.25-(-1.58)) for the case of ten years residence; a difference of almost twice as high. Another point worth mentioning is that the inertia dummy for Alt. B is both less significant and smaller in magnitude than those of Alternatives A and C implying that Alt. B might act like a *transition* location. Whether or not this implication is true cannot be verified within this modelling framework.

The telecommuting variable showed significant interactions with all other variables except the travel time to school variable. This showed that the experimental design that accounted for the existence of interaction was appropriate. The delay variable, however, showed interaction effects with the number of rooms variable only.

To better appreciate the interactions effects, Figures 7.3 through 7.16 depict the relationships that exist between telecommuting variable and others. These were drawn based on the discussion presented in Section 7.3.2.

The interactions effect between telecommuting and level of delay is shown in Figures 7.3 and 7.4. Figure 7.3 shows the marginal plot of delay for various levels of telecommuting and Figure 7.4 shows the marginal plot of telecommuting for various levels of delay. As the delay increases the utility decreases for any telecommuting level. Also, from Figure 7.4 for any given level of delay, the utility increases with increase in telecommuting level. If there were no interaction between the two variables, the three lines would be parallel to each other. However, as the graph shows the availability of telecommuting reduces the spacing between the lines as delay increases.

The same relationship exists in Figure 7.4 that depicts the marginal plot of telecommuting.

The next interaction effect is that of telecommuting and housing cost. Figure 7.5 shows the marginal plot of housing cost variable, while Figure 7.6 shows the marginal plot of telecommuting. It can be seen that as the housing cost increases the utility decreases, as expected. Also, for any given housing cost, the utility increases with increase in telecommuting level. Moreover, the three lines are not parallel to each other. That is, as Figure 7.5 shows, the availability of telecommuting reduces the spacing between the lines as the housing cost increases. The same relationship exists in Figure 7.6 that depicts the marginal plot of telecommuting.

Figure 7.3. TC-DL Interaction: Marginal Plot of Delay

Figure 7.4. TC-DL Interaction: Marginal Plot of Telecommuting

Figure 7.5. TC-HC Interaction: Marginal Plot of Housing Cost

Figure 7.6. TC-HC Interaction: Marginal Plot of Telecommuting

The interaction effects between telecommuting and number of rooms is shown in Figures 7.7 and 7.8 for Alt. A. In Figure 7.7 the utility increases with an increase in number of rooms. The rate of increase (i.e., slope) is much more when the change is from one less room to no change than from no change to one extra room. This indicates much more sensitivity in losing one room than gaining an extra room in the house. One anomaly, however, exists in this figure for telecommuting level 0, where the utility decreases with increase in number of rooms (although the slope of the line is very flat). This problem, however, does not exist for the other two alternatives, as Figures 7.9 and 7.10 show. Also, since the connecting lines in these figures are not parallel to each other, they indicate the existence of interaction between these two variables.

Another point that should be mentioned is that in Figure 7.10, the lines for Alternative C are more 'flat' than those of Alt. A and B (i.e., Figures 7.7 and 7.9, respectively). The reason might be attributed to the fact that the levels of number of rooms variable for Alt. C were (no change, +1 room, +2 rooms). Therefore, one expects the slope of the lines in Alt. C to be more or less the same as those of second part of the lines for Alt. A and B, which is the case here since it was shown that respondents were more sensitive to losing a room than gaining an extra one.

Figure 7.7. TC-RM Interaction: Marginal Plot of Number of Rooms

Figure 7.8. TC-RM Interaction: Marginal Plot of Telecommuting

Figure 7.9. TC-RM Interaction: Marginal Plot of Number of Rooms

Figure 7.10. TC-RM Interaction: Marginal Plot of Number of Rooms

As for the telecommuting-travel time to work interaction, Figures 7.11 and 7.12 show this relationship. First, recalling that travel time levels were: no change, +10 minutes, +20 minutes, the utility decreases with increase in travel time, as expected.

Secondly, the lines are almost straight indicating that respondents were as sensitive to 10 minutes extra travel times as they were to 20 minutes extra travel time. Lastly, as can be seen from Figure 7.11, the lines diverge significantly as the travel time increases, which show a clear interaction between the two variables. The same relationship exists in Figure 7.12. That is, lines converge as the level of telecommuting increases. This in turn, suggests that if a respondent, for example telecommutes two days a week, the utility values become closer to each other for various levels of travel times, indicating the benefit of telecommuting as a time saving measure.

Another interaction effect is that of telecommuting and recreational opportunities variable. The marginal plots of RC and TC are shown in Figures 7.13 and 7.14, respectively. As can be seen from these figures, any increase in the levels of telecommuting and RC quality increases the alternative's utility, as expected. Moreover, from Figure 7.13, it is observed that respondents were more sensitive in deteriorating the RC quality from 'good' to 'poor' than from 'excellent' to 'good', as judged by the slopes of the lines. This effect is also seen in Figure 7.14 by a higher distance between the bottom and middle line than between the middle and upper line. Also, although the lines in either figure are relatively parallel to each other the interaction exists. The reason for parallel lines in these figures is due to presence of quadratic RC component in the interaction equation, which has acted in such a way to produce the current line shapes.

Figure 7.11. TC-TW Interaction: Marginal Plot of Travel Time to Work

Figure 7.12. TC-TW Interaction: Marginal Plot of Telecommuting

Figure 7.13. TC-RC Interaction: Marginal Plot of Recreational Opportunities

Figure 7.14. TC-RC Interaction: Marginal Plot of Telecommuting

The last set of interactions is between the level of delay variable and number of rooms variable. The marginal plot of delay and marginal plot of number of rooms are shown in Figures 7.15 and 7.16, respectively.

As the figures show, an increase in number of rooms increases the utility and any increase in the level of delay decreases that utility. Also, in Figure 7.16, when there is no delay present the utility of Alternative C is almost the same for any given number of rooms. However, as the level of delay increases to its highest level (i.e., 10 minutes twice a week), while the utility decreases (as expected), its magnitude is much less for housing bundles with no change in number of rooms than for those with 2 extra rooms. In other words, respondents trade off longer delays for more spacious housing.

In terms of quadratic coefficients, only a few quadratic components proved to be statistically significant in the final SP model. These were number of rooms, time to school for children, and the outdoor recreational opportunity variables.

7.3.3.4. Estimating Consistent Standard Errors Using Jackknife Procedure

In SP experiments multiple responses are received from the same respondent. As such, these observations are not independent from each other. As a result, the calculated standard errors are inconsistent. In such cases, a procedure known as the *jackknife* procedure (Miller, 1974) can be used to produce consistent estimates of the standard errors.

Figure 7.15. DL-RM Interaction: Marginal Plot of Number of Rooms

Figure 7.16. DL-RM Interaction: Marginal Plot of Delay

The procedure is based on estimating a number of sub-sets of the whole sample and then estimating the variance of these sub-sets.

The following steps are taken in jackknife procedure ^{xi}:

“Let ϕ represent the sample of N observations. Partition ϕ as $\phi = \{\phi_1, \phi_2, \dots, \phi_G\}$ where G is the number of groups, each of size m, such that $G \cdot m = N$. Choose about 10-20 groups.

Let $\hat{\beta}$ represent the estimator vector obtained using all the data. Let $\hat{\beta}_{-i}$ represent the estimator vector obtained by omitting ϕ_i , for $i=1, 2, \dots, G$.

Calculate the following pseudo-values:

$$\beta_i^* = G\hat{\beta} - (G-1)\hat{\beta}_{-i} \text{ for } i=1, 2, \dots, G \quad (7.1)$$

These β_i^* can be treated like G observations of $\hat{\beta}$ (though not independent).

Calculate the sample average of the pseudo-values as below:

$$\bar{\beta}^* = \frac{1}{G} \sum_{i=1}^G \beta_i^* \quad (7.2)$$

Estimate the variance of $\hat{\beta}$ as:

$$\text{Var}(\hat{\beta}) = \frac{1}{(G-1)G} \sum_{i=1}^G (\beta_i^* - \bar{\beta}^*)(\beta_i^* - \bar{\beta}^*)' \quad (7.3)$$

Therefore, for each coefficient β_k in the original model, the corrected t-statistic, based on

the jackknife estimates of the variance, is calculated as $\frac{\hat{\beta}_k}{\sqrt{\text{Var}(\hat{\beta})_{kk}}}$ ”.

The jackknife procedure explained above was implemented within the TSP software using matrix commands.

^{xi} This is based on the course notes obtained from Prof. M. Ben-Akiva in MIT, which explained the procedure in the form of above steps.

The SP data were partitioned into 15 groups of size 231 each. The source code is presented in Appendix B.4. The results are presented in Table 7.11.

In general, the corrected t-statistic values should be (slightly) smaller than the original ones. The original t-statistics are biased upward because they don't recognize the correlations among observations from the same individual. From Table 7.11 it can be seen that the corrected t-statistic of all the parameters are close to those obtained in Table 7.7. For some attributes the t-statistic is higher and for others it is lower than the original t-statistic.

Also, it should be mentioned that the resulting $\bar{\beta}^*$ were close to the original $\hat{\beta}$. By dropping out observations the estimator just loses efficiency, but it is consistent in either case.

7.4. COMBINED RP AND SP DATA ESTIMATION

To combine the two data sources, the orthogonally coded SP data were first converted into actual magnitudes so that both RP and SP data were on the same scale.

The SP data were also centred around their mean value to minimize the correlation between the linear main effects and the intercepts. Following the sequential estimation procedure explained in Chapter III, the following steps were taken to estimate the unknown parameters:

1. The final SP model of Section 7.3 was re-estimated with re-coded data. The results are shown in Table 7.12. The estimated coefficients are in fact $\hat{\mu}\beta$ and $\hat{\mu}\gamma$.

Variable	Parameter Estimate	Corrected Standard Error	Corrected t-statistic	Original t-statistic
Telecommuting level (TC)				
Alt. A:	0.1514	0.0486	3.119	2.844
Alt. B and C:	0.2778	0.0335	8.296	7.361
Delay (DL)	-0.1111	0.0264	-4.207	-3.647
Housing cost (HC)				
Alt. A:	-0.5634	0.0484	-11.641	-10.269
Alt. B:	-0.6266	0.0499	-12.559	-9.678
Alt. C:	-0.2034	0.0445	-4.573	-4.429
Number of Rooms (RM)				
Alt. A:	0.2213	0.0377	5.871	4.054
Alt. B:	0.3415	0.0586	5.828	5.221
Alt. C:	0.0648	0.0494	1.312	1.418
Travel time to work (TW)				
Alt. A:	-0.0484	0.0268	-1.804	-0.920
Alt. B and C:	-0.3026	0.0301	-10.068	-7.988
Travel time to school (TS)	-0.2480	0.0566	-4.382	-5.302
Recreational opportunity (RC)	0.3653	0.0230	15.894	11.647
Inertia effect (IE)				
Alt. A:	0.1203	0.0453	2.657	6.735
Alt. B:	0.0214	0.0262	0.819	2.022
Alt. C:	0.2388	0.0520	4.591	9.197
TC*DL	-0.0843	0.0637	-1.324	-2.189
TC*HC	-0.0550	0.0267	-2.059	-1.460
TC*RM	0.0748	0.0405	1.848	1.963
TC*TW (specific to Alt. B and C)	0.1525	0.0686	2.224	3.221
TC*RC	0.0803	0.0277	2.900	2.061
DL*RM				
Alt. A:	0.1990	0.0888	2.241	2.964
Alt. B:	0.2204	0.1026	2.149	2.749
Alt. C:	0.0613	0.0304	2.018	1.084
Number of Rooms Quad (RMQ)				
Alt. A and B:	-0.0678	0.0162	-4.174	-2.933
Travel time to school Quad (TSQ)	-0.0920	0.0292	-3.148	-4.163
Recreational opportunity Quad (RCQ)	-0.0727	0.0140	-5.207	-4.187
Inertia effect Quad (IEQ)				
Alt. A:	-0.0040	0.0024	-1.681	-4.629
Alt. C:	-0.0097	0.0037	-2.639	-7.113
Alt. A specific constant	-0.5531	0.1654	-3.343	-7.718
Alt. B specific constant	-0.8505	0.1249	-6.810	-12.025
Alt. C specific constant	0.1646	0.0818	2.013	3.019

Table 7.11. Corrected t-Statistic of Final SP Model Based on Jackknife Procedure

2. $\mathbf{W}^{RP}$ was defined as $\mu\beta'x$. The estimated value $\hat{W}^{RP}$ was formed in the following way:

$$\hat{W}^{RP} = \hat{\mu}\hat{\beta}'x = (\hat{\mu}\hat{\beta}_{cost})(\text{housing cost}) + (\hat{\mu}\hat{\beta}_{size})(\text{number of rooms}) + (\hat{\mu}\hat{\beta}_{time})(\text{travel time})$$

The RP model of Table 7.1 was re-estimated with the estimated value $\hat{W}^{RP}$ included as a variable in the model. The results are shown in Table 7.13. The coefficient of the $\hat{W}^{RP}$ variable, $\hat{\lambda}$, was estimated to be 0.339.

Therefore, the scaling parameter μ is calculated to be $\hat{\mu} = 1/\hat{\lambda} = 2.948$. Since $\hat{\mu}$ is greater than 1, it indicates that there was more random error or noise in the RP data than the SP data.

To improve the accuracy of $\hat{\alpha}$, $\hat{\beta}$, and $\hat{\gamma}$ the following additional step was taken:

3. The SP data were multiplied by $\hat{\mu}$ to obtain a modified SP data set. The RP and modified SP data were pooled and the two models were estimated jointly.

Table 7.14 shows the final estimation results with combined RP and SP data. The computer output is presented in Appendix B.5. The model output is discussed below.

Variable	Parameter Estimate	Standard Error	t-statistics
Telecommuting level (TC)			
Alt. A:	0.1528	0.0533	2.8692
Alt. B and C:	0.2823	0.0377	7.4863
Delay (DL)	-0.0112	0.0030	-3.6918
Housing cost (HC)			
Alt. A:	-0.0039	0.0004	-10.7278
Alt. B:	-0.0043	0.0004	-9.8118
Alt. C:	-0.0014	0.0003	-4.4498
Number of Rooms (RM)			
Alt. A:	0.2164	0.0537	4.0316
Alt. B:	0.3177	0.0638	4.9792
Alt. C:	0.0616	0.0457	1.3466
Travel time to work (TW)			
Alt. A:	-0.0115	0.0105	-1.0921
Alt. B and C:	-0.0303	0.0038	-8.0084
Travel time to school (TS)	-0.0295	0.0031	-9.4106
Recreational opportunity (RC)	0.3718	0.0314	11.8264
Inertia effect (IE)			
Alt. A:	0.1215	0.0179	6.7790
Alt. B:	0.0232	0.0105	2.2011
Alt. C:	0.2493	0.0260	9.5802
TC*DL	-0.0084	0.0039	-2.1588
TC*HC	-0.0003	0.0003	-1.2425
TC*RM	0.0796	0.0377	2.1112
TC*TW (specific to Alt. B and C)	0.0154	0.0048	3.2379
TC*RC	0.0842	0.0390	2.1582
DL*RM			
Alt. A:	0.0187	0.0066	2.8426
Alt. B:	0.0208	0.0079	2.6304
Alt. C:	0.0044	0.0057	0.7700
Recreational opportunity Quad (RCQ)	-0.0717	0.0173	-4.1367
Inertia effect Quad (IEQ)			
Alt. A:	-0.0041	0.0009	-4.7526
Alt. C:	-0.0102	0.0014	-7.4853
Alt. A specific constant	-0.4386	0.0672	-6.5311
Alt. B specific constant	-0.7380	0.0662	-11.1527
Alt. C specific constant	0.2758	0.0487	5.6660
Summary Statistics:			
N=3465 L(0)=-4803.5 L(C)=-4620.9 L(B)=-4167.01 $\rho_c^2=0.098$ $\bar{\rho}_c^2 = 0.092$			
-2[L(0)-L(B)]=1273.0 $\rho^2=0.133$ $\bar{\rho}^2 = 0.126$			
-2[L(C)-L(B)]=907.8			

Table 7.12. Final Reduced SP Model With Re-Coded Data for the Whole Sample

Variable	Parameter Estimate	Standard Error	t-statistics
W^{RP} (i.e., the composite variable)	0.3392	0.1309	2.5911
Vehicle/driver (specific to Alt. B and C)	0.8999	0.3858	2.3328
Mode of travel dummy (specific to Alt. A)	1.0326	0.2745	3.7624
Single-earner dummy	0.6915	0.2538	2.7245
Double-earner dummy	0.4222	0.2314	1.8248
School-age children dummy	0.7499	0.2305	3.2539
Telecommuting dummy (specific to Alt. C)	0.5728	0.3040	1.8840
Alt. B specific constant	1.7248	0.4224	4.0837
Alt. C specific constant	0.5139	0.1902	2.7020
Summary Statistics:			
N=384 L(0)=-421.87 L(C)=-368.49 L(B)=-329.12 $\rho_c^2=0.107$ $\bar{\rho}_c^2 = 0.082$			
-2[L(0)-L(B)]=185.5 $\rho^2=0.220$ $\bar{\rho}^2 = 0.199$			
-2[L(C)-L(B)]=78.7			

Table 7.13. RP Model For the Whole Sample With W^{RP} Included as a Variable

Variable	Parameter Estimate	Standard Error	t-statistics
Telecommuting level (TC)			
Alt. A:	0.0518	0.0181	2.8684
Alt. B and C:	0.0960	0.0128	7.5038
Delay (DL)	-0.0037	0.0010	-3.6301
Housing cost (HC)			
Alt. A and B:	-0.0014	0.0001	-14.5641
Alt. C:	-0.0005	0.0001	-4.5369
Number of Rooms (RM)			
Alt. A:	0.0694	0.0176	3.9518
Alt. B:	0.1243	0.0209	5.9422
Alt. C:	0.0274	0.0153	1.7923
Travel time to work (TW)			
Alt. A:	-0.0039	0.0035	-1.1207
Alt. B and C:	-0.0103	0.0013	-8.0401
Travel time to school (TS)	-0.0100	0.0011	-9.4144
Recreational opportunity (RC)	0.1262	0.0107	11.8376
Inertia effect (IE)			
Alt. A:	0.0413	0.0061	6.7964
Alt. B:	0.0079	0.0036	2.2058
Alt. C:	0.0845	0.0088	9.5768
TC*DL	-0.0028	0.0013	-2.1542
TC*HC	-0.0001	0.0001	-1.3191
TC*RM	0.0254	0.0127	1.9932
TC*TW (specific to Alt. B and C)	0.0051	0.0016	3.2065
TC*RC	0.0287	0.0132	2.1671
DL*RM			
Alt. A and B:	0.0067	0.0018	3.6788
Recreational opportunity Quad (RCQ)	-0.0245	0.0059	-4.1769
Inertia effect Quad (IEQ)			
Alt. A:	-0.0014	0.0003	-4.7584
Alt. C:	-0.0035	0.0005	-7.4807
Vehicle/driver (specific to Alt. B and C)	0.9161	0.3836	2.3881
Mode of travel dummy (specific to Alt. A)	1.0337	0.2731	3.7857
Single-earner dummy	0.4618	0.2320	1.9906
Double-earner dummy	0.7010	0.2543	2.7564
School-age children dummy	0.7410	0.2308	3.2102
Telecommuting dummy (specific to Alt. C)	0.5794	0.3039	1.9066
Alt. A constant (SP)	-0.1500	0.0226	-6.6345
Alt. B constant (SP)	-0.2489	0.0218	-11.4146
Alt. C constant (SP)	0.0938	0.0165	5.6812
Alt. A constant (RP)	1.2617	0.2665	4.7344
Alt. B constant (RP)	-0.3288	0.1067	3.0807
Summary Statistics:			
N=3849 L(0)=-5335.84 L(C)=-5175.78 L(B)=-4502.05 $\rho_c^2=0.130$ $\bar{\rho}_c^2=0.123$			
-2[L(0)-L(B)]=1669.4 $\rho^2=0.156$ $\bar{\rho}^2=0.150$			
-2[L(C)-L(B)]=1349.6			

Table 7.14. Estimation Results with Combined RP and SP Data for the Whole Sample

7.4.1. Goodness-of-fit Measures

The values of likelihood ratios $-2[L(0)-L(\beta)]$ and $-2[L(C)-L(\beta)]$ are 1669.4 and 1349.6 respectively, both highly significant, rejecting the null hypotheses that all parameters are jointly zero, and all parameters except the intercept are jointly zero, respectively.

For this combined model, ρ_c^2 and $\bar{\rho}_c^2$ are 0.13 and 0.12 respectively, which is higher than the values obtained for the SP and RP models separately. Since we can use ρ_c^2 and $\bar{\rho}_c^2$ to compare the models calibrated with different samples, it is evident that the combined model is a stronger model than either the SP or RP model alone.

7.4.2. Validation

To test the joint model's predictability both the macro and micro validation was performed. As was mentioned in Section 7.3.2, in the SP experiments respondents express their 'stated intentions' and not their 'actual decision'. However, since the SP experiment was presented in the context of stated '*choice*', the validation procedure in here implies that respondents' stated choice is the same as their actual choice.

The results of the macro validation for the joint model are presented in Table 7.15.

From Table 7.15 it can be seen that the model overestimates 1005 choices for Alt. C while it underestimates those of alternatives A and B by 671 and 362, respectively. As a result, the overall predictability of the model is approximately 73%. Considering the complexity of the model and the nature of housing location choice, such number is acceptable.

Alternative	Number of observed choices	Number of predicted choices	Error	Overall Predictability
None	839	867	+28	73%
Alt. A	1025	354	-671	
Alt. B	613	251	-362	
Alt. C	1372	2377	+1005	
Total	3849	3849	0	

Table 7.15. Macro Validation for the Final Joint Model

The results of micro validation are shown in Table 7.16 below.

Alternative	Number of Observed Choices	Number of Choices Predicted Correctly	Percent Correct
None	839	296	35%
Alt. A	1025	242	23%
Alt. B	613	101	17%
Alt. C	1372	1061	77%
Total	3849	1700	45%

Table 7.16. Micro Validation for the Final Joint Model

From Table 7.16 it is observed that the model is doing rather poorly in estimating choices for the alternatives A and B by estimating only 23% and 17% correct, respectively, while it is higher for the other two. However, although the percent correct values are not very high, the number of correctly predicted choices is proportional to the observed ones. The

overall percent correct predictability is 45%.

7.4.3. Discussion of the Results

The telecommuting variable is again significant and has positive sign implying that utility of any given alternative increases with increase in the level of telecommuting. Moreover, as was the case with the SP-only model, its magnitude for alternatives B and C is almost twice as large as in Alternative A.

Because the SP observations were re-scaled for the joint estimation the coefficients of the SP data, variables in Table 7.12 have also been rescaled as compared to the SP model of Table 7.7 (or Table 7.8).

It can be seen that the coefficients of the three variables common between the RP and SP model, namely housing cost, housing size, and travel time to work, now have the correct signs and are highly significant as a result of pooling the two data types. The only exception is the travel time to work variable for Alternative A. Although it has the correct sign it is only significant at about 75% level. However, the possible cause for this is the small variation in the levels of this attribute in both the SP experiment and the RP observations.

The travel time delay variable is negative as expected and statistically significant as well. It indicates that everything else being equal, people would choose a residential location along transportation systems that provide them with more reliable travel times to work.

The inertia dummies defined for the three alternatives captured the preference bias towards the housing location actually chosen. In the combined model, for example, the SP Alternative A-constant estimated for the SP data is -0.112 [$= -0.15 + 0.0413 \cdot (1) -$

0.0014*(1)²] for every additional year that a household lives in Alt. A. The SP alternative-specific constants for Alternatives B and C are -0.247 and 0.183, respectively.

To test if the model based on the SP data is the same as the model produced by RP data, the likelihood ratio test was performed. The χ^2 -test statistic for this particular hypothesis testing is:

$$-2[L(\beta_R)-L(\beta_{UR})]$$

where:

$L(\beta_R)$ = the log likelihood value of the restricted model at convergence; and

$L(\beta_{UR})$ = the log likelihood value of the unrestricted model at convergence.

This statistic is χ^2 distributed with (K_U-K_R) degrees of freedom, where K_U and K_R are the number of coefficients estimated for the unrestricted and restricted models, respectively.

The χ^2 test was performed by comparing two estimation runs, one for the unrestricted and another for the restricted model. In this particular case, the likelihood value of unrestricted model was obtained by the sum of likelihood values of separate SP and RP models. The combined RP and SP model provided the likelihood value of restricted model. Thus:

$$-2[L(\beta_R)-L(\beta_{UR})] = -2[-4502.05 - (-326.1 - 4167.0)] = 17.9$$

is χ^2 distributed with $((11+30)-35)=6$ degrees of freedom under the null hypothesis. Since $\chi^2_{6,0.01} = 18.6$, we cannot reject the null hypothesis of combined RP and SP model at 1% significance level, although the computed χ^2 is close to the critical value. This indicates that choice information conveyed from the SP data as used in the combined model is

essentially the same as those from the RP data. In other words, the pooling of RP and SP data was made possible because of incorporation of parameters, which accounted for the scale difference and inertia effects (Ben-Akiva & Morikawa, 1990a).

7.5. COMPARING THE BEHAVIOUR OF TELECOMMUTERS VS. NON-TELECOMMUTERS

One of the objectives of this research was to also compare residential location choice behaviour of telecommuters (TCers) against that of non-telecommuters (NTCers). This is important since any difference between the two groups would have different implications for the housing market in the region.

To compare the two groups, the standard practice is to develop two sets of models one for the TCers group and one for the NTCers group and then test whether the two model are statistically different or not. To do this, however, one has to have a large enough sample for both groups. For the SP model in this research this condition was not met. That is, as was discussed in Chapter VI the minimum sample size requirement was to have at least 270 observations per market segment. We obtained 288 observations for the NTCers group but only 97 observations for the TCers group for the SP analysis. Therefore with 97 observations for the TCers group one would not expect to be able to estimate and test all those interaction effects and quadratic components described in Section 6.4. One way was to estimate just a 'main effect only' model with the 97 observations. This estimation was done and the results are shown in Table 7.17. As it can be seen from this table all the coefficients have correct sign. However, compared to the SP model for the whole sample, the coefficient estimates have much higher standard errors. This model may be of interest

just to visually check if any of the parameter estimates are very different from their counterparts in the NTCers group. However, a procedure was developed to use the available data in each group separately and at the same time being able to compare their behaviour with respect to the attributes of the SP model. This procedure is explained next.

7.5.1. The SP Model of NTCers vs. TCers

An alternative way to statistically test for any differences between the parameter estimates of the two groups is to do the following procedure:

1. Develop a reduced final SP model for the NTCers group. The estimation result for this group is shown in Table 7.18.
2. Using the exact set of variables in the final reduced model for the NTCers group, estimate the SP model for the TCers group.
3. Stack the 288 observations on the NTCers group and the 97 observations for the TCers group starting with observations on the NTCers group.
4. Add a new 'column group' attribute whose value is +1 if the response is from the NTCers group and -1 if that is from the TCers group.
5. Multiply the (+1,-1) column by each of the coded attributes from the final reduced model for the NTCers group to obtain the interactions mentioned. This will 'test for differences' on the main effects between the two groups.
6. Keep only the significant (or close to significant) effects in the model.

Variable	Parameter Estimate	Standard Error	t-statistics
Telecommuting level (TC)			
Alt. A:	0.384601	0.108535	3.54355
Alt. B:	0.427264	0.136849	3.12217
Alt. C:	0.362692	0.093917	3.86182
Delay (DL)			
Alt. A:	-0.095131	0.107285	-0.886707
Alt. B:	-0.189619	0.134872	-1.40592
Alt. C:	-0.170369	0.092788	-1.83612
Housing cost (HC)			
Alt. A:	-0.697372	0.11101	-6.28204
Alt. B:	-0.612481	0.140933	-4.3459
Alt. C:	-0.193897	0.091839	-2.11127
Number of Rooms (RM)			
Alt. A:	0.263684	0.106387	2.47855
Alt. B:	0.313943	0.13434	2.33693
Alt. C:	0.071814	0.092094	0.779793
Travel time to work (TW)			
Alt. A:	-0.010304	0.10807	-0.09535
Alt. B:	-0.192561	0.135764	-1.41835
Alt. C:	-0.293589	0.092517	-3.17334
Travel time to school (TS)			
Alt. A:	-0.588259	0.157263	-3.74062
Alt. B:	-0.28469	0.187313	-1.51987
Alt. C:	-0.172228	0.132479	-1.30004
Recreational opportunity (RC)			
Alt. A:	0.320409	0.107511	2.98024
Alt. B:	0.467449	0.136912	3.41424
Alt. C:	0.314132	0.09253	3.39493
Inertia effect (IE)			
Alt. A:	0.170429	0.03594	4.74198
Alt. C:	0.244278	0.059231	4.12418
Inertia effect Quad (IEQ)			
Alt. A:	-5.85E-03	1.92E-03	-3.05423
Alt. C:	-0.013902	3.87E-03	-3.59476
Alt. A specific constant	-0.781984	0.144058	-5.42827
Alt. B specific constant	-1.04139	0.136251	-7.64314
Alt. C specific constant	0.105653	0.09689	1.09045
Summary Statistics:			
N=873 L(0)=-1210.23 L(C)=-1154.39 L(B)=-1033.80 $\rho_c^2=0.104$ $\bar{\rho}_c^2 = 0.080$			
-2[L(0)-L(B)]=352.86 $\rho^2=0.146$ $\bar{\rho}^2 = 0.123$			
-2[L(C)-L(B)]=241.2			

Table 7.17. The SP Main-Effect Model for the Telecommuting Group

Variable	Parameter Estimate	Standard Error	t-statistics
Telecommuting level (TC)			
Alt. A:	0.0861	0.0618	1.3932
Alt. B and C:	0.2428	0.0432	5.6208
Delay (DL)	-0.0807	0.0344	-2.3475
Housing cost (HC)			
Alt. A:	-0.5425	0.0633	-8.5705
Alt. B:	-0.6362	0.0729	-8.7250
Alt. C:	-0.2019	0.0531	-3.8027
Number of Rooms (RM)			
Alt. A:	0.2074	0.0629	3.2970
Alt. B:	0.3244	0.0738	4.3976
Alt. C:	0.0653	0.0527	1.2394
Travel time to work (TW)			
Alt. A:	-0.0647	0.0612	-1.0573
Alt. B and C:	-0.3201	0.0434	-7.3687
Travel time to school (TS)			
Alt. A:	-0.1369	0.1048	-1.3056
Alt. B and C:	-0.2549	0.0650	-3.9237
Recreational opportunity (RC)	0.3774	0.0362	10.4318
Inertia effect (IE)			
Alt. A:	0.1023	0.0211	4.8586
Alt. B:	0.0228	0.0118	1.9265
Alt. C:	0.2704	0.0315	8.5829
TC*DL	-0.0946	0.0441	-2.1474
TC*HC	-0.0648	0.0430	-1.5060
TC*RM	0.1017	0.0437	2.3241
TC*TW (specific to Alt. B and C)	0.1497	0.0537	2.7884
TC*RC	0.0615	0.0450	1.3651
Number of Rooms Quad (RMQ)			
Alt. A and B:	-0.0631	0.0264	-2.3928
Travel time to school Quad (TSQ)			
Alt. A:	-0.2192	0.0411	-5.3382
Alt. B and C:	-0.0538	0.0288	-1.8715
Recreational opportunity Quad (RCQ)	-0.0694	0.0201	-3.4612
Inertia effect Quad (IEQ)			
Alt. A:	-0.0035	0.0010	-3.6347
Alt. C:	-0.0102	0.0015	-6.7476
Alt. A specific constant	-0.5936	0.0936	-6.3433
Alt. B specific constant	-0.6806	0.0816	-8.3396
Alt. C specific constant	0.2598	0.0650	3.9969
Summary Statistics			
N=2592 L(0)=-3593.3 L(C)=-3461.2 L(B)=-3134.56 $\rho_c^2=0.094$ $\bar{\rho}_c^2=0.086$			
-2[L(0)-L(B)]=917.5 $\rho^2=0.130$ $\bar{\rho}^2=0.120$			
-2[L(C)-L(B)]=653.3			

Table 7.18. Reduced SP Model of Non-Telecommuters

Following the above procedure, the final result is shown in Table 7.19. It should be mentioned here that in this model the coefficient of the quadratic component of the travel time to school variable was restricted to be less than 1/6 of its linear component. The source code and computer output is also presented in Appendix B.6.

7.5.1.1. Goodness-of-fit Measures

The values of likelihood ratios $-2[L(0)-L(\beta)]$ and $-2[L(C)-L(\beta)]$ are 1254.2 and 888.9 respectively, both highly significant, rejecting the null hypotheses that all parameters are jointly zero, and all parameters except the intercept are jointly zero, respectively.

For this model, ρ_c^2 and $\bar{\rho}_c^2$ are 0.096 and 0.088 respectively, which is approximately the same as those obtained for the whole sample.

7.5.1.2. Discussion of the Results

In this model only the significant ‘difference in effect’ parameters were retained. As expected, the telecommuting variable is significantly different between the two groups. That is, the telecommuting factor in Alt. A has a weight of $0.218+(-0.135)=0.083$ for NTCers whereas for the TCers the magnitude is $0.218-(-0.135)=0.353$ which is almost four times smaller. Also, for Alternatives B and C, the coefficient magnitudes are $0.319+(-0.079)=0.240$ and $0.319-(-0.079)=0.389$ for NTCers and TCers, respectively. This clearly shows that for the TCers group, telecommuting measure is far more important than their counterparts.

Variable	Parameter Estimate	Standard Error	t-statistics
Telecomm level: Average of two groups			
Alt. A:	0.2183	0.0620	3.5208
Alt. B and C:	0.3192	0.0446	7.1512
Telecomm level: Difference of two groups			
Alt. A:	-0.1351	0.0617	-2.1911
Alt. B and C:	-0.0786	0.0442	-1.7763
Delay (DL)	-0.0974	0.0300	-3.2493
Housing cost (HC)			
Alt. A:	-0.5729	0.0550	-10.4135
Alt. B:	-0.6265	0.0647	-9.6827
Alt. C:	-0.2037	0.0459	-4.4348
Number of Rooms (RM)			
Alt. A:	0.2203	0.0545	4.0393
Alt. B:	0.3287	0.0653	5.0347
Alt. C:	0.0677	0.0456	1.4866
Travel time to work (TW)			
Alt. A:	-0.0602	0.0530	-1.1356
Alt. B and C:	-0.3097	0.0379	-8.1636
Travel time to school (TS)			
Alt. A (average of the two groups):	-0.5302	0.0925	-5.7352
Alt. A (difference of the two groups):	0.3188	0.0951	3.3523
Alt. B and C:	-0.2403	0.0551	-4.3585
Recreational opportunity (RC)	0.3641	0.0314	11.6009
Inertia effect (IE)			
Alt. A:	0.1208	0.0181	6.6882
Alt. B:	0.0225	0.0105	2.1309
Alt. C:	0.2372	0.0262	9.0537
TC*DL	-0.0815	0.0383	-2.1274
TC*HC	-0.0523	0.0378	-1.3842
TC*RM	0.0791	0.0381	2.0770
TC*TW (specific to Alt. B and C)	0.1469	0.0471	3.1206
TC*RC	0.0876	0.0389	2.2508
Number of Rooms Quad (RMQ)			
Alt. A and B:	-0.0616	0.0230	-2.6766
Travel time to school Quad (TSQ)			
Alt. A:	-0.0884	0.0154	-5.7352
Alt. B and C:	-0.0179	0.0240	-0.7472
Recreational opportunity Quad (RCQ)	-0.0726	0.0173	-4.1864
Inertia effect Quad (IEQ)			
Alt. A:	-0.0041	0.0009	-4.7015
Alt. C:	-0.0095	0.0014	-6.9959
Dummy column group (Alt. A)	0.1332	0.0592	2.2509
Dummy column group (Alt. B)	0.2497	0.0688	3.6277
Dummy column group (Alt. C)	0.1571	0.0522	3.0123
Alt. A specific constant	-0.6127	0.0791	-7.7484
Alt. B specific constant	-0.8833	0.0803	-11.0034
Alt. C specific constant	0.1712	0.0612	2.7952
Summary Statistics:			
N=3465 L(0)=-4803.5 L(C)=-4620.9 L(B)=-4176.42 $\rho_c^2=0.096$ $\bar{\rho}_c^2=0.088$			
-2[L(0)-L(B)]=1254.2 $\rho^2=0.131$ $\bar{\rho}^2=0.123$			
-2[L(C)-L(B)]=888.9			

Table 7.19. The SP Model of Non-Telecommuters Vs. Telecommuters

For any given group, the telecommuting variable in Alt. B and C carries more weight than in Alt. A, indicating that telecommuting from distant suburbia is viewed more positively than from the central city due to more significant savings in travel time and cost in those areas. In addition, the coefficient of the telecommuting variable shows significant difference between TCers and NTCers, as the former placed much more weight on it than the latter for any given alternative. This suggests that telecommuters who have first-hand experience with telecommuting and its various aspects, value the importance of telecommuting more than NTCers who may just have a perception about the benefits of telecommuting. On the other hand, the magnitude of telecommuting variable for the TCers group shows small difference between Alt. A and the other two alternatives, whereas this difference is larger for the NTCers group. This suggests that telecommuters value the importance of telecommuting more or less the same in all three alternatives, whereas NTCers perceived it more significantly in distant suburbia than in central city.

All other variables in the model have the expected signs and important policy variables (i.e., housing cost, housing size, and travel times) with t-value above 1 were kept in the model. Another variable, which showed significant difference between the two groups, was travel time to school for households who lived in Alt. A. This value was estimated to be $-0.53+0.32 = -0.21$ for NTCers and $-0.53-0.32 = -0.85$ for TCers. This indicates that telecommuters were more sensitive to school accessibility for their children than non-telecommuters. This might be due to the fact that an individual on his/her telecommuting day has to make a trip and provide a ride for his/her child(ren) that, in turn, may offset the trip s/he was going to save as a result of telecommuting.

7.6. AGGREGATE FORECASTING

The disaggregate demand models developed in previous sections deal with predicting *individual* behaviour. However, in making planning and investment decisions the individual behaviour is of little use. In Section 4.6 it was mentioned that the most widely used procedure for making aggregate forecast with disaggregate models is the 'sample enumeration' method. The predicted market share for alternative i , $\hat{S}_i$, is obtained from Eq. 4.15 as an estimator for true share of i (Ben-Akiva & Lerman, 1985):

$$\hat{S}_i = \frac{1}{N} \sum_{i=1}^N P(i) = \frac{1}{N} \sum_{i=1}^N \frac{e^{v_i}}{\sum_j e^{v_j}}$$

where:

N = number of individuals in the sample

$P(i)$ = probability that individual n chooses alternative i

It should be noted that, as suggested in the literature, to obtain proper forecasts from disaggregate models with SP data, the model needs to be applied without the *inertia* and *scale* parameters. To quote Bradley and Kroes (1990):

“...This is because these parameters are essentially artifacts of the data collection and analysis method, and do not reflect the structural relationship between system attributes and actual behaviour”.

Table 7.20 shows the predicted probabilities for the survey population under the current conditions plus various scenarios defined in term of changes with respect to a number of parameters including telecommuting levels, delay, housing cost, number of rooms, travel times, and recreational opportunities. Each of these scenarios is discussed below.

	P(A)	P(B)	P(C)	TOTAL
Current Conditions	58%	20%	22%	100%
1 (extra) day of telecommuting	55%	21%	24%	100%
2 (extra) days of telecommuting	49%	23%	28%	100%
Delay level of 10 min. once a week	62%	22%	16%	100%
Delay level of 10 min. twice a week	61%	24%	11%	100%
10% Increase in housing cost in Alt. A	55%	20%	25%	100%
10% Increase in housing cost in Alt. B	59%	18%	23%	100%
10% Increase in housing cost in Alt. C	59%	20%	21%	100%
10% Increase in housing cost for all	57%	19%	24%	100%
1 extra room in Alt. A	59%	19%	22%	100%
1 extra room in Alt. B	56%	21%	23%	100%
1 extra room in Alt. C	57%	19%	24%	100%
1 extra room for all	58%	20%	22%	100%
10% Increase in travel time to work in Alt. A	58%	20%	22%	100%
10% Increase in travel time to work in Alt. B	59%	19%	22%	100%
10% Increase in travel time to work in Alt. C	59%	20%	21%	100%
10% Increase in travel time to work for all	58%	20%	22%	100%
20 min. Increase in travel time to school in Alt. A	53%	21%	26%	100%
20 min. Increase in travel time to school in Alt. B	59%	17%	24%	100%
20 min. Increase in travel time to school in Alt. C	60%	20%	20%	100%
One level upgrade in RC from 0 to 1 in Alt. A	62%	17%	21%	100%
One level upgrade in RC from 0 to 1 in Alt. B	56%	22%	22%	100%
One level upgrade in RC from 0 to 1 in Alt. C	55%	18%	27%	100%
two levels upgrade in RC from 1 to 2 in Alt. A	62%	17%	21%	100%
two levels upgrade in RC from 1 to 2 in Alt. B	55%	23%	22%	100%
two levels upgrade in RC from 1 to 2 in Alt. C	54%	18%	28%	100%
2 days of telecommuting PLUS 10% increase in housing cost	47%	21%	32%	100%

Table 7.20. Predicted Probabilities With respect to Change in Various Factors

Overall, for each possible future scenario, the resulting market shares are logical. That is, with increase in housing cost or travel times, for example, in any alternative, the probability of choosing that alternative is reduced.

Under the current situation, the model predicts a 58%, 20%, and 22% market share for Alternatives A, B, and C, respectively. This is somewhat different from the observed frequencies, which were 58%, 25%, and 17% for those alternatives. It can be seen that the model predicts exactly 58% for Alt. A whereas it under predicts and over predicts for Alt. B and C, respectively.

Telecommuting— If the whole sample telecommutes an average of 1 day per week, the probability of choosing Alt. A decreases from 58% to 55% while those of Alternatives B and C increase from 19% to 21%, and from 23% to 24%, respectively. Furthermore, if the level of telecommuting increases to 2 days per week on average, there is a further significant decline in share of Alt. A by 16% as it drops from 58% in the current scenario to 49%. Alt. C, however, absorbs most of the decline, as its market share increases from current 23% to 28%, an increase of nearly 22%. The market share for alternative B also increases from 20% to 23%, a change of 15%. This clearly shows that the adoption of telecommuting may lead to further sub-urbanization most notably toward rural areas.

Delay— In terms of the delay variable, it can be seen that an increase in the level of delay causes people to move away from Alt. C and choose Alt. A and B. for example, when the delay is increased to 10 minutes twice a week, the share of Alt. C drops from current 23% to 11%. This decline is distributed relatively evenly between Alt. A and B. This implies that people are much more sensitive to travel time variability in distant suburbia than in central city, in part due to longer travel times experienced by residents in those areas. As

such, people would choose residential location along transportation systems that provide them with more reliable travel times to work.

Housing Cost— If the monthly housing cost is increased by 10% in Alternative A, B, or C, the probability of choosing that alternative decreases by 5.0%, 10.5%, and 4.5%, respectively. Although the market share for a given alternative decreases as the housing cost for that alternative increases, the amount of change is more prominent for Alt. B, indicating that the demand for housing in Alt. B is more elastic than the other two.

Number of rooms— To see the effects of housing size represented by the number of rooms, future scenarios were developed by examining the effect of one extra room in each alternative one at a time, and for all as well. It is seen that adding one extra room in Alternative A, B, or C, increases the probability of choosing that alternative from current 58%, 19%, 23%, to 59%, 21%, and 24%, respectively, which translates into an increase of 1.7%, 10.5%, and 4.4%, respectively. Again, it is seen that providing cheaper housing in Alt. B (i.e., providing more space for the same price) causes a more elastic response than the other two alternatives, particularly Alt. A. One justification is that Alt. B might be seen as a good balance between urban living style offered in Alt. A and the rural living style offered in Alt. C. As such, any policy aimed at reducing the housing cost in Alt. B can cause significant housing relocations toward that alternative. When one extra room is added to all alternatives, the market shares for Alt. A remains the same, but that of alt. B increase to 20% whereas the share of alt. C is reduced to 22%.

Travel time to work -- If commute time is increased by 10% in Alternative A, B, or C, the probability of choosing that alternative or any other alternative changes as much as $\pm 1\%$ at the most. This indicates that the demand with respect to commute time is

inelastic. Also, when the commute time is increased in all the alternatives, the resulting market share remains unchanged.

Travel time to school— When travel time to school is increased by 20 minutes in each of the alternatives A, B, and C, the probability of selecting those alternatives decrease by 8.5%, 10.5%, and 13%, respectively. It is seen that the effect of such change is more felt in Alt. C than the other two alternatives indicating that residents in more distant communities are more sensitive to school accessibility for their children.

Outdoor recreational facilities— If outdoors recreational opportunities exist and upgraded one level (e.g., from poor to good) in each of the alternatives, one at a time, their corresponding choice probabilities increase. If such facilities are improved one further level, only the probability of choosing Alt. B and C increases another percentage point to 23% and 28%, respectively. This shows that availability and quality of outdoor amenities are more important in rural areas than others. By comparing the market shares of each alternative between the cases of one level upgrade and two levels upgrade, it is observed that most of the changes happen when there is one level upgrade implying a steeper slope of RC variable from level 0 to 1 than from level 1 to 2, something that was observed in Figures 7.13 and 7.14.

One last scenario examined the effects of not one but two factors at the same time on the housing choice probabilities. These factors were telecommuting and housing cost. From Table 7.20 it can be seen that if people telecommute two days a week and at the same time housing costs increase by 10% over the whole region, probability of selecting Alternatives A, B, and C are 47%, 21%, and 32%, respectively. This is a change of -19%, +10.5%, and +39% for each alternative, respectively, compared to the current

conditions. The first observation is that the effect of the two factors together is more than the effects of the two factors considered separately, proving that these two factors interact. Secondly, it indicates that with increase in housing costs, if people have the opportunity to telecommute, then the housing market is significantly shifted toward the rural areas.

Overall, it was seen that although all the presented variables affected the choice probabilities, telecommuting, travel time variability, travel time to school, and outdoor recreational opportunities had more significant impact on people's choices than the other variables. It also demonstrated that although transportation variables (e.g., time) do matter in residential location decisions, they might be no more critical than other factors such as outdoor amenities.

CHAPTER VIII: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

8.1. SUMMARY

The purpose of this study was to investigate the impacts of telecommuting and ITS on land use patterns, specifically on households' residential location choice decisions. To study these effects, discrete choice analysis within the well-developed random utility theory framework was adopted.

Within this framework combined revealed preference (RP) and stated preference (SP) logit analysis was performed to estimate the parameters of the utility function. The required data for the model estimation were collected through an attitudinal survey of employees of selected private and public organizations within the Ottawa-Carleton Region. The survey obtained RP information on respondents' residential, employment, and socio-economic characteristics. The survey also elicited SP responses from respondents by presenting a number of hypothetical residential choice scenarios designed according to the principles of SP experimental design.

Using the sequential maximum likelihood estimation procedure, estimates of taste parameters of the combined RP and SP multinomial logit model were made. Statistical inferences on the estimated parameters were made and measures of goodness-of-fit were also calculated and discussed.

Using the sample enumeration method, aggregate forecasts for various residential alternatives were estimated from the disaggregate demand models developed in the study. Various scenarios were defined in terms of changes made with respect to a number of model parameters. For each scenario the market share for each residential location was predicted.

Also, using the methodology explained in Section 7.5.1, the residential choice behaviour of telecommuters was compared to that of non-telecommuters for the SP data.

8.2. CONCLUSIONS

From an examination of the model results obtained through the use of methodology explained earlier, a number of conclusions are drawn.

8.2.1. General Conclusions

- Telecommuting and ITS measures were found to be highly significant factors in the residential choice model. The effects of these measures were in the direction of supporting the decentralization of land use pattern.
- Research suggests that the travel time budget, the total amount of time people spend on travel, is stable (Golob et al, 1981). Improved travel times brought about by ITS and travel time savings obtained as a result of telecommuting may lead to greater commuting distances. Therefore, adoption of telecommuting and wide implementation of ITS in conjunction with the concept of constant travel time budget will likely lead to patterns of decentralization of land use supported by the empirical model of this research. Other studies have also discussed the possibility

of dispersed land use patterns using the constant travel time budget concept (Beimborn, 1996; Grovdahl and Hill, 2000).

- The objective of ITS technologies is to increase the transportation system capacity by providing shorter and more reliable travel times using applications such as variable message signs, highway advisory radios, on-board information on traffic and incidents, advanced traffic signal systems, etc. As such, travel times are profoundly affected by the presence or absence of ITS. The SP survey in this research made an attempt to capture the effects of ITS as perceived by travellers, using travel time and travel time variability measures. Although these measures showed that they influence people's choice of housing, their magnitude were not as high as it was expected, implying that they are not as critical as they once were in the past.
- The results of this study have implications for business location choice as well. It was mentioned earlier in Section 2.7 that there is evidence that telecommunications technology affects firms' location decisions. Advances in information technology facilitate connections by means such as e-mail, fax, videoconferencing, etc. Therefore, there would be no practical obstacles for firms to conduct their activities in peripheral locations. Although no empirical business location model was developed in this study, it is likely that the incorporation of information technology measures in such a model would reinforce their dispersal impacts on office location choice, as they did for the residential model in this research.

- The results of the study also have implications for transport planning. The results support a trend toward multi-nucleated urban structure. That is, a structure where a number of urban satellite nodes are located at some distance from the central core and along a radial transportation network, as shown schematically in Figure 5.1. If the axial decentralization continues as a result of telecommuting and ITS deployment, there will be need for transportation infrastructure. Goods and services still have to be transported. The urban nodes may have to be connected to each other by circumferential roadways, as it is possible that suburban-to-suburban trips will increase.
- All the variables initially selected for the residential logit model proved to be highly significant factors affecting the housing location decisions of households. This was mostly due to the administration of the pilot survey, which helped to finalize the variables to be included in the final survey.
- Although transportation accessibility measures and housing cost and size have always been important in residential location decisions, this research showed that they are no more critical to housing choice decisions than factors related to 'quality of life' such as accessibility to outdoor amenities, which was included in this study. This conclusion is in line with that of other residential location choice studies (Deakin, 1991; Weisbrod et al, 1980).
- The logit models developed here provided much insight on how telecommuting and ITS, among other policy variables such as housing cost and size, and outdoor amenities, can affect urban development and residential land use patterns.

8.2.2. Conclusions Relating to SP Design and Pooled RP+SP Model

- The SP design matrix eliminated the collinearity problem among independent variables thereby allowing the tradeoffs to be obtained clearly among the attributes.
- The SP design allowed estimating interaction effects of telecommuting and delay variables with other variables as well as to estimate the quadratic effects (i.e., non-linear components) of the attributes included in the model. This is a significant advantage of SP models over RP models. It is highly unlikely (if not impossible) to be able to estimate these effects with RP data due to collinearity problem that exists in this data type.
- The case study provided a clear demonstration that by combining the two data sources the collinearity problem was corrected due to well-behaved SP design matrix. This was illustrated by estimating coefficients that had much higher t-statistics than in the RP model. Other studies have shown that combining data sources also corrects for sign problem occurring in RP data (Ben-Akiva and Morikawa, 1990a; Hensher et al, 1999). On the other hand, the existence of RP data contributed to the development of alternative-specific constants that reflect real-world population characteristics. This, in turn, enables one to make unbiased forecasts of actual market shares.
- The likelihood ratio test done between the restricted (i.e., combined model) and unrestricted model (i.e., separate RP and SP models) justified the pooling of RP and SP data from a statistical point of view. It showed that the hypothesis of taste parameter equality holds for the three variables namely housing cost, number of

rooms, and commute time.

- The inclusion of inertia variables captured the existing bias in the SP data towards the residential location actually chosen by respondents.
- The scale parameter, which is a measure of relative variance of the RP and SP data, was greater than one implying that there was more noise in the RP data than the SP data.
- The combined model produced a much better data fit, measured by adjusted rho-square, than the RP and SP models, separately. This indicates that the combined model was a stronger model than either of those models alone.

8.2.3. Conclusions Relating to Other Statistical Aspects of the Research

- The discrete choice analysis was done at a disaggregate (i.e., individual) level in order to include selected individual demographics, specifically inertia effect. Disaggregate discrete choice models are more realistic than conventional models of residential locations such as hedonic pricing or bid-rent theory.
- The disaggregate choice models are probabilistic by nature as opposed to the bid-rent theory, which is essentially a deterministic approach in its application to residential location and housing demand.
- The χ^2 analysis of individual characteristics of the respondents showed that there was not a significant difference between telecommuters and non-telecommuters with respect to gender and job category. On the other hand, the one-way ANOVA analysis showed that the average age of telecommuters was significantly higher than that of non-telecommuters.

- Various indicators of goodness-of-fit were used in this research. The strength and weakness of each was discussed. From the available literature, it appears that the only measures that are (more or less) universally accepted are the likelihood ratio test and adjusted rho-squared, ρ_c^2 , (or its modified form corrected for the degrees of freedom called adjusted rho-square bar, $\bar{\rho}_c^2$).
- The RP model showed that in addition to policy variables there are a number of socio-economic factors that affect housing location decisions of households such as presence of school-age children in the family, auto ownership level, and household's lifecycle (i.e., single- or double-earner households). These factors proved to be as important as policy variables like housing cost and commute time.
- The RP model estimated all the variables with correct sign. This is somewhat unusual because non-significant variable estimates and counter-intuitive signs are typical problems that often occur with RP data. The model, however, could not provide a statistically significant estimate for the travel time variable, which is an important policy variable.
- The SP model, on the other hand, provided useful information on tradeoffs among attributes. The SP model also produced more robust parameter estimates than the RP model due to wider range of attributes in the SP data as well as the well-designed SP matrix.
- In terms of forecasting future demand for the available residential alternatives, the aggregate demand scenarios showed that having the opportunity to telecommute 2 days a week on average would increase significantly the probability of living further away from the central areas of the region. The observation lends support to

the view that telecommunications technologies would cause spatial dispersion of cities (Garreau, 1991; Schuler, 1992; Hopkins et al, 1994).

- It was also shown that if delay and travel time (which are measures of ITS) increase, the probability of living within the central, built-in area of the region increases. Although the model showed that the extent of such residential relocation is not as significant as that caused by telecommuting, nonetheless it provides the evidence that ITS also reinforces the dispersed residential patterns and the move toward rural areas.
- The comparison of telecommuters and non-telecommuters proved, as expected, that there is a difference between the two groups with respect to the importance of telecommuting attribute. That is, telecommuters due to their hands-on experience with telecommuting and its various aspects placed more weight on it than non-telecommuters. This further reinforced the perspective that urban areas would experience sub-urbanization trend as a result of telecommuting.

In short, this research study described a methodology for estimating impacts of telecommuting and travel time variability, among other factors, on residential location choice decision by using RP and SP data simultaneously. The empirical case study demonstrated the practical application of the method. It is concluded that the pooled model is a useful tool for evaluating transportation investments and urban housing policies affecting the residential choice behaviour.

8.3. RECOMMENDATIONS FOR FURTHER STUDY

Further study is needed on the subject of this thesis due to the complex nature of the problem. Such a study would potentially supplement and enhance the findings of this research. The following research works are recommended:

- This study was focused on the residential side only due to financial, data requirements, and time constraints of this research thesis. It was mentioned in Chapter 3 that studying the effects of telecommuting and ITS on land use patterns should ideally incorporate both the business and residential entities, as these two elements essentially make up the cities. Therefore, the study of long-term effect of information technologies on business location choice is recommended.
- It is customary in residential location studies that job locations are given and fixed. In reality the relationship between the housing and business location is of dynamic nature rather than being static. Therefore, development of a modelling framework that allows for interaction between the housing and business elements is needed as well.
- This study focused more on transportation measures although basic important housing attributes were also included in the residential models. There are many factors that affect people's decision on where to live. These include but are not limited to: crime rate, municipal taxes, school quality, accessibility to shopping and other non-work destinations, urban services, etc. Incorporation of these measures is very desirable. However, they require a huge undertaking in terms of survey design and implementation cost as well as data processing.
- From a broader perspective, in examining the impacts of information technology

on land use patterns as well as on travel patterns, the integration of transportation models with land use models that have the capability to take into account most of the above factors is suggested for further study.

- Another issue is the model transferability (or stability) over time and space. The empirical model developed in this research was calibrated to data obtained from a survey of residents of the National Capital Area. It is often desirable to use the results of the model (or partial list of its coefficients) in another context and/or location without resorting to large-scale sampling. As such, further study is recommended on updating the model's parameters to be used in other urban areas using various tests and measures that are available for such transferability analyses.
- The framework presented for combining RP and SP data is very general. That is, it can be used in a wide variety of contexts such as combining survey and census data to estimate O-D trip tables. By using this framework one can also combine data from different areas to spatially transfer the model (Ben-Akiva and Morikawa, 1990a).

In conclusion, this research illustrated the development of disaggregate residential location choice models using combined RP and SP data that is sensitive to telecommuting and ITS measures in addition to other transportation and housing policy variables. Therefore, the results should be of interest to transportation and urban planners, as well as developers, policy makers, and other researchers.

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Appendix A1: Sample Pilot Survey

CARLETON UNIVERSITY
DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
OTTAWA, ONTARIO K1S 5B6

3 July 1997
 Q. no.

Dear National Capital Area resident:

You are invited to participate in a research project on the impacts of two transportation phenomena on housing location behaviour of households. These phenomena are explained below. After reading this introduction please take a few moments and let us know how would you respond to the situations presented on the next pages. Also, we would appreciate it if you answer background questions on the next page.

Telecommuting (or teleworking) is the first phenomenon. It is defined as the use of telecommunication technologies (such as Internet, telephones, fax machines) for working at home a few days a week as a substitution for day-to-day commuting to work. From a user's perspective, working at home will reduce weekly commute trips considerably, which translates into savings of time and money for the telecommuter.

Another transportation phenomenon is called Intelligent Transportation Systems (ITS). ITS use "real-time" information to manage and control car traffic on urban roads. By the use of central computer system, satellites and on-road sensors and beacons, motorists are advised about the latest traffic conditions by various means such as radio messages, changeable signs on freeways, or in-vehicle displays. The ITS will reduce variability of your travel time substantially as well as reducing travel time itself.

The ITS and telecommuting have the potential to reduce traffic congestion in urban areas. In the long-run, these technologies may cause some people to move away from the central city and live in distant suburbia where housing is less costly and more spacious.

Your answers will help us a great deal to determine whether this will happen in the future. The information you provide here **will be kept confidential** and used only for statistical analyses. The master list of questionnaire numbers will be kept in a locked cabinet. In the statistical analyses, the identity of participants will not be shown.

There are no risks to participants of this study. You can, of course, withdraw from this survey at any time. On the other hand, the benefits will be a better knowledge base on residential choice behaviour in the light of telecommuting and ITS, which will help regional planners and decision makers to establish land use and transportation investment policies and measures that best meet your needs.

If you have any questions or need further assistance please do not hesitate to contact me at:

Department of Civil & Environmental Engineering, Carleton University

Tel: (613) 520-2600 Ext. 7475

Fax: (613) 520-3951

E-mail: mtayyara@ccs.carleton.ca

Sincerely,

M.R. Tayyaran

Project manager

Ph.D. Candidate, Department of Civil & Environmental Engineering, Carleton University

Background Questions:

A: Housing Information:

- 1) Where do you currently live? City (or township) _____ Street name
- 2) Total approximate liveable floor area of your home: _____ ft² (or _____ m²)
- 3) Type of tenure: ☐ Own ☐ Rent
- 4) How much is (was) the latest monthly rent or mortgage (including taxes) for your home? \$
- 5) How far approximately is your home from your work place? _____ km
- 6) How long have you lived in your current residence: : _____ year _____ months

B: Job and Travel-to-work Information:

- 7) Where do you work? City (or township) _____ Street name
- 8) Which one of these categories best describes your position level? (check only one)
 - ☐ Professional ☐ Technical ☐ Finance/Accounting ☐ Management/Executive
 - ☐ Project work ☐ Sales ☐ Clerical/Administrative ☐ Other
- 9) Do you work : ☐ part-time (20 hours or less /week) ☐ full-time
- 10) What is the major mode of your travel to work? (check only one)
 - ☐ Drive alone ☐ Park and ride ☐ Walk
 - ☐ Car/van pool ☐ Bus ☐ Bicycle
- 11) How long is your usual travel time to work (door-to-door)? _____ minutes
- 12) Do you currently telecommute?
 - ☐ Yes → If Yes:
 - How many days per week (on average)? _____ day(s)
 - Duration of participation? _____ years _____ months
 - ☐ No → If No:
 - Do you think your job is suitable for telecommuting? ☐ Yes ☐ No ☐ Not sure
 - Assuming that your job is suitable for telecommuting, if you are given the opportunity, would you telecommute:
 - ☐ Definitely yes ☐ Probably yes ☐ Not sure ☐ Probably not ☐ Definitely not
- 13) In your last working week, approximately how much total time was spent **travelling in-vehicle plus access/egress (i.e., not the time on the chores or activities, but just travel time):**

	On days When you were not teleworking	On days When you were teleworking (if applicable)
for household chores, etc.:	_____ min./week	_____ min./week
for leisure activities:	_____ min./week	_____ min./week

Continues on the next page →

C: Household and Demographic Information:

14) How old are you? ____ years

15) What is your sex? ☐ Male ☐ Female

16) How many people are in your household?
____ adults (16 and over including you) ____ children (under 16)

17) How many vehicles does your household own/lease? ____ vehicles

18) How many people with driver's licence are at your household? ____ driver(s)

19) What is your total household income before tax?
☐ under \$20,000 ☐ \$20,001-\$35,000 ☐ \$35,001-\$50,000
☐ \$50,001-\$75,000 ☐ \$75,001-\$100,000 ☐ over \$100,000

20) Do you have a spouse (or common-law partner) who works? ☐ Yes ☐ No
If your answer is yes:
- does s/he work: ☐ full-time or ☐ part-time
- her/his workplace: City (or (or township) _____ .
- approximate distance to your home: ____ km

Housing Location Alternatives Definition

Suppose that you can **only** choose from the residential area opportunities described below. These alternatives are described by a number of factors (e.g. housing cost, travel time, etc.). On the next page you are presented with 10 choice scenarios. In each scenario, the alternatives available to you are the same (i.e., alternatives A, B, and C). However, the combination of factors for each alternative is different. Please look at each scenario and answer which housing location you would most likely choose as the place to live in (please check only one location).

Of course, there might be other factors that may be important for you when you decide about your housing location such as crime rate, recreational opportunities, etc. However, **assume that such factors are identical among these 3 locational alternatives. Also, when choosing your preferred alternative, please take into account the needs and wants of your family.**

Definition of the housing location alternatives and a schematic diagram of their location within the National Capital Region are given below:

Alt. A - Central area of the Region inside the Green Belt consisting of Cities of Ottawa, Vanier, Nepean, Gloucester, Village of Rockcliffe, and City of Hull (in Quebec).

Alt. B - First-tier satellite nodes including Cities of Kanata, Aylmer (in Quebec), Gatineau (in Quebec), and Townships of Cumberland (i.e., Orleans), Barrhaven, and Chelsea (in Quebec).

Alt. C - Second-tier satellite nodes such as Buckingham and Rockland in east, Rideau and Osgoode in south, West Carleton and Goulbourn in west, and Clarence and Val-des-mont in north (in Quebec).

CHOICE OF HOUSING LOCATION

In this section, suppose that your entire household is moving to a new housing in the Region. Also, assume you will continue to work at your current workplace. For the 10 different scenarios presented below, we want you to indicate for each scenario which location (as defined in the previous page) you would choose to live in (please check only one).

Please remember that although these scenarios are hypothetical, take into account the needs and wants of your family when choosing your preferred residential location.

Moreover, please note that two of the housing factors shown here, namely "Housing Size" and "Travel time to work", are presented in terms of "*change with respect to your current situation*". Also, the factor "Time to School" applies to you only if you have school-age child(ren).

Assume you are able to telecommute.

Choice Scenarios	Housing Location Alternatives	FEATURES OF HOUSING LOCATION ALTERNATIVES							Chosen Alternative: (A, B, or C)?
		Level of Telecommuting (per week)	Possible Delay** (min.)	Housing Cost (\$/month)	% Change in Housing Size	% Change in Time to Work	Time to School (min.)	Availability of Outdoor Recreational Opportunities	
1	A (area inside the Green Belt):	2 days	10 min. once a month	700	-20%	0%	60	Excellent	----
	B (first-tier suburban nodes):	3-4 days	20 min. once a week	700	0%	-50%	60	Excellent	
	C (second-tier suburban nodes):	3-4 days	20 min. once a week	500	+20%	0%	60	Good	
2	A (area inside the Green Belt):	0 day	5 min. once a week	500	+20%	-50%	60	Excellent	----
	B (first-tier suburban nodes):	3-4 days	20 min. once a week	1000	-20%	+50%	60	Poor	
	C (second-tier suburban nodes):	0 day	5 min. twice a week	700	0%	-50%	60	Excellent	
3	A (area inside the Green Belt):	3-4 days	10 min. twice a week	500	-20%	0%	20	Poor	----
	B (first-tier suburban nodes):	1 day	30 min. twice a week	1300	+20%	+50%	40	Poor	
	C (second-tier suburban nodes):	1 day	10 min. once a month	700	+20%	+50%	20	Poor	

Note:

** This is the level of delay that might occur due to accidents, road repairs, unexpected congestion, etc. and that you cannot avoid or predict.
Continued on the next page ---->

CHOICE OF HOUSING LOCATION (CONT'D.)

Please note that two of the housing factors shown here, namely "**Housing Size**" and "**Travel time to work**", are presented in terms of "**change with respect to your current situation**". Also, the factor "**Time to School**" applies to you only if you have school-age child(ren).

Assume you are able to telecommute.

Choice Scenarios	Housing Location Alternatives	FEATURES OF HOUSING LOCATION ALTERNATIVES							chosen Alternative: (A, B, or C)?
		Level of Telecom muting (per week)	Possible Delay** (min.)	Housing Cost (\$/month)	% change in Housing Size	% Change in Time to Work	Time to School (min.)	Availability of Outdoor Recreational Opportunities	
4	A (area inside the Green Belt):	0 day	10 min. twice a week	700	+20%	-50%	20	Excellent	----
	B (first-tier suburban nodes):	3-4 days	10 min. once a month	700	-20%	-50%	40	Excellent	
	C (second-tier suburban nodes):	1 day	20 min. once a week	1000	-20%	+50%	40	Poor	
5	A (area inside the Green Belt):	2 days	5 min. twice a week	700	+20%	-50%	20	Good	----
	B (first-tier suburban nodes):	3-4 days	30 min. once a month	1000	+20%	0%	20	Poor	
	C (second-tier suburban nodes):	1 day	20 min. twice a week	1300	+20%	0%	40	Excellent	
6	A (area inside the Green Belt):	3-4 days	5 min. twice a week	500	-20%	0%	60	Excellent	----
	B (first-tier suburban nodes):	3-4 days	5 min. once a month	500	-20%	-50%	60	Good	
	C (second-tier suburban nodes):	2 days	20 min. twice a week	1000	-20%	0%	40	Excellent	
7	A (area inside the Green Belt):	0 day	10 min. twice a week	500	-20%	-50%	60	Poor	----
	B (first-tier suburban nodes):	1 day	30 min. twice a week	500	-20%	0%	40	Poor	
	C (second-tier suburban nodes):	2 days	20 min. twice a week	1000	+20%	0%	60	Excellent	

Note:

** This is the level of delay that might occur due to accidents, road repairs, unexpected congestion, etc. and that you cannot avoid or predict.

Continued on the next page --->

CHOICE OF HOUSING LOCATION (CONT'D.)

Please note that two of the housing factors shown here, namely "Housing Size" and "Travel time to work", are presented in terms of "*change with respect to your current situation*". Also, the factor "Time to School" applies to you only if you have school-age child(ren).

Assume you are able to telecommute.

Choice Scenarios	Housing Location Alternatives	FEATURES OF HOUSING LOCATION ALTERNATIVES							Chosen Alternative: (A, B, or C)?
		Level of Telecommuting (per week)	Possible Delay** (min.)	Housing Cost (\$/month)	% Change in Housing Size	% Change in Time to Work	Time to School (min.)	Availability of Outdoor Recreational Opportunities	
8	A (area inside the Green Belt):	3-4 days	10 min. once a month	1000	+20%	+50%	40	Poor	---
	B (first-tier suburban nodes):	1 day	20 min. once a week	1000	0%	+50%	20	Good	
	C (second-tier suburban nodes):	2 days	5 min. twice a week	1300	-20%	0%	40	Poor	
9	A (area inside the Green Belt):	1 day	5 min. once a month	1300	-20%	-50%	60	Poor	----
	B (first-tier suburban nodes):	2 days	5 min. twice a week	500	+20%	0%	20	Poor	
	C (second-tier suburban nodes):	3-4 days	20 min. twice a week	700	0%	-50%	60	Poor	
10	A (area inside the Green Belt):	3-4 days	20 min. once a month	1300	-20%	0%	20	Good	----
	B (first-tier suburban nodes):	2 days	20 min. once a week	1300	0%	-50%	20	Excellent	
	C (second-tier suburban nodes):	0 day	10 min. once a week	1000	-20%	+50%	60	Poor	

Note:

** This is the level of delay that might occur due to accidents, road repairs, unexpected congestion, etc. and that you cannot avoid or predict.

Please take a few more moments to tell us what you think of this survey. Your comments and feedbacks will enable us to further improve the quality of this survey:

- Are the instructions clear?
- Is the experiment too lengthy or too complicated? How so?
- Do the attribute levels in the survey Table seem reasonable?
- Are any of the questions ambiguous? Which ones?
- Are there any factors other than those mentioned in here that you think are important in your decision for the housing location choice?
- OTHER COMMENTS AND SUGGESTIONS:

<<THANK YOU FOR PARTICPATING IN THIS SURVEY>>

Appendix A2: Correlation Matrix for the Experimental Design

TSP Version 4.3A
(10/26/95) DOS/Win 4MB
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07/16/98 9:33 AM

In case of questions or problems, see your local TSP
consultant or send a description of the problem and the
associated TSP output to:

TSP International
P.O. Box 61015, Station A
Palo Alto, CA 94306
USA

```

PROGRAM
LINE *****
1 NAME CORREL 'Example of Logit';
2 READ (FILE='CORRALTA.PRN',FORMAT='(7F4.0,F8.0,10F4.0,F8.0,6F4.0)')
2   AL1 BL1 CL1 DL1 EL1 FL1 GL1 ALBL1 ALCL1 ALDL1 ALEL1 ALFL1 ALGL1
2   BLCL1 BLDL1 BLEL1 BLFL1 BLGL1 AQ1 BQ1 CQ1 DQ1 EQ1 FQ1 GQ1;
3 READ (FILE='CORRALTB.PRN',FORMAT='(7F4.0,F8.0,10F4.0,F8.0,6F4.0)')
3   AL2 BL2 CL2 DL2 EL2 FL2 GL2 ALBL2 ALCL2 ALDL2 ALEL2 ALFL2 ALGL2
3   BLCL2 BLDL2 BLEL2 BLFL2 BLGL2 AQ2 BQ2 CQ2 DQ2 EQ2 FQ2 GQ2;
4 READ (FILE='CORRALTC.PRN',FORMAT='(7F4.0,F8.0,10F4.0,F8.0,6F4.0)')
4   AL3 BL3 CL3 DL3 EL3 FL3 GL3 ALBL3 ALCL3 ALDL3 ALEL3 ALFL3 ALGL3
4   BLCL3 BLDL3 BLEL3 BLFL3 BLGL3 AQ3 BQ3 CQ3 DQ3 EQ3 FQ3 GQ3;
5
5 MSD (CORR) AL1 BL1 CL1 DL1 EL1 FL1 GL1 ALBL1 ALCL1 ALDL1 ALEL1
ALFL1 ALGL1
5   BLCL1 BLDL1 BLEL1 BLFL1 BLGL1 AL2 BL2 CL2 DL2 EL2 FL2 GL2 ALBL2
ALCL2 ALDL2 ALEL2 ALFL2 ALGL2
5   BLCL2 BLDL2 BLEL2 BLFL2 BLGL2 AL3 BL3 CL3 DL3 EL3 FL3 GL3 ALBL3
ALCL3 ALDL3 ALEL3 ALFL3 ALGL3
5   CL3 BLDL3 BLEL3 BLFL3 BLGL3;
6
6 MSD (CORR) AL1 BL1 CL1 DL1 EL1 FL1 GL1 AQ1 BQ1 CQ1 DQ1 EQ1 FQ1 GQ1
6   AL2 BL2 CL2 DL2 EL2 FL2 GL2 AQ2 BQ2 CQ2 DQ2 EQ2 FQ2 GQ2
6   AL3 BL3 CL3 DL3 EL3 FL3 GL3 AQ3 BQ3 CQ3 DQ3 EQ3 FQ3 GQ3;
7 END;
EXECUTION

```

Current sample: 1 to 81

Results of Covariance procedure =====

Number of Observations: 81

	Mean	Std Dev	Minimum	Maximum
AL1	0.00000	0.82158	-1.00000	1.00000
BL1	0.00000	0.82158	-1.00000	1.00000
CL1	0.00000	0.82158	-1.00000	1.00000
DL1	0.00000	0.82158	-1.00000	1.00000
EL1	0.00000	0.82158	-1.00000	1.00000
FL1	0.00000	0.82158	-1.00000	1.00000
GL1	0.00000	0.82158	-1.00000	1.00000
ALBL1	0.00000	0.67082	-1.00000	1.00000
ALCL1	0.00000	0.67082	-1.00000	1.00000
ALDL1	0.00000	0.67082	-1.00000	1.00000
ALEL1	0.00000	0.67082	-1.00000	1.00000
ALFL1	0.00000	0.67082	-1.00000	1.00000
ALGL1	0.00000	0.67082	-1.00000	1.00000
BLCL1	0.00000	0.67082	-1.00000	1.00000

BLDL1	0.00000	0.67082	-1.00000	1.00000
BLEL1	0.00000	0.67082	-1.00000	1.00000
BLFL1	0.00000	0.67082	-1.00000	1.00000
BLGL1	0.00000	0.67082	-1.00000	1.00000
AL2	0.00000	0.82158	-1.00000	1.00000
BL2	0.00000	0.82158	-1.00000	1.00000
CL2	0.00000	0.82158	-1.00000	1.00000
DL2	0.00000	0.82158	-1.00000	1.00000
EL2	0.00000	0.82158	-1.00000	1.00000
FL2	0.00000	0.82158	-1.00000	1.00000
GL2	0.00000	0.82158	-1.00000	1.00000
ALBL2	0.00000	0.67082	-1.00000	1.00000
ALCL2	0.00000	0.67082	-1.00000	1.00000
ALDL2	0.00000	0.67082	-1.00000	1.00000
ALEL2	0.00000	0.67082	-1.00000	1.00000
ALFL2	0.00000	0.67082	-1.00000	1.00000
ALGL2	0.00000	0.67082	-1.00000	1.00000
BLCL2	0.00000	0.67082	-1.00000	1.00000
BLDL2	0.00000	0.67082	-1.00000	1.00000
BLEL2	0.00000	0.67082	-1.00000	1.00000
BLFL2	0.00000	0.67082	-1.00000	1.00000
BLGL2	0.00000	0.67082	-1.00000	1.00000
AL3	0.00000	0.82158	-1.00000	1.00000
BL3	0.00000	0.82158	-1.00000	1.00000
CL3	0.00000	0.82158	-1.00000	1.00000
DL3	0.00000	0.82158	-1.00000	1.00000
EL3	0.00000	0.82158	-1.00000	1.00000
FL3	0.00000	0.82158	-1.00000	1.00000
GL3	0.00000	0.82158	-1.00000	1.00000
ALBL3	0.00000	0.67082	-1.00000	1.00000
ALCL3	0.00000	0.67082	-1.00000	1.00000
ALDL3	0.00000	0.67082	-1.00000	1.00000
ALEL3	0.00000	0.67082	-1.00000	1.00000
ALFL3	0.00000	0.67082	-1.00000	1.00000
ALGL3	0.00000	0.67082	-1.00000	1.00000
CL3	0.00000	0.82158	-1.00000	1.00000
BLDL3	0.00000	0.67082	-1.00000	1.00000
BLEL3	0.00000	0.67082	-1.00000	1.00000
BLFL3	0.00000	0.67082	-1.00000	1.00000
BLGL3	0.00000	0.67082	-1.00000	1.00000

	Sum	Variance	Skewness	Kurtosis
AL1	0.00000	0.67500	0.00000	-1.51899
BL1	0.00000	0.67500	0.00000	-1.51899
CL1	0.00000	0.67500	0.00000	-1.51899
DL1	0.00000	0.67500	0.00000	-1.51899
EL1	0.00000	0.67500	0.00000	-1.51899
FL1	0.00000	0.67500	0.00000	-1.51899
GL1	0.00000	0.67500	0.00000	-1.51899
ALBL1	0.00000	0.45000	0.00000	-0.72055
ALCL1	0.00000	0.45000	0.00000	-0.72055
ALDL1	0.00000	0.45000	0.00000	-0.72055
ALEL1	0.00000	0.45000	0.00000	-0.72055
ALFL1	0.00000	0.45000	0.00000	-0.72055
ALGL1	0.00000	0.45000	0.00000	-0.72055
BLCL1	0.00000	0.45000	0.00000	-0.72055
BLDL1	0.00000	0.45000	0.00000	-0.72055
BLEL1	0.00000	0.45000	0.00000	-0.72055
BLFL1	0.00000	0.45000	0.00000	-0.72055
BLGL1	0.00000	0.45000	0.00000	-0.72055
AL2	0.00000	0.67500	0.00000	-1.51899
BL2	0.00000	0.67500	0.00000	-1.51899
CL2	0.00000	0.67500	0.00000	-1.51899
DL2	0.00000	0.67500	0.00000	-1.51899
EL2	0.00000	0.67500	0.00000	-1.51899

FL2	0.00000	0.67500	0.00000	-1.51899
GL2	0.00000	0.67500	0.00000	-1.51899
ALBL2	0.00000	0.45000	0.00000	-0.72055
ALCL2	0.00000	0.45000	0.00000	-0.72055
ALDL2	0.00000	0.45000	0.00000	-0.72055
ALEL2	0.00000	0.45000	0.00000	-0.72055
ALFL2	0.00000	0.45000	0.00000	-0.72055
ALGL2	0.00000	0.45000	0.00000	-0.72055
BLCL2	0.00000	0.45000	0.00000	-0.72055
BLDL2	0.00000	0.45000	0.00000	-0.72055
BLEL2	0.00000	0.45000	0.00000	-0.72055
BLFL2	0.00000	0.45000	0.00000	-0.72055
BLGL2	0.00000	0.45000	0.00000	-0.72055
AL3	0.00000	0.67500	0.00000	-1.51899
BL3	0.00000	0.67500	0.00000	-1.51899
CL3	0.00000	0.67500	0.00000	-1.51899
DL3	0.00000	0.67500	0.00000	-1.51899
EL3	0.00000	0.67500	0.00000	-1.51899
FL3	0.00000	0.67500	0.00000	-1.51899
GL3	0.00000	0.67500	0.00000	-1.51899
ALBL3	0.00000	0.45000	0.00000	-0.72055
ALCL3	0.00000	0.45000	0.00000	-0.72055
ALDL3	0.00000	0.45000	0.00000	-0.72055
ALEL3	0.00000	0.45000	0.00000	-0.72055
ALFL3	0.00000	0.45000	0.00000	-0.72055
ALGL3	0.00000	0.45000	0.00000	-0.72055
CL3	0.00000	0.67500	0.00000	-1.51899
BLDL3	0.00000	0.45000	0.00000	-0.72055
BLEL3	0.00000	0.45000	0.00000	-0.72055
BLFL3	0.00000	0.45000	0.00000	-0.72055
BLGL3	0.00000	0.45000	0.00000	-0.72055

Correlation Matrix

	AL1	BL1	CL1	DL1
AL1	1.00000			
BL1	0.00000	1.00000		
CL1	0.00000	0.00000	1.00000	
DL1	0.00000	0.00000	0.00000	1.00000
EL1	0.00000	0.00000	0.00000	0.00000
FL1	0.00000	0.00000	0.00000	0.00000
GL1	0.00000	0.00000	0.00000	0.00000
ALBL1	0.00000	0.00000	0.00000	0.00000
ALCL1	0.00000	0.00000	0.00000	0.00000
ALDL1	0.00000	0.00000	0.00000	0.00000
ALEL1	0.00000	0.00000	0.00000	0.00000
ALFL1	0.00000	0.00000	0.00000	0.00000
ALGL1	0.00000	0.00000	0.00000	0.00000
BLCL1	0.00000	0.00000	0.00000	0.00000
BLDL1	0.00000	0.00000	0.00000	0.00000
BLEL1	0.00000	0.00000	0.00000	0.00000
BLFL1	0.00000	0.00000	0.00000	0.00000
BLGL1	0.00000	0.00000	0.00000	0.00000
AL2	0.00000	0.00000	0.00000	0.00000
BL2	0.00000	0.00000	0.00000	0.00000
CL2	0.00000	0.00000	0.00000	0.00000
DL2	0.00000	0.00000	0.00000	0.00000
EL2	0.00000	0.00000	0.00000	0.00000
FL2	0.00000	0.00000	0.00000	0.00000
GL2	0.00000	0.00000	0.00000	0.00000
ALBL2	0.00000	0.00000	0.00000	0.00000
ALCL2	0.00000	0.00000	0.00000	0.00000
ALDL2	0.00000	0.00000	0.00000	0.00000
ALEL2	0.00000	0.00000	0.00000	0.00000
ALFL2	0.00000	0.00000	0.00000	0.00000
ALGL2	0.00000	0.00000	0.00000	0.00000

BLCL2	0.00000	0.00000	0.00000	0.00000
BLDL2	0.00000	0.00000	0.00000	0.00000
BLEL2	0.00000	0.00000	0.00000	0.00000
BLFL2	0.00000	0.00000	0.00000	0.00000
BLGL2	0.00000	0.00000	0.00000	0.00000
AL3	0.00000	0.00000	0.00000	0.00000
BL3	0.00000	0.00000	0.00000	0.00000
CL3	0.00000	0.00000	0.00000	0.00000
DL3	0.00000	0.00000	0.00000	0.00000
EL3	0.00000	0.00000	0.00000	0.00000
FL3	0.00000	0.00000	0.00000	0.00000
GL3	0.00000	0.00000	0.00000	0.00000
ALBL3	0.00000	0.00000	-0.61237	0.00000
ALCL3	0.00000	0.00000	0.00000	0.00000
ALDL3	0.00000	0.00000	0.00000	-0.61237
ALEL3	0.00000	0.00000	0.00000	0.00000
ALFL3	0.00000	0.00000	0.00000	0.00000
ALGL3	0.00000	0.00000	0.00000	0.00000
CL3	0.00000	0.00000	0.00000	0.00000
BLDL3	0.00000	0.00000	0.00000	0.00000
BLEL3	0.00000	0.00000	0.00000	0.00000
BLFL3	0.00000	0.00000	0.00000	0.00000
BLGL3	0.00000	0.00000	0.00000	0.00000

	EL1	FL1	GL1	ALBL1
EL1	1.00000			
FL1	0.00000	1.00000		
GL1	0.00000	0.00000	1.00000	
ALBL1	0.00000	0.00000	0.00000	1.00000
ALCL1	0.00000	0.00000	0.00000	0.00000
ALDL1	0.00000	0.00000	0.00000	0.00000
ALEL1	0.00000	0.00000	0.00000	0.00000
ALFL1	0.00000	0.00000	0.00000	0.00000
ALGL1	0.00000	0.00000	0.00000	0.00000
BLCL1	0.00000	0.00000	0.00000	0.00000
BLDL1	0.00000	0.00000	0.00000	0.00000
BLEL1	0.00000	0.00000	0.00000	0.00000
BLFL1	0.00000	0.00000	0.00000	0.00000
BLGL1	0.00000	0.00000	0.00000	0.00000
AL2	0.00000	0.00000	0.00000	0.00000
BL2	0.00000	0.00000	0.00000	0.00000
CL2	0.00000	0.00000	0.00000	0.00000
DL2	0.00000	0.00000	0.00000	0.00000
EL2	0.00000	0.00000	0.00000	0.00000
FL2	0.00000	0.00000	0.00000	0.00000
GL2	0.00000	0.00000	0.00000	0.00000
ALBL2	0.00000	0.00000	0.00000	0.00000
ALCL2	0.00000	0.00000	0.00000	0.00000
ALDL2	0.00000	0.00000	0.00000	0.00000
ALEL2	0.00000	0.00000	0.00000	0.00000
ALFL2	0.00000	0.00000	0.00000	0.00000
ALGL2	0.00000	0.00000	-0.61237	0.50000
BLCL2	0.00000	0.00000	0.00000	0.00000
BLDL2	0.00000	0.00000	0.00000	0.00000
BLEL2	0.00000	0.00000	0.00000	0.00000
BLFL2	0.00000	0.00000	0.00000	0.00000
BLGL2	-0.61237	0.00000	0.00000	0.00000
AL3	0.00000	0.00000	0.00000	0.00000
BL3	0.00000	0.00000	0.00000	0.00000
CL3	0.00000	0.00000	0.00000	0.00000
DL3	0.00000	0.00000	0.00000	0.00000
EL3	0.00000	0.00000	0.00000	0.00000
FL3	0.00000	0.00000	0.00000	0.00000
GL3	0.00000	0.00000	0.00000	0.00000
ALBL3	0.00000	0.00000	0.00000	0.00000

ALCL3	0.00000	0.00000	0.00000	0.00000
ALDL3	0.00000	0.00000	0.00000	0.00000
ALEL3	0.00000	0.00000	0.00000	0.50000
ALFL3	0.00000	0.00000	0.00000	0.50000
ALGL3	0.00000	0.00000	0.00000	0.00000
CL3	0.00000	0.00000	0.00000	0.00000
BLDL3	0.00000	0.00000	0.00000	0.00000
BLEL3	0.00000	0.00000	0.00000	0.00000
BLFL3	0.00000	0.00000	0.00000	0.00000
BLGL3	0.00000	0.00000	0.00000	0.00000

	ALCL1	ALDL1	ALEL1	ALFL1
ALCL1	1.00000			
ALDL1	0.00000	1.00000		
ALEL1	0.00000	0.00000	1.00000	
ALFL1	0.00000	0.00000	0.00000	1.00000
ALGL1	0.00000	0.00000	0.00000	0.00000
BLCL1	0.00000	0.00000	0.00000	0.00000
BLDL1	0.00000	0.00000	-0.25000	0.00000
BLEL1	0.00000	-0.25000	0.00000	0.00000
BLFL1	0.00000	0.00000	0.00000	0.00000
BLGL1	0.00000	0.00000	0.00000	0.00000
AL2	0.00000	0.00000	0.00000	0.00000
BL2	0.00000	0.00000	0.00000	0.00000
CL2	0.00000	0.00000	0.00000	0.00000
DL2	0.00000	0.00000	0.00000	0.00000
EL2	-0.61237	0.00000	0.00000	0.00000
FL2	-0.61237	0.00000	0.00000	0.00000
GL2	0.00000	0.00000	0.00000	0.00000
ALBL2	0.00000	0.00000	0.00000	0.00000
ALCL2	0.00000	0.00000	0.00000	0.00000
ALDL2	0.00000	-0.25000	0.00000	0.25000
ALEL2	0.00000	0.00000	0.50000	0.00000
ALFL2	0.00000	0.00000	0.25000	0.00000
ALGL2	0.00000	0.00000	0.00000	0.00000
BLCL2	0.00000	0.00000	0.00000	0.00000
BLDL2	0.00000	0.00000	-0.25000	0.00000
BLEL2	0.00000	0.50000	0.00000	0.00000
BLFL2	0.00000	0.25000	0.00000	0.00000
BLGL2	0.00000	0.00000	0.00000	0.00000
AL3	0.00000	0.00000	0.00000	0.00000
BL3	0.00000	0.00000	0.00000	0.00000
CL3	0.00000	0.00000	0.00000	0.00000
DL3	0.00000	0.00000	0.00000	-0.61237
EL3	0.00000	0.00000	0.00000	0.00000
FL3	0.00000	0.00000	0.00000	0.00000
GL3	0.00000	0.00000	0.00000	0.00000
ALBL3	0.00000	0.00000	0.25000	0.00000
ALCL3	0.00000	0.00000	0.00000	0.00000
ALDL3	0.00000	0.00000	0.00000	0.00000
ALEL3	0.00000	0.00000	0.00000	0.00000
ALFL3	0.00000	0.00000	0.00000	0.00000
ALGL3	0.00000	0.50000	0.00000	0.50000
CL3	0.00000	0.00000	0.00000	0.00000
BLDL3	0.00000	0.00000	0.00000	0.00000
BLEL3	0.00000	0.00000	0.00000	0.00000
BLFL3	0.00000	0.25000	0.00000	0.00000
BLGL3	0.00000	0.00000	0.00000	0.00000

	ALGL1	BLCL1	BLDL1	BLEL1
ALGL1	1.00000			
BLCL1	0.00000	1.00000		
BLDL1	0.00000	0.00000	1.00000	
BLEL1	0.00000	0.00000	0.00000	1.00000

BLFL1	0.00000	0.00000	0.00000	0.00000
BLGL1	0.00000	0.00000	0.00000	0.00000
AL2	0.00000	0.00000	0.00000	0.00000
BL2	0.00000	0.00000	0.00000	0.00000
CL2	0.00000	-0.61237	0.00000	0.00000
DL2	0.00000	-0.61237	0.00000	0.00000
EL2	0.00000	0.00000	0.00000	0.00000
FL2	0.00000	0.00000	0.00000	0.00000
GL2	0.00000	0.00000	0.00000	0.00000
ALBL2	0.00000	0.00000	0.00000	0.00000
ALCL2	0.00000	0.00000	0.00000	0.25000
ALDL2	0.00000	0.00000	0.00000	0.50000
ALEL2	0.00000	0.00000	-0.25000	0.00000
ALFL2	0.00000	0.00000	0.00000	0.00000
ALGL2	0.00000	0.00000	0.00000	0.00000
BLCL2	0.00000	0.00000	0.25000	0.00000
BLDL2	0.00000	0.00000	0.50000	0.00000
BLEL2	0.25000	0.00000	0.00000	-0.25000
BLFL2	0.50000	0.00000	0.00000	0.00000
BLGL2	0.00000	0.00000	0.00000	0.00000
AL3	0.00000	0.00000	0.00000	0.00000
BL3	0.00000	0.00000	0.00000	0.00000
CL3	0.00000	0.00000	0.00000	0.00000
DL3	0.00000	0.00000	0.00000	0.00000
EL3	-0.61237	0.00000	0.00000	0.00000
FL3	0.00000	0.00000	0.00000	0.00000
GL3	0.00000	0.00000	0.00000	0.00000
ALBL3	0.00000	0.00000	0.25000	0.00000
ALCL3	0.00000	0.00000	0.00000	0.00000
ALDL3	0.00000	0.25000	0.00000	0.00000
ALEL3	0.00000	0.00000	0.00000	0.00000
ALFL3	0.25000	0.00000	0.00000	0.00000
ALGL3	0.00000	0.00000	0.00000	0.00000
CL3	0.00000	0.00000	0.00000	0.00000
BLDL3	0.00000	0.00000	0.00000	0.00000
BLEL3	0.00000	0.00000	0.00000	0.00000
BLFL3	0.00000	0.00000	0.00000	0.00000
BLGL3	-0.25000	0.00000	0.00000	0.50000

	BLFL1	BLGL1	AL2	BL2
BLFL1	1.00000			
BLGL1	0.00000	1.00000		
AL2	0.00000	0.00000	1.00000	
BL2	0.00000	0.00000	0.00000	1.00000
CL2	0.00000	0.00000	0.00000	0.00000
DL2	0.00000	0.00000	0.00000	0.00000
EL2	0.00000	0.00000	0.00000	0.00000
FL2	0.00000	0.00000	0.00000	0.00000
GL2	0.00000	0.00000	0.00000	0.00000
ALBL2	0.00000	0.00000	0.00000	0.00000
ALCL2	0.00000	0.00000	0.00000	0.00000
ALDL2	0.00000	0.00000	0.00000	0.00000
ALEL2	0.25000	0.00000	0.00000	0.00000
ALFL2	0.00000	0.00000	0.00000	0.00000
ALGL2	0.00000	0.00000	0.00000	0.00000
BLCL2	0.00000	0.50000	0.00000	0.00000
BLDL2	0.00000	0.25000	0.00000	0.00000
BLEL2	0.00000	0.00000	0.00000	0.00000
BLFL2	0.00000	0.00000	0.00000	0.00000
BLGL2	0.00000	0.00000	0.00000	0.00000
AL3	0.00000	-0.61237	0.00000	0.00000
BL3	0.00000	0.00000	0.00000	0.00000
CL3	0.00000	0.00000	0.00000	0.00000
DL3	0.00000	0.00000	0.00000	0.00000
EL3	0.00000	0.00000	0.00000	0.00000

FL3	0.00000	0.00000	0.00000	0.00000
GL3	0.00000	0.00000	0.00000	0.00000
ALBL3	0.00000	0.00000	0.00000	0.00000
ALCL3	0.00000	0.00000	-0.61237	0.00000
ALDL3	0.00000	0.00000	0.00000	0.00000
ALEL3	0.00000	0.00000	0.00000	0.00000
ALFL3	0.00000	0.00000	0.00000	0.00000
ALGL3	0.00000	0.00000	0.00000	0.00000
CL3	0.00000	0.00000	0.00000	0.00000
BLDL3	0.00000	0.00000	0.00000	-0.61237
BLEL3	0.00000	0.00000	0.00000	0.00000
BLFL3	0.00000	0.00000	0.00000	0.00000
BLGL3	0.00000	0.00000	0.00000	0.00000

	CL2	DL2	EL2	FL2
CL2	1.00000			
DL2	0.00000	1.00000		
EL2	0.00000	0.00000	1.00000	
FL2	0.00000	0.00000	0.00000	1.00000
GL2	0.00000	0.00000	0.00000	0.00000
ALBL2	0.00000	0.00000	0.00000	0.00000
ALCL2	0.00000	0.00000	0.00000	0.00000
ALDL2	0.00000	0.00000	0.00000	0.00000
ALEL2	0.00000	0.00000	0.00000	0.00000
ALFL2	0.00000	0.00000	0.00000	0.00000
ALGL2	0.00000	0.00000	0.00000	0.00000
BLCL2	0.00000	0.00000	0.00000	0.00000
BLDL2	0.00000	0.00000	0.00000	0.00000
BLEL2	0.00000	0.00000	0.00000	0.00000
BLFL2	0.00000	0.00000	0.00000	0.00000
BLGL2	0.00000	0.00000	0.00000	0.00000
AL3	0.00000	0.00000	0.00000	0.00000
BL3	0.00000	0.00000	0.00000	0.00000
CL3	0.00000	0.00000	0.00000	0.00000
DL3	0.00000	0.00000	0.00000	0.00000
EL3	0.00000	0.00000	0.00000	0.00000
FL3	0.00000	0.00000	0.00000	0.00000
GL3	0.00000	0.00000	0.00000	0.00000
ALBL3	0.00000	0.00000	0.00000	0.00000
ALCL3	0.00000	0.00000	0.00000	0.00000
ALDL3	0.00000	-0.61237	0.00000	0.00000
ALEL3	0.00000	0.00000	0.00000	0.00000
ALFL3	0.00000	0.00000	0.00000	0.00000
ALGL3	0.00000	0.00000	0.00000	0.00000
CL3	0.00000	0.00000	0.00000	0.00000
BLDL3	0.00000	0.00000	0.00000	0.00000
BLEL3	0.00000	0.00000	0.00000	0.00000
BLFL3	0.00000	0.00000	0.00000	0.00000
BLGL3	0.00000	0.00000	0.00000	0.00000

	GL2	ALBL2	ALCL2	ALDL2
GL2	1.00000			
ALBL2	0.00000	1.00000		
ALCL2	0.00000	0.00000	1.00000	
ALDL2	0.00000	0.00000	0.00000	1.00000
ALEL2	0.00000	0.00000	0.00000	0.00000
ALFL2	0.00000	0.00000	0.00000	0.00000
ALGL2	0.00000	0.00000	0.00000	0.00000
BLCL2	0.00000	0.00000	0.00000	0.00000
BLDL2	0.00000	0.00000	0.00000	0.00000
BLEL2	0.00000	0.00000	0.00000	-0.25000
BLFL2	0.00000	0.00000	0.00000	0.00000
BLGL2	0.00000	0.00000	0.00000	0.00000
AL3	0.00000	0.00000	0.00000	0.00000

BL3	0.00000	0.00000	0.00000	0.00000
CL3	0.00000	0.00000	0.00000	0.00000
DL3	0.00000	0.00000	0.00000	0.00000
EL3	0.00000	0.00000	0.00000	0.00000
FL3	0.00000	0.00000	0.00000	0.00000
GL3	0.00000	0.00000	0.00000	0.00000
ALBL3	0.00000	0.00000	0.00000	0.00000
ALCL3	0.00000	0.00000	0.00000	0.00000
ALDL3	0.00000	0.00000	0.00000	0.00000
ALEL3	-0.61237	0.00000	0.00000	0.00000
ALFL3	0.00000	0.00000	0.00000	0.00000
ALGL3	0.00000	0.00000	0.00000	0.25000
CL3	0.00000	0.00000	0.00000	0.00000
BLDL3	0.00000	0.00000	0.00000	0.00000
BLEL3	0.00000	0.50000	0.00000	0.00000
BLFL3	0.00000	0.25000	0.00000	0.00000
BLGL3	0.00000	0.00000	0.25000	0.00000

	ALEL2	ALFL2	ALGL2	BLCL2
ALEL2	1.00000			
ALFL2	0.00000	1.00000		
ALGL2	0.00000	0.00000	1.00000	
BLCL2	0.00000	0.00000	0.00000	1.00000
BLDL2	-0.25000	0.00000	0.00000	0.00000
BLEL2	0.00000	0.00000	0.00000	0.00000
BLFL2	0.00000	0.00000	0.00000	0.00000
BLGL2	0.00000	0.00000	0.00000	0.00000
AL3	0.00000	0.00000	0.00000	-0.61237
BL3	0.00000	-0.61237	0.00000	0.00000
CL3	0.00000	0.00000	0.00000	0.00000
DL3	0.00000	0.00000	0.00000	0.00000
EL3	0.00000	0.00000	0.00000	0.00000
FL3	0.00000	0.00000	0.00000	0.00000
GL3	0.00000	0.00000	0.00000	0.00000
ALBL3	0.25000	0.00000	0.00000	0.00000
ALCL3	0.00000	0.00000	0.00000	0.00000
ALDL3	0.00000	0.00000	0.00000	0.00000
ALEL3	0.00000	0.00000	0.00000	0.00000
ALFL3	0.00000	0.00000	0.50000	0.00000
ALGL3	0.00000	0.00000	0.00000	0.00000
CL3	0.00000	0.00000	0.00000	0.00000
BLDL3	0.00000	0.00000	0.00000	0.00000
BLEL3	0.00000	0.00000	0.00000	0.00000
BLFL3	0.00000	0.00000	0.00000	0.00000
BLGL3	0.00000	0.00000	0.00000	0.00000

	BLDL2	BLEL2	BLFL2	BLGL2
BLDL2	1.00000			
BLEL2	0.00000	1.00000		
BLFL2	0.00000	0.00000	1.00000	
BLGL2	0.00000	0.00000	0.00000	1.00000
AL3	0.00000	0.00000	0.00000	0.00000
BL3	0.00000	0.00000	0.00000	0.00000
CL3	0.00000	0.00000	0.00000	0.00000
DL3	0.00000	0.00000	0.00000	0.00000
EL3	0.00000	0.00000	-0.61237	0.00000
FL3	0.00000	0.00000	0.00000	0.00000
GL3	0.00000	0.00000	0.00000	-0.61237
ALBL3	0.25000	0.00000	0.00000	0.00000
ALCL3	0.00000	0.00000	0.00000	0.00000
ALDL3	0.00000	0.00000	0.00000	0.00000
ALEL3	0.00000	0.00000	0.00000	0.00000
ALFL3	0.00000	0.50000	0.00000	0.00000
ALGL3	0.00000	0.00000	0.25000	0.00000

CL3	0.00000	0.00000	0.00000	0.00000
BLDL3	0.00000	0.00000	0.00000	0.00000
BLEL3	0.00000	0.00000	0.00000	0.00000
BLFL3	0.00000	0.00000	-0.25000	0.00000
BLGL3	0.00000	0.25000	0.00000	0.00000

	AL3	BL3	CL3	DL3
AL3	1.00000			
BL3	0.00000	1.00000		
CL3	0.00000	0.00000	1.00000	
DL3	0.00000	0.00000	0.00000	1.00000
EL3	0.00000	0.00000	0.00000	0.00000
FL3	0.00000	0.00000	0.00000	0.00000
GL3	0.00000	0.00000	0.00000	0.00000
ALBL3	0.00000	0.00000	0.00000	0.00000
ALCL3	0.00000	0.00000	0.00000	0.00000
ALDL3	0.00000	0.00000	0.00000	0.00000
ALEL3	0.00000	0.00000	0.00000	0.00000
ALFL3	0.00000	0.00000	0.00000	0.00000
ALGL3	0.00000	0.00000	0.00000	0.00000
CL3	0.00000	0.00000	1.00000	0.00000
BLDL3	0.00000	0.00000	0.00000	0.00000
BLEL3	0.00000	0.00000	0.00000	0.00000
BLFL3	0.00000	0.00000	0.00000	0.00000
BLGL3	0.00000	0.00000	0.00000	0.00000

	EL3	FL3	GL3	ALBL3
EL3	1.00000			
FL3	0.00000	1.00000		
GL3	0.00000	0.00000	1.00000	
ALBL3	0.00000	0.00000	0.00000	1.00000
ALCL3	0.00000	0.00000	0.00000	0.00000
ALDL3	0.00000	0.00000	0.00000	0.00000
ALEL3	0.00000	0.00000	0.00000	0.00000
ALFL3	0.00000	0.00000	0.00000	0.00000
ALGL3	0.00000	0.00000	0.00000	0.00000
CL3	0.00000	0.00000	0.00000	0.00000
BLDL3	0.00000	0.00000	0.00000	0.00000
BLEL3	0.00000	0.00000	0.00000	0.00000
BLFL3	0.00000	0.00000	0.00000	0.00000
BLGL3	0.00000	0.00000	0.00000	0.00000

	ALCL3	ALDL3	ALEL3	ALFL3
ALCL3	1.00000			
ALDL3	0.00000	1.00000		
ALEL3	0.00000	0.00000	1.00000	
ALFL3	0.00000	0.00000	0.00000	1.00000
ALGL3	0.00000	0.00000	0.00000	0.00000
CL3	0.00000	0.00000	0.00000	0.00000
BLDL3	0.00000	0.00000	0.00000	0.00000
BLEL3	0.00000	0.00000	0.00000	0.00000
BLFL3	0.00000	0.00000	0.00000	0.00000
BLGL3	0.00000	0.00000	0.00000	0.25000

	ALGL3	CL3	BLDL3	BLEL3
ALGL3	1.00000			
CL3	0.00000	1.00000		
BLDL3	0.00000	0.00000	1.00000	
BLEL3	0.00000	0.00000	0.00000	1.00000
BLFL3	0.25000	0.00000	0.00000	0.00000
BLGL3	0.00000	0.00000	0.00000	0.00000

	BLFL3	BLGL3
BLFL3	1.00000	
BLGL3	0.00000	1.00000

Results of Covariance procedure

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Number of Observations: 81

	Mean	Std Dev	Minimum	Maximum
AL1	0.00000	0.82158	-1.00000	1.00000
BL1	0.00000	0.82158	-1.00000	1.00000
CL1	0.00000	0.82158	-1.00000	1.00000
DL1	0.00000	0.82158	-1.00000	1.00000
EL1	0.00000	0.82158	-1.00000	1.00000
FL1	0.00000	0.82158	-1.00000	1.00000
GL1	0.00000	0.82158	-1.00000	1.00000
AQ1	0.00000	1.42302	-2.00000	1.00000
BQ1	0.00000	1.42302	-2.00000	1.00000
CQ1	0.00000	1.42302	-2.00000	1.00000
DQ1	0.00000	1.42302	-2.00000	1.00000
EQ1	0.00000	1.42302	-2.00000	1.00000
FQ1	0.00000	1.42302	-2.00000	1.00000
GQ1	0.00000	1.42302	-2.00000	1.00000
AL2	0.00000	0.82158	-1.00000	1.00000
BL2	0.00000	0.82158	-1.00000	1.00000
CL2	0.00000	0.82158	-1.00000	1.00000
DL2	0.00000	0.82158	-1.00000	1.00000
EL2	0.00000	0.82158	-1.00000	1.00000
FL2	0.00000	0.82158	-1.00000	1.00000
GL2	0.00000	0.82158	-1.00000	1.00000
AQ2	0.00000	1.42302	-2.00000	1.00000
BQ2	0.00000	1.42302	-2.00000	1.00000
CQ2	0.00000	1.42302	-2.00000	1.00000
DQ2	0.00000	1.42302	-2.00000	1.00000
EQ2	0.00000	1.42302	-2.00000	1.00000
FQ2	0.00000	1.42302	-2.00000	1.00000
GQ2	0.00000	1.42302	-2.00000	1.00000
AL3	0.00000	0.82158	-1.00000	1.00000
BL3	0.00000	0.82158	-1.00000	1.00000
CL3	0.00000	0.82158	-1.00000	1.00000
DL3	0.00000	0.82158	-1.00000	1.00000
EL3	0.00000	0.82158	-1.00000	1.00000
FL3	0.00000	0.82158	-1.00000	1.00000
GL3	0.00000	0.82158	-1.00000	1.00000
AQ3	0.00000	1.42302	-2.00000	1.00000
BQ3	0.00000	1.42302	-2.00000	1.00000
CQ3	0.00000	1.42302	-2.00000	1.00000
DQ3	0.00000	1.42302	-2.00000	1.00000
EQ3	0.00000	1.42302	-2.00000	1.00000
FQ3	0.00000	1.42302	-2.00000	1.00000
GQ3	0.00000	1.42302	-2.00000	1.00000

	Sum	Variance	Skewness	Kurtosis
AL1	0.00000	0.67500	0.00000	-1.51899
BL1	0.00000	0.67500	0.00000	-1.51899
CL1	0.00000	0.67500	0.00000	-1.51899
DL1	0.00000	0.67500	0.00000	-1.51899
EL1	0.00000	0.67500	0.00000	-1.51899
FL1	0.00000	0.67500	0.00000	-1.51899
GL1	0.00000	0.67500	0.00000	-1.51899
AQ1	0.00000	2.02500	-0.72052	-1.51899
BQ1	0.00000	2.02500	-0.72052	-1.51899

CQ1	0.00000	2.02500	-0.72052	-1.51899
DQ1	0.00000	2.02500	-0.72052	-1.51899
EQ1	0.00000	2.02500	-0.72052	-1.51899
FQ1	0.00000	2.02500	-0.72052	-1.51899
GQ1	0.00000	2.02500	-0.72052	-1.51899
AL2	0.00000	0.67500	0.00000	-1.51899
BL2	0.00000	0.67500	0.00000	-1.51899
CL2	0.00000	0.67500	0.00000	-1.51899
DL2	0.00000	0.67500	0.00000	-1.51899
EL2	0.00000	0.67500	0.00000	-1.51899
FL2	0.00000	0.67500	0.00000	-1.51899
GL2	0.00000	0.67500	0.00000	-1.51899
AQ2	0.00000	2.02500	-0.72052	-1.51899
BQ2	0.00000	2.02500	-0.72052	-1.51899
CQ2	0.00000	2.02500	-0.72052	-1.51899
DQ2	0.00000	2.02500	-0.72052	-1.51899
EQ2	0.00000	2.02500	-0.72052	-1.51899
FQ2	0.00000	2.02500	-0.72052	-1.51899
GQ2	0.00000	2.02500	-0.72052	-1.51899
AL3	0.00000	0.67500	0.00000	-1.51899
BL3	0.00000	0.67500	0.00000	-1.51899
CL3	0.00000	0.67500	0.00000	-1.51899
DL3	0.00000	0.67500	0.00000	-1.51899
EL3	0.00000	0.67500	0.00000	-1.51899
FL3	0.00000	0.67500	0.00000	-1.51899
GL3	0.00000	0.67500	0.00000	-1.51899
AQ3	0.00000	2.02500	-0.72052	-1.51899
BQ3	0.00000	2.02500	-0.72052	-1.51899
CQ3	0.00000	2.02500	-0.72052	-1.51899
DQ3	0.00000	2.02500	-0.72052	-1.51899
EQ3	0.00000	2.02500	-0.72052	-1.51899
FQ3	0.00000	2.02500	-0.72052	-1.51899
GQ3	0.00000	2.02500	-0.72052	-1.51899

Correlation Matrix

	AL1	BL1	CL1	DL1
AL1	1.00000			
BL1	0.00000	1.00000		
CL1	0.00000	0.00000	1.00000	
DL1	0.00000	0.00000	0.00000	1.00000
EL1	0.00000	0.00000	0.00000	0.00000
FL1	0.00000	0.00000	0.00000	0.00000
GL1	0.00000	0.00000	0.00000	0.00000
AQ1	0.00000	0.00000	0.00000	0.00000
BQ1	0.00000	0.00000	0.00000	0.00000
CQ1	0.00000	0.00000	0.00000	0.00000
DQ1	0.00000	0.00000	0.00000	0.00000
EQ1	0.00000	0.00000	0.00000	0.00000
FQ1	0.00000	0.00000	0.00000	0.00000
GQ1	0.00000	0.00000	0.00000	0.00000
AL2	0.00000	0.00000	0.00000	0.00000
BL2	0.00000	0.00000	0.00000	0.00000
CL2	0.00000	0.00000	0.00000	0.00000
DL2	0.00000	0.00000	0.00000	0.00000
EL2	0.00000	0.00000	0.00000	0.00000
FL2	0.00000	0.00000	0.00000	0.00000
GL2	0.00000	0.00000	0.00000	0.00000
AQ2	0.00000	0.00000	0.00000	0.00000
BQ2	0.00000	0.00000	0.00000	0.00000
CQ2	0.00000	0.00000	0.00000	0.00000
DQ2	0.00000	0.00000	0.00000	0.00000
EQ2	0.00000	0.00000	0.00000	0.00000
FQ2	0.00000	0.00000	0.00000	0.00000
GQ2	0.00000	0.00000	0.00000	0.00000
AL3	0.00000	0.00000	0.00000	0.00000

BL3	0.00000	0.00000	0.00000	0.00000
CL3	0.00000	0.00000	0.00000	0.00000
DL3	0.00000	0.00000	0.00000	0.00000
EL3	0.00000	0.00000	0.00000	0.00000
FL3	0.00000	0.00000	0.00000	0.00000
GL3	0.00000	0.00000	0.00000	0.00000
AQ3	0.00000	0.00000	0.00000	0.00000
BQ3	0.00000	0.00000	0.00000	0.00000
CQ3	0.00000	0.00000	0.00000	0.00000
DQ3	0.00000	0.00000	0.00000	0.00000
EQ3	0.00000	0.00000	0.00000	0.00000
FQ3	0.00000	0.00000	0.00000	0.00000
GQ3	0.00000	0.00000	0.00000	0.00000

	EL1	FL1	GL1	AQ1
EL1	1.00000			
FL1	0.00000	1.00000		
GL1	0.00000	0.00000	1.00000	
AQ1	0.00000	0.00000	0.00000	1.00000
BQ1	0.00000	0.00000	0.00000	0.00000
CQ1	0.00000	0.00000	0.00000	0.00000
DQ1	0.00000	0.00000	0.00000	0.00000
EQ1	0.00000	0.00000	0.00000	0.00000
FQ1	0.00000	0.00000	0.00000	0.00000
GQ1	0.00000	0.00000	0.00000	0.00000
AL2	0.00000	0.00000	0.00000	0.00000
BL2	0.00000	0.00000	0.00000	0.00000
CL2	0.00000	0.00000	0.00000	0.00000
DL2	0.00000	0.00000	0.00000	0.00000
EL2	0.00000	0.00000	0.00000	0.00000
FL2	0.00000	0.00000	0.00000	0.00000
GL2	0.00000	0.00000	0.00000	0.00000
AQ2	0.00000	0.00000	0.00000	0.00000
BQ2	0.00000	0.00000	0.00000	0.00000
CQ2	0.00000	0.00000	0.00000	0.00000
DQ2	0.00000	0.00000	0.00000	0.00000
EQ2	0.00000	0.00000	0.00000	0.00000
FQ2	0.00000	0.00000	0.00000	0.00000
GQ2	0.00000	0.00000	0.00000	0.00000
AL3	0.00000	0.00000	0.00000	0.00000
BL3	0.00000	0.00000	0.00000	0.00000
CL3	0.00000	0.00000	0.00000	0.00000
DL3	0.00000	0.00000	0.00000	0.00000
EL3	0.00000	0.00000	0.00000	0.00000
FL3	0.00000	0.00000	0.00000	0.00000
GL3	0.00000	0.00000	0.00000	0.00000
AQ3	0.00000	0.00000	0.00000	0.00000
BQ3	0.00000	0.00000	0.00000	0.00000
CQ3	0.00000	0.00000	0.00000	0.00000
DQ3	0.00000	0.00000	0.00000	0.00000
EQ3	0.00000	0.00000	0.00000	0.00000
FQ3	0.00000	0.00000	0.00000	0.00000
GQ3	0.00000	0.00000	0.00000	0.00000

	BQ1	CQ1	DQ1	EQ1
BQ1	1.00000			
CQ1	0.00000	1.00000		
DQ1	0.00000	0.00000	1.00000	
EQ1	0.00000	0.00000	0.00000	1.00000
FQ1	0.00000	0.00000	0.00000	0.00000
GQ1	0.00000	0.00000	0.00000	0.00000
AL2	0.00000	0.00000	0.00000	0.00000
BL2	0.00000	0.00000	0.00000	0.00000
CL2	0.00000	0.00000	0.00000	0.00000

AQ2	0.00000	0.00000	0.00000	0.00000
BQ2	0.00000	0.00000	0.00000	0.00000
CQ2	0.00000	0.00000	0.00000	0.00000
DQ2	0.00000	0.00000	0.00000	0.00000
EQ2	0.00000	0.00000	0.00000	0.00000
FQ2	0.00000	0.00000	0.00000	0.00000
GQ2	0.00000	0.00000	0.00000	0.00000
AL3	0.00000	0.00000	0.00000	0.00000
BL3	0.00000	0.00000	0.00000	0.00000
CL3	0.00000	0.00000	0.00000	0.00000
DL3	0.00000	0.00000	0.00000	0.00000
EL3	0.00000	0.00000	0.00000	0.00000
FL3	0.00000	0.00000	0.00000	0.00000
GL3	0.00000	0.00000	0.00000	0.00000
AQ3	0.00000	0.00000	0.00000	0.00000
BQ3	0.00000	0.00000	0.00000	0.00000
CQ3	0.00000	0.00000	0.00000	0.00000
DQ3	0.00000	0.00000	0.00000	0.00000
EQ3	0.00000	0.00000	0.00000	0.00000
FQ3	0.00000	0.00000	0.00000	0.00000
GQ3	0.00000	0.00000	0.00000	0.00000

	GL2	AQ2	BQ2	CQ2
GL2	1.00000			
AQ2	0.00000	1.0000		
BQ2	0.00000	0.00000	1.0000	
CQ2	0.00000	0.00000	0.00000	1.0000
DQ2	0.00000	0.00000	0.00000	0.00000
EQ2	0.00000	0.00000	0.00000	0.00000
FQ2	0.00000	0.00000	0.00000	0.00000
GQ2	0.00000	0.00000	0.00000	0.00000
AL3	0.00000	0.00000	0.00000	0.00000
BL3	0.00000	0.00000	0.00000	0.00000
CL3	0.00000	0.00000	0.00000	0.00000
DL3	0.00000	0.00000	0.00000	0.00000
EL3	0.00000	0.00000	0.00000	0.00000
FL3	0.00000	0.00000	0.00000	0.00000
GL3	0.00000	0.00000	0.00000	0.00000
AQ3	0.00000	0.00000	0.00000	0.00000
BQ3	0.00000	0.00000	0.00000	0.00000
CQ3	0.00000	0.00000	0.00000	0.00000
DQ3	0.00000	0.00000	0.00000	0.00000
EQ3	0.00000	0.00000	0.00000	0.00000
FQ3	0.00000	0.00000	0.00000	0.00000
GQ3	0.00000	0.00000	0.00000	0.00000

	DQ2	EQ2	FQ2	GQ2
DQ2	1.00000			
EQ2	0.000000	1.00000		
FQ2	0.000000	0.000000	1.00000	
GQ2	0.000000	0.000000	0.000000	1.00000
AL3	0.000000	0.000000	0.000000	0.000000
BL3	0.000000	0.000000	0.000000	0.000000
CL3	0.000000	0.000000	0.000000	0.000000
DL3	0.000000	0.000000	0.000000	0.000000
EL3	0.000000	0.000000	0.000000	0.000000
FL3	0.000000	0.000000	0.000000	0.000000
GL3	0.000000	0.000000	0.000000	0.000000
AQ3	0.000000	0.000000	0.000000	0.000000
BQ3	0.000000	0.000000	0.000000	0.000000
CQ3	0.000000	0.000000	0.000000	0.000000
DQ3	0.000000	0.000000	0.000000	0.000000
EQ3	0.000000	0.000000	0.000000	0.000000
FQ3	0.000000	0.000000	0.000000	0.000000

GQ3	0.00000	0.00000	0.00000	0.00000
-----	---------	---------	---------	---------

	AL3	BL3	CL3	DL3
AL3	1.00000			
BL3	0.00000	1.00000		
CL3	0.00000	0.00000	1.00000	
DL3	0.00000	0.00000	0.00000	1.00000
EL3	0.00000	0.00000	0.00000	0.00000
FL3	0.00000	0.00000	0.00000	0.00000
GL3	0.00000	0.00000	0.00000	0.00000
AQ3	0.00000	0.00000	0.00000	0.00000
BQ3	0.00000	0.00000	0.00000	0.00000
CQ3	0.00000	0.00000	0.00000	0.00000
DQ3	0.00000	0.00000	0.00000	0.00000
EQ3	0.00000	0.00000	0.00000	0.00000
FQ3	0.00000	0.00000	0.00000	0.00000
GQ3	0.00000	0.00000	0.00000	0.00000

	EL3	FL3	GL3	AQ3
EL3	1.00000			
FL3	0.00000	1.00000		
GL3	0.00000	0.00000	1.00000	
AQ3	0.00000	0.00000	0.00000	1.00000
BQ3	0.00000	0.00000	0.00000	0.00000
CQ3	0.00000	0.00000	0.00000	0.00000
DQ3	0.00000	0.00000	0.00000	0.00000
EQ3	0.00000	0.00000	0.00000	0.00000
FQ3	0.00000	0.00000	0.00000	0.00000
GQ3	0.00000	0.00000	0.00000	0.00000

	BQ3	CQ3	DQ3	EQ3
BQ3	1.00000			
CQ3	0.00000	1.00000		
DQ3	0.00000	0.00000	1.00000	
EQ3	0.00000	0.00000	0.00000	1.00000
FQ3	0.00000	0.00000	0.00000	0.00000
GQ3	0.00000	0.00000	0.00000	0.00000

	FQ3	GQ3
FQ3	1.00000	
GQ3	0.00000	1.00000

END OF OUTPUT FOR USER CORREL

MEMORY USAGE:	ITEM:	DATA ARRAY	TOTAL MEMORY
	UNITS:	(4-BYTE WORDS)	(MEGABYTES)
MEMORY ALLOCATED	:	500000	4.0
MEMORY ACTUALLY REQUIRED	:	27563	2.2
CURRENT VARIABLE STORAGE	:	12010	

Appendix A3: Sample Final Survey

CARLETON UNIVERSITY
DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
OTTAWA, ONTARIO K1S 5B6

Dear Madam/Sir:

Q. no. ____

You are invited to participate in a research project on the impacts of *telecommuting* (also called *teleworking*) on residential location choice.

Telecommuting is defined as the use of telecommunication technologies (such as Internet, telephones, fax machines) for working at home a few days a week as a substitution for day-to-day commuting to work. From a user's perspective, working at home may reduce weekly commute trips considerably, which translates into savings of time and money for the telecommuter.

Telecommuting has the potential to reduce traffic congestion in urban areas. In the long-run, however, it may cause some people to move away from the central city and live in distant suburbia where housing is less costly and more spacious due to less need for daily commute to work.

Your answers will help us a great deal to determine whether this will happen in the future. The responses you provide here **will be kept confidential** and used only for aggregate statistical analyses.

There are no risks to participants of this study. You can, of course, withdraw from this survey at any time. On the other hand, the benefits will be a better knowledge base on residential choice behaviour in the light of telecommuting, which will help regional planners and decision makers establish land use and transportation investment policies and measures that best meet your needs.

After reading this introduction please take a few moments and let us know how would you respond to the scenarios presented on the next pages. Also, we would appreciate it if you could answer background questions on the next page.

If you have any questions or need further assistance please do not hesitate to contact me at:

Department of Civil & Environmental Engineering, Carleton University

Tel: (613) 520-2600 Ext. 7475

Fax: (613) 520-3951

E-mail: mtayyara@ccs.carleton.ca

Sincerely,

M.R. Tayyaran

Project manager

Ph.D. Candidate, Department of Civil & Environmental Engineering, Carleton University

A: Housing Information:

- 1) Your current address: City (or township) _____ Street name _____
- 2) Total approximate liveable floor area of your home: _____ sq.ft (or _____ sq.m.)
- 3) Number of bedrooms in your home: _____ bedrooms
- 4) Number of rooms in your home (DO NOT INCLUDE bathrooms and garages): _____ rooms
- 5) Type of tenure: ☐ Own ☐ Rent
- 6) How much was the latest monthly rent or mortgage (including taxes) for your home? \$ _____
- 7) How far approximately is your home from your work place? _____ km (or _____ mi)
- 8) How long have you lived in your current residence: _____ years _____ months

B: Job and Travel-to-work Information:

- 9) Where do you work? City (or township) _____ Street name _____
- 10) Which one of these categories best describes your position level? (check only one)

☐ Professional /Technical	☐ Finance/Accounting	☐ Management/Executive
☐ Sales/Marketing	☐ Clerical/Administrative	☐ Other _____
- 11) Do you work : ☐ 20 hours or less /week ☐ 21-34 hours/week ☐ 35 hours or more/week
- 12) What is the major mode of your travel to work? (check only one)

☐ Drive alone	☐ Park and ride	☐ Walk/Bicycle
☐ Car/van pool	☐ Bus	☐ Other _____
- 13) How long is your usual travel time to work (door-to-door)? _____ minutes
- 14) Do you currently telecommute?

☐ No → If No:

 - Do you think your job is suitable for telecommuting? ☐ Yes ☐ No ☐ Not sure
 - Regardless of your answer above, if you are given the opportunity, would you telecommute:

☐ Definitely yes	☐ Probably yes	☐ Not sure	☐ Probably not	☐ Definitely not
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(Please go to Q. 15 on the next page) →

☐ Yes → If Yes:

 - How many hours per week (on average)? _____ hour(s)
 - Duration of participation? _____ years _____ months

- Since working at home, have you ever contemplated moving or actually moved because telecommuting gave you freedom to live where you want:

☐ have moved ☐ thought of moving ☐ N/A

COMMENTS _____

- If you did move or want to move to another location, please check one of the following:

☐ Same area ☐ Closer to downtown ☐ Further from downtown ☐ Outside city limits ☐ Other _____

COMMENTS _____

C: Household and Demographic Information:

15) What is your year of birth? 19____

16) What is your sex? ☐ Male ☐ Female

17) How many people are in your household?

Adults (16 and over including you) _____ children (under 16) _____

18) How many vehicles does your household own/lease? _____ vehicles

19) How many licensed drivers are at your household? _____ driver(s)

20) What is your total household income before tax?

☐ Under \$20,000 ☐ \$20,001-\$35,000 ☐ \$35,001-\$50,000

☐ \$50,001-\$75,000 ☐ \$75,001-\$100,000 ☐ Over \$100,000

21) Do you have a spouse (or common-law partner) who works? ☐ Yes ☐ No

If your answer is yes: - does s/he work: ☐ 20 hours or less /week ☐ 21-34 hours/week
☐ 35 hours or more/week

- location of her/his workplace: City (or township) _____

- approximate distance to your home: ____ km (____ mi)

22) Assuming that only the following 7 factors play a role in residential location decisions, how would you rank each of them in terms of their importance to you:

Factor: _____

Rank (1 = highest; 7 = lowest):

Travel time to work

Housing cost

Number of rooms

Travel time to school for your child(ren)

Availability of outdoor recreational opportunities

Travel time delay to work

Ability to telecommute

PART 2: HOUSING LOCATION CHOICE GAME

This part of the survey booklet contains nine scenarios which describe possible residential location scenarios in the National Capital Area and beyond. As you may know, various ideas are being tried by many cities to encourage telecommuting to reduce traffic congestion and delays.

The scenarios presented in the next pages describe a variety of possibilities suggested by local transport professionals as well as ideas being tried or considered in many cities. Your nine scenarios may look similar, but in fact they all differ. They are part of a much larger set that describes many hundreds, if not thousands, of possibilities that might be considered.

Your responses are very important because this will help to ensure that the survey represents the views of residents of the region as a whole. In fact, we used a statistical procedure to select you and the other survey recipients from the entire population of the region. This procedure assumes that you and all other survey recipients will participate in the survey in order to produce valid and reliable results. Thus, **it is VERY important that you complete the survey in order for us to represent the views of all residents in the region accurately.**

What we want you to do is simple. Suppose that your entire family is moving to a new place in the region. Simply evaluate each scenario and tell us whether you would choose to live in Metropolitan Ottawa-Hull Central (called Alternative A), a first-tier satellite community in the region (called Alternative B), a second-tier satellite community in the region (called Alternative C), or remain at your present residential location (called None) if the scenario came to pass in the near future in the region. That's all you have to do!

Detailed definition of these housing location alternatives and a schematic diagram of their location are shown in the next page.

Previous research tells us that many respondents find the survey interesting and fun, and many report that they learn a lot about their priorities and preferences. You probably will find that the first couple of scenarios take a bit of time because you have to decide what matters to you and how you might react. After you evaluate the first couple of scenarios, you should find that you can complete the rest much faster because you will have a better idea of what matters and what doesn't. Below is a complete example scenario to show you how to respond:

Alt. A - Central area of the Region inside the Green Belt consisting of Cities of Ottawa, Vanier, Nepean, Gloucester, Village of Rockcliffe, and City of Hull (in Quebec).

Alt. B - First-tier satellite communities including Cities of Kanata, Aylmer (in Quebec), Gatineau (in Quebec), and Townships of Cumberland (i.e., Orleans), Barrhaven, and Chelsea (in Quebec).

Alt. C - Second-tier satellite communities such as Buckingham, Clarence and Rockland in east, Rideau and Osgoode in south, West Carleton and Goulbourn in west, and Pontiac and Val-des-mont in north (in Quebec).

Example Scenario:

Suppose that the following choice scenario is presented to you:

FEATURES OF RESIDENTIAL LOCATION AREAS	FUTURE ALT. A SITUATION	FUTURE ALT. B SITUATION	FUTURE ALT. C SITUATION
Telecommuting level	none	2 days per week	1 day per week
Possible delay	no delay at all	10 min. once a week	10 min. once a week
Monthly housing cost	\$150 more/month	\$300 more/month	\$150 less/month
Number of rooms	1 more room	no change	1 more room
Travel time one-way between home and work	10 more minutes	no change	20 more minutes
Travel time one-way between home and school	30 minutes	20 minutes	20 minutes
Availability of outdoor recreational opportunities	good	good	excellent

Given the above conditions, where would you choose to live? (CHECK ONE BOX ONLY)

☐ ALT. A ☐ ALT. B ☐ ALT. C ☐ NONE

First, the definitions of terms used here are as follows:

Telecommuting level - Average number of days per week that you telecommute (i.e., work at home).

Possible delay - The level of delay that might occur due to accidents, road repairs, unexpected congestion, etc. **that you cannot avoid or predict.**

Monthly housing cost - Last monthly rent (for renters) or mortgage (for homeowners). It is expressed in terms of change with respect to your current situation.

Number of rooms - Total number of rooms in your home such as bedrooms, living room, dining room, den, attic, furnished basement, kitchen, storage room, etc. (please remember that bathrooms and garages don't count as rooms). It is expressed in terms of change with respect to your current situation.

Travel time one-way between home and work - Amount of time it takes for your commute (door-to-door) in one direction by any motorised mode you currently use. It is expressed in terms of change with respect to your current situation.

Travel time one-way between home and school - Travel time in one direction between home and your child(ren)'s school, by any transportation means they currently use. This factor applies to you if you have school-age child(ren).

Availability of outdoor recreational opportunities - Represents how readily available and close-by are outdoor amenities such as parks, lakes, golf course, etc.

SECONDLY, THE WAY YOU MAY WANT TO READ THE TABLE IS AS FOLLOWS:

Living in Alt. A (i.e., central Ottawa-Hull area) means:

I will not telecommute any day of the week, I will experience no delays at all, I will pay \$150 more a month for my home, I'll have 1 more room in my house, it takes additional 10 minutes to get to work, it takes my child(ren) 30 minutes to go to school, and I will have good accessibility to outdoor amenities.

AND living in Alt. B (i.e., first-tier satellite communities) means:

I will have the opportunity to telecommute 2 days a week, I will have 10 minutes of commute delays once a week, I will pay \$300 more a month for my home, there will be no change in the number of rooms I'll have in my house, there will be no change in the amount of time it takes to get to work, it takes my child(ren) 20 minutes to go to school, and I will have good accessibility to outdoor amenities.

AND living in Alt. C (i.e., second-tier satellite communities) means:

I will have the opportunity to telecommute 1 day a week, I will have 10 minutes of commute delays twice a week, I will pay \$150 less a month for my home, I will have one more room available in my house, it takes 20 more minutes to get to work, it takes my child(ren) 20 minutes to go to school, and I will have excellent accessibility to outdoor amenities.

After evaluating these 3 residential areas based on their features presented in the Table, as well as taking into account the needs and wants of your family, choose your most preferred residential location area. Please make sure to CHECK ONE AND ONLY ONE BOX. Repeat the same selection process for all 9 choice scenarios.

CHOICE OF RESIDENTIAL LOCATION AREA**SCENARIO 1:**

Assume you are able to telecommute.

FEATURES OF RESIDENTIAL LOCATION AREAS	FUTURE ALT. A SITUATION	FUTURE ALT. B SITUATION	FUTURE ALT. C SITUATION
Telecommuting level	none	1 day a week	1 day a week
Possible delay	no delay at all	10 min. once a week	10 min. once a week
Monthly housing cost	\$300 more/month	\$300 more/month	no change
Number of rooms	1 less room	1 more room	2 more rooms
Travel time one-way between home and work	no change	20 more minutes	10 more minutes
Travel time one-way between home and school	30 minutes	30 minutes	30 minutes
Availability of outdoor recreational opportunities	good	excellent	good

BL. 1

Given the above conditions, where would you choose to live? (CHECK ONE BOX ONLY)

☐ ALT. A

☐ ALT. B

☐ ALT. C

☐ NONE

CHOICE OF RESIDENTIAL LOCATION AREA**SCENARIO 2:**

Assume you are able to telecommute.

FEATURES OF RESIDENTIAL LOCATION AREAS	FUTURE ALT. A SITUATION	FUTURE ALT. B SITUATION	FUTURE ALT. C SITUATION
Telecommuting level	2 days a week	2 days a week	1 day a week
Possible delay	10 min. twice a week	10 min. twice a week	10 min. once a week
Monthly housing cost	\$300 more/month	no change	\$300 less/month
Number of rooms	no change	no change	no change
Travel time one-way between home and work	5 more minutes	10 more minutes	10 more minutes
Travel time one-way between home and school	30 minutes	10 minutes	10 minutes
Availability of outdoor recreational opportunities	poor	excellent	poor

BL. 1

Given the above conditions, where would you choose to live? (CHECK ONE BOX ONLY)

☐ ALT. A

☐ ALT. B

☐ ALT. C

☐ NONE

CHOICE OF RESIDENTIAL LOCATION AREA

SCENARIO 3:

Assume you are able to telecommute.

FEATURES OF RESIDENTIAL LOCATION AREAS	FUTURE ALT. A SITUATION	FUTURE ALT. B SITUATION	FUTURE ALT. C SITUATION
Telecommuting level	1 day a week	1 day a week	2 days a week
Possible delay	10 min. once a week	10 min. once a week	10 min. twice a week
Monthly housing cost	\$150 more/month	no change	\$300 less/month
Number of rooms	1 more room	1 more room	no change
Travel time one-way between home and work	10 more minutes	20 more minutes	20 more minutes
Travel time one-way between home and school	20 minutes	10 minutes	10 minutes
Availability of outdoor recreational opportunities	poor	good	poor

BL. 1

Given the above conditions, where would you choose to live? (CHECK ONE BOX ONLY)

☐ ALT. A

☐ ALT. B

☐ ALT. C

☐ NONE

CHOICE OF RESIDENTIAL LOCATION AREA

SCENARIO 4:

Assume you are able to telecommute.

FEATURES OF RESIDENTIAL LOCATION AREAS	FUTURE ALT. A SITUATION	FUTURE ALT. B SITUATION	FUTURE ALT. C SITUATION
Telecommuting level	1 day a week	none	1 day a week
Possible delay	10 min. once a week	no delay at all	10 min. once a week
Monthly housing cost	\$300 more/month	\$150 more/month	\$150 less/month
Number of rooms	1 more room	1 less room	1 more room
Travel time one-way between home and work	10 more minutes	no change	10 more minutes
Travel time one-way between home and school	30 minutes	20 minutes	20 minutes
Availability of outdoor recreational opportunities	excellent	excellent	excellent

BL. 1

Given the above conditions, where would you choose to live? (CHECK ONE BOX ONLY)

☐ ALT. A

☐ ALT. B

☐ ALT. C

☐ NONE

CHOICE OF RESIDENTIAL LOCATION AREA

SCENARIO 5:

- Assume you are able to telecommute.

FEATURES OF RESIDENTIAL LOCATION AREAS	FUTURE ALT. A SITUATION	FUTURE ALT. B SITUATION	FUTURE ALT. C SITUATION
Telecommuting level	2 days a week	1 day a week	none
Possible delay	10 min. twice a week	10 min. once a week	no delay at all
Monthly housing cost	no change	\$150 more/month	\$150 less/month
Number of rooms	no change	1 more room	1 more room
Travel time one-way between home and work	5 more minutes	20 more minutes	no change
Travel time one-way between home and school	10 minutes	20 minutes	20 minutes
Availability of outdoor recreational opportunities	excellent	poor	excellent

BL. 1

Given the above conditions, where would you choose to live? (CHECK ONE BOX ONLY)

☐ ALT. A

☐ ALT. B

☐ ALT. C

☐ NONE

CHOICE OF RESIDENTIAL LOCATION AREA**SCENARIO 6:**

Assume you are able to telecommute.

FEATURES OF RESIDENTIAL LOCATION AREAS	FUTURE ALT. A SITUATION	FUTURE ALT. B SITUATION	FUTURE ALT. C SITUATION
Telecommuting level	none	2 days a week	2 days a week
Possible delay	no delay at all	10 min. twice a week	10 min. twice a week
Monthly housing cost	\$150 more/month	\$150 more/month	\$150 less/month
Number of rooms	1 less room	no change	1 more room
Travel time one-way between home and work	no change	10 more minutes	20 more minutes
Travel time one-way between home and school	20 minutes	20 minutes	20 minutes
Availability of outdoor recreational opportunities	excellent	good	excellent

BL. 1

Given the above conditions, where would you choose to live? (CHECK ONE BOX ONLY)

☐ ALT. A

☐ ALT. B

☐ ALT. C

☐ NONE

CHOICE OF RESIDENTIAL LOCATION AREA**SCENARIO 7:**

Assume you are able to telecommute.

FEATURES OF RESIDENTIAL LOCATION AREAS	FUTURE ALT. A SITUATION	FUTURE ALT. B SITUATION	FUTURE ALT. C SITUATION
Telecommuting level	none	none	none
Possible delay	no delay at all	no delay at all	no delay at all
Monthly housing cost	no change	no change	\$300 less/month
Number of rooms	1 less room	1 less room	no change
Travel time one-way between home and work	no change	no change	no change
Travel time one-way between home and school	10 minutes	10 minutes	10 minutes
Availability of outdoor recreational opportunities	poor	poor	poor

BL. 1

Given the above conditions, where would you choose to live? (CHECK ONE BOX ONLY)

☐ ALT. A

☐ ALT. B

☐ ALT. C

☐ NONE

CHOICE OF RESIDENTIAL LOCATION AREA

SCENARIO 8:

Assume you are able to telecommute.

FEATURES OF RESIDENTIAL LOCATION AREAS	FUTURE ALT. A SITUATION	FUTURE ALT. B SITUATION	FUTURE ALT. C SITUATION
Telecommuting level	1 day a week	2 days a week	none
Possible delay	10 min. once a week	10 min. twice a week	no delay at all
Monthly housing cost	no change	\$300 more/month	no change
Number of rooms	1 more room	no change	2 more rooms
Travel time one-way between home and work	10 more minutes	10 more minutes	no change
Travel time one-way between home and school	10 minutes	30 minutes	30 minutes
Availability of outdoor recreational opportunities	good	poor	good

BL. 1

Given the above conditions, where would you choose to live? (CHECK ONE BOX ONLY)

☐ ALT. A

☐ ALT. B

☐ ALT. C

☐ NONE

CHOICE OF RESIDENTIAL LOCATION AREA

SCENARIO 9:

Assume you are able to telecommute.

FEATURES OF RESIDENTIAL LOCATION AREAS	FUTURE ALT. A SITUATION	FUTURE ALT. B SITUATION	FUTURE ALT. C SITUATION
Telecommuting level	2 days a week	none	2 days a week
Possible delay	10 min. twice a week	no delay at all	10 min. twice a week
Monthly housing cost	\$150 more/month	\$300 more/month	no change
Number of rooms	no change	1 less room	2 more rooms
Travel time one-way between home and work	5 more minutes	no change	20 more minutes
Travel time one-way between home and school	20 minutes	30 minutes	30 minutes
Availability of outdoor recreational opportunities	good	good	good

BL. 1

Given the above conditions, where would you choose to live? (CHECK ONE BOX ONLY)

☐ ALT. A ☐ ALT. B ☐ ALT. C ☐ NONE

COMMENTS:

<<THANK YOU FOR PARTICIPATING IN THIS SURVEY>>

Appendix B1: RP Model Source Code and Output

TSP Version 4.3A
 (10/26/95) DOS/Win 4MB
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 03/01/00 4:13 PM

In case of questions or problems, see your local TSP
 consultant or send a description of the problem and the
 associated TSP output to:

TSP International
 P.O. Box 61015, Station A
 Palo Alto, CA 94306
 USA

PROGRAM

```

LINE *****
1 NAME MOHAMMAD 'FINAL RP DATA ANALYSIS';
2 SMPL 2 385;
3 READ (FILE='F:\TSP43\FINALNEW\RPDAT\TSP.XLS') N Z RPHC1 RPHC2 RPHC3
RPRM1
3 RPRM2 RPRM3 RPTW1 RPTW2 RPTW3 MMODE AGE AUDR PTNR PCITY TELE
TENR INC
3 NHH MODE WCITY NCHLD;
4
4 DUALS=WCITY*PCITY;
5 GENR DUAL1= DUALS=1;
6 GENR DUAL2= DUALS=4;
7 GENR DUAL3= DUALS=9;
8
8 GENR WORK1= WCITY=1;
9 GENR WORK2= WCITY=2;
10 GENR WORK3= WCITY=3;
11
11 ONEWORKS=(1-PTNR)*WCITY;
12 GENR WKALONE1= ONEWORKS=1;
13 GENR WKALONE2= ONEWORKS=2;
14 GENR WKALONE3= ONEWORKS=3;
15
15 GENR SCHOOL= NCHLD^=0;
16 SCHLBC1=0; SCHLBC2=SCHOOL; SCHLBC3=SCHOOL;
19 CHLDBC1=0; CHLDBC2=NCHLD; CHLDBC3=NCHLD;
22
22 AUDRBC1=0; AUDRBC2=AUDR; AUDRBC3=AUDR; AUDRBC0=0;
26 AUDRB1=0; AUDRB3=0; AUDRB2=AUDR; AUDRB0=0;
30 AUDRC1=0; AUDRC2=0; AUDRC3=AUDR; AUDRC0=0;
34 AGEA2=0; AGEA3=0; AGEA1=AGE; AGEA0=0;
38 MODEA2=0; MODEA3=0; MODEA1=MODE; MODEA0=0;
42 NHHBC1=0; NHHBC2=NHH; NHHBC3=NHH; NHHBC0=0;
46
46 TELEC1=0; TELEC2=0; TELEC3=TELE; TELEC0=0;
50 TELEBC1=0; TELEBC2=TELE; TELEBC3=TELE; TELEBC0=0;
54
54 MSD (NOPRINT,CORR) RPHC1 RPHC2 RPHC3 RPRM1 RPRM2 RPRM3 RPTW1 RPTW2
RPTW3;

```

```

55 MRPHC1=-@MEAN(1)+RPHC1;
56 MRPHC2=-@MEAN(2)+RPHC2;
57 MRPHC3=-@MEAN(3)+RPHC3;
58 MRPRM1=-@MEAN(4)+RPRM1;
59 MRPRM2=-@MEAN(5)+RPRM2;
60 MRPRM3=-@MEAN(6)+RPRM3;
61 MRPTW1=-@MEAN(7)+RPTW1;
62 MRPTW2=-@MEAN(8)+RPTW2;
63 MRPTW3=-@MEAN(9)+RPTW3;
64
64 E11=1; E12=0; E13=0;
67 E22=1; E21=0; E23=0;
70 E33=1; E32=0; E31=0;
73
73 SUPRES @DPDX;
74 SUPRES @DPDZ;
75
75 SMPL 2 385;
76 SET LL0=-421.87;
77 SET LLC=-368.49;
78
78 MSD (CORR) Z RPHC1 RPHC2 RPHC3 RPRM1 RPRM2 RPRM3 RPTW1 RPTW2 RPTW3
MODE NHH NCHLD
78 WKALONE1 WKALONE2 WKALONE3 DUAL1 DUAL2 DUAL3 INC TELE;
79
79 PRINT (FORMAT="('FINAL RP MODEL')");
80 LOGIT (COND, NCHOICE=3, MAXIT=10) Z MRPHC MRPRM MRPTW AUDRBC MODEA
80 WKALONE DUAL SCHLBC TELEC E1 E2;
81 SET LL6=@LOGL;
82 SET RHO2=1-(LL6/LL0);
83 SET RHOBAR=1-((LL6-@NCOEF)/LL0);
84 SET LR0= -2*(LL0 -LL6);
85 SET LRC= -2*(LLC -LL6);
86 PRINT @NCOEF RHO2 RHOBAR LR0 LRC;
87
87 PRINT (FORMAT="('CONSTRAINED RP MODEL: NO INTERCEPTS')");
88 LOGIT (COND, NCHOICE=3, MAXIT=10) Z MRPHC MRPRM MRPTW AUDRBC MODEA
88 WKALONE DUAL SCHLBC TELEC;
89 SET LL6=@LOGL;
90 SET RHO2=1-(LL6/LL0);
91 SET RHOBAR=1-((LL6-@NCOEF)/LL0);
92 SET LR0= -2*(LL0 -LL6);
93 SET LRC= -2*(LLC -LL6);
94 PRINT @NCOEF RHO2 RHOBAR LR0 LRC;
95 END;

```

EXECUTION

Current sample: 2 to 385

Current sample: 2 to 385

Results of Covariance procedure
=====

Number of Observations: 384

	Mean	Std Dev	Minimum	Maximum
Z	1.58333	0.76019	1.00000	3.00000
RPHC1	966.07552	202.12063	400.00000	1400.00000
RPHC2	1002.77188	239.96666	370.64999	1800.00000
RPHC3	954.93880	258.52930	381.14999	1710.00000
RPRM1	7.06901	1.94969	1.00000	14.00000
RPRM2	7.29010	1.60866	3.90000	14.00000
RPRM3	7.29479	1.57142	3.00000	16.00000
RPTW1	21.06510	7.41732	2.00000	50.00000
RPTW2	30.43490	5.60081	5.00000	60.00000
RPTW3	45.27344	5.13430	10.00000	75.00000
MODE	0.35677	0.47967	0.00000	1.00000
NHH	2.95573	1.32287	1.00000	7.00000
NCHLD	0.78385	1.04352	0.00000	4.00000
WKALONE1	0.30469	0.46088	0.00000	1.00000
WKALONE2	0.039063	0.19400	0.00000	1.00000
WKALONE3	0.00000	0.00000	0.00000	0.00000
DUAL1	0.48177	0.50032	0.00000	1.00000
DUAL2	0.026042	0.15947	0.00000	1.00000
DUAL3	0.00000	0.00000	0.00000	0.00000
INC	4.60156	1.23909	1.00000	6.00000
TELE	0.25260	0.43507	0.00000	1.00000

	Sum	Variance	Skewness	Kurtosis
Z	608.00000	0.57789	0.86297	-0.74749
RPHC1	370973.00159	40852.74972	-0.31566	-0.38774
RPHC2	385064.40012	57583.99905	0.14376	0.075467
RPHC3	366696.49942	66837.39892	0.059655	-0.48242
RPRM1	2714.50001	3.80131	-0.19125	0.87296
RPRM2	2799.40001	2.58779	0.20462	1.53915
RPRM3	2801.20000	2.46937	0.054878	2.47690
RPTW1	8089.00000	55.01664	0.56146	1.72439
RPTW2	11687.00000	31.36912	0.50159	7.83654
RPTW3	17385.00000	26.36107	0.64644	15.99126
MODE	137.00000	0.23008	0.60032	-1.64822
NHH	1135.00000	1.74999	0.38099	-0.50642
NCHLD	301.00000	1.08893	1.10711	0.16959
WKALONE1	117.00000	0.21241	0.85201	-1.28078
WKALONE2	15.00000	0.037635	4.77690	20.92774
WKALONE3	0.00000	0.00000	.	.
DUAL1	185.00000	0.25032	0.073252	-2.00510
DUAL2	10.00000	0.025430	5.97540	33.88189
DUAL3	0.00000	0.00000	.	.
INC	1767.00000	1.53535	-0.62334	-0.32890
TELE	97.00000	0.18929	1.14322	-0.69671

Correlation Matrix

	Z	RPHC1	RPHC2	RPHC3
Z	1.00000			
RPHC1	0.19368	1.00000		
RPHC2	0.12620	0.53925	1.0000	
RPHC3	0.040778	0.42512	0.46239	1.0000
RPRM1	0.14699	0.63552	0.52316	0.45662

RPRM2	0.17490	0.54052	0.69648	0.48901
RPRM3	0.20385	0.44918	0.47895	0.64216
RPTW1	-0.0011962	0.018853	-0.013996	0.018041
RPTW2	0.046963	0.074011	0.052099	0.10615
RPTW3	-0.051008	0.11929	0.094525	0.10654
MODE	-0.35026	-0.13940	-0.15952	-0.068724
NHH	0.17633	0.37595	0.28484	0.22750
NCHLD	0.17581	0.20950	0.13954	0.069855
WKALONE1	-0.19562	-0.29176	-0.28843	-0.29502
WKALONE2	-0.013278	-0.010044	-0.020627	-0.011853
WKALONE3	0.00000	0.00000	0.00000	0.00000
DUAL1	-0.013158	0.25048	0.24673	0.29009
DUAL2	0.046666	0.059090	-0.036051	0.0027399
DUAL3	0.00000	0.00000	0.00000	0.00000
INC	0.11157	0.45339	0.59389	0.54697
TELE	0.082233	0.037505	0.11023	0.042337

	RPRM1	RPRM2	RPRM3	RPTW1
RPRM1	1.0000			
RPRM2	0.55608	1.0000		
RPRM3	0.48154	0.56251	1.00000	
RPTW1	-0.0030377	-0.033119	0.025700	1.00000
RPTW2	0.072872	0.063972	0.089404	0.17580
RPTW3	0.12135	0.096272	0.11878	0.023185
MODE	-0.21177	-0.17813	-0.16102	0.013269
NHH	0.46048	0.44897	0.38083	-0.11865
NCHLD	0.26414	0.26687	0.19643	-0.064968
WKALONE1	-0.36924	-0.37169	-0.33128	0.049938
WKALONE2	0.0025185	0.0079351	0.040923	-0.028990
WKALONE3	0.00000	0.00000	0.00000	0.00000
DUAL1	0.35394	0.31575	0.24762	-0.047170
DUAL2	0.016879	0.011185	-0.035925	0.0095999
DUAL3	0.00000	0.00000	0.00000	0.00000
INC	0.49830	0.64811	0.57821	-0.032965
TELE	0.11914	0.11923	0.10390	-0.034236

	RPTW2	RPTW3	MODE	NHH
RPTW2	1.0000			
RPTW3	0.13659	1.0000		
MODE	0.042198	0.082205	1.00000	
NHH	0.016701	0.0056311	-0.13552	1.00000
NCHLD	-0.024974	-0.020616	-0.14286	0.77420
WKALONE1	0.014280	-0.0077152	0.25107	-0.33327
WKALONE2	-0.20792	0.015462	-0.037923	0.047452
WKALONE3	0.00000	0.00000	0.00000	0.00000
DUAL1	0.0042342	-0.031088	-0.065306	0.18222
DUAL2	0.11007	-0.0087198	-0.12178	0.10449
DUAL3	0.00000	0.00000	0.00000	0.00000
INC	0.039706	0.043846	-0.20829	0.28389
TELE	-0.023771	-0.0017807	0.0049197	0.037627

	NCHLD	WKALONE1	WKALONE2	WKALONE3
NCHLD	1.00000			

WKALONE1	-0.15044	1.00000		
WKALONE2	0.0031236	-0.13347	1.00000	
WKALONE3	0.00000	0.00000	0.00000	0.00000
DUAL1	0.064947	-0.63826	-0.19440	0.00000
DUAL2	0.11237	-0.10824	-0.032968	0.00000
DUAL3	0.00000	0.00000	0.00000	0.00000
INC	0.098803	-0.53211	-0.011116	0.00000
TELE	0.063066	-0.046287	-0.024409	0.00000

	DUAL1	DUAL2	DUAL3	INC
DUAL1	1.00000			
DUAL2	-0.15766	1.00000		
DUAL3	0.00000	0.00000	0.00000	
INC	0.46206	0.013007	0.00000	1.00000
TELE	0.12317	-0.057429	0.00000	0.10969

	TELE
TELE	1.00000

FINAL RP MODEL

Equation 1
=====

CONDITIONAL LOGIT ESTIMATION

CHOICE	FREQUENCY	PERCENT
1	224	58.3333
2	96	25.0000
3	64	16.6667

Working space used: 28821

STARTING VALUES

	MRPHC	MRPRM	MRPTW	AUDRBC	MODEA
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000

	WKALONE	DUAL	SCHLBC	TELEC	E1
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000

	E2
VALUE	0.00000

F=	421.87	FNEW=	327.26	ISQZ=	0	STEP=	1.0000	CRIT=	193.96
F=	327.26	FNEW=	326.07	ISQZ=	0	STEP=	1.0000	CRIT=	2.3156
F=	326.07	FNEW=	326.06	ISQZ=	0	STEP=	1.0000	CRIT=	0.73485E-02
F=	326.06	FNEW=	326.06	ISQZ=	0	STEP=	1.0000	CRIT=	0.16415E-06

CONVERGENCE ACHIEVED AFTER 4 ITERATIONS

8 FUNCTION EVALUATIONS.

DEPENDENT VARIABLE: Z

LOG OF LIKELIHOOD FUNCTION = -326.064
 NUMBER OF CASES = 384
 NUMBER OF CHOICES = 1152

Parameter	Estimate	Standard Error	t-statistic
MRPHC	-.103775E-02	.447094E-03	-2.32110
MRPRM	.201550	.063514	3.17329
MRPTW	-.898560E-02	.011892	-.755596
AUDRBC	.877990	.387677	2.26474
MODEA	1.07155	.276828	3.87080
WKALONE	.722365	.256372	2.81765
DUAL	.355840	.233721	1.52250
SCHLBC	.803395	.232755	3.45167
TELEC	.581904	.306227	1.90024
E1	1.75822	.423435	4.15228
E2	.529570	.190992	2.77273

Standard Errors computed from analytic second derivatives
 (Newton)

	@NCOEF	RHO2	RHOBAR	LR0	LRC
Value	11.00000	0.22710	0.20102	191.61103	84.85103

CONSTRAINED RP MODEL: NO INTERCEPTS

Equation 2
 =====

CONDITIONAL LOGIT ESTIMATION

CHOICE	FREQUENCY	PERCENT
1	224	58.3333
2	96	25.0000
3	64	16.6667

Working space used: 24109

STARTING VALUES

	MRPHC	MRPRM	MRPTW	AUDRBC	MODEA
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000

	WKALONE	DUAL	SCHLBC	TELEC
VALUE	0.00000	0.00000	0.00000	0.00000

F= 421.87	FNEW= 336.40	ISQZ= 0	STEP= 1.0000	CRIT= 178.11
F= 336.40	FNEW= 336.10	ISQZ= 0	STEP= 1.0000	CRIT= 0.57859
F= 336.10	FNEW= 336.10	ISQZ= 0	STEP= 1.0000	CRIT= 0.20105E-03
F= 336.10	FNEW= 336.10	ISQZ= 0	STEP= 1.0000	CRIT= 0.11017E-09

CONVERGENCE ACHIEVED AFTER 4 ITERATIONS

8 FUNCTION EVALUATIONS.

DEPENDENT VARIABLE: Z

LOG OF LIKELIHOOD FUNCTION = -336.104
 NUMBER OF CASES = 384
 NUMBER OF CHOICES = 1152

Parameter	Estimate	Standard Error	t-statistic
MRPHC	-.997710E-03	.440069E-03	-2.26717
MRPRM	.195022	.062641	3.11332
MRPTW	-.688590E-02	.011832	-.581992
AUDRBC	-.196698	.223623	-.879596
MODEA	1.48012	.248598	5.95388
WKALONE	1.05431	.243191	4.33530
DUAL	.703695	.221721	3.17378
SCHLBC	.623619	.229504	2.71724
TELEC	.111714	.265262	.421146

Standard Errors computed from analytic second derivatives
 (Newton)

	@NCOEF	RHO2	RHOBAR	LR0	LRC
Value	9.00000	0.20330	0.18197	171.53130	64.77130

END OF OUTPUT FOR USER MOHAMMAD

MEMORY USAGE:	ITEM:	DATA ARRAY	TOTAL MEMORY
	UNITS:	(4-BYTE WORDS)	(MEGABYTES)
MEMORY ALLOCATED	:	500000	4.0
MEMORY ACTUALLY REQUIRED	:	73201	2.4
CURRENT VARIABLE STORAGE	:	42618	

Appendix B2: Base SP Model Source Code and Output

TSP Version 4.3A
 (10/26/95) DOS/Win 20MB
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 03/02/00 2:23 PM

In case of questions or problems, see your local TSP
 consultant or send a description of the problem and the
 associated TSP output to:

TSP International
 P.O. Box 61015, Station A
 Palo Alto, CA 94306
 USA

PROGRAM

```

LINE *****
1  OPTIONS MEMORY= 20;
2  NAME REZA 'FINAL SURVEY ANALYSIS';
2  FREQ N;
3  SMPL 2 3466;
4  READ (FILE='f:\TSP43\FINALNEW\SPALLNEW.XLS') OBS Y TC1 TC2 TC3 DL1
DL2 DL3
4  HC1 HC2 HC3 RM1 RM2 RM3 TW1 TW2 TW3 TS1 TS2 TS3 RC1 RC2 RC3 IA
IB IC CHLD;
5
5  TC0=0; DL0=0; HC0=0; RM0=0; TW0=0; TS0=0; RC0=0;
12
12  TCA1=TC1; TCA2=0; TCA3=0; TCA0=0;
16  TCB2=TC2; TCB1=0; TCB3=0; TCB0=0;
20  TCC3=TC3; TCC2=0; TCC1=0; TCC0=0;
24
24  DLA1=DL1; DLA2=0; DLA3=0; DLA0=0;
28  DLB2=DL2; DLB1=0; DLB3=0; DLB0=0;
32  DLC3=DL3; DLC2=0; DLC1=0; DLC0=0;
36
36  HCA1=HC1; HCA2=0; HCA3=0; HCA0=0;
40  HCB2=HC2; HCB1=0; HCB3=0; HCB0=0;
44  HCC3=HC3; HCC2=0; HCC1=0; HCC0=0;
48
48  RMA1=RM1; RMA2=0; RMA3=0; RMA0=0;
52  RMB2=RM2; RMB1=0; RMB3=0; RMB0=0;
56  RMC3=RM3; RMC2=0; RMC1=0; RMC0=0;
60
60  TWA1=TW1; TWA2=0; TWA3=0; TWA0=0;
64  TWB2=TW2; TWB1=0; TWB3=0; TWB0=0;
68  TWC3=TW3; TWC2=0; TWC1=0; TWC0=0;
72
72  TSA1=TS1; TSA2=0; TSA3=0; TSA0=0;
76  TSB2=TS2; TSB1=0; TSB3=0; TSB0=0;
80  TSC3=TS3; TSC2=0; TSC1=0; TSC0=0;
84
84  RCA1=RC1; RCA2=0; RCA3=0; RCA0=0;
88  RCB2=RC2; RCB1=0; RCB3=0; RCB0=0;
92  RCC3=RC3; RCC2=0; RCC1=0; RCC0=0;
96

```



```

96  IA1=IA; IA2=0; IA3=0; IA0=0;
100 IB2=IB; IB1=0; IB3=0; IB0=0;
104 IC3=IC; IC2=0; IC1=0; IC0=0;
108
108  IAQ1=IA1**2; IAQ2=0; IAQ3=0; IAQ0=0;
112  IBQ2=IB2**2; IBQ1=0; IBQ3=0; IBQ0=0;
116  ICQ3=IC3**2; ICQ2=0; ICQ1=0; ICQ0=0;
120
120  DTS0=0; DTS1=TS1*CHLD; DTS2=TS2*CHLD; DTS3=TS3*CHLD;
124
124  DTSA1=DTS1; DTSA2=0; DTSA3=0; DTSA0=0;
128  DTSB2=DTS2; DTSB1=0; DTSB3=0; DTSB0=0;
132  DTSC3=DTS3; DTSC2=0; DTSC1=0; DTSC0=0;
136
136  TCQA1=((TC1**2)-2/3)*3; TCQA2=0; TCQA3=0; TCQA0=0;
140  TCQB2=((TC2**2)-2/3)*3; TCQB1=0; TCQB3=0; TCQB0=0;
144  TCQC3=((TC3**2)-2/3)*3; TCQC2=0; TCQC1=0; TCQC0=0;
148
148  DLQA1=((DL1**2)-2/3)*3; DLQA2=0; DLQA3=0; DLQA0=0;
152  DLQB2=((DL2**2)-2/3)*3; DLQB1=0; DLQB3=0; DLQB0=0;
156  DLQC3=((DL3**2)-2/3)*3; DLQC2=0; DLQC1=0; DLQC0=0;
160
160  HCQA1=((HC1**2)-2/3)*3; HCQA2=0; HCQA3=0; HCQA0=0;
164  HCQB2=((HC2**2)-2/3)*3; HCQB1=0; HCQB3=0; HCQB0=0;
168  HCQC3=((HC3**2)-2/3)*3; HCQC2=0; HCQC1=0; HCQC0=0;
172
172  RMQA1=((RM1**2)-2/3)*3; RMQA2=0; RMQA3=0; RMQA0=0;
176  RMQB2=((RM2**2)-2/3)*3; RMQB1=0; RMQB3=0; RMQB0=0;
180  RMQC3=((RM3**2)-2/3)*3; RMQC2=0; RMQC1=0; RMQC0=0;
184
184  TWQA1=((TW1**2)-2/3)*3; TWQA2=0; TWQA3=0; TWQA0=0;
188  TWQB2=((TW2**2)-2/3)*3; TWQB1=0; TWQB3=0; TWQB0=0;
192  TWQC3=((TW3**2)-2/3)*3; TWQC2=0; TWQC1=0; TWQC0=0;
196
196  TSQA1=((TS1**2)-2/3)*3; TSQA2=0; TSQA3=0; TSQA0=0;
200  TSQB2=((TS2**2)-2/3)*3; TSQB1=0; TSQB3=0; TSQB0=0;
204  TSQC3=((TS3**2)-2/3)*3; TSQC2=0; TSQC1=0; TSQC0=0;
208
208  DTSQA1=((DTS1**2)-2/3)*3; DTSQA2=0; DTSQA3=0; DTSQA0=0;
212  DTSQB2=((DTS2**2)-2/3)*3; DTSQB1=0; DTSQB3=0; DTSQB0=0;
216  DTSQC3=((DTS3**2)-2/3)*3; DTSQC2=0; DTSQC1=0; DTSQC0=0;
220
220  RCQA1=((RC1**2)-2/3)*3; RCQA2=0; RCQA3=0; RCQA0=0;
224  RCQB2=((RC2**2)-2/3)*3; RCQB1=0; RCQB3=0; RCQB0=0;
228  RCQC3=((RC3**2)-2/3)*3; RCQC2=0; RCQC1=0; RCQC0=0;
232
232  TCDLA1=TC1*DL1; TCDLA2=0; TCDLA3=0; TCDLA0=0;
236  TCDLB2=TC2*DL2; TCDLB1=0; TCDLB3=0; TCDLB0=0;
240  TCDLC3=TC3*DL3; TCDLC2=0; TCDLC1=0; TCDLC0=0;
244
244  TCHCA1=TC1*HC1; TCHCA2=0; TCHCA3=0; TCHCA0=0;
248  TCHCB2=TC2*HC2; TCHCB1=0; TCHCB3=0; TCHCB0=0;
252  TCHCC3=TC3*HC3; TCHCC2=0; TCHCC1=0; TCHCC0=0;
256
256  TCRMA1=TC1*RM1; TCRMA2=0; TCRMA3=0; TCRMA0=0;
260  TCRMB2=TC2*RM2; TCRMB1=0; TCRMB3=0; TCRMB0=0;

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264   TCRM3=TC3*RM3; TCRM2=0; TCRM1=0; TCRM0=0;
268
268   TCTWA1=TC1*TW1; TCTWA2=0; TCTWA3=0; TCTWA0=0;
272   TCTWB2=TC2*TW2; TCTWB1=0; TCTWB3=0; TCTWB0=0;
276   TCTWC3=TC3*TW3; TCTWC2=0; TCTWC1=0; TCTWC0=0;
280
280   TCTSA1=TC1*TS1; TCTSA2=0; TCTSA3=0; TCTSA0=0;
284   TCTSB2=TC2*TS2; TCTSB1=0; TCTSB3=0; TCTSB0=0;
288   TCTSC3=TC3*TS3; TCTSC2=0; TCTSC1=0; TCTSC0=0;
292
292   TCDTSA1=TC1*DTS1; TCDTSA2=0; TCDTSA3=0; TCDTSA0=0;
296   TCDTSB2=TC2*DTS2; TCDTSB1=0; TCDTSB3=0; TCDTSB0=0;
300   TCDTSC3=TC3*DTS3; TCDTSC2=0; TCDTSC1=0; TCDTSC0=0;
304
304   TCRCA1=TC1*RC1; TCRCA2=0; TCRCA3=0; TCRCA0=0;
308   TCRCB2=TC2*RC2; TCRCB1=0; TCRCB3=0; TCRCB0=0;
312   TCRCC3=TC3*RC3; TCRCC2=0; TCRCC1=0; TCRCC0=0;
316
316   DLHCA1=DL1*HC1; DLHCA2=0; DLHCA3=0; DLHCA0=0;
320   DLHCB2=DL2*HC2; DLHCB1=0; DLHCB3=0; DLHCB0=0;
324   DLHCC3=DL3*HC3; DLHCC2=0; DLHCC1=0; DLHCC0=0;
328
328   DLRMA1=DL1*RM1; DLRMA2=0; DLRMA3=0; DLRMA0=0;
332   DLRMB2=DL2*RM2; DLRMB1=0; DLRMB3=0; DLRMB0=0;
336   DLRLC3=DL3*RM3; DLRLC2=0; DLRLC1=0; DLRLC0=0;
340
340   DLTWA1=DL1*TW1; DLTWA2=0; DLTWA3=0; DLTWA0=0;
344   DLTWB2=DL2*TW2; DLTWB1=0; DLTWB3=0; DLTWB0=0;
348   DLTWC3=DL3*TW3; DLTWC2=0; DLTWC1=0; DLTWC0=0;
352
352   DL TSA1=DL1*TS1; DL TSA2=0; DL TSA3=0; DL TSA0=0;
356   DL TSB2=DL2*TS2; DL TSB1=0; DL TSB3=0; DL TSB0=0;
360   DL TSC3=DL3*TS3; DL TSC2=0; DL TSC1=0; DL TSC0=0;
364
364   DLD TSA1=DL1*DTS1; DLD TSA2=0; DLD TSA3=0; DLD TSA0=0;
368   DLD TSB2=DL2*DTS2; DLD TSB1=0; DLD TSB3=0; DLD TSB0=0;
372   DLD TSC3=DL3*DTS3; DLD TSC2=0; DLD TSC1=0; DLD TSC0=0;
376
376   DL RCA1=DL1*RC1; DL RCA2=0; DL RCA3=0; DL RCA0=0;
380   DL RCB2=DL2*RC2; DL RCB1=0; DL RCB3=0; DL RCB0=0;
384   DL RCC3=DL3*RC3; DL RCC2=0; DL RCC1=0; DL RCC0=0;
388
388   TCDL0=0; TCDL1=TC1*DL1; TCDL2=TC2*DL2; TCDL3=TC3*DL3;
392   TCHC0=0; TCHC1=TC1*HC1; TCHC2=TC2*HC2; TCHC3=TC3*HC3;
396   TCRM0=0; TCRM1=TC1*RM1; TCRM2=TC2*RM2; TCRM3=TC3*RM3;
400   TCTW0=0; TCTW1=TC1*TW1; TCTW2=TC2*TW2; TCTW3=TC3*TW3;
404   TCTS0=0; TCTS1=TC1*TS1; TCTS2=TC2*TS2; TCTS3=TC3*TS3;
408   TCDTS0=0; TCDTS1=TC1*DTS1; TCDTS2=TC2*DTS2; TCDTS3=TC3*DTS3;
412   TCRC0=0; TCRC1=TC1*RC1; TCRC2=TC2*RC2; TCRC3=TC3*RC3;
416   DLHC0=0; DLHC1=DL1*HC1; DLHC2=DL2*HC2; DLHC3=DL3*HC3;
420   DLRM0=0; DLRM1=DL1*RM1; DLRM2=DL2*RM2; DLRM3=DL3*RM3;
424   DLTW0=0; DLTW1=DL1*TW1; DLTW2=DL2*TW2; DLTW3=DL3*TW3;
428   DLTS0=0; DLTS1=DL1*TS1; DLTS2=DL2*TS2; DLTS3=DL3*TS3;
432   DLDTS0=0; DLDTS1=DL1*DTS1; DLDTS2=DL2*DTS2; DLDTS3=DL3*DTS3;
436   DLRC0=0; DLRC1=DL1*RC1; DLRC2=DL2*RC2; DLRC3=DL3*RC3;
440

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440 TCQ0=0; TCQ1=((TC1**2)-2/3)*3; TCQ2=((TC2**2)-2/3)*3;
TCQ3=((TC3**2)-2/3)*3;
444 DLQ0=0; DLQ1=((DL1**2)-2/3)*3; DLQ2=((DL2**2)-2/3)*3;
DLQ3=((DL3**2)-2/3)*3;
448 HCQ0=0; HCQ1=((HC1**2)-2/3)*3; HCQ2=((HC2**2)-2/3)*3;
HCQ3=((HC3**2)-2/3)*3;
452 RMQ0=0; RMQ1=((RM1**2)-2/3)*3; RMQ2=((RM2**2)-2/3)*3;
RMQ3=((RM3**2)-2/3)*3;
456 TWQ0=0; TWQ1=((TW1**2)-2/3)*3; TWQ2=((TW2**2)-2/3)*3;
TWQ3=((TW3**2)-2/3)*3;
460 TSQ0=0; TSQ1=((TS1**2)-2/3)*3; TSQ2=((TS2**2)-2/3)*3;
TSQ3=((TS3**2)-2/3)*3;
464 RCQ0=0; RCQ1=((RC1**2)-2/3)*3; RCQ2=((RC2**2)-2/3)*3;
RCQ3=((RC3**2)-2/3)*3;
468 DTSQ0=0; DTSQ1=((DTS1**2)-2/3)*3; DTSQ2=((DTS2**2)-2/3)*3;
DTSQ3=((DTS3**2)-2/3)*3;
472
472 SET LL0=-4803.51;
473 SET LLC=-4620.90;
474 SMPL 2 3466;
475 SUPRES @DPDX;
476 SUPRES @DPDZ;
477
477 PRINT (FORMAT="( 'MAIN EFFECTS + ALL INTERACTIONS + ALL QUADS' )");
478 LOGIT (COND, NCHOICE=4, MAXIT=20) Y TCA TCB TCC DLA DLB DLC HCA HCB
HCC
478 RMA RMB RMC TWA TWB TWC DTSA DTSB DTSC RCA RCB RCC IA IB IC
TCDLA TCDLB
478 TCDLC TCHCA TCHCB TCHCC TCRMA TCRMB TCRMC TCTWA TCTWB TCTWC
TCDTSA
478 TCDTSB TCDTSC TCRCA TCRCB TCRCC DLHCA DLHCB DLHCC DLRMA DLRMB
DLRMC
478 DLTWA DLTWB DLTWC DLD TSA DLDTSB DLDTSB DLRCA DLRCB DLRCB TCQA
TCQB TCQC
478 DLQA DLQB DLQC HCQA HCQB HCQC RMQA RMQB RMQC TWQA TWQB TWQC
478 DTSQA DTSQB DTSQC RCQA RCQB RCQC IAQ IBQ ICQ | C;
479 SET LL6=@LOGL;
480 SET RHO2=1-(LL6/LL0);
481 SET RHOBAR=1-((LL6-@NCOEF)/LL0);
482 SET LR0= -2*(LL0 -LL6);
483 SET LRC= -2*(LLC -LL6);
484 PRINT @NCOEF RHO2 RHOBAR LR0 LRC;
485 END;

```

EXECUTION

Current sample: 2 to 3466

Current sample: 2 to 3466

MAIN EFFECTS + ALL INTERACTIONS + ALL QUADS

Equation 1
=====

MIXED LOGIT ESTIMATION

CHOICE	FREQUENCY	PERCENT	
0	839	24.2136	(COEFFICIENTS NORMALIZED TO ZERO)
1	801	23.1169	
2	517	14.9206	
3	1308	37.7489	

Working space used: 2302059

STARTING VALUES

VALUE	TCA	TCB	TCC	DLA	DLB
	0.00000	0.00000	0.00000	0.00000	0.00000
VALUE	DLC	HCA	HCB	HCC	RMA
	0.00000	0.00000	0.00000	0.00000	0.00000
VALUE	RMB	RMC	TWA	TWB	TWC
	0.00000	0.00000	0.00000	0.00000	0.00000
VALUE	DTSA	DTSB	DTSC	RCA	RCB
	0.00000	0.00000	0.00000	0.00000	0.00000
VALUE	RCC	IA	IB	IC	TCDLA
	0.00000	0.00000	0.00000	0.00000	0.00000
VALUE	TCDLB	TCDLC	TCHCA	TCHCB	TCHCC
	0.00000	0.00000	0.00000	0.00000	0.00000
VALUE	TCRMA	TCRMB	TCRMC	TCTWA	TCTWB
	0.00000	0.00000	0.00000	0.00000	0.00000
VALUE	TCTWC	TCDTSA	TCDTSB	TCDTSC	TCRCA
	0.00000	0.00000	0.00000	0.00000	0.00000
VALUE	TCRCB	TCRCC	DLHCA	DLHCB	DLHCC
	0.00000	0.00000	0.00000	0.00000	0.00000
VALUE	DLRMA	DLRMB	DLRMC	DLTWA	DLTWB
	0.00000	0.00000	0.00000	0.00000	0.00000
VALUE	DLTWC	DLDTSA	DLDTSB	DLDTSC	DLRCA
	0.00000	0.00000	0.00000	0.00000	0.00000
VALUE	DLRCB	DLRCC	TCQA	TCQB	TCQC
	0.00000	0.00000	0.00000	0.00000	0.00000
VALUE	DLQA	DLQB	DLQC	HCQA	HCQB
	0.00000	0.00000	0.00000	0.00000	0.00000
VALUE	HCQC	RMQA	RMQB	RMQC	TWQA
	0.00000	0.00000	0.00000	0.00000	0.00000
VALUE	TWQB	TWQC	DTSQA	DTSQB	DTSQC
	0.00000	0.00000	0.00000	0.00000	0.00000
VALUE	RCQA	RCQB	RCQC	IAQ	IBQ
	0.00000	0.00000	0.00000	0.00000	0.00000
VALUE	ICQ	C1	C2	C3	
	0.00000	0.00000	0.00000	0.00000	

F=	4803.5	FNEW=	4183.3	ISQZ=	0	STEP=	1.0000	CRIT=	1276.3
F=	4183.3	FNEW=	4147.9	ISQZ=	0	STEP=	1.0000	CRIT=	67.289
F=	4147.9	FNEW=	4146.9	ISQZ=	0	STEP=	1.0000	CRIT=	1.8714
F=	4146.9	FNEW=	4146.9	ISQZ=	0	STEP=	1.0000	CRIT=	0.76625E-02
F=	4146.9	FNEW=	4146.9	ISQZ=	0	STEP=	1.0000	CRIT=	0.20249E-06

CONVERGENCE ACHIEVED AFTER 5 ITERATIONS

10 FUNCTION EVALUATIONS.

DEPENDENT VARIABLE: Y

LOG OF LIKELIHOOD FUNCTION = -4146.90
 NUMBER OF CASES = 3465
 NUMBER OF CHOICES = 13860

Parameter	Estimate	Standard Error	t-statistic
TCA	.126047	.056407	2.23458
TCB	.263697	.075033	3.51442
TCC	.294649	.050074	5.88431
DLA	-.090146	.055859	-1.61379
DLB	-.104965	.073819	-1.42192
DLC	-.102181	.046973	-2.17531
HCA	-.574139	.057796	-9.93392
HCB	-.627967	.069362	-9.05342
HCC	-.187266	.046218	-4.05181
RMA	.226458	.057652	3.92803
RMB	.374295	.070916	5.27803
RMC	.062748	.046904	1.33779
TWA	-.053716	.056969	-.942910
TWB	-.250819	.067579	-3.71150
TWC	-.344259	.049416	-6.96652
DTSA	-.297077	.090412	-3.28584
DTSB	-.237446	.093335	-2.54403
DTSC	-.217217	.070089	-3.09917
RCA	.310808	.056010	5.54916
RCB	.362465	.069237	5.23511
RCC	.396586	.047957	8.26971
IA	.124135	.018275	6.79266
IB	.040019	.024344	1.64394
IC	.238575	.026295	9.07311
TCDLA	-.045784	.070177	-.652402
TCDLB	-.242912	.084416	-2.87757
TCDLC	-.065408	.060850	-1.07490
TCHCA	-.174407	.069859	-2.49654
TCHCB	-.065607	.085342	-.768756
TCHCC	-.319558E-02	.061323	-.052111
TCRMA	.160238	.073231	2.18811
TCRMB	-.027286	.090396	-.301856
TCRMC	.065007	.062611	1.03826
TCTWA	-.191230	.070286	-2.72075
TCTWB	.075901	.089246	.850475
TCTWC	.191527	.062022	3.08806
TCDTSA	-.089708	.113347	-.791449
TCDTSB	.027150	.118919	.228310
TCDTSC	.058938	.090216	.653294
TCRCA	.122256	.072863	1.67790
TCRCB	.139757	.087900	1.58995
TCRCC	.052349	.060896	.859643
DLHCA	-.025947	.071397	-.363416
DLHCB	.114748	.084816	1.35291
DLHCC	-.022500	.062767	-.358464
DLRMA	.169111	.071925	2.35120
DLRMB	.235710	.089216	2.64202
DLRMC	.083834	.061075	1.37263
DLTWA	-.131753	.071567	-1.84098

DLTWB	-.040302	.086365	-.466641
DLTWC	.133269	.058351	2.28393
DLDTSA	-.079080	.109809	-.720162
DLDTSB	.028456	.119355	.238413
DLDTSC	.088454	.086849	1.01848
DLRCA	-.077445	.070998	-1.09081
DLRCB	.100298	.085574	1.17207
DLRCC	-.078287	.060626	-1.29131
TCQA	-.036371	.032193	-1.12977
TCQB	-.063883	.036664	-1.74242
TCQC	-.014430	.027065	-.533157
DLQA	.011380	.032574	.349371
DLQB	-.026344	.037378	-.704803
DLQC	.010011	.026816	.373311
HCQA	-.012841	.031808	-.403713
HCQB	-.022673	.038509	-.588769
HCQC	.033466	.026770	1.25013
RMQA	-.073415	.031485	-2.33176
RMQB	-.078877	.036807	-2.14296
RMQC	.360332E-03	.026955	.013368
TWQA	-.023804	.031505	-.755538
TWQB	-.017099	.037145	-.460346
TWQC	-.034568	.026747	-1.29242
DTSQA	-.217854	.035496	-6.13735
DTSQB	-.874497E-02	.037826	-.231188
DTSQC	-.062595	.028808	-2.17286
RCQA	-.072961	.031098	-2.34620
RCQB	-.107273	.036805	-2.91465
RCQC	-.051729	.026670	-1.93958
IAQ	-.435688E-02	.885293E-03	-4.92140
IBQ	-.991243E-03	.111391E-02	-.889874
ICQ	-.971496E-02	.136964E-02	-7.09308
C1	-.710051	.083366	-8.51729
C2	-.798857	.084029	-9.50689
C3	.192362	.059158	3.25166

Standard Errors computed from analytic second derivatives
(Newton)

	@NCOEF	RHO2	RHOBAR	LR0	LRC
Value	84.00000	0.13669	0.11921	1313.22234	948.00234

END OF OUTPUT FOR USER REZA

MEMORY USAGE:	ITEM:	DATA ARRAY	TOTAL MEMORY
	UNITS:	(4-BYTE WORDS)	(MEGABYTES)
MEMORY ALLOCATED	:	4500000	20.0
MEMORY ACTUALLY REQUIRED	:	4078409	18.4
CURRENT VARIABLE STORAGE	:	1766032	

Appendix B3: Final SP Model Source Code and Output (The restricted and unrestricted models)

TSP Version 4.3A
(10/26/95) DOS/Win 16MB
Copyright (C) 1995 TSP International
ALL RIGHTS RESERVED
03/02/00 2:45 PM

In case of questions or problems, see your local TSP
consultant or send a description of the problem and the
associated TSP output to:

TSP International
P.O. Box 61015, Station A
Palo Alto, CA 94306
USA

PROGRAM

```

LINE *****
1  OPTIONS MEMORY= 16;
2  NAME REZA 'FINAL SURVEY ANALYSIS';
2  FREQ N;
3  SMPL 2 3466;
4  READ (FILE='f:\TSP43\FINALNEW\SPALLNEW.XLS') OBS Y TC1 TC2 TC3 DL1
DL2 DL3
4  HC1 HC2 HC3 RM1 RM2 RM3 TW1 TW2 TW3 TS1 TS2 TS3 RC1 RC2 RC3 IA
IB IC CHLD;
5
5  TC0=0; DL0=0; HC0=0; RM0=0; TW0=0; TS0=0; RC0=0;
12
12  TCA1=TC1; TCA2=0; TCA3=0; TCA0=0;
16  TCB2=TC2; TCB1=0; TCB3=0; TCB0=0;
20  TCC3=TC3; TCC2=0; TCC1=0; TCC0=0;
24
24  DLA1=DL1; DLA2=0; DLA3=0; DLA0=0;
28  DLB2=DL2; DLB1=0; DLB3=0; DLB0=0;
32  DLC3=DL3; DLC2=0; DLC1=0; DLC0=0;
36
36  HCA1=HC1; HCA2=0; HCA3=0; HCA0=0;
40  HCB2=HC2; HCB1=0; HCB3=0; HCB0=0;
44  HCC3=HC3; HCC2=0; HCC1=0; HCC0=0;
48
48  RMA1=RM1; RMA2=0; RMA3=0; RMA0=0;
52  RMB2=RM2; RMB1=0; RMB3=0; RMB0=0;
56  RMC3=RM3; RMC2=0; RMC1=0; RMC0=0;
60
60  TWA1=TW1; TWA2=0; TWA3=0; TWA0=0;
64  TWB2=TW2; TWB1=0; TWB3=0; TWB0=0;
68  TWC3=TW3; TWC2=0; TWC1=0; TWC0=0;
72
72  TSA1=TS1; TSA2=0; TSA3=0; TSA0=0;
76  TSB2=TS2; TSB1=0; TSB3=0; TSB0=0;
80  TSC3=TS3; TSC2=0; TSC1=0; TSC0=0;
84
84  RCA1=RC1; RCA2=0; RCA3=0; RCA0=0;
88  RCB2=RC2; RCB1=0; RCB3=0; RCB0=0;

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92  RCC3=RC3; RCC2=0; RCC1=0; RCC0=0;
96
96  IA1=IA; IA2=0; IA3=0; IA0=0;
100 IB2=IB; IB1=0; IB3=0; IB0=0;
104 IC3=IC; IC2=0; IC1=0; IC0=0;
108
108  IAQ1=IA1**2; IAQ2=0; IAQ3=0; IAQ0=0;
112 IBQ2=IB2**2; IBQ1=0; IBQ3=0; IBQ0=0;
116 ICQ3=IC3**2; ICQ2=0; ICQ1=0; ICQ0=0;
120
120  DTS0=0; DTS1=TS1*CHLD; DTS2=TS2*CHLD; DTS3=TS3*CHLD;
124 DTSA1=DTS1; DTSA2=0; DTSA3=0; DTSA0=0;
128 DTSB2=DTS2; DTSB1=0; DTSB3=0; DTSB0=0;
132 DTSC3=DTS3; DTSC2=0; DTSC1=0; DTSC0=0;
136
136  TCQA1=((TC1**2)-2/3)*3; TCQA2=0; TCQA3=0; TCQA0=0;
140 TCQB2=((TC2**2)-2/3)*3; TCQB1=0; TCQB3=0; TCQB0=0;
144 TCQC3=((TC3**2)-2/3)*3; TCQC2=0; TCQC1=0; TCQC0=0;
148
148  DLQA1=((DL1**2)-2/3)*3; DLQA2=0; DLQA3=0; DLQA0=0;
152 DLQB2=((DL2**2)-2/3)*3; DLQB1=0; DLQB3=0; DLQB0=0;
156 DLQC3=((DL3**2)-2/3)*3; DLQC2=0; DLQC1=0; DLQC0=0;
160
160  HCQA1=((HC1**2)-2/3)*3; HCQA2=0; HCQA3=0; HCQA0=0;
164 HCQB2=((HC2**2)-2/3)*3; HCQB1=0; HCQB3=0; HCQB0=0;
168 HCQC3=((HC3**2)-2/3)*3; HCQC2=0; HCQC1=0; HCQC0=0;
172
172  RMQA1=((RM1**2)-2/3)*3; RMQA2=0; RMQA3=0; RMQA0=0;
176 RMQB2=((RM2**2)-2/3)*3; RMQB1=0; RMQB3=0; RMQB0=0;
180 RMQC3=((RM3**2)-2/3)*3; RMQC2=0; RMQC1=0; RMQC0=0;
184
184  TWQA1=((TW1**2)-2/3)*3; TWQA2=0; TWQA3=0; TWQA0=0;
188 TWQB2=((TW2**2)-2/3)*3; TWQB1=0; TWQB3=0; TWQB0=0;
192 TWQC3=((TW3**2)-2/3)*3; TWQC2=0; TWQC1=0; TWQC0=0;
196
196  TSQA1=((TS1**2)-2/3)*3; TSQA2=0; TSQA3=0; TSQA0=0;
200 TSQB2=((TS2**2)-2/3)*3; TSQB1=0; TSQB3=0; TSQB0=0;
204 TSQC3=((TS3**2)-2/3)*3; TSQC2=0; TSQC1=0; TSQC0=0;
208
208  DTSQA1=((DTS1**2)-2/3)*3; DTSQA2=0; DTSQA3=0; DTSQA0=0;
212 DTSQB2=((DTS2**2)-2/3)*3; DTSQB1=0; DTSQB3=0; DTSQB0=0;
216 DTSQC3=((DTS3**2)-2/3)*3; DTSQC2=0; DTSQC1=0; DTSQC0=0;
220
220  RCQA1=((RC1**2)-2/3)*3; RCQA2=0; RCQA3=0; RCQA0=0;
224 RCQB2=((RC2**2)-2/3)*3; RCQB1=0; RCQB3=0; RCQB0=0;
228 RCQC3=((RC3**2)-2/3)*3; RCQC2=0; RCQC1=0; RCQC0=0;
232
232  TCDLA1=TC1*DL1; TCDLA2=0; TCDLA3=0; TCDLA0=0;
236 TCDLB2=TC2*DL2; TCDLB1=0; TCDLB3=0; TCDLB0=0;
240 TCDLC3=TC3*DL3; TCDLC2=0; TCDLC1=0; TCDLC0=0;
244
244  TCHCA1=TC1*HC1; TCHCA2=0; TCHCA3=0; TCHCA0=0;
248 TCHCB2=TC2*HC2; TCHCB1=0; TCHCB3=0; TCHCB0=0;
252 TCHCC3=TC3*HC3; TCHCC2=0; TCHCC1=0; TCHCC0=0;
256
256  TCRMA1=TC1*RM1; TCRMA2=0; TCRMA3=0; TCRMA0=0;

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260  TCRMB2=TC2*RM2; TCRMB1=0; TCRMB3=0; TCRMB0=0;
264  TCRMC3=TC3*RM3; TCRMC2=0; TCRMC1=0; TCRMC0=0;
268
268  TCTWA1=TC1*TW1; TCTWA2=0; TCTWA3=0; TCTWA0=0;
272  TCTWB2=TC2*TW2; TCTWB1=0; TCTWB3=0; TCTWB0=0;
276  TCTWC3=TC3*TW3; TCTWC2=0; TCTWC1=0; TCTWC0=0;
280
280  TCTSA1=TC1*TS1; TCTSA2=0; TCTSA3=0; TCTSA0=0;
284  TCTSB2=TC2*TS2; TCTSB1=0; TCTSB3=0; TCTSB0=0;
288  TCTSC3=TC3*TS3; TCTSC2=0; TCTSC1=0; TCTSC0=0;
292
292  TCDTSA1=TC1*DTS1; TCDTSA2=0; TCDTSA3=0; TCDTSA0=0;
296  TCDTSB2=TC2*DTS2; TCDTSB1=0; TCDTSB3=0; TCDTSB0=0;
300  TCDTSC3=TC3*DTS3; TCDTSC2=0; TCDTSC1=0; TCDTSC0=0;
304
304  TCRCA1=TC1*RC1; TCRCA2=0; TCRCA3=0; TCRCA0=0;
308  TCRCB2=TC2*RC2; TCRCB1=0; TCRCB3=0; TCRCB0=0;
312  TCRCC3=TC3*RC3; TCRCC2=0; TCRCC1=0; TCRCC0=0;
316
316  DLHCA1=DL1*HC1; DLHCA2=0; DLHCA3=0; DLHCA0=0;
320  DLHCB2=DL2*HC2; DLHCB1=0; DLHCB3=0; DLHCB0=0;
324  DLHCC3=DL3*HC3; DLHCC2=0; DLHCC1=0; DLHCC0=0;
328
328  DLRMA1=DL1*RM1; DLRMA2=0; DLRMA3=0; DLRMA0=0;
332  DLRMB2=DL2*RM2; DLRMB1=0; DLRMB3=0; DLRMB0=0;
336  DLRMC3=DL3*RM3; DLRMC2=0; DLRMC1=0; DLRMC0=0;
340
340  DLTWA1=DL1*TW1; DLTWA2=0; DLTWA3=0; DLTWA0=0;
344  DLTWB2=DL2*TW2; DLTWB1=0; DLTWB3=0; DLTWB0=0;
348  DLTWC3=DL3*TW3; DLTWC2=0; DLTWC1=0; DLTWC0=0;
352
352  DL TSA1=DL1*TS1; DL TSA2=0; DL TSA3=0; DL TSA0=0;
356  DL TSB2=DL2*TS2; DL TSB1=0; DL TSB3=0; DL TSB0=0;
360  DL TSC3=DL3*TS3; DL TSC2=0; DL TSC1=0; DL TSC0=0;
364
364  DLDTSA1=DL1*DTS1; DLDTSA2=0; DLDTSA3=0; DLDTSA0=0;
368  DLDTSB2=DL2*DTS2; DLDTSB1=0; DLDTSB3=0; DLDTSB0=0;
372  DLDTSC3=DL3*DTS3; DLDTSC2=0; DLDTSC1=0; DLDTSC0=0;
376
376  DL RCA1=DL1*RC1; DL RCA2=0; DL RCA3=0; DL RCA0=0;
380  DL RCB2=DL2*RC2; DL RCB1=0; DL RCB3=0; DL RCB0=0;
384  DL RCC3=DL3*RC3; DL RCC2=0; DL RCC1=0; DL RCC0=0;
388
388  TCDL0=0; TCDL1=TC1*DL1; TCDL2=TC2*DL2; TCDL3=TC3*DL3;
392  TCHC0=0; TCHC1=TC1*HC1; TCHC2=TC2*HC2; TCHC3=TC3*HC3;
396  TCRM0=0; TCRM1=TC1*RM1; TCRM2=TC2*RM2; TCRM3=TC3*RM3;
400  TCTW0=0; TCTW1=TC1*TW1; TCTW2=TC2*TW2; TCTW3=TC3*TW3;
404  TCTS0=0; TCTS1=TC1*TS1; TCTS2=TC2*TS2; TCTS3=TC3*TS3;
408  TCDTS0=0; TCDTS1=TC1*DTS1; TCDTS2=TC2*DTS2; TCDTS3=TC3*DTS3;
412  TCRC0=0; TCRC1=TC1*RC1; TCRC2=TC2*RC2; TCRC3=TC3*RC3;
416  DLHC0=0; DLHC1=DL1*HC1; DLHC2=DL2*HC2; DLHC3=DL3*HC3;
420  DLRM0=0; DLRM1=DL1*RM1; DLRM2=DL2*RM2; DLRM3=DL3*RM3;
424  DLTW0=0; DLTW1=DL1*TW1; DLTW2=DL2*TW2; DLTW3=DL3*TW3;
428  DLTS0=0; DLTS1=DL1*TS1; DLTS2=DL2*TS2; DLTS3=DL3*TS3;
432  DL DTS0=0; DL DTS1=DL1*DTS1; DL DTS2=DL2*DTS2; DL DTS3=DL3*DTS3;
436  DLRC0=0; DLRC1=DL1*RC1; DLRC2=DL2*RC2; DLRC3=DL3*RC3;

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440
440 TCQ0=0; TCQ1=((TC1**2)-2/3)*3; TCQ2=((TC2**2)-2/3)*3;
TCQ3=((TC3**2)-2/3)*3;
444 DLQ0=0; DLQ1=((DL1**2)-2/3)*3; DLQ2=((DL2**2)-2/3)*3;
DLQ3=((DL3**2)-2/3)*3;
448 HCQ0=0; HCQ1=((HC1**2)-2/3)*3; HCQ2=((HC2**2)-2/3)*3;
HCQ3=((HC3**2)-2/3)*3;
452 RMQ0=0; RMQ1=((RM1**2)-2/3)*3; RMQ2=((RM2**2)-2/3)*3;
RMQ3=((RM3**2)-2/3)*3;
456 TWQ0=0; TWQ1=((TW1**2)-2/3)*3; TWQ2=((TW2**2)-2/3)*3;
TWQ3=((TW3**2)-2/3)*3;
460 TSQ0=0; TSQ1=((TS1**2)-2/3)*3; TSQ2=((TS2**2)-2/3)*3;
TSQ3=((TS3**2)-2/3)*3;
464 RCQ0=0; RCQ1=((RC1**2)-2/3)*3; RCQ2=((RC2**2)-2/3)*3;
RCQ3=((RC3**2)-2/3)*3;
468 DTSQ0=0; DTSQ1=((DTS1**2)-2/3)*3; DTSQ2=((DTS2**2)-2/3)*3;
DTSQ3=((DTS3**2)-2/3)*3;
472
472 TCBORC2=TC2; TCBORC1=0; TCBORC3=TC3; TCBORC0=0;
476 TWBORC2=TW2; TWBORC1=0; TWBORC3=TW3; TWBORC0=0;
480 DTSBORC2=DTS2; DTSBORC1=0; DTSBORC3=DTS3; DTSBORC0=0;
484 TCR CAB1=TCRC1; TCR CAB2=TCRC2; TCR CAB3=0; TCR CAB0=0;
488 TCTWBC1=0; TCTWBC2=TCTW2; TCTWBC3=TCTW3; TCTWBC0=0;
492 RMQAB1=RMQ1; RMQAB2=RMQ2; RMQAB3=0; RMQAB0=0;
496
496 SMPL 2 3466;
497 SUPRES @DPDX;
498 SUPRES @DPDZ;
499 SET LL0=-4803.51;
500 SET LLC=-4620.90;
501
501 PRINT (FORMAT="( 'FINAL SP MODEL FOR ALL: NO RESTRICTION ON DTSQ' )");
502 LOGIT (COND, NCHOICE=4, MAXIT=20) Y TCA TCBORC DL HCA HCB HCC RMA
RMB RMC
502 TWA TWBORC DTS RC IA IB IC TCDL TCHC TCRM TCTWBC TCRC
502 DLRMA DLRMB DLRMC RMQAB DTSQ RCQ IAQ ICQ | C;
503 SET LL6=@LOGL;
504 SET RHO2=1-(LL6/LL0);
505 SET RHOBAR=1-((LL6-@NCOEF)/LL0);
506 SET LR0= -2*(LL0 -LL6);
507 SET LRC= -2*(LLC -LL6);
508 PRINT @NCOEF RHO2 RHOBAR LR0 LRC;
509
509 ? USING THE GENERAL ML METHOD:
509 GENR Y_0= Y=0;
510 GENR Y_1= Y=1;
511 GENR Y_2= Y=2;
512 GENR Y_3= Y=3;
513
513 ? **IMPOSING RESRTICTIONS ON DTSQ**
513 FRML EQ1 LOGL= Y_1*V1 + Y_2*V2 + Y_3*V3 - LOG[1+EXP(V1)+EXP(V2)+
EXP(V3)];
514 FRML EQV1 V1= D10 + C_TCA*(TCA1-TCA0)+ C_DL*(DL1-DL0)+
C_HCA*(HCA1-HCA0)+ C_RMA*(RMA1-RMA0)
514 + C_TWA*(TWA1-TWA0)+ C_DTS*(DTS1-DTS0)+
C_RC*(RC1-RC0)+ C_IA*(IA1-IA0)

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514          + C_TCDL*(TCDL1-TCDL0) + C_TCHC*(TCHC1-TCHC0) +
C_TCRM*(TCRM1-TCRM0) +
514          + C_TCRC*(TCRC1-TCRC0) + C_RMQAB*(RMQAB1-RMQAB0) +
(C_DTS/6+D*D)*(DTSQ1-DTSQ0)
514          + C_RCQ*(RCQ1-RCQ0) + C_IAQ*(IAQ1-IAQ0)
+C_DLRMA*(DLRMA1-DLRMA0);
515
515  FRML EQV2 V2= D20 + C_TCBC*(TCBORC2-TCBORC0) + C_DL*(DL2-DL0) +
C_HCB*(HCB2-HCB0) + C_RMB*(RMB2-RMB0)
515          + C_TWBC*(TWBORC2-TWBORC0) + C_DTS*(DTS2-DTS0) +
C_RC*(RC2-RC0) + C_IB*(IB2-IB0)
515          + C_TCDL*(TCDL2-TCDL0) + C_TCHC*(TCHC2-TCHC0) +
C_TCRM*(TCRM2-TCRM0) + C_TCTWBC*(TCTWBC2-TCTWBC0)
515          + C_TCRC*(TCRC2-TCRC0) + C_RMQAB*(RMQAB2-RMQAB0) +
(C_DTS/6+D*D)*(DTSQ2-DTSQ0) +
515          + C_RCQ*(RCQ2-RCQ0) + C_DLRMB*(DLRMB2-DLRMB0);
516
516  FRML EQV3 V3= D30 + C_TCBC*(TCBORC3-TCBORC0) + C_DL*(DL3-DL0) +
C_HCC*(HCC3-HCB0) + C_RMC*(RMC3-RMC0)
516          + C_TWBC*(TWBORC3-TWBORC0) + C_DTS*(DTS3-DTS0) +
C_RC*(RC3-RC0) + C_IC*(IC3-IC0)
516          + C_TCDL*(TCDL3-TCDL0) + C_TCHC*(TCHC3-TCHC0) +
C_TCRM*(TCRM3-TCRM0) + C_TCTWBC*(TCTWBC3-TCTWBC0)
516          + C_TCRC*(TCRC3-TCRC0) + (C_DTS/6+D*D)*(DTSQ3-DTSQ0) +
516          + C_RCQ*(RCQ3-RCQ0) +
C_ICQ*(ICQ3-ICQ0) + C_DLRMC*(DLRMC3-DLRMC0);
517
517  PRINT (FORMAT="('IMPOSING RESRTICTIONS ON DTSQ')");
518  FRML C_DTSQ C_DTS/6 + D*D;
519
519  EQSUB(NAME=LOGIT3) EQ1 EQV1 EQV2 EQV3;
520  PARAM D,1;
521  PARAM D10 D20 D30 C_TCA C_TCBC C_DL C_HCA C_HCB C_HCC C_RMA C_RMB
C_RMC
521          C_TWA C_TWBC C_DTS C_RC C_IA C_IB C_IC C_TCDL C_TCHC C_TCRM
521          C_TCTWBC C_TCRC C_DLRMA C_DLRMB C_DLRMC C_RMQAB C_RCQ C_IAQ
C_ICQ;
522
522  PRINT (FORMAT="('THE FINAL SP MODEL FOR ALL WITH IMPOSED
RESRTICTION: DTSQ<1/6DTS')");
523  ML(HITER=N,HCOV=N) LOGIT3;
524  SET LL6=@LOGL;
525  SET RHO2=1-(LL6/LL0);
526  SET RHOBAR=1-((LL6-@NCOEF)/LL0);
527  SET LR0= -2*(LL0 -LL6);
528  SET LRC= -2*(LLC -LL6);
529  PRINT @NCOEF RHO2 RHOBAR LR0 LRC;
530  ANALYZ C_DTSQ;
531  END;

```

EXECUTION

Current sample: 2 to 3466

Current sample: 2 to 3466

FINAL SP MODEL FOR ALL: NO RESTRICTION ON DTSQ

Equation 1
=====

MIXED LOGIT ESTIMATION

CHOICE	FREQUENCY	PERCENT	
0	839	24.2136	(COEFFICIENTS NORMALIZED TO ZERO)
1	801	23.1169	
2	517	14.9206	
3	1308	37.7489	

Working space used: 847931

STARTING VALUES

	TCA	TCBORC	DL	HCA	HCB
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000
	HCC	RMA	RMB	RMC	TWA
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000
	TWBORC	DTS	RC	IA	IB
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000
	IC	TCDL	TCHC	TCRM	TCTWBC
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000
	TCRC	DLRMA	DLRMB	DLRMC	RMQAB
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000
	DTSQ	RCQ	IAQ	ICQ	C1
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000
	C2	C3			
VALUE	0.00000	0.00000			

F=	4803.5	FNEW=	4212.3	ISQZ=	0	STEP=	1.0000	CRIT=	1180.6
F=	4212.3	FNEW=	4185.9	ISQZ=	0	STEP=	1.0000	CRIT=	50.762
F=	4185.9	FNEW=	4185.6	ISQZ=	0	STEP=	1.0000	CRIT=	0.65049
F=	4185.6	FNEW=	4185.6	ISQZ=	0	STEP=	1.0000	CRIT=	0.34953E-03
F=	4185.6	FNEW=	4185.6	ISQZ=	0	STEP=	1.0000	CRIT=	0.12480E-09

CONVERGENCE ACHIEVED AFTER 5 ITERATIONS

10 FUNCTION EVALUATIONS.

DEPENDENT VARIABLE: Y

LOG OF LIKELIHOOD FUNCTION = -4185.57
NUMBER OF CASES = 3465
NUMBER OF CHOICES = 13860

Parameter	Estimate	Standard Error	t-statistic
TCA	.151434	.053248	2.84394
TCBORC	.277754	.037732	7.36126
DL	-.111116	.030469	-3.64686
HCA	-.563427	.054866	-10.2692
HCB	-.626565	.064740	-9.67818
HCC	-.203379	.045921	-4.42886
RMA	.221277	.054588	4.05359
RMB	.341472	.065401	5.22117

RMC	.064786	.045678	1.41832
TWA	-.048419	.052617	-.920209
TWBORC	-.302577	.037880	-7.98787
DTS	-.247953	.046768	-5.30181
RC	.365315	.031366	11.6468
IA	.120342	.017868	6.73488
IB	.021431	.010601	2.02152
IC	.238803	.025966	9.19681
TCDL	-.084280	.038508	-2.18864
TCHC	-.055034	.037691	-1.46015
TCRM	.074782	.038092	1.96319
TCTWBC	.152470	.047340	3.22075
TCRC	.080259	.038936	2.06131
DLRMA	.199005	.067133	2.96435
DLRMB	.220448	.080192	2.74900
DLRMC	.061343	.056600	1.08380
RMQAB	-.067820	.023120	-2.93343
DTSQ	-.092007	.022100	-4.16328
RCQ	-.072651	.017350	-4.18748
IAQ	-.399829E-02	.863700E-03	-4.62926
ICQ	-.966425E-02	.135875E-02	-7.11259
C1	-.553111	.071661	-7.71844
C2	-.850462	.070727	-12.0246
C3	.164610	.054522	3.01913

Standard Errors computed from analytic second derivatives
(Newton)

	@NCOEF	RHO2	RHOBAR	LRO	LRC
Value	32.00000	0.12864	0.12198	1235.87654	870.65654

IMPOSING RESRTICTIONS ON DTSQ

THE FINAL SP MODEL FOR ALL WITH IMPOSED RESRTICTION: DTSQ<1/6DTS

MAXIMUM LIKELIHOOD ESTIMATION

=====

EQUATION: LOGIT3

Working space used: 594663

STARTING VALUES

	D30	C_TCBC	C_DL	C_HCC	C_RMC
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000
	C_TWBC	C_DTS	C_RC	C_IC	C_TCDL
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000
	C_TCHC	C_TCRM	C_TCTWBC	C_TCRC	D
VALUE	0.00000	0.00000	0.00000	0.00000	1.00000
	C_RCQ	C_ICQ	C_DLRMC	D20	C_HCB
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000
	C_RMB	C_IB	C_RMQAB	C_DLRMB	D10
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000
	C_TCA	C_HCA	C_RMA	C_TWA	C_IA
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000

VALUE	C_IAQ 0.00000	C_DLRMA 0.00000				
F= 6539.5	FNEW= 4515.2	ISQZ= 0	STEP= 1.0000	CRIT= 4714.3		
F= 4515.2	FNEW= 4239.0	ISQZ= 0	STEP= 1.0000	CRIT= 665.72		
F= 4239.0	FNEW= 4193.9	ISQZ= 0	STEP= 1.0000	CRIT= 82.493		
F= 4193.9	FNEW= 4189.2	ISQZ= 0	STEP= 1.0000	CRIT= 7.7070		
F= 4189.2	FNEW= 4188.1	ISQZ= 0	STEP= 1.0000	CRIT= 1.8143		
F= 4188.1	FNEW= 4188.0	ISQZ= 0	STEP= 1.0000	CRIT= 0.19657		
F= 4188.0	FNEW= 4188.0	ISQZ= 0	STEP= 1.0000	CRIT= 0.17732E-02		
F= 4188.0	FNEW= 4188.0	ISQZ= 0	STEP= 1.0000	CRIT= 0.11168E-06		
F= 4188.0	FNEW= 4188.0	ISQZ= 1	STEP= 0.50000	CRIT= 0.42977E-15		

CONVERGENCE ACHIEVED AFTER 9 ITERATIONS

18 FUNCTION EVALUATIONS.

LOG OF LIKELIHOOD FUNCTION = -4188.02
NUMBER OF OBSERVATIONS = 3465

Parameter	Estimate	Standard Error	t-statistic
D30	.216936	.049135	4.41507
C_TCBC	.277688	.037730	7.35987
C_DL	-.112444	.030463	-3.69112
C_HCC	-.204926	.045923	-4.46236
C_RMC	.063159	.045647	1.38365
C_TWBC	-.302909	.037884	-7.99576
C_DTS	-.275982	.044559	-6.19362
C_RC	.363966	.031350	11.6099
C_IC	.236163	.025923	9.11029
C_TCDL	-.083101	.038501	-2.15839
C_TCHC	-.053115	.037695	-1.40908
C_TCRM	.076130	.038105	1.99788
C_TCTWBC	.153992	.047377	3.25034
C_TCRC	.083554	.038905	2.14765
D	.118993E-08	.071920	.165452E-07
C_RCQ	-.070839	.017314	-4.09143
C_ICQ	-.953925E-02	.135682E-02	-7.03057
C_DLRMC	.059488	.056548	1.05199
D20	-.800556	.067023	-11.9445
C_HCB	-.626380	.064738	-9.67562
C_RMB	.343977	.065428	5.25730
C_IB	.021285	.010580	2.01186
C_RMQAB	-.068399	.023100	-2.96091
C_DLRMB	.223575	.080229	2.78671
D10	-.501798	.067748	-7.40686
C_TCA	.149094	.053215	2.80173
C_HCA	-.565921	.054857	-10.3162
C_RMA	.224031	.054580	4.10459
C_TWA	-.053933	.052555	-1.02622
C_IA	.119893	.017847	6.71802
C_IAQ	-.396608E-02	.862417E-03	-4.59879
C_DLRMA	.198023	.067146	2.94912

Standard Errors computed from analytic second derivatives
(Newton)

	@NCOEF	RHO2	RHOBAR	LR0	LRC
Value	32.00000	0.12813	0.12147	1230.98173	865.76173

Results of Parameter Analysis

=====

Parameter	Estimate	Standard Error	t-statistic
C_DTSQ	-.045997	.742651E-02	-6.19362

Wald Test for the Hypothesis that the given set of Parameters are jointly zero:

CHISQ(1) = 38.360898 ; P-value = 0.00000

END OF OUTPUT FOR USER REZA

MEMORY USAGE:	ITEM:	DATA ARRAY	TOTAL MEMORY
	UNITS:	(4-BYTE WORDS)	(MEGABYTES)
MEMORY ALLOCATED	:	3500000	16.0
MEMORY ACTUALLY REQUIRED	:	2715951	13.0
CURRENT VARIABLE STORAGE	:	1860428	

Appendix B4: Source Code for the Jackknife Procedure

```

OPTIONS MEMORY= 30;
FREQ N;
SMPL 2 3466;
READ (FILE='F:\TSP43\FINALNEW\SPJACK.XLS') OBS Y TC1 TC2 TC3 DL1 DL2 DL3
  HC1 HC2 HC3 RM1 RM2 RM3 TW1 TW2 TW3 TS1 TS2 TS3 RC1 RC2 RC3 IA IB IC CHLD JACK;

TC0=0; DL0=0; HC0=0; RM0=0; TW0=0; TS0=0; RC0=0;
TCA1=TC1; TCA2=0; TCA3=0; TCA0=0;
TCB2=TC2; TCB1=0; TCB3=0; TCB0=0;
TCC3=TC3; TCC2=0; TCC1=0; TCC0=0;

DLA1=DL1; DLA2=0; DLA3=0; DLA0=0;
DLB2=DL2; DLB1=0; DLB3=0; DLB0=0;
DLC3=DL3; DLC2=0; DLC1=0; DLC0=0;

HCA1=HC1; HCA2=0; HCA3=0; HCA0=0;
HCB2=HC2; HCB1=0; HCB3=0; HCB0=0;
HCC3=HC3; HCC2=0; HCC1=0; HCC0=0;

RMA1=RM1; RMA2=0; RMA3=0; RMA0=0;
RMB2=RM2; RMB1=0; RMB3=0; RMB0=0;
RMC3=RM3; RMC2=0; RMC1=0; RMC0=0;

TWA1=TW1; TWA2=0; TWA3=0; TWA0=0;
TWB2=TW2; TWB1=0; TWB3=0; TWB0=0;
TWC3=TW3; TWC2=0; TWC1=0; TWC0=0;

TSA1=TS1; TSA2=0; TSA3=0; TSA0=0;
TSB2=TS2; TSB1=0; TSB3=0; TSB0=0;
TSC3=TS3; TSC2=0; TSC1=0; TSC0=0;

RCA1=RC1; RCA2=0; RCA3=0; RCA0=0;
RCB2=RC2; RCB1=0; RCB3=0; RCB0=0;
RCC3=RC3; RCC2=0; RCC1=0; RCC0=0;

IA1=IA; IA2=0; IA3=0; IA0=0; IB2=IB; IB1=0; IB3=0; IB0=0; IC3=IC; IC2=0; IC1=0; IC0=0;
IAQ1=IA1**2; IAQ2=0; IAQ3=0; IAQ0=0;
IBQ2=IB2**2; IBQ1=0; IBQ3=0; IBQ0=0;
ICQ3=IC3**2; ICQ2=0; ICQ1=0; ICQ0=0;

DTS0=0; DTS1=TS1*CHLD; DTS2=TS2*CHLD; DTS3=TS3*CHLD;
DTSA1=DTS1; DTSA2=0; DTSA3=0; DTSA0=0;
DTSB2=DTS2; DTSB1=0; DTSB3=0; DTSB0=0;
DTSC3=DTS3; DTSC2=0; DTSC1=0; DTSC0=0;

TCQA1=((TC1**2)-2/3)*3; TCQA2=0; TCQA3=0; TCQA0=0;
TCQB2=((TC2**2)-2/3)*3; TCQB1=0; TCQB3=0; TCQB0=0;
TCQC3=((TC3**2)-2/3)*3; TCQC2=0; TCQC1=0; TCQC0=0;

DLQA1=((DL1**2)-2/3)*3; DLQA2=0; DLQA3=0; DLQA0=0;
DLQB2=((DL2**2)-2/3)*3; DLQB1=0; DLQB3=0; DLQB0=0;
DLQC3=((DL3**2)-2/3)*3; DLQC2=0; DLQC1=0; DLQC0=0;

```


HCQA1=((HC1**2)-2/3)*3; HCQA2=0; HCQA3=0; HCQA0=0;
 HCQB2=((HC2**2)-2/3)*3; HCQB1=0; HCQB3=0; HCQB0=0;
 HCQC3=((HC3**2)-2/3)*3; HCQC2=0; HCQC1=0; HCQC0=0;

RMQA1=((RM1**2)-2/3)*3; RMQA2=0; RMQA3=0; RMQA0=0;
 RMQB2=((RM2**2)-2/3)*3; RMQB1=0; RMQB3=0; RMQB0=0;
 RMQC3=((RM3**2)-2/3)*3; RMQC2=0; RMQC1=0; RMQC0=0;

TWQA1=((TW1**2)-2/3)*3; TWQA2=0; TWQA3=0; TWQA0=0;
 TWQB2=((TW2**2)-2/3)*3; TWQB1=0; TWQB3=0; TWQB0=0;
 TWQC3=((TW3**2)-2/3)*3; TWQC2=0; TWQC1=0; TWQC0=0;

TSQA1=((TS1**2)-2/3)*3; TSQA2=0; TSQA3=0; TSQA0=0;
 TSQB2=((TS2**2)-2/3)*3; TSQB1=0; TSQB3=0; TSQB0=0;
 TSQC3=((TS3**2)-2/3)*3; TSQC2=0; TSQC1=0; TSQC0=0;

DTSQA1=((DTS1**2)-2/3)*3; DTSQA2=0; DTSQA3=0; DTSQA0=0;
 DTSQB2=((DTS2**2)-2/3)*3; DTSQB1=0; DTSQB3=0; DTSQB0=0;
 DTSQC3=((DTS3**2)-2/3)*3; DTSQC2=0; DTSQC1=0; DTSQC0=0;

RCQA1=((RC1**2)-2/3)*3; RCQA2=0; RCQA3=0; RCQA0=0;
 RCQB2=((RC2**2)-2/3)*3; RCQB1=0; RCQB3=0; RCQB0=0;
 RCQC3=((RC3**2)-2/3)*3; RCQC2=0; RCQC1=0; RCQC0=0;

TCDLA1=TC1*DL1; TCDLA2=0; TCDLA3=0; TCDLA0=0;
 TCDLB2=TC2*DL2; TCDLB1=0; TCDLB3=0; TCDLB0=0;
 TCDLC3=TC3*DL3; TCDLC2=0; TCDLC1=0; TCDLC0=0;

TCHCA1=TC1*HC1; TCHCA2=0; TCHCA3=0; TCHCA0=0;
 TCHCB2=TC2*HC2; TCHCB1=0; TCHCB3=0; TCHCB0=0;
 TCHCC3=TC3*HC3; TCHCC2=0; TCHCC1=0; TCHCC0=0;

TCRMA1=TC1*RM1; TCRMA2=0; TCRMA3=0; TCRMA0=0;
 TCRMB2=TC2*RM2; TCRMB1=0; TCRMB3=0; TCRMB0=0;
 TCRMC3=TC3*RM3; TCRMC2=0; TCRMC1=0; TCRMC0=0;

TCTWA1=TC1*TW1; TCTWA2=0; TCTWA3=0; TCTWA0=0;
 TCTWB2=TC2*TW2; TCTWB1=0; TCTWB3=0; TCTWB0=0;
 TCTWC3=TC3*TW3; TCTWC2=0; TCTWC1=0; TCTWC0=0;

TCTSA1=TC1*TS1; TCTSA2=0; TCTSA3=0; TCTSA0=0;
 TCTSB2=TC2*TS2; TCTSB1=0; TCTSB3=0; TCTSB0=0;
 TCTSC3=TC3*TS3; TCTSC2=0; TCTSC1=0; TCTSC0=0;

TCDTSA1=TC1*DTS1; TCDTSA2=0; TCDTSA3=0; TCDTSA0=0;
 TCDTSB2=TC2*DTS2; TCDTSB1=0; TCDTSB3=0; TCDTSB0=0;
 TCDTSC3=TC3*DTS3; TCDTSC2=0; TCDTSC1=0; TCDTSC0=0;

TCRCA1=TC1*RC1; TCRCA2=0; TCRCA3=0; TCRCA0=0;
 TCRCB2=TC2*RC2; TCRCB1=0; TCRCB3=0; TCRCB0=0;
 TCRCC3=TC3*RC3; TCRCC2=0; TCRCC1=0; TCRCC0=0;

DLHCA1=DL1*HC1; DLHCA2=0; DLHCA3=0; DLHCA0=0;
 DLHCB2=DL2*HC2; DLHCB1=0; DLHCB3=0; DLHCB0=0;
 DLHCC3=DL3*HC3; DLHCC2=0; DLHCC1=0; DLHCC0=0;

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DLRMA1=DL1*RM1; DLRMA2=0; DLRMA3=0; DLRMA0=0;
DLRMB2=DL2*RM2; DLRMB1=0; DLRMB3=0; DLRMB0=0;
DLRMC3=DL3*RM3; DLRMC2=0; DLRMC1=0; DLRMC0=0;

DLTWA1=DL1*TW1; DLTWA2=0; DLTWA3=0; DLTWA0=0;
DLTWB2=DL2*TW2; DLTWB1=0; DLTWB3=0; DLTWB0=0;
DLTWC3=DL3*TW3; DLTWC2=0; DLTWC1=0; DLTWC0=0;

DLTSA1=DL1*TS1; DLTSA2=0; DLTSA3=0; DLTSA0=0;
DLTSB2=DL2*TS2; DLTSB1=0; DLTSB3=0; DLTSB0=0;
DLTSC3=DL3*TS3; DLTSC2=0; DLTSC1=0; DLTSC0=0;

DLDTSA1=DL1*DTS1; DLDTSA2=0; DLDTSA3=0; DLDTSA0=0;
DLDTSB2=DL2*DTS2; DLDTSB1=0; DLDTSB3=0; DLDTSB0=0;
DLDTSC3=DL3*DTS3; DLDTSC2=0; DLDTSC1=0; DLDTSC0=0;

DLRCA1=DL1*RC1; DLRCA2=0; DLRCA3=0; DLRCA0=0;
DLRCB2=DL2*RC2; DLRCB1=0; DLRCB3=0; DLRCB0=0;
DLRCC3=DL3*RC3; DLRCC2=0; DLRCC1=0; DLRCC0=0;

TCDL0=0; TCDL1=TC1*DL1; TCDL2=TC2*DL2; TCDL3=TC3*DL3;
TCHC0=0; TCHC1=TC1*HC1; TCHC2=TC2*HC2; TCHC3=TC3*HC3;
TCRM0=0; TCRM1=TC1*RM1; TCRM2=TC2*RM2; TCRM3=TC3*RM3;
TCTW0=0; TCTW1=TC1*TW1; TCTW2=TC2*TW2; TCTW3=TC3*TW3;
TCTS0=0; TCTS1=TC1*TS1; TCTS2=TC2*TS2; TCTS3=TC3*TS3;
TCDS0=0; TCDS1=TC1*DTS1; TCDS2=TC2*DTS2; TCDS3=TC3*DTS3;
TCRC0=0; TCRC1=TC1*RC1; TCRC2=TC2*RC2; TCRC3=TC3*RC3;
DLHC0=0; DLHC1=DL1*HC1; DLHC2=DL2*HC2; DLHC3=DL3*HC3;
DLRM0=0; DLRM1=DL1*RM1; DLRM2=DL2*RM2; DLRM3=DL3*RM3;
DLTW0=0; DLTW1=DL1*TW1; DLTW2=DL2*TW2; DLTW3=DL3*TW3;
DLTS0=0; DLTS1=DL1*TS1; DLTS2=DL2*TS2; DLTS3=DL3*TS3;
DLDS0=0; DLDS1=DL1*DTS1; DLDS2=DL2*DTS2; DLDS3=DL3*DTS3;
DLRC0=0; DLRC1=DL1*RC1; DLRC2=DL2*RC2; DLRC3=DL3*RC3;

TCQ0=0; TCQ1=((TC1**2)-2/3)*3; TCQ2=((TC2**2)-2/3)*3; TCQ3=((TC3**2)-2/3)*3;
DLQ0=0; DLQ1=((DL1**2)-2/3)*3; DLQ2=((DL2**2)-2/3)*3; DLQ3=((DL3**2)-2/3)*3;
HCQ0=0; HCQ1=((HC1**2)-2/3)*3; HCQ2=((HC2**2)-2/3)*3; HCQ3=((HC3**2)-2/3)*3;
RMQ0=0; RMQ1=((RM1**2)-2/3)*3; RMQ2=((RM2**2)-2/3)*3; RMQ3=((RM3**2)-2/3)*3;
TWQ0=0; TWQ1=((TW1**2)-2/3)*3; TWQ2=((TW2**2)-2/3)*3; TWQ3=((TW3**2)-2/3)*3;
TSQ0=0; TSQ1=((TS1**2)-2/3)*3; TSQ2=((TS2**2)-2/3)*3; TSQ3=((TS3**2)-2/3)*3;
RCQ0=0; RCQ1=((RC1**2)-2/3)*3; RCQ2=((RC2**2)-2/3)*3; RCQ3=((RC3**2)-2/3)*3;
DTSQ0=0; DTSQ1=((DTS1**2)-2/3)*3; DTSQ2=((DTS2**2)-2/3)*3; DTSQ3=((DTS3**2)-2/3)*3;

TCBORC2=TC2; TCBORC1=0; TCBORC3=TC3; TCBORC0=0; TWBORC2=TW2; TWBORC1=0;
TWBORC3=TW3; TWBORC0=0; DTSBORC2=DTS2; DTSBORC1=0; DTSBORC3=DTS3; DTSBORC0=0;
TCRCAB1=TCRC1; TCRCAB2=TCRC2; TCRCAB3=0; TCRCAB0=0; TCTWBC1=0; TCTWBC2=TCTW2;
TCTWBC3=TCTW3; TCTWBC0=0; RMQAB1=RMQ1; RMQAB2=RMQ2; RMQAB3=0; RMQAB0=0;

SMPL 2 3466;
SUPRES @DPDX;
SUPRES @DPDZ;
SET LL0=-4803.51;
SET LLC=-4620.90;
PRINT (FORMAT="('FINAL SP MODEL FOR ALL: ABOVE WITHOUT TCTWA')");
LOGIT (COND, NCHOICE=4, MAXIT=20) Y TCA TCBORC DL HCA HCB HCC RMA RMB RMC

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      TWA TWBORC DTS RC IA IB IC TCDL TCHC TCRM TCTWBC TCRC
      DLRMA DLRMB DLRMC RMQAB DTSQ RCQ IAQ ICQ | C;
SET LL6=@LOGL;
SET RHO2=1-(LL6/LL0);
SET RHOBAR=1-((LL6-@NCOEF)/LL0);
SET LR0= -2*(LL0 -LL6);
SET LRC= -2*(LLC -LL6);
PRINT @NCOEF RHO2 RHOBAR LR0 LRC;
? *****
? ***Matrix operation to obtain modified t-stats***
? *****
MAT BB=@COEF;
MAT TST=@T;
SET G=15; SET I=1;
SET K=@NCOEF;
SMPL 1 K;
X=0;
MMAKE BBAR X;
SET J=K*k;
SMPL 1 J;
X=0;
MFORM (TYPE=GENERAL, NCOL=K, NROW=K) X VARB;
DOT 1-15;
  SMPL 2 3466;
  SMPLIF JACK ^=I;
  LOGIT (COND, NCHOICE=4, MAXIT=20) Y TCA TCBORC DL HCA HCB HCC RMA RMB RMC
      TWA TWBORC DTS RC IA IB IC TCDL TCHC TCRM TCTWBC TCRC
      DLRMA DLRMB DLRMC RMQAB DTSQ RCQ IAQ ICQ | C;
  SET LL6=@LOGL;
  SET RHO2=1-(LL6/LL0);
  SET RHOBAR=1-((LL6-@NCOEF)/LL0);
  SET LR0= -2*(LL0 -LL6);
  SET LRC= -2*(LLC -LL6);
  PRINT @NCOEF RHO2 RHOBAR LR0 LRC;
  MAT BST.=(BB*G)-((G-1)*@COEF);
  MAT BBAR=BBAR+(BST./G);
  SET I=I+1;
ENDDOT;
PRINT BBAR;
SET GG=G*(G-1);
DOT 1-15;
  MAT Q=BST.-BBAR;
  MAT VARB=VARB+(Q*Q')/GG;
ENDDOT;
MAT VARBDIAG=DIAG(VARB);
PRINT VARBDIAG;

SMPL 1 K;
UNMAKE VARBDIAG SDIAG;
SDIAGSQ=SQRT(SDIAG);
UNMAKE BB BORIG;
UNMAKE TST TSTORIG;
TSTNEW=BORIG/SDIAGSQ;
PRINT BORIG SDIAGSQ TSTNEW TSTORIG;
END;

```

Appendix B5: Combined RP+SP Model Source Code and Output

TSP Version 4.3A
 (10/26/95) DOS/Win 25MB
 Copyright (C) 1995 TSP International
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 03/01/00 4:29 PM

In case of questions or problems, see your local TSP
 consultant or send a description of the problem and the
 associated TSP output to:

TSP International
 P.O. Box 61015, Station A
 Palo Alto, CA 94306
 USA

PROGRAM

```

LINE *****
1  OPTIONS MEMORY= 25;
2  ?*** JOINT RP AND SP DATA FOR THE WHOLE SAMPLE
2  FREQ N;
3  SMPL 1 3465;
4  READ (FILE='F:\TSP43\FINALNEW\SPJNTNEW.XLS') OBS Y TC1 TC2 TC3 DL1
DL2 DL3 HC1 HC2 HC3 RM1 RM2 RM3 TW1 TW2 TW3 TS1 TS2 TS3 RC1 RC2 RC3 IA IB
IC CHLD NRC1 NRC2 NRC3 NTC1 NTC2 NTC3;
5  TC0=0; DL0=0; HC0=0; RM0=0; TW0=0; TS0=0; RC0=0; NRC0=0; NTC0=0;
14 DTS0=0;DTS1=TS1*CHLD;DTS2=TS2*CHLD;DTS3=TS3*CHLD;
18
18  SET MU=2.948;
19
19  D11=MU; D12=0; D13=0; D10=0;
23  D22=MU; D21=0; D23=0; D20=0;
27  D33=MU; D32=0; D31=0; D30=0;
31
31  TC1=TC1*MU;TC2=TC2*MU;TC3=TC3*MU;
34
34  TCDL0=0;TCDL1=TC1*DL1;TCDL2=TC2*DL2;TCDL3=TC3*DL3;
38  TCHC0=0;TCHC1=TC1*HC1;TCHC2=TC2*HC2;TCHC3=TC3*HC3;
42  TCRM0=0;TCRM1=TC1*RM1;TCRM2=TC2*RM2;TCRM3=TC3*RM3;
46  TCTW0=0;TCTW1=TC1*TW1;TCTW2=TC2*TW2;TCTW3=TC3*TW3;
50  TCTS0=0;TCTS1=TC1*TS1;TCTS2=TC2*TS2;TCTS3=TC3*TS3;
54  TCDTS0=0;TCDTS1=TC1*DTS1;TCDTS2=TC2*DTS2;TCDTS3=TC3*DTS3;
58  TCRC0=0;TCRC1=TC1*RC1;TCRC2=TC2*RC2;TCRC3=TC3*RC3;
62
62  TCDLA1=TC1*DL1; TCDLA2=0; TCDLA3=0; TCDLA0=0;
66  TCDLB2=TC2*DL2; TCDLB1=0; TCDLB3=0; TCDLB0=0;
70  TCDLC3=TC3*DL3; TCDLC2=0; TCDLC1=0; TCDLC0=0;
74
74  TCHCA1=TC1*HC1; TCHCA2=0; TCHCA3=0; TCHCA0=0;
78  TCHCB2=TC2*HC2; TCHCB1=0; TCHCB3=0; TCHCB0=0;
82  TCHCC3=TC3*HC3; TCHCC2=0; TCHCC1=0; TCHCC0=0;
86
86  TCRMA1=TC1*RM1; TCRMA2=0; TCRMA3=0; TCRMA0=0;
90  TCRMB2=TC2*RM2; TCRMB1=0; TCRMB3=0; TCRMB0=0;
94  TCRMC3=TC3*RM3; TCRMC2=0; TCRMC1=0; TCRMC0=0;
98

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98  TCTWA1=TC1*TW1; TCTWA2=0; TCTWA3=0; TCTWA0=0;
102 TCTWB2=TC2*TW2; TCTWB1=0; TCTWB3=0; TCTWB0=0;
106 TCTWC3=TC3*TW3; TCTWC2=0; TCTWC1=0; TCTWC0=0;
110
110 TCTSA1=TC1*TS1; TCTSA2=0; TCTSA3=0; TCTSA0=0;
114 TCTSB2=TC2*TS2; TCTSB1=0; TCTSB3=0; TCTSB0=0;
118 TCTSC3=TC3*TS3; TCTSC2=0; TCTSC1=0; TCTSC0=0;
122
122 TCDTSA1=TC1*DTS1; TCDTSA2=0; TCDTSA3=0; TCDTSA0=0;
126 TCDTSB2=TC2*DTS2; TCDTSB1=0; TCDTSB3=0; TCDTSB0=0;
130 TCDTSC3=TC3*DTS3; TCDTSC2=0; TCDTSC1=0; TCDTSC0=0;
134
134 TCRCA1=TC1*RC1; TCRCA2=0; TCRCA3=0; TCRCA0=0;
138 TCRCB2=TC2*RC2; TCRCB1=0; TCRCB3=0; TCRCB0=0;
142 TCRCC3=TC3*RC3; TCRCC2=0; TCRCC1=0; TCRCC0=0;
146
146
146 TCBORC2=TC2; TCBORC1=0; TCBORC3=TC3; TCBORC0=0;
150 TCR CAB1=TCRC1; TCR CAB2=TCRC2; TCR CAB3=0; TCR CAB0=0;
154 TCTWBC1=0; TCTWBC2=TC2*TW2; TCTWBC3=TC3*TW3; TCTWBC0=0;
158
158 DTSQ0=0; DTSQ1=(DTS1**2)*MU; DTSQ2=(DTS2**2)*MU; DTSQ3=(DTS3**2)*MU;
162 RMQ0=0; RMQ1=(RM1**2)*MU; RMQ2=(RM2**2)*MU; RMQ3=(RM3**2)*MU;
166 RCQ0=0; RCQ1=(RC1**2)*MU; RCQ2=(RC2**2)*MU; RCQ3=(RC3**2)*MU;
170
170 DL1=DL1*MU; DL2=DL2*MU; DL3=DL3*MU;
173 HC1=HC1*MU; HC2=HC2*MU; HC3=HC3*MU;
176 RM1=RM1*MU; RM2=RM2*MU; RM3=RM3*MU;
179 TW1=TW1*MU; TW2=TW2*MU; TW3=TW3*MU;
182 TS1=TS1*MU; TS2=TS2*MU; TS3=TS3*MU;
185 DTS1=DTS1*MU; DTS2=DTS2*MU; DTS3=DTS3*MU;
188 RC1=RC1*MU; RC2=RC2*MU; RC3=RC3*MU;
191
191 TCA1=TC1; TCA2=0; TCA3=0; TCA0=0;
195 TCB2=TC2; TCB1=0; TCB3=0; TCB0=0;
199 TCC3=TC3; TCC2=0; TCC1=0; TCC0=0;
203
203 DLA1=DL1; DLA2=0; DLA3=0; DLA0=0;
207 DLB2=DL2; DLB1=0; DLB3=0; DLB0=0;
211 DLC3=DL3; DLC2=0; DLC1=0; DLC0=0;
215
215 HCA1=HC1; HCA2=0; HCA3=0; HCA0=0;
219 HCB2=HC2; HCB1=0; HCB3=0; HCB0=0;
223 HCC3=HC3; HCC2=0; HCC1=0; HCC0=0;
227
227 RMA1=RM1; RMA2=0; RMA3=0; RMA0=0;
231 RMB2=RM2; RMB1=0; RMB3=0; RMB0=0;
235 RMC3=RM3; RMC2=0; RMC1=0; RMC0=0;
239
239 TWA1=TW1; TWA2=0; TWA3=0; TWA0=0;
243 TWB2=TW2; TWB1=0; TWB3=0; TWB0=0;
247 TWC3=TW3; TWC2=0; TWC1=0; TWC0=0;
251
251 TSA1=TS1; TSA2=0; TSA3=0; TSA0=0;
255 TSB2=TS2; TSB1=0; TSB3=0; TSB0=0;
259 TSC3=TS3; TSC2=0; TSC1=0; TSC0=0;

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263
263 RCA1=RC1; RCA2=0; RCA3=0; RCA0=0;
267 RCB2=RC2; RCB1=0; RCB3=0; RCB0=0;
271 RCC3=RC3; RCC2=0; RCC1=0; RCC0=0;
275
275 IA1=IA*MU; IA2=0; IA3=0; IA0=0;
279 IB2=IB*MU; IB1=0; IB3=0; IB0=0;
283 IC3=IC*MU; IC2=0; IC1=0; IC0=0;
287
287 IAQ1=(IA**2)*MU; IAQ2=0; IAQ3=0; IAQ0=0;
291 IBQ2=(IB**2)*MU; IBQ1=0; IBQ3=0; IBQ0=0;
295 ICQ3=(IC**2)*MU; ICQ2=0; ICQ1=0; ICQ0=0;
299
299 DTS1=DTS1; DTS2=0; DTS3=0; DTS0=0;
303 DTSB2=DTS2; DTSB1=0; DTSB3=0; DTSB0=0;
307 DTSC3=DTS3; DTSC2=0; DTSC1=0; DTSC0=0;
311
311 TWBORC2=TW2; TWBORC1=0; TWBORC3=TW3; TWBORC0=0;
315 DTSBORC2=DTS2; DTSBORC1=0; DTSBORC3=DTS3; DTSBORC0=0;
319 RMQAB1=RMQ1; RMQAB2=RMQ2; RMQAB3=0; RMQAB0=0;
323 DLRM0=0; DLRM1=DL1*RM1/MU; DLRM2=DL2*RM2/MU; DLRM3=DL3*RM3/MU;
327
327 MSD(NOPRINT, CORR) TC1 TC2 TC3 DL1 DL2 DL3 HC1 HC2 HC3 RM1 RM2 RM3
TW1 TW2 TW3 DTS1 DTS2 DTS3 TCDL1 TCDL2 TCDL3 TCRM1 TCRM2 TCRM3 TCTW1
TCTW2 TCTW3 RMQ1 RMQ2 RMQ3 DTSQ1 DTSQ2 DTSQ3 RC1 RC2 RC3 RCQ1 RCQ2 RCQ3
TCHC1 TCHC2 TCHC3 TCRC1 TCRC2 TCRC3 DLRM1 DLRM2 DLRM3;
328
328 SET MEANHC1=@MEAN(7); SET MEANHC2=@MEAN(8); SET MEANHC3=@MEAN(9);
331 SET MEANRM1=@MEAN(10); SET MEANRM2=@MEAN(11); SET MEANRM3=@MEAN(12);
334 SET MEANTW1=@MEAN(13); SET MEANTW2=@MEAN(14); SET MEANTW3=@MEAN(15);
337
337 MTC1=-@MEAN(1)+TC1; MTC2=-@MEAN(2)+TC2; MTC3=-@MEAN(3)+TC3;
340 MDL1=-@MEAN(4)+DL1; MDL2=-@MEAN(5)+DL2; MDL3=-@MEAN(6)+DL3;
343 MHC1=-@MEAN(7)+HC1; MHC2=-@MEAN(8)+HC2; MHC3=-@MEAN(9)+HC3;
346 MRM1=-@MEAN(10)+RM1; MRM2=-@MEAN(11)+RM2; MRM3=-@MEAN(12)+RM3;
349 MTW1=-@MEAN(13)+TW1; MTW2=-@MEAN(14)+TW2; MTW3=-@MEAN(15)+TW3;
352 MDTS1=-@MEAN(16)+DTS1; MDTS2=-@MEAN(17)+DTS2; MDTS3=-@MEAN(18)+DTS3;
355 MTCDL1=-@MEAN(19)+TCDL1; MTCDL2=-@MEAN(20)+TCDL2;
MTCDL3=-@MEAN(21)+TCDL3;
358 MTCRM1=-@MEAN(22)+TCRM1; MTCRM2=-@MEAN(23)+TCRM2;
MTCRM3=-@MEAN(24)+TCRM3;
361 MTCTW1=-@MEAN(25)+TCTW1; MTCTW2=-@MEAN(26)+TCTW2;
MTCTW3=-@MEAN(27)+TCTW3;
364 MRMQ1=-@MEAN(28)+RMQ1; MRMQ2=-@MEAN(29)+RMQ2; MRMQ3=-@MEAN(30)+RMQ3;
367 MDTSQ1=-@MEAN(31)+DTSQ1; MDTSQ2=-@MEAN(32)+DTSQ2;
MDTSQ3=-@MEAN(33)+DTSQ3;
370 MRC1=-@MEAN(34)+RC1; MRC2=-@MEAN(35)+RC2; MRC3=-@MEAN(36)+RC3;
373 MRCQ1=-@MEAN(37)+RCQ1; MRCQ2=-@MEAN(38)+RCQ2; MRCQ3=-@MEAN(39)+RCQ3;
376 MTCHC1=-@MEAN(40)+TCHC1; MTCHC2=-@MEAN(41)+TCHC2;
MTCHC3=-@MEAN(42)+TCHC3;
379 MTCRC1=-@MEAN(43)+TCRC1; MTCRC2=-@MEAN(44)+TCRC2;
MTCRC3=-@MEAN(45)+TCRC3;
382 MDLRM1=-@MEAN(46)+DLRM1; MDLRM2=-@MEAN(47)+DLRM2;
MDLRM3=-@MEAN(48)+DLRM3;
385
385 MTC0=0; MDL0=0; MHC0=0; MRM0=0; MTW0=0; MDTS0=0; MRC0=0;

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392  MTCDL0=0; MTCRM0=0; MTCTW0=0; MRMQ0=0; MDTSQ0=0; MRCQ0=0; MTCHC0=0;
MTCRC0=0; MDLRM0=0;
401
401  MTCA1=MTC1; MTCA2=0; MTCA3=0; MTCA0=0;
405  MTCB2=MTC2; MTCB1=0; MTCB3=0; MTCB0=0;
409  MTCC3=MTC3; MTCC2=0; MTCC1=0; MTCC0=0;
413
413  MDLA1=MDL1; MDLA2=0; MDLA3=0; MDLA0=0;
417  MDLB2=MDL2; MDLB1=0; MDLB3=0; MDLB0=0;
421  MDLC3=MDL3; MDLC2=0; MDLC1=0; MDLC0=0;
425
425  MHCA1=MHC1; MHCA2=0; MHCA3=0; MHCA0=0;
429  MHCB2=MHC2; MHCB1=0; MHCB3=0; MHCB0=0;
433  MHCC3=MHC3; MHCC2=0; MHCC1=0; MHCC0=0;
437
437  MRMA1=MRM1; MRMA2=0; MRMA3=0; MRMA0=0;
441  MRMB2=MRM2; MRMB1=0; MRMB3=0; MRMB0=0;
445  MRMC3=MRM3; MRMC2=0; MRMC1=0; MRMC0=0;
449
449  MTWA1=MTW1; MTWA2=0; MTWA3=0; MTWA0=0;
453  MTWB2=MTW2; MTWB1=0; MTWB3=0; MTWB0=0;
457  MTWC3=MTW3; MTWC2=0; MTWC1=0; MTWC0=0;
461
461  MDTSA1=MDTS1; MDTSA2=0; MDTSA3=0; MDTSA0=0;
465  MDTSB2=MDTS2; MDTSB1=0; MDTSB3=0; MDTSB0=0;
469  MDTSC3=MDTS3; MDTSC2=0; MDTSC1=0; MDTSC0=0;
473
473  MTCDL0=0; MTCDL1=MTC1*MDL1/MU; MTCDL2=MTC2*MDL2/MU; MTCDL3=MTC3*MDL3/MU;
477  MTCRM0=0; MTCRM1=MTC1*MRM1/MU; MTCRM2=MTC2*MRM2/MU; MTCRM3=MTC3*MRM3/MU;
481  MTCTWA1=MTC1*MTW1/MU; MTCTWA2=0; MTCTWA3=0; MTCTWA0=0;
485  MTCTWBC2=MTC2*MTW2/MU; MTCTWBC1=0; MTCTWBC3=MTC3*MTW3/MU; MTCTWBC0=0;
489  MTCHC0=0; MTCHC1=MTC1*MHC1/MU; MTCHC2=MTC2*MHC2/MU;
MTCHC3=MTC3*MHC3/MU;
493  MTCRC0=0; MTCRC1=MTC1*MRC1/MU; MTCRC2=MTC2*MRC2/MU;
MTCRC3=MTC3*MRC3/MU;
497  MDLRMA0=0; MDLRMA1=MDL1*MRM1/MU; MDLRMA2=0; MDLRMA3=0;
501  MDLRMB0=0; MDLRMB2=MDL2*MRM2/MU; MDLRMB3=0; MDLRMB1=0;
505  MDLRMC0=0; MDLRMC3=MDL3*MRM3/MU; MDLRMC2=0; MDLRMC1=0;
509
509  MTCBORC2=MTC2; MTCBORC1=0; MTCBORC3=MTC3; MTCBORC0=0;
513  MTWBORC2=MTW2; MTWBORC1=0; MTWBORC3=MTW3; MTWBORC0=0;
517  MTSBORC2=MDTS2; MTSBORC1=0; MTSBORC3=MDTS3; MTSBORC0=0;
521  MHCAORB1=MHC1; MHCAORB2=MHC2; MHCAORB3=0; MHCAORB0=0;
525  MDLRMAB1=MDLRMA1; MDLRMAB2=MDLRMB2; MDLRMAB3=0; MDLRMAB0=0;
529
529  MRMQAB1=MRMQ1; MRMQAB2=MRMQ2; MRMQAB3=0; MRMQAB0=0;
533  MRMQC3=MRMQ3; MRMQC2=0; MRMQC1=0; MRMQC0=0;
537
537
NRCQ1=((NRC1**2)-2/3)*3*MU; NRCQ2=((NRC2**2)-2/3)*3*MU; NRCQ3=((NRC3**2)-2/
3)*3*MU; NRCQ0=0;
541  NRC1=NRC1*MU; NRC2=NRC2*MU; NRC3=NRC3*MU;
544  NTC1=NTC1*MU; NTC2=NTC2*MU; NTC3=NTC3*MU;
547  NTCA1=NTC1; NTCA2=0; NTCA3=0; NTCA0=0;
551  NTCBORC2=NTC2; NTCBORC3=NTC3; NTCBORC1=0; NTCBORC0=0;
555  NTCDL0=0; NTCDL1=NTC1*DL1/MU; NTCDL2=NTC2*DL2/MU; NTCDL3=NTC3*DL3/MU;

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559  NTCRM0=0; NTCRM1=NTC1*RM1/MU; NTCRM2=NTC2*RM2/MU; NTCRM3=NTC3*RM3/MU;
563  NTCTW0=0; NTCTW1=NTC1*TW1/MU; NTCTW2=NTC2*TW2/MU; NTCTW3=NTC3*TW3/MU;
567
567  MSD(NOPRINT,CORR) NTC1 NTC2 NTC3 NTCDL1 NTCDL2 NTCDL3 NTCRM1 NTCRM2
NTCRM3 NTCTW1 NTCTW2 NTCTW3 NRC1 NRC2 NRC3 NRCQ1 NRCQ2 NRCQ3;
568  MNTC1=-@MEAN(1)+NTC1; MNTC2=-@MEAN(2)+NTC2; MNTC3=-@MEAN(3)+NTC3;
571
MNTCDL1=-@MEAN(4)+NTCDL1;MNTCDL2=-@MEAN(5)+NTCDL2;MNTCDL3=-@MEAN(6)+
NTCDL3;
574
MNTCRM1=-@MEAN(7)+NTCRM1;MNTCRM2=-@MEAN(8)+NTCRM2;MNTCRM3=-@MEAN(9)+
NTCRM3;
577
MNTCTW1=-@MEAN(10)+NTCTW1;MNTCTW2=-@MEAN(11)+NTCTW2;MNTCTW3=-@MEAN(12)+
NTCTW3;
580  MNRC1=-@MEAN(13)+NRC1; MNRC2=-@MEAN(14)+NRC2; MNRC3=-@MEAN(15)+NRC3;
583  MNRCQ1=-@MEAN(16)+NRCQ1; MNRCQ2=-@MEAN(17)+NRCQ2;
MNRCQ3=-@MEAN(18)+NRCQ3;
586
586  MNTCDL0=0; MNTCRM0=0; MNTCTW0=0; MNTC0=0; MNRC0=0; MNRCQ0=0;
592  MNTCA1=MNTC1; MNTCA2=0; MNTCA3=0; MNTCA0=0;
596  MNTCBC2=MNTC2; MNTCBC1=0; MNTCBC3=MNTC3; MNTCBC0=0;
600  MNTCTWA1=MNTCTW1; MNTCTWA2=0; MNTCTWA3=0; MNTCTWA0=0;
604  MNTTWBC2=MNTCTW2; MNTTWBC1=0; MNTTWBC3=MNTCTW3; MNTTWBC0=0;
608
608
MTCNRC0=0;MTCNRC1=MTC1*MNRC1/MU;MTCNRC2=MTC2*MNRC2/MU;MTCNRC3=MTC3*MNRC3/
MU;
612  ?*****
612  ?***Data from the RP part***
612  ?*****
612  RAUDRBC0=0; RAUDRBC1=0; RAUDRBC2=0; RAUDRBC3=0;
616  RPMODEA0=0; RPMODEA1=0; RPMODEA2=0; RPMODEA3=0;
620  RPNHHBC0=0; RPNHHBC1=0; RPNHHBC2=0; RPNHHBC3=0;
624  RPC11=0; RPC12=0; RPC13=0; RPC10=0;
628  RPC22=0; RPC21=0; RPC23=0; RPC20=0;
632  RPC33=0; RPC32=0; RPC31=0; RPC30=0;
636  RSCHLBC0=0; RSCHLBC1=0; RSCHLBC2=0; RSCHLBC3=0;
640  RPTELEC0=0; RPTELEC1=0; RPTELEC2=0; RPTELEC3=0;
644  RPDUAL0=0; RPDUAL1=0; RPDUAL2=0; RPDUAL3=0;
648  RPALONE0=0; RPALONE1=0; RPALONE2=0; RPALONE3=0;
652  ?*****
652
652  SMPL 1 385;
653  READ (FILE='F:\TSP43\FINALNEW\RPJNTFIN.XLS') N Z RPHC1 RPHC2 RPHC3
RPRM1 RPRM2 RPRM3 RPTW1 RPTW2 RPTW3 MMODE AGE AUDR PTNR PCITY TELE TENR
INC NHH MODE WCITY NCHLD;
654  RPHC0=0; RPRM0=0; RPTW0=0;
657
657  DUALS=WCITY*PCITY;
658  GENR DUAL1= DUALS=1;
659  GENR DUAL2= DUALS=4;
660  GENR DUAL3= DUALS=9;
661  DUAL0=0;
662
662  GENR WORK1= WCITY=1;

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663  GENR WORK2= WCITY=2;
664  GENR WORK3= WCITY=3;
665
665  ONEWORKS=(1-PTNR)*WCITY;
666  GENR WKALONE1= ONEWORKS=1;
667  GENR WKALONE2= ONEWORKS=2;
668  GENR WKALONE3= ONEWORKS=3;
669  WKALONE0=0;
670
670  GENR SCHOOL= NCHLD^=0;
671  SCHLBC1=0; SCHLBC2=SCHOOL; SCHLBC3=SCHOOL; SCHLBC0=0;
675  CHLDBC1=0; CHLDBC2=NCHLD; CHLDBC3=NCHLD; CHLDBC0=0;
679
679  TENR11=TENR; TENR12=0; TENR13=0; TENR10=0;
683  TENR22=TENR; TENR21=0; TENR23=0; TENR20=0;
687  TENR33=TENR; TENR32=0; TENR31=0; TENR30=0;
691
691  E11=1; E12=0; E13=0; E10=0;
695  E22=1; E21=0; E23=0; E20=0;
699  E33=1; E32=0; E31=0; E30=0;
703
703  RPHCA1=RPHC1; RPHCA2=0;RPHCA3=0; RPHCA0=0;
707  RPHCB2=RPHC2; RPHCB1=0;RPHCB3=0; RPHCB0=0;
711  RPHCC3=RPHC3; RPHCC2=0;RPHCC1=0; RPHCC0=0;
715
715  RPTWA1=RPTW1; RPTWA2=0;RPTWA3=0; RPTWA0=0;
719  RPTWB2=RPTW2; RPTWB1=0;RPTWB3=0; RPTWB0=0;
723  RPTWC3=RPTW3; RPTWC2=0;RPTWC1=0; RPTWC0=0;
727
727  RPRMA1=RPRM1; RPRMA2=0;RPRMA3=0; RPRMA0=0;
731  RPRMB2=RPRM2; RPRMB1=0;RPRMB3=0; RPRMB0=0;
735  RPRMC3=RPRM3; RPRMC2=0;RPRMC1=0; RPRMC0=0;
739
739  AUDRBC1=0; AUDRBC2=AUDR; AUDRBC3=AUDR; AUDRBC0=0;
743  AUDRB1=0; AUDRB3=0; AUDRB2=AUDR; AUDRB0=0;
747  AUDRC1=0; AUDRC2=0; AUDRC3=AUDR; AUDRC0=0;
751  AGEA2=0; AGEA3=0; AGEA1=AGE; AGEA0=0;
755  MODEA2=0; MODEA3=0; MODEA1=MODE; MODEA0=0;
759  NHHBC1=0; NHHBC2=NHH; NHHBC3=NHH; NHHBC0=0;
763
763  TELEC1=0; TELEC2=0; TELEC3=TELE; TELEC0=0;
767  TELEBC1=0; TELEBC2=TELE; TELEBC3=TELE; TELEBC0=0;
771
771  MRPHC1=-MEANHC1+RPHC1;MRPHC2=-MEANHC2+RPHC2;MRPHC3=-MEANHC3+RPHC3;
774  MRPRM1=-MEANRM1+RPRM1;MRPRM2=-MEANRM2+RPRM2;MRPRM3=-MEANRM3+RPRM3;
777  MRPTW1=-MEANTW1+RPTW1;MRPTW2=-MEANTW2+RPTW2;MRPTW3=-MEANTW3+RPTW3;
780  MRPHC0=0; MRPRM0=0; MRPTW0=0;
783
783  MRPHCA1=MRPHC1; MRPHCA2=0; MRPHCA3=0; MRPHCA0=0;
787  MRPHCB2=MRPHC2; MRPHCB1=0; MRPHCB3=0; MRPHCB0=0;
791  MRPHCC3=MRPHC3; MRPHCC2=0; MRPHCC1=0; MRPHCC0=0;
795
795  MRPRMA1=MRPRM1; MRPRMA2=0; MRPRMA3=0; MRPRMA0=0;
799  MRPRMB2=MRPRM2; MRPRMB1=0; MRPRMB3=0; MRPRMB0=0;
803  MRPRMC3=MRPRM3; MRPRMC2=0; MRPRMC1=0; MRPRMC0=0;
807

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807 MRPTWA1=MRPTW1; MRPTWA2=0; MRPTWA3=0; MRPTWA0=0;
811 MRPTWB2=MRPTW2; MRPTWB1=0; MRPTWB3=0; MRPTWB0=0;
815 MRPTWC3=MRPTW3; MRPTWC2=0; MRPTWC1=0; MRPTWC0=0;
819
819 MRPTWBC2=MRPTW2; MRPTWBC3=MRPTW3; MRPTWBC1=0; MRPTWBC0=0;
823 MRPHCAB1=MRPHC1; MRPHCAB2=MRPHC2; MRPHCAB3=0; MRPHCAB0=0;
827
827 A=0;
828 SMPL 3466 3850;
829 D10=A(-3465);D11=A(-3465);D12=A(-3465);D13=A(-3465);
833 D20=A(-3465);D21=A(-3465);D22=A(-3465);D23=A(-3465);
837 D30=A(-3465);D31=A(-3465);D32=A(-3465);D33=A(-3465);
841
841 DUM10=A(-3465);DUM11=A(-3465);DUM12=A(-3465);DUM13=A(-3465);
845 DUM20=A(-3465);DUM21=A(-3465);DUM22=A(-3465);DUM23=A(-3465);
849 DUM30=A(-3465);DUM31=A(-3465);DUM32=A(-3465);DUM33=A(-3465);
853
853 MTCA0=A(-3465);MTCA1=A(-3465);MTCA2=A(-3465);MTCA3=A(-3465);
857
MTCBORC0=A(-3465);MTCBORC1=A(-3465);MTCBORC2=A(-3465);MTCBORC3=A(-3465);
861 MDL0=A(-3465);MDL1=A(-3465);MDL2=A(-3465);MDL3=A(-3465);
865 MDT0=A(-3465);MDT1=A(-3465);MDT2=A(-3465);MDT3=A(-3465);
869 MNRC0=A(-3465);MNRC1=A(-3465);MNRC2=A(-3465);MNRC3=A(-3465);
873 IA0=A(-3465);IA1=A(-3465);IA2=A(-3465);IA3=A(-3465);
877 IB0=A(-3465);IB1=A(-3465);IB2=A(-3465);IB3=A(-3465);
881 IC0=A(-3465);IC1=A(-3465);IC2=A(-3465);IC3=A(-3465);
885
885 MNRCQ0=A(-3465);MNRCQ1=A(-3465);MNRCQ2=A(-3465);MNRCQ3=A(-3465);
889 IAQ0=A(-3465);IAQ1=A(-3465);IAQ2=A(-3465);IAQ3=A(-3465);
893 IBQ0=A(-3465);IBQ1=A(-3465);IBQ2=A(-3465);IBQ3=A(-3465);
897 ICQ0=A(-3465);ICQ1=A(-3465);ICQ2=A(-3465);ICQ3=A(-3465);
901 MDTSQ0=A(-3465);MDTSQ1=A(-3465);MDTSQ2=A(-3465);MDTSQ3=A(-3465);
905 MRMQAB0=A(-3465);MRMQAB1=A(-3465);MRMQAB2=A(-3465);MRMQAB3=A(-3465);
909
909 MTCDL0=A(-3465);MTCDL1=A(-3465);MTCDL2=A(-3465);MTCDL3=A(-3465);
913 MTCRM0=A(-3465);MTCRM1=A(-3465);MTCRM2=A(-3465);MTCRM3=A(-3465);
917 MTCTWA0=A(-3465);MTCTWA1=A(-3465);MTCTWA2=A(-3465);MTCTWA3=A(-3465);
921
MTCTWBC0=A(-3465);MTCTWBC1=A(-3465);MTCTWBC2=A(-3465);MTCTWBC3=A(-3465);
925
925 ? ** THE FOLLOWINGS ARE EXTRA TERMS FOR THE WHOLE SAMPLE **
925 MTCHC0=A(-3465);MTCHC1=A(-3465);MTCHC2=A(-3465);MTCHC3=A(-3465);
929 MTCNRC0=A(-3465);MTCNRC1=A(-3465);MTCNRC2=A(-3465);MTCNRC3=A(-3465);
933 MDLRMA0=A(-3465);MDLRMA1=A(-3465);MDLRMA2=A(-3465);MDLRMA3=A(-3465);
937 MDLRMB0=A(-3465);MDLRMB1=A(-3465);MDLRMB2=A(-3465);MDLRMB3=A(-3465);
941 MDLRMC0=A(-3465);MDLRMC1=A(-3465);MDLRMC2=A(-3465);MDLRMC3=A(-3465);
945
MDLRMAB0=A(-3465);MDLRMAB1=A(-3465);MDLRMAB2=A(-3465);MDLRMAB3=A(-3465);
949 ? *****
949
949 ZTCBORC2=A(-3465);ZTCBORC1=A(-3465);ZTCBORC3=A(-3465);
ZTCBORC0=A(-3465);
953 ZTCA1=A(-3465);ZTCA2=A(-3465);ZTCA3=A(-3465);ZTCA0=A(-3465);
957 ZDTS1=A(-3465);ZDTS2=A(-3465);ZDTS3=A(-3465);ZDTS0=A(-3465);
961 ZTCTWA1=A(-3465);ZTCTWA2=A(-3465);ZTCTWA3=A(-3465);
ZTCTWA0=A(-3465);

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965
965  ?***DO NOT NEED***
965  TCTS0=A(-3465);TCTS1=A(-3465);TCTS2=A(-3465);TCTS3=A(-3465);
969  TCDTS0=A(-3465);TCSTS1=A(-3465);TCDTS2=A(-3465);TCDTS3=A(-3465);
973  TCRC0=A(-3465);TCRC1=A(-3465);TCRC2=A(-3465);TCRC3=A(-3465);
977  DLHC0=A(-3465);DLHC1=A(-3465);DLHC2=A(-3465);DLHC3=A(-3465);
981  DLRM0=A(-3465);DLRM1=A(-3465);DLRM2=A(-3465);DLRM3=A(-3465);
985  DLTW0=A(-3465);DLTW1=A(-3465);DLTW2=A(-3465);DLTW3=A(-3465);
989  DLTS0=A(-3465);DLTS1=A(-3465);DLTS2=A(-3465);DLTS3=A(-3465);
993  DLRC0=A(-3465);DLRC1=A(-3465);DLRC2=A(-3465);DLRC3=A(-3465);
997  ?*****
997
    HC0=MRPHC0(-3465);HC1=MRPHC1(-3465);HC2=MRPHC2(-3465);HC3=MRPHC3(-3465);
1001
    RM0=MRPRM0(-3465);RM1=MRPRM1(-3465);RM2=MRPRM2(-3465);RM3=MRPRM3(-3465);
1005
    TW0=MRPTW0(-3465);TW1=MRPTW1(-3465);TW2=MRPTW2(-3465);TW3=MRPTW3(-3465);
1009
1009
    MHCA0=MRPHCA0(-3465);MHCA1=MRPHCA1(-3465);MHCA2=MRPHCA2(-3465);MHCA3=
    MRPHCA3(-3465);
1013
1013  MHCB0=MRPHCB0(-3465);
1014  MHCB1=MRPHCB1(-3465);
1015  MHCB2=MRPHCB2(-3465);
1016  MHCB3=MRPHCB3(-3465);
1017
1017  MHCC0=MRPHCC0(-3465);
1018  MHCC1=MRPHCC1(-3465);
1019  MHCC2=MRPHCC2(-3465);
1020  MHCC3=MRPHCC3(-3465);
1021
1021  MRMA0=MRPRMA0(-3465);
1022  MRMA1=MRPRMA1(-3465);
1023  MRMA2=MRPRMA2(-3465);
1024  MRMA3=MRPRMA3(-3465);
1025
1025  MRMB0=MRPRMB0(-3465);
1026  MRMB1=MRPRMB1(-3465);
1027  MRMB2=MRPRMB2(-3465);
1028  MRMB3=MRPRMB3(-3465);
1029
1029  MRMC0=MRPRMC0(-3465);
1030  MRMC1=MRPRMC1(-3465);
1031  MRMC2=MRPRMC2(-3465);
1032  MRMC3=MRPRMC3(-3465);
1033
1033  MTWA0=MRPTWA0(-3465);
1034  MTWA1=MRPTWA1(-3465);
1035  MTWA2=MRPTWA2(-3465);
1036  MTWA3=MRPTWA3(-3465);
1037
1037  MTWB0=MRPTWB0(-3465);
1038  MTWB1=MRPTWB1(-3465);
1039  MTWB2=MRPTWB2(-3465);
1040  MTWB3=MRPTWB3(-3465);

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```
1041
1041 MTWC0=MRPTWC0 (-3465);
1042 MTWC1=MRPTWC1 (-3465);
1043 MTWC2=MRPTWC2 (-3465);
1044 MTWC3=MRPTWC3 (-3465);
1045
1045 MTWBORC0=MRPTWBC0 (-3465);
1046 MTWBORC1=MRPTWBC1 (-3465);
1047 MTWBORC2=MRPTWBC2 (-3465);
1048 MTWBORC3=MRPTWBC3 (-3465);
1049
1049 MHCAORB0=MRPHCAB0 (-3465);
1050 MHCAORB1=MRPHCAB1 (-3465);
1051 MHCAORB2=MRPHCAB2 (-3465);
1052 MHCAORB3=MRPHCAB3 (-3465);
1053
1053 RAUDRBC0=AUDRBC0 (-3465);
1054 RAUDRBC1=AUDRBC1 (-3465);
1055 RAUDRBC2=AUDRBC2 (-3465);
1056 RAUDRBC3=AUDRBC3 (-3465);
1057
1057 RPAUDRB0=AUDRB0 (-3465);
1058 RPAUDRB1=AUDRB1 (-3465);
1059 RPAUDRB2=AUDRB2 (-3465);
1060 RPAUDRB3=AUDRB3 (-3465);
1061
1061 RPAUDRC0=AUDRC0 (-3465);
1062 RPAUDRC1=AUDRC1 (-3465);
1063 RPAUDRC2=AUDRC2 (-3465);
1064 RPAUDRC3=AUDRC3 (-3465);
1065
1065 RPMODEA2=MODEA2 (-3465);
1066 RPMODEA3=MODEA3 (-3465);
1067 RPMODEA0=MODEA0 (-3465);
1068 RPMODEA1=MODEA1 (-3465);
1069
1069 RPNHHBC0=NHHCBC0 (-3465);
1070 RPNHHBC1=NHHCBC1 (-3465);
1071 RPNHHBC2=NHHCBC2 (-3465);
1072 RPNHHBC3=NHHCBC3 (-3465);
1073
1073 RSCHLBC0=SCHLBC0 (-3465);
1074 RSCHLBC1=SCHLBC1 (-3465);
1075 RSCHLBC2=SCHLBC2 (-3465);
1076 RSCHLBC3=SCHLBC3 (-3465);
1077
1077 RPTELEC2=TELEC2 (-3465);
1078 RPTELEC3=TELEC3 (-3465);
1079 RPTELEC1=TELEC1 (-3465);
1080 RPTELEC0=TELEC0 (-3465);
1081
1081 RPDUAL2=DUAL2 (-3465);
1082 RPDUAL3=DUAL3 (-3465);
1083 RPDUAL1=DUAL1 (-3465);
1084 RPDUAL0=DUAL0 (-3465);
1085
```

```

1085  RPALONE2=WKALONE2(-3465);
1086  RPALONE3=WKALONE3(-3465);
1087  RPALONE1=WKALONE1(-3465);
1088  RPALONE0=WKALONE0(-3465);
1089
1089  RPC10=E10(-3465);RPC11=E11(-3465);RPC12=E12(-3465);RPC13=E13(-3465);
1093  RPC20=E20(-3465);RPC21=E21(-3465);RPC22=E22(-3465);RPC23=E23(-3465);
1097  RPC30=E30(-3465);RPC31=E31(-3465);RPC32=E32(-3465);RPC33=E33(-3465);
1101
1101  Y=Z(-3465);
1102
1102  SUPRES @DPDX;
1103  SUPRES @DPDZ;
1104  SMPL 1 3850;
1105  SET LL0=-5337.23;
1106  SET LLC=-5177.30;
1107
1107  PRINT (FORMAT="( 'JOINT ESTIMATE OF PARAMETERS FOR THE WHOLE
      SAMPLE' ) ");
1108  LOGIT (COND, NCHOICE=4, MAXIT=35) Y MTCA MTCBORC MDL MHCAORB MHCC
      MRMA MRMB MRMC MTWA MTWBORC MDTs MNRC IA IB IC MTCDL MTCHC MTCRM
      MTCTWBC MTCNRC MDLRMAB MNRCQ IAQ ICQ RAUDRBC RPMODEA RPDUAL RPALONE
      RSCHLBC RPTELEC D1 D2 D3 RPC1 RPC2 RPC3;
1109  SET LL6=@LOGL;
1110  SET RHO2=1-(LL6/LL0);
1111  SET RHOBAR=1-((LL6-(@NCOEF))/LL0);
1112  SET LR0= -2*(LL0 -LL6);
1113  SET LRC= -2*(LLC -LL6);
1114  PRINT @NCOEF RHO2 RHOBAR LR0 LRC;
1115
1115  END;
      EXECUTION

```

Current sample: 1 to 3465

Current sample: 1 to 385

Current sample: 3466 to 3850

Current sample: 1 to 3850

JOINT ESTIMATE OF PARAMETERS FOR THE WHOLE SAMPLE

Equation 1
=====

MIXED LOGIT ESTIMATION

CHOICE	FREQUENCY	PERCENT	
0	840	21.8182	(COEFFICIENTS NORMALIZED TO ZERO)
1	1025	26.6234	
2	613	15.9221	
3	1372	35.6364	

Working space used: 1158549

STARTING VALUES

VALUE	MTCA 0.00000	MTCBORC 0.00000	MDL 0.00000	MHCZORB 0.00000	MHCC 0.00000
VALUE	MRMA 0.00000	MRMB 0.00000	MRMC 0.00000	MTWA 0.00000	MTWBORC 0.00000
VALUE	MDTS 0.00000	MNRC 0.00000	IA 0.00000	IB 0.00000	IC 0.00000
VALUE	MTCDL 0.00000	MTCHC 0.00000	MTCRM 0.00000	MTCZWBBC 0.00000	MTCNRC 0.00000
VALUE	MDLRMAB 0.00000	MNRCQ 0.00000	IAQ 0.00000	ICQ 0.00000	RAUDRBC 0.00000
VALUE	RPMODEA 0.00000	RPDUAL 0.00000	RPALONE 0.00000	RSCHLBC 0.00000	RPTELEC 0.00000
VALUE	D1 0.00000	D2 0.00000	D3 0.00000	RPC1 0.00000	RPC2 0.00000
VALUE	RPC3 0.00000	C1 0.00000	C2 0.00000	C3 0.00000	

F= 5337.2	FNEW= 4555.1	ISQZ= 0	STEP= 1.0000	CRIT= 1575.0
F= 4555.1	FNEW= 4508.6	ISQZ= 0	STEP= 1.0000	CRIT= 86.247
F= 4508.6	FNEW= 4503.9	ISQZ= 0	STEP= 1.0000	CRIT= 7.7999
F= 4503.9	FNEW= 4502.7	ISQZ= 0	STEP= 1.0000	CRIT= 1.9402
F= 4502.7	FNEW= 4502.1	ISQZ= 0	STEP= 1.0000	CRIT= 0.32982
F= 4502.1	FNEW= 4502.1	ISQZ= 0	STEP= 1.0000	CRIT= 0.17781E-01
F= 4502.1	FNEW= 4502.1	ISQZ= 0	STEP= 1.0000	CRIT= 0.71471E-04
F= 4502.1	FNEW= 4502.1	ISQZ= 0	STEP= 1.0000	CRIT= 0.12582E-08

CONVERGENCE ACHIEVED AFTER 8 ITERATIONS

16 FUNCTION EVALUATIONS.

DEPENDENT VARIABLE: Y

LOG OF LIKELIHOOD FUNCTION = -4502.052
NUMBER OF CASES = 3850
NUMBER OF CHOICES = 15400

		Standard	
Parameter	Estimate	Error	t-statistic
MTCA	.051829	.018069	2.86842
MTCBORC	.095978	.012791	7.50382

MDL	-.372430E-02	.102595E-02	-3.63009
MHCAORB	-.135775E-02	.932255E-04	-14.5641
MHCC	-.464990E-03	.102491E-03	-4.53690
MRMA	.069397	.017561	3.95178
MRMB	.124342	.020925	5.94215
MRMC	.027420	.015299	1.79229
MTWA	-.389386E-02	.347437E-02	-1.12074
MTWBORC	-.010302	.128136E-02	-8.04011
MDTS	-.010008	.106306E-02	-9.41435
MNRC	.126209	.010662	11.8376
IA	.041308	.607793E-02	6.79642
IB	.787051E-02	.356808E-02	2.20581
IC	.084524	.882587E-02	9.57680
MTCDL	-.281690E-02	.130761E-02	-2.15424
MTCHC	-.112559E-03	.853272E-04	-1.31914
MTCRM	.025398	.012743	1.99316
MTCTWBC	.514176E-02	.160353E-02	3.20652
MTCNRC	.028675	.013232	2.16708
MDLRMAB	.670190E-02	.182176E-02	3.67880
MNRCQ	-.024537	.587440E-02	-4.17687
IAQ	-.140228E-02	.294696E-03	-4.75839
ICQ	-.345868E-02	.462346E-03	-7.48072
RAUDRBC	.916094	.383608	2.38810
RPMODEA	1.03368	.273052	3.78567
RPDUAL	.461762	.231977	1.99055
RPALONE	.700989	.254313	2.75640
RSCHLBC	.741031	.230839	3.21017
RPTELEC	.579432	.303917	1.90655
D1	-.149951	.022602	-6.63453
D2	-.248916	.021807	-11.4146
D3	.093781	.016507	5.68116
RPC1	4.85944	1.02640	4.73444
RPC2	3.28690	1.06694	3.08068
RPC3	3.59774	1.07492	3.34698

Standard Errors computed from analytic second derivatives
(Newton)

	@NCOEF	RHO2	RHOBAR	LRO	LRC
Value	36.00000	0.15639	0.14965	1669.42092	1349.56092

END OF OUTPUT.

TOTAL NUMBER OF WARNING MESSAGES: 1

MEMORY USAGE:	ITEM:	DATA ARRAY	TOTAL MEMORY
	UNITS:	(4-BYTE WORDS)	(MEGABYTES)
MEMORY ALLOCATED	:	5750000	25.0
MEMORY ACTUALLY REQUIRED	:	4354895	19.5
CURRENT VARIABLE STORAGE	:	3170078	

Appendix B6: Source Code and Output for Comparing TCers and NTCers

TSP Version 4.3A
 (10/26/95) DOS/Win 25MB
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03/01/00 5:15 PM

In case of questions or problems, see your local TSP
 consultant or send a description of the problem and the
 associated TSP output to:

TSP International
 P.O. Box 61015, Station A
 Palo Alto, CA 94306
 USA

PROGRAM

```

LINE *****
1  OPTIONS MEMORY= 25;
2  NAME REZA 'FINAL SURVEY ANALYSIS';
2  FREQ N;
3  SMPL 2 3466;
4  READ (FILE='f:\TSP43\FINALNEW\SPALLNEW.XLS') OBS Y TC1 TC2 TC3 DL1
DL2 DL3 HC1 HC2 HC3 RM1 RM2 RM3 TW1 TW2 TW3 TS1 TS2 TS3 RC1 RC2 RC3 IA IB
IC CHLD;
5  TC0=0; DL0=0; HC0=0; RM0=0; TW0=0; TS0=0; RC0=0;
12
12  TCA1=TC1; TCA2=0; TCA3=0; TCA0=0;
16  TCB2=TC2; TCB1=0; TCB3=0; TCB0=0;
20  TCC3=TC3; TCC2=0; TCC1=0; TCC0=0;
24
24  DLA1=DL1; DLA2=0; DLA3=0; DLA0=0;
28  DLB2=DL2; DLB1=0; DLB3=0; DLB0=0;
32  DLC3=DL3; DLC2=0; DLC1=0; DLC0=0;
36
36  HCA1=HC1; HCA2=0; HCA3=0; HCA0=0;
40  HCB2=HC2; HCB1=0; HCB3=0; HCB0=0;
44  HCC3=HC3; HCC2=0; HCC1=0; HCC0=0;
48
48  RMA1=RM1; RMA2=0; RMA3=0; RMA0=0;
52  RMB2=RM2; RMB1=0; RMB3=0; RMB0=0;
56  RMC3=RM3; RMC2=0; RMC1=0; RMC0=0;
60
60  TWA1=TW1; TWA2=0; TWA3=0; TWA0=0;
64  TWB2=TW2; TWB1=0; TWB3=0; TWB0=0;
68  TWC3=TW3; TWC2=0; TWC1=0; TWC0=0;
72
72  TSA1=TS1; TSA2=0; TSA3=0; TSA0=0;
76  TSB2=TS2; TSB1=0; TSB3=0; TSB0=0;
80  TSC3=TS3; TSC2=0; TSC1=0; TSC0=0;
84
84  RCA1=RC1; RCA2=0; RCA3=0; RCA0=0;
88  RCB2=RC2; RCB1=0; RCB3=0; RCB0=0;
92  RCC3=RC3; RCC2=0; RCC1=0; RCC0=0;
96
96  IA1=IA; IA2=0; IA3=0; IA0=0;
100 IB2=IB; IB1=0; IB3=0; IB0=0;

```



```

104 IC3=IC; IC2=0; IC1=0; IC0=0;
108
108 IAQ1=IA1**2; IAQ2=0; IAQ3=0; IAQ0=0;
112 IBQ2=IB2**2; IBQ1=0; IBQ3=0; IBQ0=0;
116 ICQ3=IC3**2; ICQ2=0; ICQ1=0; ICQ0=0;
120
120 DTS0=0; DTS1=TS1*CHLD; DTS2=TS2*CHLD; DTS3=TS3*CHLD;
124
124 DTSA1=DTS1; DTSA2=0; DTSA3=0; DTSA0=0;
128 DTSB2=DTS2; DTSB1=0; DTSB3=0; DTSB0=0;
132 DTSC3=DTS3; DTSC2=0; DTSC1=0; DTSC0=0;
136
136 TCQA1=((TC1**2)-2/3)*3; TCQA2=0; TCQA3=0; TCQA0=0;
140 TCQB2=((TC2**2)-2/3)*3; TCQB1=0; TCQB3=0; TCQB0=0;
144 TCQC3=((TC3**2)-2/3)*3; TCQC2=0; TCQC1=0; TCQC0=0;
148
148 DLQA1=((DL1**2)-2/3)*3; DLQA2=0; DLQA3=0; DLQA0=0;
152 DLQB2=((DL2**2)-2/3)*3; DLQB1=0; DLQB3=0; DLQB0=0;
156 DLQC3=((DL3**2)-2/3)*3; DLQC2=0; DLQC1=0; DLQC0=0;
160
160 HCQA1=((HC1**2)-2/3)*3; HCQA2=0; HCQA3=0; HCQA0=0;
164 HCQB2=((HC2**2)-2/3)*3; HCQB1=0; HCQB3=0; HCQB0=0;
168 HCQC3=((HC3**2)-2/3)*3; HCQC2=0; HCQC1=0; HCQC0=0;
172
172 RMQA1=((RM1**2)-2/3)*3; RMQA2=0; RMQA3=0; RMQA0=0;
176 RMQB2=((RM2**2)-2/3)*3; RMQB1=0; RMQB3=0; RMQB0=0;
180 RMQC3=((RM3**2)-2/3)*3; RMQC2=0; RMQC1=0; RMQC0=0;
184
184 TWQA1=((TW1**2)-2/3)*3; TWQA2=0; TWQA3=0; TWQA0=0;
188 TWQB2=((TW2**2)-2/3)*3; TWQB1=0; TWQB3=0; TWQB0=0;
192 TWQC3=((TW3**2)-2/3)*3; TWQC2=0; TWQC1=0; TWQC0=0;
196
196 TSQA1=((TS1**2)-2/3)*3; TSQA2=0; TSQA3=0; TSQA0=0;
200 TSQB2=((TS2**2)-2/3)*3; TSQB1=0; TSQB3=0; TSQB0=0;
204 TSQC3=((TS3**2)-2/3)*3; TSQC2=0; TSQC1=0; TSQC0=0;
208
208 DTSQA1=((DTS1**2)-2/3)*3; DTSQA2=0; DTSQA3=0; DTSQA0=0;
212 DTSQB2=((DTS2**2)-2/3)*3; DTSQB1=0; DTSQB3=0; DTSQB0=0;
216 DTSQC3=((DTS3**2)-2/3)*3; DTSQC2=0; DTSQC1=0; DTSQC0=0;
220
220 RCQA1=((RC1**2)-2/3)*3; RCQA2=0; RCQA3=0; RCQA0=0;
224 RCQB2=((RC2**2)-2/3)*3; RCQB1=0; RCQB3=0; RCQB0=0;
228 RCQC3=((RC3**2)-2/3)*3; RCQC2=0; RCQC1=0; RCQC0=0;
232
232 TCDLA1=TC1*DL1; TCDLA2=0; TCDLA3=0; TCDLA0=0;
236 TCDLB2=TC2*DL2; TCDLB1=0; TCDLB3=0; TCDLB0=0;
240 TCDLC3=TC3*DL3; TCDLC2=0; TCDLC1=0; TCDLC0=0;
244
244 TCHCA1=TC1*HC1; TCHCA2=0; TCHCA3=0; TCHCA0=0;
248 TCHCB2=TC2*HC2; TCHCB1=0; TCHCB3=0; TCHCB0=0;
252 TCHCC3=TC3*HC3; TCHCC2=0; TCHCC1=0; TCHCC0=0;
256
256 TCRMA1=TC1*RM1; TCRMA2=0; TCRMA3=0; TCRMA0=0;
260 TCRMB2=TC2*RM2; TCRMB1=0; TCRMB3=0; TCRMB0=0;
264 TCRMC3=TC3*RM3; TCRMC2=0; TCRMC1=0; TCRMC0=0;
268

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```

268 TCTWA1=TC1*TW1; TCTWA2=0; TCTWA3=0; TCTWA0=0;
272 TCTWB2=TC2*TW2; TCTWB1=0; TCTWB3=0; TCTWB0=0;
276 TCTWC3=TC3*TW3; TCTWC2=0; TCTWC1=0; TCTWC0=0;
280
280 TCTSA1=TC1*TS1; TCTSA2=0; TCTSA3=0; TCTSA0=0;
284 TCTSB2=TC2*TS2; TCTSB1=0; TCTSB3=0; TCTSB0=0;
288 TCTSC3=TC3*TS3; TCTSC2=0; TCTSC1=0; TCTSC0=0;
292
292 TCDTSA1=TC1*DTS1; TCDTSA2=0; TCDTSA3=0; TCDTSA0=0;
296 TCDTSB2=TC2*DTS2; TCDTSB1=0; TCDTSB3=0; TCDTSB0=0;
300 TCDTSC3=TC3*DTS3; TCDTSC2=0; TCDTSC1=0; TCDTSC0=0;
304
304 TCRCA1=TC1*RC1; TCRCA2=0; TCRCA3=0; TCRCA0=0;
308 TCRCB2=TC2*RC2; TCRCB1=0; TCRCB3=0; TCRCB0=0;
312 TCRC3=TC3*RC3; TCRC2=0; TCRC1=0; TCRC0=0;
316
316 DLHCA1=DL1*HC1; DLHCA2=0; DLHCA3=0; DLHCA0=0;
320 DLHCB2=DL2*HC2; DLHCB1=0; DLHCB3=0; DLHCB0=0;
324 DLHCC3=DL3*HC3; DLHCC2=0; DLHCC1=0; DLHCC0=0;
328
328 DLRMA1=DL1*RM1; DLRMA2=0; DLRMA3=0; DLRMA0=0;
332 DLRMB2=DL2*RM2; DLRMB1=0; DLRMB3=0; DLRMB0=0;
336 DLRMC3=DL3*RM3; DLRMC2=0; DLRMC1=0; DLRMC0=0;
340
340 DLTWA1=DL1*TW1; DLTWA2=0; DLTWA3=0; DLTWA0=0;
344 DLTWB2=DL2*TW2; DLTWB1=0; DLTWB3=0; DLTWB0=0;
348 DLTWC3=DL3*TW3; DLTWC2=0; DLTWC1=0; DLTWC0=0;
352
352 DL TSA1=DL1*TS1; DL TSA2=0; DL TSA3=0; DL TSA0=0;
356 DL TSB2=DL2*TS2; DL TSB1=0; DL TSB3=0; DL TSB0=0;
360 DL TSC3=DL3*TS3; DL TSC2=0; DL TSC1=0; DL TSC0=0;
364
364 DLD TSA1=DL1*DTS1; DLD TSA2=0; DLD TSA3=0; DLD TSA0=0;
368 DLD TSB2=DL2*DTS2; DLD TSB1=0; DLD TSB3=0; DLD TSB0=0;
372 DLD TSC3=DL3*DTS3; DLD TSC2=0; DLD TSC1=0; DLD TSC0=0;
376
376 DLRCA1=DL1*RC1; DLRCA2=0; DLRCA3=0; DLRCA0=0;
380 DLRCB2=DL2*RC2; DLRCB1=0; DLRCB3=0; DLRCB0=0;
384 DLRC3=DL3*RC3; DLRC2=0; DLRC1=0; DLRC0=0;
388
388 TCDL0=0; TCDL1=TC1*DL1; TCDL2=TC2*DL2; TCDL3=TC3*DL3;
392 TCHC0=0; TCHC1=TC1*HC1; TCHC2=TC2*HC2; TCHC3=TC3*HC3;
396 TCRM0=0; TCRM1=TC1*RM1; TCRM2=TC2*RM2; TCRM3=TC3*RM3;
400 TCTW0=0; TCTW1=TC1*TW1; TCTW2=TC2*TW2; TCTW3=TC3*TW3;
404 TCTS0=0; TCTS1=TC1*TS1; TCTS2=TC2*TS2; TCTS3=TC3*TS3;
408 TCDTS0=0; TCDTS1=TC1*DTS1; TCDTS2=TC2*DTS2; TCDTS3=TC3*DTS3;
412 TCRC0=0; TCRC1=TC1*RC1; TCRC2=TC2*RC2; TCRC3=TC3*RC3;
416 DLHC0=0; DLHC1=DL1*HC1; DLHC2=DL2*HC2; DLHC3=DL3*HC3;
420 DLRM0=0; DLRM1=DL1*RM1; DLRM2=DL2*RM2; DLRM3=DL3*RM3;
424 DLTW0=0; DLTW1=DL1*TW1; DLTW2=DL2*TW2; DLTW3=DL3*TW3;
428 DLTS0=0; DLTS1=DL1*TS1; DLTS2=DL2*TS2; DLTS3=DL3*TS3;
432 DLDTS0=0; DLDTS1=DL1*DTS1; DLDTS2=DL2*DTS2; DLDTS3=DL3*DTS3;
436 DLRC0=0; DLRC1=DL1*RC1; DLRC2=DL2*RC2; DLRC3=DL3*RC3;
440
440 TCQ0=0; TCQ1=((TC1**2)-2/3)*3; TCQ2=((TC2**2)-2/3)*3;
TCQ3=((TC3**2)-2/3)*3;

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```

444 DLQ0=0; DLQ1=((DL1**2)-2/3)*3; DLQ2=((DL2**2)-2/3)*3;
DLQ3=((DL3**2)-2/3)*3;
448 HCQ0=0; HCQ1=((HC1**2)-2/3)*3; HCQ2=((HC2**2)-2/3)*3;
HCQ3=((HC3**2)-2/3)*3;
452 RMQ0=0; RMQ1=((RM1**2)-2/3)*3; RMQ2=((RM2**2)-2/3)*3;
RMQ3=((RM3**2)-2/3)*3;
456 TWQ0=0; TWQ1=((TW1**2)-2/3)*3; TWQ2=((TW2**2)-2/3)*3;
TWQ3=((TW3**2)-2/3)*3;
460 TSQ0=0; TSQ1=((TS1**2)-2/3)*3; TSQ2=((TS2**2)-2/3)*3;
TSQ3=((TS3**2)-2/3)*3;
464 RCQ0=0; RCQ1=((RC1**2)-2/3)*3; RCQ2=((RC2**2)-2/3)*3;
RCQ3=((RC3**2)-2/3)*3;
468 DTSQ0=0; DTSQ1=((DTS1**2)-2/3)*3; DTSQ2=((DTS2**2)-2/3)*3;
DTSQ3=((DTS3**2)-2/3)*3;
472
472 TCBORC2=TC2; TCBORC1=0; TCBORC3=TC3; TCBORC0=0;
476 TWBORC2=TW2; TWBORC1=0; TWBORC3=TW3; TWBORC0=0;
480 DTSBORC2=DTS2; DTSBORC1=0; DTSBORC3=DTS3; DTSBORC0=0;
484 TCRCAB1=TCRC1; TCRCAB2=TCRC2; TCRCAB3=0; TCRCAB0=0;
488 TCTWBC1=0; TCTWBC2=TCTW2; TCTWBC3=TCTW3; TCTWBC0=0;
492 RMQAB1=RMQ1; RMQAB2=RMQ2; RMQAB3=0; RMQAB0=0;
496 DTSQBC2=DTSQ2; DTSQBC1=0; DTSQBC3=DTSQ3; DTSQBC0=0;
500 DTSQA2=0; DTSQA1=DTSQ1; DTSQA3=0; DTSQA0=0;
504
504 SMPL 2 2593;
505 DUM=1;
506 SMPL 2594 3466;
507 DUM=-1;
508
508 SMPL 2 3466;
509 NTCBORC2=DUM*TCBORC2; NTCBORC1=0; NTCBORC3=DUM*TCBORC3; NTCBORC0=0;
513 NTWBORC2=DUM*TWBORC2; NTWBORC1=0; NTWBORC3=DUM*TWBORC3; NTWBORC0=0;
517 NDTSBC2=DUM*DTS2; NDTSBC1=0; NDTSBC3=DUM*DTS3; NDTSBC0=0;
521 NTCTWBC1=0; NTCTWBC2=DUM*TCTWBC2; NTCTWBC3=DUM*TCTWBC3; NTCTWBC0=0;
525 NRMQAB1=DUM*RMQAB1; NRMQAB2=DUM*RMQAB2; NRMQAB3=0; NRMQAB0=0;
529
529 NTCA1=DUM*TCA1; NTCA2=0; NTCA3=0; NTCA0=0;
533 NDL1=DUM*DL1; NDL2=DUM*DL2; NDL3=DUM*DL3; NDL0=0;
537
537 NHCA1=DUM*HCA1; NHCA2=0; NHCA3=0; NHCA0=0;
541 NHCB2=DUM*HCB2; NHCB1=0; NHCB3=0; NHCB0=0;
545 NHCC3=DUM*HCC3; NHCC2=0; NHCC1=0; NHCC0=0;
549
549 NRMA1=DUM*RMA1; NRMA2=0; NRMA3=0; NRMA0=0;
553 NRMB2=DUM*RMB2; NRMB1=0; NRMB3=0; NRMB0=0;
557 NRMC3=DUM*RMC3; NRMC2=0; NRMC1=0; NRMC0=0;
561
561 NTWA1=DUM*TWA1; NTWA2=0; NTWA3=0; NTWA0=0;
565 NDTSA1=DUM*DTSA1; NDTSA2=0; NDTSA3=0; NDTSA0=0;
569 NRC1=DUM*RC1; NRC2=DUM*RC2; NRC3=DUM*RC3; NRC0=0;
573
573 NIA1=DUM*IA1; NIA2=0; NIA3=0; NIA0=0;
577 NIB2=DUM*IB2; NIB1=0; NIB3=0; NIB0=0;
581 NIC3=DUM*IC3; NIC2=0; NIC1=0; NIC0=0;
585
585 NTCDL1=DUM*TCDL1; NTCDL2=DUM*TCDL2; NTCDL3=DUM*TCDL3; NTCDL0=0;

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589 NTCHC1=DUM*TCHC1; NTCHC2=DUM*TCHC2; NTCHC3=DUM*TCHC3; NTCHC0=0;
593 NTCRM1=DUM*TCRM1; NTCRM2=DUM*TCRM2; NTCRM3=DUM*TCRM3; NTCRM0=0;
597 NTCRC1=DUM*TCRC1; NTCRC2=DUM*TCRC2; NTCRC3=DUM*TCRC3; NTCRC0=0;
601
601 NTCTWA1=DUM*TCTWA1; NTCTWA2=0; NTCTWA3=0; NTCTWA0=0;
605 NDTSQ1=DUM*DTSQ1; NDTSQ2=DUM*DTSQ2; NDTSQ3=DUM*DTSQ3; NDTSQ0=0;
609 NRCQ1=DUM*RCQ1; NRCQ2=DUM*RCQ2; NRCQ3=DUM*RCQ3; NRCQ0=0;
613 NIAQ1=DUM*IAQ1; NIAQ2=0; NIAQ3=0; NIAQ0=0;
617 NICQ3=DUM*ICQ3; NICQ2=0; NICQ1=0; NICQ0=0;
621
621 SUPRES @DPDX;
622 SUPRES @DPDZ;
623
623 SET LL0=-4803.51;
624 SET LLC=-4620.90;
625 PRINT (FORMAT=('NON-TELE MODEL - TELE MODEL WITH SIGNIFICANT
INTERACTIONS ONLY')));
626 LOGIT (COND, NCHOICE=4, MAXIT=20) Y TCA TCBORC DL HCA HCB HCC RMA
RMB RMC
626          TWA TWBORC DTSQ DTSBORC RC IA IB IC TCDL TCHC TCRM TCTWBC TCRC
RMQAB
626          DTSQA DTSQBC RCQ IAQ ICQ NTCA NTCBORC NDTSA | C DUM;
627 SET LL6=@LOGL;
628 SET RHO2=1-(LL6/LL0);
629 SET RHOBAR=1-((LL6-@NCOEF)/LL0);
630 SET LR0= -2*(LL0 -LL6);
631 SET LRC= -2*(LLC -LL6);
632 PRINT @NCOEF RHO2 RHOBAR LR0 LRC;
633
633 ? USING THE GENERAL ML METHOD:
633 GENR Y_0= Y=0;
634 GENR Y_1= Y=1;
635 GENR Y_2= Y=2;
636 GENR Y_3= Y=3;
637
637 FRML EQ2 LOGL= Y_1*V1 + Y_2*V2 + Y_3*V3 - LOG[1+EXP(V1)+EXP(V2)+
EXP(V3)];
638 FRML EQV1 V1= D1+ C_DUM1*DUM+ C_TCA*(TCA1-TCA0) +
C_DL*(DL1-DL0)+ C_HCA*(HCA1-HCA0)+ C_RMA*(RMA1-RMA0)
638          + C_TWA*(TWA1-TWA0)+ C_DTSA*(DTSA1-DTSA0)+
C_RC*(RC1-RC0)+ C_IA*(IA1-IA0)
638          + C_TCDL*(TCDL1-TCDL0)+ C_TCRM*(TCRM1-TCRM0)+
C_TCHC*(TCHC1-TCHC0)
638          + C_RMQAB*(RMQAB1-RMQAB0)+ C_DTSQA*(DTSQA1-DTSQA0)+
C_TCRC*(TCRC1-TCRC0)
638          + C_RCQ*(RCQ1-RCQ0)+ C_IAQ*(IAQ1-IAQ0)
638          + C_NTCA*(NTCA1-NTCA0)+ C_NDTSA*(NDTSA1-NDTSA0);
639
639 FRML EQV2 V2= D2+ C_DUM2*DUM+ C_TCBORC*(TCBORC2-TCBORC0)+
C_DL*(DL2-DL0)+ C_HCB*(HCB2-HCB0)+ C_RMB*(RMB2-RMB0)
639          + C_TWBC*(TWBORC2-TWBORC0)+
C_DTSBC*(DTSBORC2-DTSBORC0)+ C_RC*(RC2-RC0)+ C_IB*(IB2-IB0)
639          + C_TCDL*(TCDL2-TCDL0)+ C_TCRM*(TCRM2-TCRM0)+
C_TCTWBC*(TCTWBC2-TCTWBC0)
639          + C_RMQAB*(RMQAB2-RMQAB0)+ C_DTSQBC*(DTSQBC2-DTSQBC0)+
C_RCQ*(RCQ2-RCQ0)

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639          + C_NTCBC*(NTCBORC2-NTCBORC0) + C_TCHC*(TCHC2-TCHC0) +
C_TCRC*(TCRC2-TCRC0);
640
640 FRML EQV3 V3= D3+ C_DUM3*DUM+ C_TCBC*(TCBORC3-TCBORC0) +
C_DL*(DL3-DL0) + C_HCC*(HCC3-HCB0) + C_RMC*(RMC3-RMC0)
640          + C_TWBC*(TWBORC3-TWBORC0) +
C_DTSBC*(DTSBORC3-DTSBORC0) + C_RC*(RC3-RC0) + C_IC*(IC3-IC0)
640          + C_TCDL*(TCDL3-TCDL0) + C_TCRM*(TCRM3-TCRM0) +
C_TCTWBC*(TCTWBC3-TCTWBC0)
640          + C_DTSQBC*(DTSQBC3-DTSQBC0) + C_RCQ*(RCQ3-RCQ0) +
C_ICQ*(ICQ3-ICQ0)
640          + C_NTCBC*(NTCBORC3-NTCBORC0) + C_TCHC*(TCHC3-TCHC0) +
C_TCRC*(TCRC3-TCRC0);
641
641 EQSUB(NAME=LOGIT2) EQ2 EQV1 EQV2 EQV3;
642 PARAM D1 D2 D3 C_DUM1 C_DUM2 C_DUM3 C_TCA C_TCBC C_DL C_HCA C_HCB
C_HCC
642          C_RMA C_RMB C_RMC C_TWA C_TWBC C_DTSA C_DTSBC C_RC C_IA C_IB
C_IC
642          C_TCDL C_TCRM C_TCTWBC C_TCHC C_TCRC C_RMQAB C_RCQ C_IAQ
C_ICQ C_DTSQA C_DTSQBC
642          C_NTCA C_NTCBC C_NDTSA;
643
643 PRINT (FORMAT="( 'SAME AS ABOVE MODEL USING GENERAL ML' )");
644 ML(HITER=N,HCOV=N) LOGIT2;
645 SET LL6=@LOGL;
646 SET RHO2=1-(LL6/LL0);
647 SET RHOBAR=1-((LL6-@NCOEF)/LL0);
648 SET LR0= -2*(LL0 -LL6);
649 SET LRC= -2*(LLC -LL6);
650 PRINT @NCOEF RHO2 RHOBAR LR0 LRC;
651
651 ? **IMPOSING RESRTICTION ON DTSQA**
651 FRML EQ3 LOGL= Y_1*V1 + Y_2*V2 + Y_3*V3 - LOG[1+EXP(V1)+EXP(V2) +
EXP(V3)];
652 FRML EQV1 V1= D1+ C_DUM1*DUM+ C_TCA*(TCA1-TCA0)          +
C_DL*(DL1-DL0) + C_HCA*(HCA1-HCA0) + C_RMA*(RMA1-RMA0)
652          + C_TWA*(TWA1-TWA0) + C_DTSA*(DTSA1-DTSA0) +
C_RC*(RC1-RC0) + C_IA*(IA1-IA0)
652          + C_TCDL*(TCDL1-TCDL0) + C_TCRM*(TCRM1-TCRM0) +
+C_TCHC*(TCHC1-TCHC0) + C_TCRC*(TCRC1-TCRC0)
652          + C_RMQAB*(RMQAB1-RMQAB0) +
(C_DTSA/6+E*E)*(DTSQA1-DTSQA0)
652          + C_RCQ*(RCQ1-RCQ0) + C_IAQ*(IAQ1-IAQ0)
652          + C_NTCA*(NTCA1-NTCA0) + C_NDTSA*(NDTSA1-NDTSA0);
653
653 FRML EQV2 V2= D2+ C_DUM2*DUM+ C_TCBC*(TCBORC2-TCBORC0) +
C_DL*(DL2-DL0) + C_HCB*(HCB2-HCB0) + C_RMB*(RMB2-RMB0)
653          + C_TWBC*(TWBORC2-TWBORC0) +
C_DTSBC*(DTSBORC2-DTSBORC0) + C_RC*(RC2-RC0) + C_IB*(IB2-IB0)
653          + C_TCDL*(TCDL2-TCDL0) + C_TCRM*(TCRM2-TCRM0) +
C_TCTWBC*(TCTWBC2-TCTWBC0)
653          + C_RMQAB*(RMQAB2-RMQAB0) + C_RCQ*(RCQ2-RCQ0) +
C_DTSQBC*(DTSQBC2-DTSQBC0)
653          + C_NTCBC*(NTCBORC2-NTCBORC0) + C_TCHC*(TCHC2-TCHC0) +
C_TCRC*(TCRC2-TCRC0);

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654      FRML EQV3 V3= D3+ C_DUM3*DUM+ C_TCBC*(TCBORC3-TCBORC0)+
C_DL*(DL3-DL0)+ C_HCC*(HCC3-HCB0)+ C_RMC*(RMC3-RMC0)
654      + C_TWBC*(TWBORC3-TWBORC0)+
C_DTSBC*(DTSBORC3-DTSBORC0)+ C_RC*(RC3-RC0)+ C_IC*(IC3-IC0)
654      + C_TCDL*(TCDL3-TCDL0)+ C_TCRM*(TCRM3-TCRM0)+
C_TCTWBC*(TCTWBC3-TCTWBC0)
654      + C_RCQ*(RCQ3-RCQ0)+ C_ICQ*(ICQ3-ICQ0)
+C_DTSQBC*(DTSQBC3-DTSQBC0)
654      + C_NTCBC*(NTCBORC3-NTCBORC0)+ C_TCHC*(TCHC3-TCHC0)+
C_TCRC*(TCRC3-TCRC0);
655
655      PRINT (FORMAT="('IMPOSING RESRTICTION ON DTSQ')");
656      FRML C_DTSQA C_DTSA/6 + E*E;
657
657      EQSUB(NAME=LOGIT3) EQ3 EQV1 EQV2 EQV3;
658      PARAM E,1;
659      PARAM D1 D2 D3 C_DUM1 C_DUM2 C_DUM3 C_TCA C_TCBC C_DL C_HCA C_HCB
C_HCC
659      C_RMA C_RMB C_RMC C_TWA C_TWBC C_DTSA C_DTSBC C_RC C_IA C_IB
C_IC
659      C_TCDL C_TCRM C_TCTWBC C_TCHC C_TCRC C_RMQAB C_RCQ C_IAQ C_ICQ
C_NTCA C_NTCBC
659      C_NDTSA C_DTSQBC;
660
660      PRINT (FORMAT="('THE FINAL NON-TELE VS TELE GROUP: IMPOSED
RESRTICTION: DTSQA<1/6DTSA')");
661      ML(HITER=N,HCOV=N) LOGIT3;
662      SET LL6=@LOGL;
663      SET RHO2=1-(LL6/LL0);
664      SET RHOBAR=1-((LL6-@NCOEF)/LL0);
665      SET LR0= -2*(LL0 -LL6);
666      SET LRC= -2*(LLC -LL6);
667      PRINT @NCOEF RHO2 RHOBAR LR0 LRC;
668      ANALYZ C_DTSQA;
669
669      END;

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EXECUTION

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Current sample: 2 to 3466

Current sample: 2 to 2593

Current sample: 2594 to 3466

Current sample: 2 to 3466

NON-TELE MODEL - TELE MODEL WITH SIGNIFICANT INTERACTIONS ONLY

Equation 1
=====

MIXED LOGIT ESTIMATION

CHOICE	FREQUENCY	PERCENT
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0 839 24.2136 (COEFFICIENTS NORMALIZED TO ZERO)
 1 801 23.1169
 2 517 14.9206
 3 1308 37.7489
 Working space used: 911051

STARTING VALUES

	TCA	TCBORC	DL	HCA	HCB
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000

	HCC	RMA	RMB	RMC	TWA
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000

	TWBORC	DTSA	DTSBORC	RC	IA
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000

	IB	IC	TCDL	TCHC	TCRM
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000

	TCTWBC	TCRC	RMQAB	DTSQA	DTSQBC
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000

	RCQ	IAQ	ICQ	NTCA	NTCBORC
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000

	NDTSA	C1	DUM1	C2	DUM2
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000

	C3	DUM3
VALUE	0.00000	0.00000

F= 4803.5	FNEW= 4196.3	ISQZ= 0	STEP= 1.0000	CRIT= 1208.7
F= 4196.3	FNEW= 4168.8	ISQZ= 0	STEP= 1.0000	CRIT= 52.702
F= 4168.8	FNEW= 4168.5	ISQZ= 0	STEP= 1.0000	CRIT= 0.61826
F= 4168.5	FNEW= 4168.5	ISQZ= 0	STEP= 1.0000	CRIT= 0.27921E-03
F= 4168.5	FNEW= 4168.5	ISQZ= 0	STEP= 1.0000	CRIT= 0.76222E-10

CONVERGENCE ACHIEVED AFTER 5 ITERATIONS

10 FUNCTION EVALUATIONS.

DEPENDENT VARIABLE: Y

LOG OF LIKELIHOOD FUNCTION = -4168.51
 NUMBER OF CASES = 3465
 NUMBER OF CHOICES = 13860

Standard

Parameter	Estimate	Error	t-statistic
TCA	.220796	.061999	3.56126
TCBORC	.319629	.044607	7.16536
DL	-.096588	.029997	-3.21993
HCA	-.569579	.055094	-10.3383
HCB	-.627009	.064725	-9.68732
HCC	-.200966	.045936	-4.37490
RMA	.212671	.054607	3.89458
RMB	.326141	.065283	4.99581
RMC	.068057	.045590	1.49282
TWA	-.049968	.053233	-.938675
TWBORC	-.310326	.037945	-8.17833
DTSA	-.405402	.101588	-3.99064
DTSBORC	-.243227	.055078	-4.41601
RC	.364966	.031436	11.6097
IA	.124137	.018246	6.80359
IB	.022034	.010567	2.08526
IC	.235995	.026220	9.00057
TCDL	-.082396	.038331	-2.14957
TCHC	-.052536	.037805	-1.38967
TCRM	.080710	.038029	2.12232
TCTWBC	.145560	.047025	3.09536
TCRC	.085178	.038928	2.18810
RMQAB	-.060702	.023075	-2.63061
DTSQA	-.212602	.035447	-5.99781
DTSQBC	-.040491	.024538	-1.65010
RCQ	-.074175	.017399	-4.26327
IAQ	-.432261E-02	.882148E-03	-4.90010
ICQ	-.947316E-02	.136521E-02	-6.93897
NTCA	-.134194	.061650	-2.17673
NTCBORC	-.079600	.044224	-1.79992
NDTSA	.270657	.100841	2.68399
C1	-.756167	.088297	-8.56391
DUM1	.120939	.059042	2.04836
C2	-.906235	.080397	-11.2720
DUM2	.248759	.068847	3.61320
C3	.147476	.061294	2.40605
DUM3	.156034	.052168	2.99101

Standard Errors computed from analytic second derivatives
(Newton)

	@NCOEF	RHO2	RHOBAR	LR0	LRC
Value	37.00000	0.13219	0.12449	1269.99968	904.77968

SAME AS ABOVE MODEL USING GENERAL ML

MAXIMUM LIKELIHOOD ESTIMATION
=====

EQUATION: LOGIT2

Working space used: 629133

STARTING VALUES

	D3	C_DUM3	C_TCBC	C_DL	C_HCC
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000

	C_RMC	C_TWBC	C_DTSBC	C_RC	C_IC
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000

	C_TCDL	C_TCRM	C_TCTWBC	C_DTSQBC	C_RCQ
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000

	C_ICQ	C_NTCBC	C_TCHC	C_TCRC	D2
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000

	C_DUM2	C_HCB	C_RMB	C_IB	C_RMQAB
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000

	D1	C_DUM1	C_TCA	C_HCA	C_RMA
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000

	C_TWA	C_DTSA	C_IA	C_DTSQA	C_IAQ
VALUE	0.00000	0.00000	0.00000	0.00000	0.00000

	C_NTCA	C_NDTSA
VALUE	0.00000	0.00000

F=	4803.5	FNEW=	4196.3	ISQZ=	0	STEP=	1.0000	CRIT=	1208.7
F=	4196.3	FNEW=	4168.8	ISQZ=	0	STEP=	1.0000	CRIT=	52.702
F=	4168.8	FNEW=	4168.5	ISQZ=	0	STEP=	1.0000	CRIT=	0.61826
F=	4168.5	FNEW=	4168.5	ISQZ=	0	STEP=	1.0000	CRIT=	0.27921E-03
F=	4168.5	FNEW=	4168.5	ISQZ=	0	STEP=	1.0000	CRIT=	0.76222E-10

CONVERGENCE ACHIEVED AFTER 5 ITERATIONS

10 FUNCTION EVALUATIONS.

LOG OF LIKELIHOOD FUNCTION = -4168.51
NUMBER OF OBSERVATIONS = 3465

Parameter	Estimate	Standard Error	t-statistic
D3	.147476	.061294	2.40605
C_DUM3	.156034	.052168	2.99101
C_TCBC	.319629	.044607	7.16536
C_DL	-.096588	.029997	-3.21993
C_HCC	-.200966	.045936	-4.37490
C_RMC	.068057	.045590	1.49282
C_TWBC	-.310326	.037945	-8.17833
C_DTSBC	-.243227	.055078	-4.41601

C_RC	.364966	.031436	11.6097
C_IC	.235995	.026220	9.00057
C_TCDL	-.082396	.038331	-2.14957
C_TCRM	.080710	.038029	2.12232
C_TCTWBC	.145560	.047025	3.09536
C_DTSQBC	-.040491	.024538	-1.65010
C_RCQ	-.074175	.017399	-4.26327
C_ICQ	-.947316E-02	.136521E-02	-6.93897
C_NTCBC	-.079600	.044224	-1.79992
C_TCHC	-.052536	.037805	-1.38967
C_TCRC	.085178	.038928	2.18810
D2	-.906235	.080397	-11.2720
C_DUM2	.248759	.068847	3.61320
C_HCB	-.627009	.064725	-9.68732
C_RMB	.326141	.065283	4.99581
C_IB	.022034	.010567	2.08526
C_RMQAB	-.060702	.023075	-2.63061
D1	-.756167	.088297	-8.56391
C_DUM1	.120939	.059042	2.04836
C_TCA	.220796	.061999	3.56126
C_HCA	-.569579	.055094	-10.3383
C_RMA	.212671	.054607	3.89458
C_TWA	-.049968	.053233	-.938675
C_DTSA	-.405402	.101588	-3.99064
C_IA	.124137	.018246	6.80359
C_DTSQA	-.212602	.035447	-5.99781
C_IAQ	-.432261E-02	.882148E-03	-4.90010
C_NTCA	-.134194	.061650	-2.17673
C_NDTSA	.270657	.100841	2.68399

Standard Errors computed from analytic second derivatives
(Newton)

	@NCOEF	RHO2	RHOBAR	LRO	LRC
Value	37.00000	0.13219	0.12449	1269.99968	904.77968

IMPOSING RESRTICTION ON DTSQ

THE FINAL NON-TELE VS TELE GROUP: IMPOSED RESRTICTION: DTSQA<1/6DTSA

MAXIMUM LIKELIHOOD ESTIMATION =====

EQUATION: LOGIT3

Working space used: 629205

STARTING VALUES

	D3	C_DUM3	C_TCBC	C_DL	C_HCC
VALUE	0.14748	0.15603	0.31963	-0.096588	-0.20097
	C_RMC	C_TWBC	C_DTSBC	C_RC	C_IC
VALUE	0.068057	-0.31033	-0.24323	0.36497	0.23600

	C_TCDL	C_TCRM	C_TCTWBC	C_RCQ	C_ICQ
VALUE	-0.082396	0.080710	0.14556	-0.074175	-0.0094732

	C_DTSQBC	C_NTCBC	C_TCHC	C_TCRC	D2
VALUE	-0.040491	-0.079600	-0.052536	0.085178	-0.90624

	C_DUM2	C_HCB	C_RMB	C_IB	C_RMQAB
VALUE	0.24876	-0.62701	0.32614	0.022034	-0.060702

	D1	C_DUM1	C_TCA	C_HCA	C_RMA
VALUE	-0.75617	0.12094	0.22080	-0.56958	0.21267

	C_TWA	C_DTSA	C_IA	E	C_IAQ
VALUE	-0.049968	-0.40540	0.12414	1.00000	-0.0043226

	C_NTCA	C_NDTSA
VALUE	-0.13419	0.27066

F=	5024.7	FNEW=	4553.7	ISQZ=	0	STEP=	1.0000	CRIT=	1877.4
F=	4553.7	FNEW=	4236.3	ISQZ=	4	STEP=	0.62500E-01	CRIT=	4778.6
F=	4236.3	FNEW=	4187.7	ISQZ=	0	STEP=	1.0000	CRIT=	122.34
F=	4187.7	FNEW=	4177.3	ISQZ=	0	STEP=	1.0000	CRIT=	19.492
F=	4177.3	FNEW=	4176.4	ISQZ=	0	STEP=	1.0000	CRIT=	1.5640
F=	4176.4	FNEW=	4176.4	ISQZ=	0	STEP=	1.0000	CRIT=	0.50457E-01
F=	4176.4	FNEW=	4176.4	ISQZ=	0	STEP=	1.0000	CRIT=	0.49017E-04
F=	4176.4	FNEW=	4176.4	ISQZ=	0	STEP=	1.0000	CRIT=	0.52808E-10

CONVERGENCE ACHIEVED AFTER 8 ITERATIONS

20 FUNCTION EVALUATIONS.

LOG OF LIKELIHOOD FUNCTION = -4176.42
NUMBER OF OBSERVATIONS = 3465

Parameter	Estimate	Standard Error	t-statistic
D3	.171167	.061235	2.79523
C_DUM3	.157116	.052159	3.01227
C_TCBC	.319165	.044631	7.15122
C_DL	-.097378	.029969	-3.24931
C_HCC	-.203691	.045930	-4.43483
C_RMC	.067729	.045559	1.48663
C_TWBC	-.309735	.037941	-8.16360
C_DTSBC	-.240341	.055144	-4.35845
C_RC	.364137	.031389	11.6009
C_IC	.237178	.026197	9.05366
C_TCDL	-.081480	.038300	-2.12740
C_TCRM	.079093	.038081	2.07695
C_TCTWBC	.146852	.047058	3.12064

C_RCQ	-.072631	.017349	-4.18644
C_ICQ	-.954565E-02	.136446E-02	-6.99591
C_DTSQBC	-.017899	.023954	-.747211
C_NTCBC	-.078581	.044239	-1.77629
C_TCHC	-.052287	.037774	-1.38419
C_TCRC	.087591	.038916	2.25075
D2	-.883336	.080278	-11.0034
C_DUM2	.249670	.068824	3.62765
C_HCB	-.626546	.064708	-9.68273
C_RMB	.328724	.065292	5.03465
C_IB	.022467	.010544	2.13090
C_RMQAB	-.061635	.023027	-2.67659
D1	-.612709	.079075	-7.74842
C_DUM1	.133158	.059156	2.25094
C_TCA	.218333	.062012	3.52080
C_HCA	-.572928	.055018	-10.4135
C_RMA	.220262	.054530	4.03925
C_TWA	-.060241	.053046	-1.13562
C_DTSA	-.530246	.092455	-5.73518
C_IA	.120813	.018064	6.68818
E	.445864E-12	.067149	.663995E-11
C_IAQ	-.408903E-02	.869722E-03	-4.70153
C_NTCA	-.135136	.061675	-2.19111
C_NDTSA	.318813	.095103	3.35230

Standard Errors computed from analytic second derivatives
(Newton)

	@NCOEF	RHO2	RHOBAR	LR0	LRC
Value	37.00000	0.13055	0.12285	1254.17624	888.95624

Results of Parameter Analysis =====

Parameter	Estimate	Standard Error	t-statistic
C_DTSQA	-.088374	.015409	-5.73518

Wald Test for the Hypothesis that the given set of Parameters are jointly zero:

CHISQ(1) = 32.892335 ; P-value = 0.00000

END OF OUTPUT FOR USER REZA

MEMORY USAGE:	ITEM:	DATA ARRAY	TOTAL MEMORY
	UNITS:	(4-BYTE WORDS)	(MEGABYTES)
MEMORY ALLOCATED	:	5750000	25.0
MEMORY ACTUALLY REQUIRED	:	3192809	14.9
CURRENT VARIABLE STORAGE	:	2277040	