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A STUDY OF WORK-BASED TRAVEL IN VICTORIA

by

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B.Sc., University of Victoria, 1973

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS

in the department
of
Geography

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ABSTRACT

This thesis documents the development and application of a disaggregate mode choice model calibrated for Victoria, B.C. A major objective of this work is to show that state-of-the-art methods in mode choice forecasting can be undertaken in smaller and medium sized cities of well under half a million population. This objective has been made possible by using a smaller cost effective data base where quality data is the important factor compared with traditionally voluminous and expensive data bases associated with the transport studies of the late 1950's and '60's. The advent of smaller transport data bases affords the use of smaller more accessible computers including full optioned micro computers.

The mode choice model developed is a binary choice LOGIT model using maximum likelihood estimation to derive model coefficients. The dependent variable is the binary choices of transit and auto modes. Six explanatory variables were found to be most useful and were included in four final model designs.

The LOGIT model was calibrated using an origin-destination home interview survey conducted in Victoria during the summer of 1977. The data base was restricted to work-based trips between home and work producing 623 trip records amongst 215 sampled households.

The useful independent variables in order of their significance in the main model are car availability which is based on the household's car ownership and the number of employed persons. The second is relative level-of-service expressed as the ratio between the levels-of-service for transit and auto modes. The third is the out-of-vehicle travel time which is calculated as the difference between the out-of-vehicle times for transit and auto. The fourth variable is the relative out-of-pocket costs of transit and auto. The fifth and sixth variables are age and sex taken directly from the 1977 travel survey. All six variables were found to have satisfactory significance or better for all four model designs. The model designs included a general work-based model, a peak-period work-based model, a downtown-based model and a non-peak, non-downtown work-based model.

An important aspect of the model development is the application of the model as a key part of the transport forecasting process. A scenario analysis is designed to illustrate the model's use in transit planning. In this context it is shown that an optimization problem can be solved by comparing transit options on service levels and various fare charges using the model's estimates. A trip generation and distribution component is included in the example application to best illustrate the practical use of a disaggregate mode choice model in transit planning.

Examiners:

Dr. G.M. Barber, Geography Department

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TABLE OF CONTENTS

		Page No.
TITLE PAGE		i
ABSTRACT		ii
TABLE OF CONTENTS		iv
LIST OF TABLES		vi
LIST OF FIGURES		viii
ACKNOWLEDGEMENTS		ix
DEDICATION		x
CHAPTER I -	INTRODUCTION	1
1.1	Goals	2
1.2	Background	3
1.3	Needs for an Econometric Model for Transit	6
1.4	Methodologies	6
1.5	Transportation Planning - An Overview	13
1.6	Summary	13
	References	16
CHAPTER II -	THEORY AND PRACTICE IN TRAVEL CHOICE MODELLING	18
2.1	Traditional Techniques	18
2.2	Behavioural Travel-Demand Models	21
2.3	Assumptions - Travel-Demand Behaviour vs. LOGIT Assumptions	26
2.4	Choosing a Statistical Tool to Calibrate a Binary Choice Model	33
2.5	Summary and Conclusions	42
	References	45
CHAPTER III -	THE DATA	48
3.1	1977 Travel Survey	51
3.2	Useable Survey Data	57
3.3	Additional Data Appended	65

TABLE OF CONTENTS (Continued)

Page No.

3.4 Conclusions 83

References 87

CHAPTER IV - CALIBRATION OF THE VICTORIA MODEL 89

4.1 Model Stratification 89

4.2 A Note on Model Computer Software 92

4.3 Relative Variable Measurements - Some Considerations 95

4.4 The LOGIT Form 99

4.5 A Methodology to Analyse Model Significance. 100

4.6 Analysis of Model Performance 104

4.7 Conclusions 130

References 134

CHAPTER V - APPLICATION OF THE MODEL 135

5.1 Hypothetical Case Study of Transit Options Using a Victoria Transit Planning Area 136

5.2 Special Model Applications 159

5.3 Limitations to the Model 160

5.4 Model and Data Matrix Management 162

5.5 Summary 165

References 176

BIBLIOGRAPHY 177

APPENDIX A - Computer Summary of Model Calibrations 181

A1: FDTF1 (General Model) uses the 6 favoured independent variables plus TIM, OUT, TRNSFERS, TPROP 182

A2: FDIF2 (General Model) used the 6 favoured independent variables only. The SER variable is expressed by transit auto difference 187

A3: FMIX1 (General Model) used the 6 favoured independent variables plus the household income status variable (HINC) 192

A4: FMIX2 (General Model) uses only the 6 favoured independent variables. The SER variable is expressed as a transit-auto ratio 197

A5: PKMIX (Peak Period Model) same variables as A4 202

TABLE OF CONTENTS (Continued)

Page No.

A6: DTNMIX (Downtown-Based Model) same variables as A4 206

A7: NOPDMIX (non-Peak and Non-Downtown Based Model) same variables as A4 210

APPENDIX B - Sample Survey Form 215
(1977 CRD Transportation Study; Home Interview)

APPENDIX C - Traffic Zones (Geographical areas enumerated for the data set) 217

APPENDIX D - Study Scenario Computer Output Forms (Model Application Examples) 219

APPENDIX E - Trip Generation in Victoria Using Cross-Classification (Aggregate model using 1977 CRD interview data) 234

APPENDIX F - Trip Generation Using Multiple Regression (Aggregate model using 1977 CRD interview data) 281

APPENDIX G - Government Publications On Victoria Transit Operations used in this study 301

LIST OF TABLES

Table Number	Title	Page
2.1	A Comparison of Modelling Approaches	23
2.2	Comparison of Work and Non-Work Based Trips Against Travel Mode	27
3.1	Data Specifications	49-50
3.2	Household Categories	52
3.3	Household Categories by Percentages	53
3.4	Interview Responses by Household Category (Percentages)	54
3.5	Information Categories, 1977 Transportation Study/Home Interview	55-57
3.6	Final Data Set	68-69
3.7	LSERVT Measurement Scale	75
3.8	Calibration Variables	85
3.9	Selected Explanatory Variables in Mode Choice Studies	86
4.1	General Work-Based Victoria Model	93
4.2	Special Work-Based Victoria Models	94
4.3	Comparison of Difference Versus Ratio Approach for Car Availability (CARAVAIL)	97
4.4	Covariance Matrix	103
4.5	Mode Choice Significance Test Results: T-Ratios and Chi Square	106
4.6	Significance of Car Availability (General Work-Based Victoria Model)	107
4.7	Significance of SER (GWBVM)	107
4.8	Significance of OUT (GWBVM)	109
4.9	Significance of COST (GWBVM)	111
4.10	Significance of SEX (GWBVM)	111
4.11	Significance of AGE (GWBVM)	113
4.12	Significance of TIM, TRNSERS and TPROP (GWBVM)	113
4.13	Significance of HINC (GWBVM)	115
4.14	Significance of CARAVAIL (Special Work-Based Victoria Models)	118
4.15	Significance of OUT (SWBVM)	119

LIST OF TABLES (Continued)

Table Number	Title	Page
4.16	Significance of SER (SWBVM)	121
4.17	Significance of COST (SWBVM)	121
4.18	Significance of AGE (SWBVM)	122
4.19	Significance of SEX (SWBVM)	124
4.20	Chi-Square - Model Significance	128
4.21	Transit Utility Functions - G($\underline{X}$)	132-133
5.1	Case Study Data Matrix	143-145
5.2	Work-Based Trip Generation Estimates	148
5.3	Trip Distribution Matrix, P.M. Peak Hour Trips	149

LIST OF FIGURES

Figure Number	Title	Page
1.1	Core Municipalities of Greater Victoria	4
1.2	Provision System for Public Transit in British Columbia	7
1.3	Transportation Planning Process	14
2.1	Transportation Forecasting Process	19
2.2	Standard Normal and Weibull Probability Distributions	31
2.3	Distribution of Discriminant Function	35
2.4	Cumulative Probability (P) Distribution	37
3.1	Super Districts of the Capital Regional District	60
3.2	Bi-Hourly Trip Frequency	66
3.3	Downtown Traffic Zones - Victoria CBC	78
4.1	Linear Relationship for Mode Choice	101
4.2	Logistic Relationship for Mode Choice	101
5.1	Study Area of Scenario Analysis	138
5.2	Scenario Model Inputs and Outputs	140
5.3	Input/Output Screen Form	151
5.4	Study Area Bus Routes	153
5.5	Service Level Options	154
5.6	Transit Fare Options	156
5.7	Input/Output Form: Using 5 & 10 min. Headway and $1.00 Fare	158
5.8	Model and Data Management FLOW CHART	164

ACKNOWLEDGEMENTS

The author wishes to thank the following persons and agencies:

1. A committee composed of Professor G. Barber as Chairman and Thesis Advisor, Professors T. Lambe of the School of Public Administration and P. Murphy of the Geography Department, all at the University of Victoria.

2. Capital Regional District, (CRD) and in particular, Varghese Cherian and David Langley of the CRD Transportation group.

3. University of Victoria Computing Centre, and particularly Mel Klassen.

4. University of British Columbia Computing Centre, and in particular, Malcolm Grieg.

5. My wife, Victoria Hogan, M.A., whose typing and support were instrumental in completing this document.

6. Lavalin, Inc. for their support at work.

DEDICATION

To My Wife,
Vickie

CHAPTER I

INTRODUCTION

A vital aspect of urban transit and transportation planning is the ability to forecast travel demand with reliability and confidence. Traffic congestion along our transport corridors has been with us since man created his first cities. It therefore seems apparent that greater foresight and understanding of a society's transport needs is deserving of increased research and development. This thesis will address an important aspect of transport demand analysis, namely, forecasting travel mode choice using a predictive mathematical model. Taking advantage of a travel survey done by the Capital Regional District, it has been possible to tailor a model of individual mode choice for Victoria, capital city of British Columbia.

The purpose of this thesis, then, is to develop and implement a mode choice model based on individuals' choice behaviour. The model uses logistic analysis (LOGIT) which has been successfully used in many transport studies.[1] A more central objective is to calibrate a LOGIT model and demonstrate its usefulness in transit and transportation planning, both in Victoria, and more generally, in the context of smaller urban areas.

The LOGIT model has been shown to produce economical and reliable information on urban travel mode behaviour, particularly as it concerns peak hour travel and the journey to work.[2] For those planners, particularly for smaller urban areas, who have been reluctant to use mathematical models, it is hoped that this study may help persuade them to consider the new methods in cost-effective transport modelling. They may become more aware that cost-effective modelling means quality data, not

the great quantity of data that typified models of the late '50's and the '60's.[3] In order to accomplish this, the author hopes to successfully communicate the use of one such model so that more than descriptive statistics can be derived from travel surveys and various socio-economic data bases. While the focus of this study is travel behaviour in Victoria, it is important to be able to relate the principles and results more to urban communities that share generally similar populations and culture.

In Chapter I, a statement of the goals will be made, followed by background information on the status of transit planning in the study area. The background is intended to identify the traditional techniques used in transit planning, to highlight the shortcomings of such techniques, and to establish a need for model building mode choice in transit planning for smaller urban areas. Following the background will be an introduction to the methodologies used in this study with a brief overview of the LOGIT model statistical technique and the application of this technique in transit problem solving.

1.1 Goals

The general objective of the study is to introduce mode choice modelling as a possibility to public transit planning in Victoria. The following goals have been set to accomplish the above objective.

1. To bring together available data and organize it into a usable and unified data base.
2. To develop a set of explanatory variables which can be used as independent variables in the LOGIT model calibration process.

3. To employ available computer software to process the data base to produce the model's coefficients.
4. To develop useful model designs which can be applied to practical transport problems that require the prediction of travel behaviour.
5. To demonstrate the use of the model using a practical example.
6. To fully document the model and its rationale, and defend its applicability to modern transit planning.
7. To discuss and recommend possible improvements to the model and the data base.
8. To discuss maintenance implications and model recalibration considerations.

1.2 Background

Victoria, as the capital city of the province of British Columbia, occupies the peninsula of land at the southern tip of Vancouver Island, with an area population of about a quarter of a million. Its population is supported by several basic activities including the provincial government headquarters, deep-sea harbour services, forest products and an extensive armed forces establishment. The Capital Regional District is a county-like political unit comprising the greater Victoria region which includes seven municipalities and a number of unorganized communities.[4] (See Fig. 1.1).[5]

1.2.1 Transit Planning in the Capital Regional District

Through the years from the early days of B.C. Hydro transit in the mid-1950's to the creation of the B.C. Transit Authority in the late 1970's, planning for transit was an exercise of "trial and error", of "scheduling experiments" and of hindsight responses to problems and even service crises.[6] This planning record has been due almost solely to lack

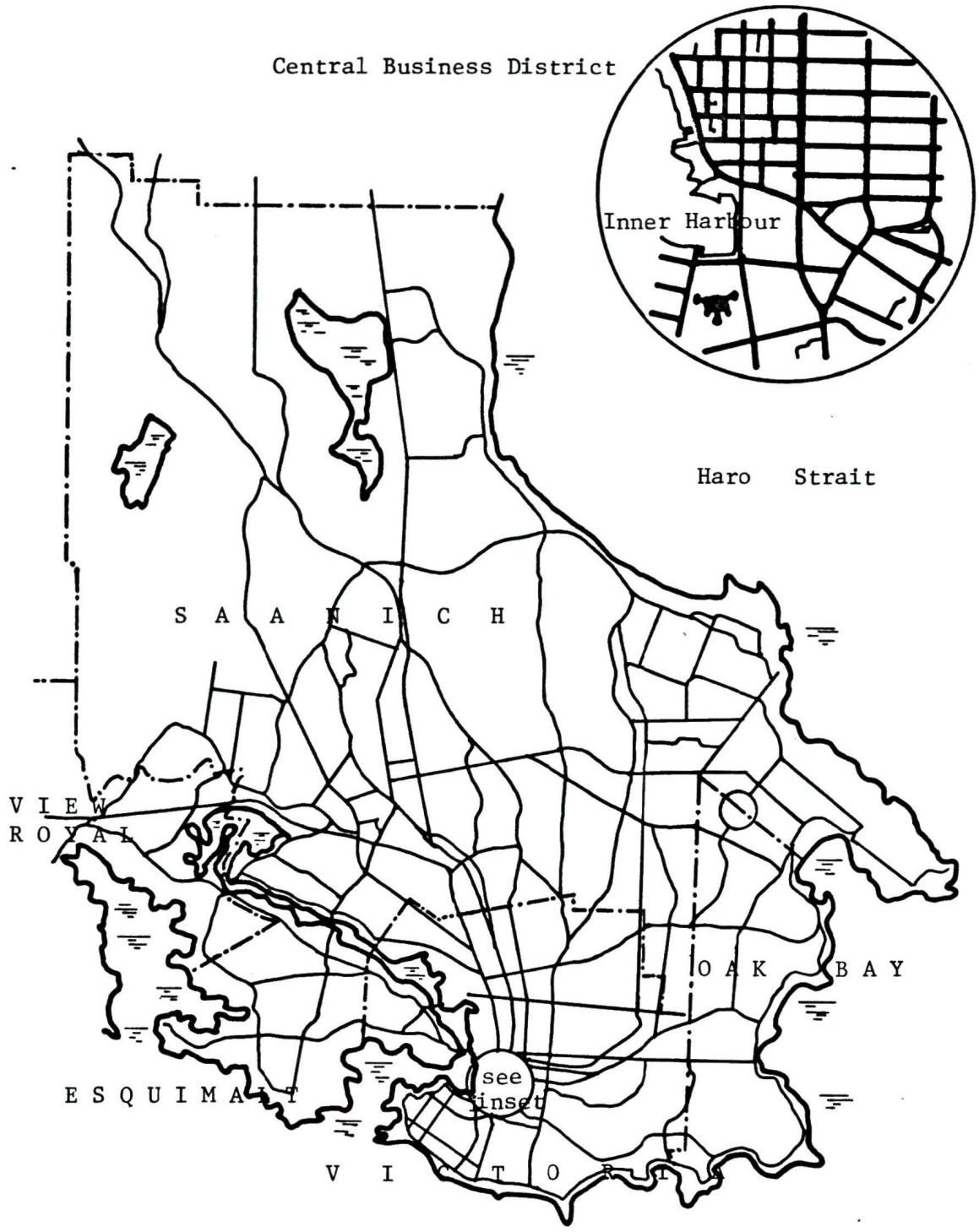


Figure 1.1 Core Municipalities of Greater Victoria

of reliable and consistent data on ridership and travel behaviour.[7]

Typically, smaller transit systems have collected data intended to solve a single problem or cover a narrowly-scoped planning area. For example, in Victoria, on-bus on-off ridership counts were collected for particular routes. Such data were never collected consistently or in a regular manner resulting in gaps and unknown sampling information which precludes first class statistical analysis and the development of a long term data base. While effort was given to data collection, its use was only seen in the short term to answer a specific question about a particular route. Naturally, the problem routes were surveyed with greater frequency though very often the "problem routes" remained the problem routes.[8]

The history of transit-related data collection for greater Victoria is one of many small data bases held in time and offering little or no opportunity for practical statistical comparisons. Thus, any analysis could not connect information over the years or permit routes to be accurately compared in the same year. As a consequence, the results of this study must stand on the rigor of the study using a rather qualitative and descriptive evaluation. This involves the comparison of results with actual ridership data collected by the Capital Region Transit Planning Department in 1981 and 1982.

1.2.2 B.C. Transit and Public Transit in the Province

In Victoria, traditional planning methods are being employed with the same relative success as has been experienced in past years. It is the intention of this thesis to identify another dimension to this process which employs established predictive modelling techniques using a cost effective and rigorously collected data set. In Chapter III,

details of such a data set will be covered. The subject of traditional methods for both Victoria and in the broader context of North American systems will be reviewed in Chapter II.

The provision system for public transit does have a contextual importance to the how and what is practical and possible in the area of data collection, system monitoring and information analysis given B.C. Transit's size and overall resources for undertaking planning studies. In Fig. 1.2, a flow chart of the B.C. Transit's organizational structure is represented, including the political and financial arrangements that are provided for in the transit act.

1.3 Needs for an Econometric Model for Transit

The transit planning process attempts to provide more effective and cost efficient transit service. This process requires rational ways to predict potential transit patronage which will enable the provision of effective levels of service. The modal split models that have been developed in the past 15 years have progressed substantially with regard to reliability, costs of implementation and the level and amount of required input data.

Specifically, the LOGIT model may be used to estimate transportation modal split from a relatively small data set. The emphasis on smaller data sets is possible by collecting individual and trip specific information on a household-by-household basis. The resultant "quality" data base is often referred to as a disaggregate base; that is, information is collected from the smallest unit, the individual, and the accounts of actual trips taken during the sampling period.

1.4 Methodologies

Four steps were used to accomplish the goals set out in section 1.1.

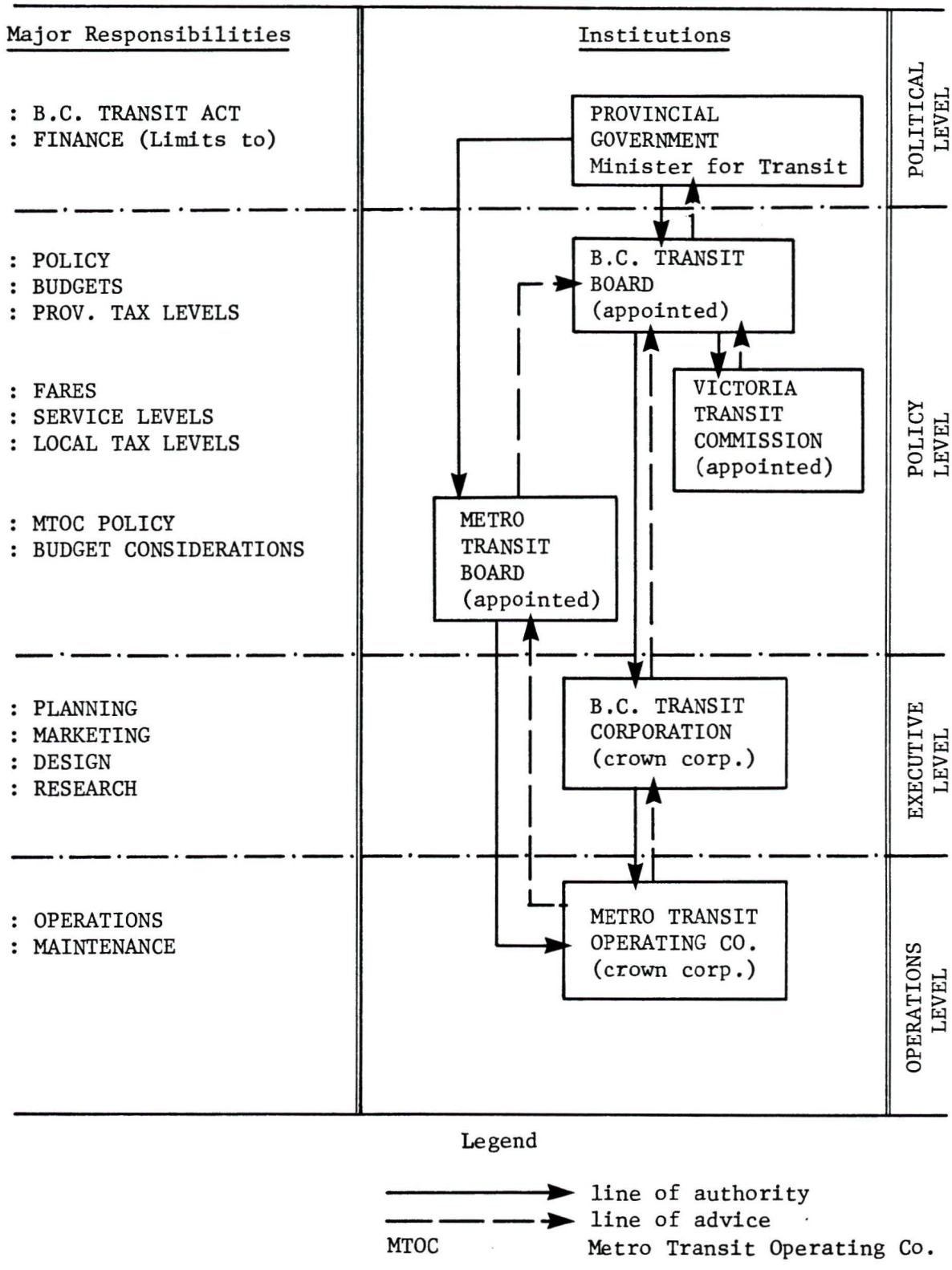


Figure 1.2 PROVISION SYSTEM FOR PUBLIC TRANSIT IN BRITISH COLUMBIA

They are: 1) editing the baseline survey; 2) testing the reliability of the survey using cross-classification techniques; 3) calibrating the Victoria mode choice (LOGIT) model, and 4) applying the model in a scenario analysis.

The first step was obtaining permission to use the origin-destination survey which forms the baseline data in the study. The survey was originally conducted by the transportation group of the Capital Regional District in the summer of 1977.[9] It was then necessary to edit and stratify the original data set in preparation for model development and calibration.[10]

In step two, a preliminary analysis was made using the survey data. This analysis was a cross-classification exercise to empirically derive non-linear relationships on travel behaviour. The original analysis is reproduced in Appendix E. The results of the cross-classification served to confirm the reliability and consistency of the baseline survey, thus paving the way to developing the more powerful LOGIT model.

The LOGIT analysis including all its variable preparation formed step three. The LOGIT model is not a unique transportation specific data processing technique. The LOGIT model has been used by biologists, economists, sociologists and geographers. Within transport studies LOGIT models have found a very key application in predicting travel behaviour regarding the choice of transport mode and particularly the modes of bus transit versus the private automobile.

The final step of the study involves the application of the model in a scenario analysis. Given an opportunity to predict travel mode choice, it is possible to play a gaming exercise which allows planners to estimate (with reliability) the answers to a variety of "what if?"

type questions on new transit service alternatives. The aid of micro computers easily facilitates such exercises at low cost and great time savings. In effect, a planner, a politician or senior administrator can interact with such "computer games" to effectively view the possible impacts of a decision. It is in this arena of decision making that models find great application. A very simplified but practical application is to be demonstrated in Chapter V.

1.4.1 Editing the Baseline Survey

The original origin-destination survey formally referred to as the CRD 1977 Transportation Study/Home Interview Survey was instituted for several purposes including the eventual development of a mode choice predictive model.[11]* The CRD did not take the time to undertake the necessary editing which was considered by staff as a significant task and necessary exercise before it could be used in any disaggregate form.[12] Thus, the focus of the LOGIT analysis of mode choice begins with a data base which comprises over 3600 person-trip records. This data set is distilled down to include only those records which satisfy a specific trip purpose and trip mode.

The trip purpose used in this revised data set is the journey to and from work. The trip modes to be considered are restricted to the transit passenger, the car driver and the car passenger. The advantage of narrowing the data set to these three trip modes and the single trip purpose is summarized in the following three points. First, the data set covers the

---

* Mr. V. Cherian of the CRD transportation group in earlier (1980) discussions encouraged the author to consider calibrating a mode choice model for Victoria to complete the last component of the CRD Transportation Model. Mr. Cherian is sited in the acknowledgements.

critical time period during the a.m. and p.m. peaks. This enables a good focus on the majority of transportation problems related to road and transit capacity. Second, fewer assumptions about travel behaviour need be made since only the journey to work is being considered, and lastly, the relative homogeneity of the data enables a smaller data set to be used while preserving confidence levels.

1.4.2 Testing the Reliability of the Survey

The cross-classification procedure also requires origin-destination data to estimate trip generation by various socio-economic strata. However, its use is in an aggregate form. To quote from the report contained in Appendix E, "Cross-classification involves a quantitative ordering of (explicatory) variables into a matrix to reveal relationships between pairs or triads of independent variables to the dependent variable of person trips per household".[13]

The results of the cross-classification have permitted a comparison of the survey data with the literature and the now generally accepted theory on the relationships between certain a priori variables.[14] Two conclusions summarize this work. First, the survey data compares favourably with urban areas in the same population range of 100-500 thousand population, and second, a priori variables of car ownership, income and household population were confirmed and subsequently used in the model with certain limitations which will be detailed in Chapter III.

1.4.3 Calibrating the Victoria Mode Choice Model

LOGIT analysis has been chosen as the statistical technique in developing a mathematical model for predicting travel mode choice (also called mode split). This technique will be fully detailed in Chapters II and IV where the specific calibration results for the Victoria LOGIT model will

be described and illustrated.

In brief, the LOGIT model as used in this study is an econometric model of the binary choice form.[15]

$$P_j^i = \frac{e^{G^i(X_{jk})}}{1 + e^{G^i(X_{jk})}} \qquad (1.1)$$

where: P_j^i = probability of the i-th person choosing the j-th travel mode (i.e., transit or auto) as opposed to the alternative k-th travel mode;

e = (also exp) the base of the natural logarithm of numbers;

$G^i(X_{jk})$ = a linear function of attributes (X) of alternative mode j against alternative k.

X_{jk} = each attribute "X" in the binary choice formulation is a relative measure of the comparative differences between modes j and k; for example, bus transit versus automobile.

The decision to use the binary model is based on two premises; 1) that only two modes effectively define the competitive alternatives in Victoria, and 2) the shared ride (auto passenger) mode on its own has no solid foundation to base assumptions on choice behaviour. Both premises have their basis in the assumptions of probability theory, that is, that all modes must be available to all respondents if given the financial means. This implies that a competing mode must be potentially available in the normal and consistent journey to work activity. The shared ride individual has a travel status that is not easily determined from the survey. For example, the behaviour associated with the shared ride may be an infrequent favour to a spouse, or an occasional arrangement with a friend, or possibly a car pooling arrangement which consistently uses one member's car. In contrast, such shared ride situations may be

permanent arrangements with a friend or spouse. The distinction between auto driver and passenger then becomes difficult to determine in the data set. It was observed that much of the "noise" or anomalies in the data set relate to the shared ride component.[16] More details on this issue and the larger aspects of the dependent variable are reserved for Chapters III and IV. Given the limitations to the shared ride travel mode, it can be argued that a binary choice model, being both more easily interpreted and computationally less complex, is a favourable model formulation for the Victoria situation.[17]

1.4.4 Applying the Model

The process of calibrating or customizing a LOGIT model for Victoria brings with it the possibility of applying the model to both general and specific transport and transit planning problems. This study is to focus on scenario issues related to transit planning and illustrate one such hypothetical scenario.

In transit planning it has always been a concern whether or not the level of service--and for this discussion we can say the level of service is the frequency or interval between buses on a bus route--is an optimum, given the policy and cost constraints considered to be desirable for the system as a whole.

The Victoria model in itself produces a starting point from which route costing and transit ridership can be estimated. In the past, given field data on a particular bus route, it was difficult to estimate or more realistically guess what impact a major change might have on the parameters by which a route is assessed and planned for. Such parameters would include ridership, annual operating costs, annual costs per ride and possibly costs per ride by diurnal time periods.[18]

In this study, a scenario analysis of a bus route with approximated characteristics will be tested against alternative levels of service scenarios in an effort to permit comparisons between desirable ridership and costs per ride levels, against the actual measures experienced by a given level of service.

1.5 Transportation Planning - An Overview

The focus of the study can be seen within a framework for transportation planning. It is not the intention to review the overall planning process, but rather to illustrate the relationships between the inputs and the outputs of the process. In Fig. 1.3 an overview of the planning process is shown. Within the transportation planning model (see centre of Fig. 1.3) is the domain of predictive transport models that can be classed into four basic tasks. These are trip generation, trip distribution, mode choice (also modal split) and trip assignment. In Chapter II a brief introduction to the area of transport modelling will be made.

1.6 Summary

In Chapter I, it was established that cost-effective predictive modelling can potentially replace traditional methods in smaller city transit planning. Moreover, quality data makes possible smaller surveys, thus allowing big city methods to be used in smaller urban areas such as Victoria. A case for calibrating a binary choice LOGIT model was introduced with the four step process. This process began with a home interview baseline survey and progressed to a calibrated mode choice model using logistic analysis and ended with its application in a "what if?" styled scenario analysis.

In Chapter II, the discussion will turn to the theory underlying individual choice behaviour and the assumptions in the LOGIT model itself.

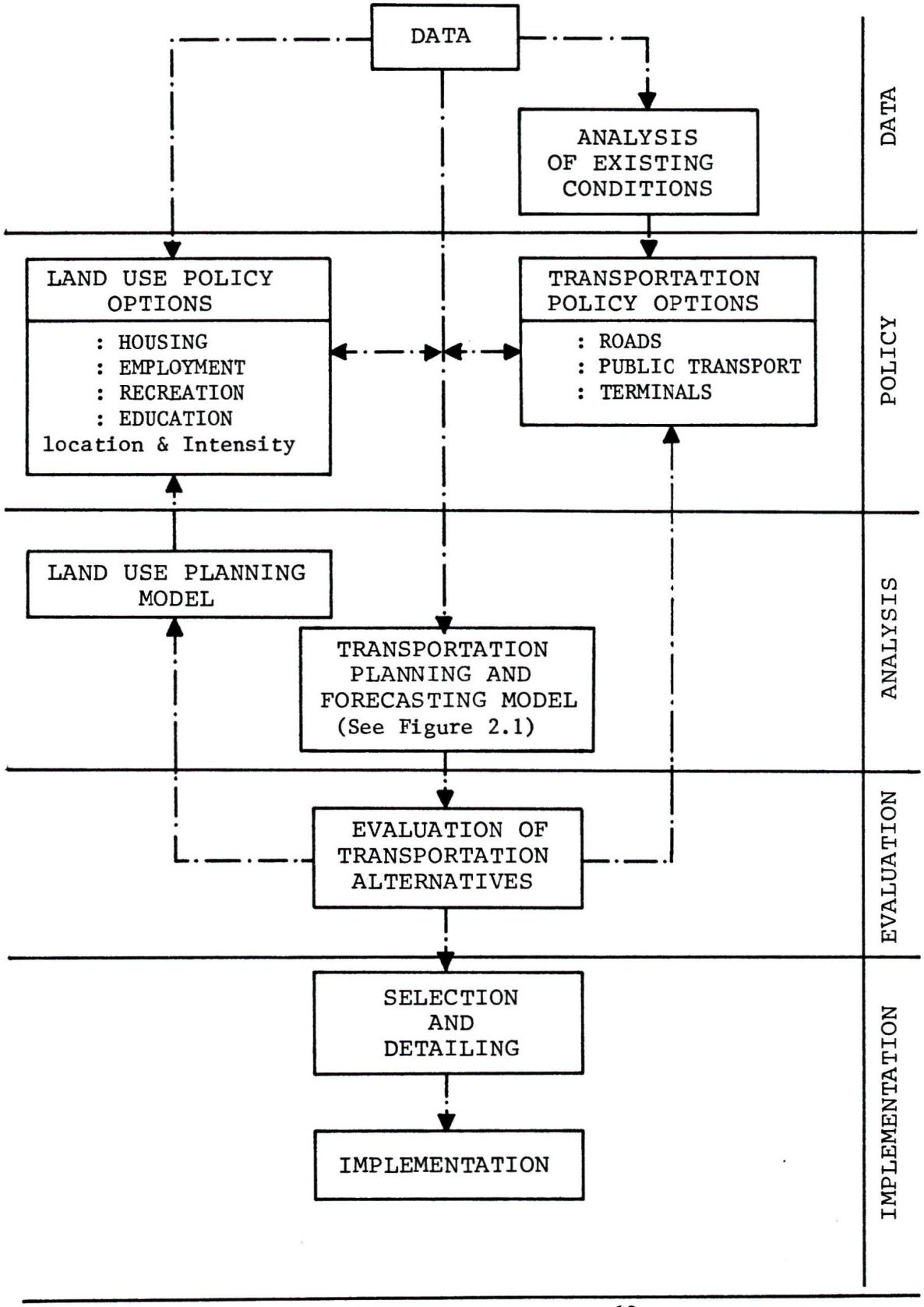


Figure 1.3 TRANSPORTATION PLANNING PROCESS[19]

A review of mode choice modelling will be made with a particular focus on the group of so-called behavioural disaggregate probabilistic models of which logistic analysis is a part. A comparison of traditional and new methods is made. The overall purpose of Chapter II is to review travel mode choice methods, past and present, and to detail the LOGIT model technique which is the underlying tool in this study.

In Chapter III the subject of data is fully introduced and detailed. The purpose is to explain a process which begins with a raw data base and follows its development to a set of satisfactory independent variables for use in calibrating a set of LOGIT models. In so doing, the discussion will employ the theory and assumptions developed in Chapter II and detail the problems incurred with the data set.

The LOGIT model calibration process is the subject of Chapter IV. In this chapter the rationale for more than one LOGIT model is made along with a brief discussion of software used and its availability. The purpose of Chapter IV is to describe and detail each of the proposed models and illustrate their evolution in the context of a set of Victoria specific mode choice LOGIT models.

In Chapter V, the models described in Chapter IV are applied to a hypothetical problem set based on a possible Victoria scenario. The purpose of this chapter is to introduce a transportation planning tool to Victoria, and to identify what it can and cannot do. A discussion on future enhancements is presented, along with recommended courses of action for maintaining the model.

Finally, Chapter VI will present a summary and conclusions to this study.

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1. The bibliography contains several volumes on mode choice studies; they include: Bee, C.K., Brown, G.R., Cherian, V., Domencich, T.A., Donnea, F.X., Hanna, H.N., Manning, I., Morrall, J.F., San Diego Model prepared by Peat, Marwick, Mitchell & Co., Smith, D.P., Stopher, P.R., USDT, and Watson, P.L.

2. Domencich, T.A. and D. McFadden, Urban Travel Demand, A Behavioural Analysis, pp. 11-12, 21-32 and 108-112.

3. A recent study in the Kingston Township (Ontario) demonstrates the use of the LOGIT model in mode choice decision making for the relatively small urban area of Kingston. Curtis, F.A., "Work trip demand modelling for small communities", Plan Canada 21:4, 1982.

4. At the time of the home interview survey which forms the baseline data in this study, there were seven municipalities and an extensive area of unorganized communities referred to as the western communities and Sooke. Today the western communities are one by one becoming incorporated.

5. The Province of British Columbia is divided into 29 regional districts. This fourth level of government falls under the municipal act and functions as a regional municipality with some county-like responsibilities including hospitals, water, recreation and regional parks, special engineering works, planning and transit planning during the years 1979 to 1982.

6. A transit crisis occurs when a scheduled route cannot meet its planned schedule or the typical patronage exceeds the installed service levels and the use of "full-time" overload buses becomes necessary for each and every peak or rush hour period. Some routes in Victoria have operated for years with overload buses running head to toe with the regular bus.

7. The CRD planning department issued its first report on transit data in June of 1982. This contained a first comprehensive assembly of transit data that could be used in conjunction with the home interview survey conducted five years earlier in 1977.

8. The bus services for the north-east quadrant of the urban core (Gordon Head) had remained a problem sub-system for many years. To this day, service levels remain uneven and ridership is far from being optimised.

9. The principal transportation planner, David Langley, and Varghese Cherian et al designed and implemented the 1977 Home Interview Survey of travel behaviour (see Chapter III for survey details).

10. The editing process was a major undertaking and is discussed more fully in Chapter III.

11. The primary survey designer (Varghese Cherian) was never given the opportunity to fully apply the survey to a mode choice model design due to a shortage of staff, money and time. At the time of the survey, the CRD had not assumed the transit planning function.

12. The author obtained access to the original data set and survey forms with the warning that editing is necessary if disaggregate applications are anticipated. Source: Mr. C. Wakelin, former Director of Regional Planning, CRD.

13. The dependent variable is the person-trip mode for both the cross-classification exercise and the primary model in this study; that is, the journey mode taken by one sampled individual for a single trip with a single overall trip purpose as described by the respondent. More detail on the dependent variable will be given in Chapter III.

14. The source document used for the cross-classification was "Trip Generation Analysis" produced by the U.S. Dept. of Transportation, August, 1975 (please refer to bibliography under FHWA).

15. Stopher, et al, "Behavioural Travel-Demand Models", pp. 24-26.

16. An examination of the individual record scatter diagram produced by the model software reveals the non-conforming records. Some 50 percent of the shared ride records were incorrectly predicted by the model. (Please refer to section 4).

17. It is important to note that while only buses are used in Victoria public transit system, cities with additional transit technologies must resort to a multi-nomial model design. Vancouver, for example, is developing rapid transit, a wholly new rail-based transit mode. The market forces attracting ridership to rapid transit would be expected to differ significantly from conventional buses. Thus ridership behaviour must be analysed separately within this type of model.

18. The Victoria division of B.C. Transit continues from its predecessor to produce route by route data on costs and ridership.

19. Roads and Transportation Association of Canada, "Urban Transportation Planning Guide", p. 8.

CHAPTER II

THEORY AND PRACTICE IN TRAVEL CHOICE MODELLING

The objective of Chapter II is to review the development of behavioural travel choice modelling. Included will be a brief discussion of traditional methods and assumptions. The array of modern mode-choice models developed in the past twenty years or so are compared with regard to their underlying assumptions and limitations. The LOGIT model receives special attention as the favoured model formulation and as described in Chapter I, is the selected model in this study.

The transportation forecasting process has been classically thought of as a four-part process whereby special techniques are employed to reduce transport and/or transit data to facilitate the transportation decision and policy formation process. The data base is usually surveyed trip records containing specific information on transportation behaviour. Figure 2.1 shows this four-step process.[1] The focus of this study is to develop a model to predict modal split (mode choice) which will complement trip generation and distribution transport model components developed by the Capital Regional District Planning Department.

2.1. Traditional Techniques

The analytical techniques that describe the LOGIT model belong to the behavioural disaggregate, probabilistic travel-demand group,[2] now more succinctly referred to as "individual choice models". Since the early 1960's, transport research has devoted much attention to mode choice models as the key to breaking through some of the problems of interpreting the results of transport models.[3]

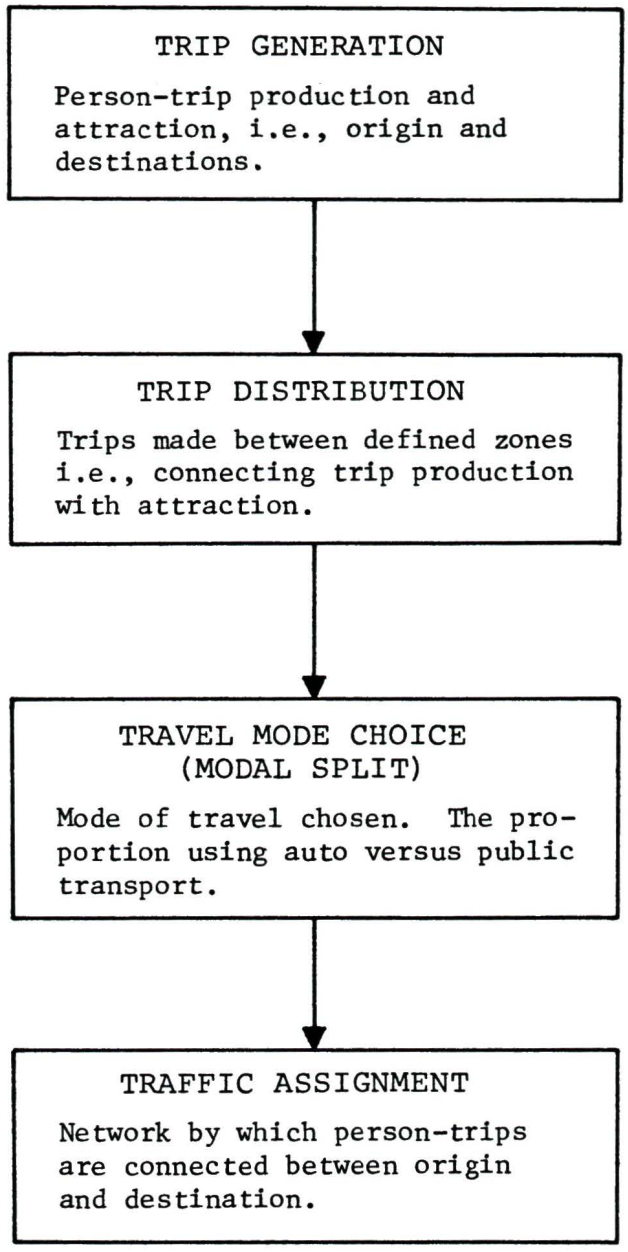


Figure 2.1 TRANSPORTATION FORECASTING PROCESS

Traditional techniques in transport forecasting employed aggregate data using regression and category (also called cross-classification) analysis to calibrate the empirical data set which groups travel information on a zonal basis.[4] The fundamental problems with such approaches, whether they are growth factor models, intervening opportunity models or classical gravity models, is their limitation to aggregate data formulations. As Morrall (32, p. 4) aptly describes, "total person trips are distributed when in actual fact total person trips are composed of a wide range of person types who may be captive to a given transport system"; thus any total person trip formulation loses individual person types into a single trip group. Morrall further adds that aggregate models preclude proper evaluation of transport system characteristics. Noteably, the use of disaggregate methods has been most successful in mode choice forecasting.

The second drawback to aggregate model techniques is obsolescence occurring far sooner than the disaggregate group of individual based models. This observation is due to the more indirect measures of individual behaviour used by aggregate models. These parameters are typically demographic data collected by census tract or other spatial unit and include population, employment, labour force, household size, etc. This type of data is only indirectly related to individual behaviour. Thus, such indirect measures can lose model significance where major changes in land use occur. These changes may not have so direct a bearing on actual individual behaviour. Clearly, the individual parameters which include actual individual income, age, sex, trip costs and trip time details relate more directly to travel choice considerations.

The development in the 1960's of useful models of individual's choice is perhaps attributable to a number of reasons summarized by Stopher and Meyburg (44, p. 27):

1. Travel mode choice is one of the most easily defined choices in the transportation planning process.
2. Mode choice models using aggregate formulations were among the most unsatisfactory models in the travel-forecasting process.
3. Mode choice studies allow the most effective policy-relevant studies in the transport planning process.
4. Critical travel volumes are associated with the peak journey to/from work which constitutes the primary focus of transport planning policy and decision making. Mode choice is best suited and most efficient when trip purpose is narrowed to the critical travel period making it an attractive approach to transport model development.
5. The journey to work trip purpose as the focus in mode choice studies takes advantage of the more habitual and repetitive nature of the work trip which implies that the consumer's knowledge of alternative travel modes would be greatest and therefore most predictable.

Over the past thirty years transport analysis has moved towards modelling travel demand behaviour, finding a theoretical base in the economics of consumer behaviour, and the psychology of choice behaviour.[6]

2.2 Behavioural Travel-Demand Models

The specific term, "behavioural" can be somewhat misleading since many aggregate, deterministic models which are not considered behavioural have a theoretical foundation based on hypotheses of human behaviour. In this study, as is generally accepted in transport research, the term

"behavioural demand-model" carries the following characteristics:

1. These models use a disaggregate data set, that is, information from the traveller and individual person-trips.
2. These models are designed on a stochastic assumption where the dependent variable is a binary or multinomial set of discrete events. In particular the LOGIT model avoids three major problems associated with the linear probability function: heteroskedasticity, non-normal distribution of E_i (the disturbance error term of least squares estimates of the coefficients), and the unbounded predictions of the dependent variable which must be restricted to the range 0,1.
3. These models employ theories of economic consumer behaviour and psychological choice behaviour with a set of implicit assumptions.

An effective approach to identifying the new breed of disaggregate behavioural models is to compare disaggregate and aggregate modal choice models. The following Table 2.1 compares several characteristics and attributes.

The final consideration when using the mode choice model is the traditional binary mode choice design of auto vs. public transit against a multinomial design where the bicycle, walking, rapid transit, shared ride, taxis, etc. are also included into the modal choice equation. There are advantages and disadvantages to each of these approaches. These relate to the basic differences in the assumptions between the binary and multinomial approach. As was indicated in Chapter I, the selected model in this study is the binary mode choice model. The reasons are primarily specific to the study area; however, arguments can be raised which might challenge the multinomial approach on more general grounds.

Table 2.1

A Comparison of Modelling Approaches

Traditional Aggregate Approach	Behavioural Disaggregate Approach
Models at the level of traffic zones defined in a sometimes arbitrary fashion.	Models at the level of decision-making unit.
Theoretical basis of models developed from heterogeneous aggregates of individuals.	Theoretical basis of models developed from individuals' behaviour.
System and socio-economic characteristics must be averages by zones.	System and socio-economic characteristics are individual or household specific and trip specific.
Causal influences on behaviour are difficult to make with geographically grouped data.	It is possible to infer information on the value individuals attach to some attributes of the transport modes, particularly, the value of time.
Aggregate models generally require larger data bases to permit stratification by zone.	Disaggregate models are calibrated at the level of the individual, thereby avoiding large data bases to fill empty or deficient cells in the group matrix.
The dynamics of choice behaviour may not hold true for averaged data.	Individuals' choice behaviour is not subject to averaging fallacies.
Models are restricted to a function of zonal averages precluding intra-zonal variations.	Models can work with several scales from the individual up to city-wide aggregates.

The data base used for any mode choice survey generally contains travel information for all major modes and all basic purposes.[10] The model most frequently stratifies the data set either for the peak travel period or to work-based trips or both. Given this form, the travel modes are generally dominated by either the private automobile or bus mode public transit.

Two key questions dominate the question of the appropriate specification:

1. Do people simultaneously consider all the travel mode alternatives open to them and weigh the merits of each in a total decision manner?[11]
2. Are all possible travel modes that are available to an individual actually in competition with each other as being practical alternatives worthy of consideration?

These two considerations call upon the market theories of individuals' consumer choice and the general psychology of individual choice behaviour. In practical terms, the journey to work does not put the walking mode in competition with auto or transit modes; furthermore, the bicycle in most Canadian cities is an atypical work based travel mode.

In the first consideration, the argument of all alternatives being considered is a complex one of comparing value, comfort and status which includes cultural norms as well as individual considerations. The transport planning process in the public sector has an objective of developing policies for both private vehicular facilities and public transit. Such policy development has often been an either/or experience, since policies for transit were seen as being in conflict with traffic policies. An

examination of the primary modes operating during the peak travel times or using the majority trip purpose serves to address the essence of the urban transportation problem, namely congestion.

The second consideration challenges the notion that all modes of travel operate as latent alternatives, only differing in cost, comfort and social status, and whose attributes are carefully weighed by the individual. This study is to make some clear assumptions concerning the "minority" modes and trip purposes in an effort to address the central concern of transit planning--and that is the issue of marketing to improve ridership and ensuring that public transit is a responsible reflection of public policy on transit. In most urban planning environments transit policy is intended to impact private auto use. The bicycle and pedestrian modes are separate issues worthy of separate and non-conflicting solutions.

The second consideration might be rephrased as an issue related to irrelevant alternatives and their assumed independence from the two possible choices provided for in the binary model. The assumption of independence is really a question of relative independence. Given a statement of the problem of predicting mode choice connected with work-based trips, it is possible to narrow or specify the assumptions so as to further restrict the set of individuals' choice behaviour assumptions. Clearly this study utilizes the assumption that realistically competing modes can only be included in the model. For the work-based trip the majority of individuals make a binary choice between the auto and public transit (84%). There is a statistically known residual population using "non-competing" modes for their journey to work. This population can be said

to combine other trip purposes that take into account other attributes, not a priori, to the work journey. These might include recreational and health travel purposes that involve a seperate set of explanatory variables which are capable of predicting these so-called "residual" travel modes. A complete breakdown of work and non-work trips against travel mode is contained in Table 2.2 This table shows that 35% of trips are work-based and 84% of these are transit or auto related. This study uses 60% of the total by taking only core municipalities and further removing incomplete trip records.

2.3 Assumptions - Travel-Demand Behaviour Vs. LOGIT Assumptions

Earlier in this chapter it was pointed out that any theoretical constructs or assumptions in travel behaviour must agree fundamentally with the statistical techniques being used to predict travel behaviour. The discussion of discriminant analysis revealed a marked separation between the technique and the assumptions of choice behaviour. Discriminant analysis is a classificatory technique needing a logit-like transformation to produce probabilities. This less direct approach is shown to produce poorer results that uncovers a theoretical inconsistency of defining two discrete populations that are not a precondition of the sample tripmaker. Both LOGIT and probit techniques attempt to make a probability statement about the behaviour of the individual for the event at hand given known circumstances associated with the trip event.

The underlying assumptions that have shaped travel-demand research begins with the hypothesis:

> "The traveller will choose the mode whose speed, cost and comfort advantages, weighted by their importance to him, produce the most favourable combination relative to other modes. The weights will be in some part determined by the characteristics of the traveller himself, his environment and the trip he is making."[12]

Table 2.2*

Comparison of Work and Non-Work Based Trips Against Travel Mode

MODE ➤ / PURPOSE ▼		AUTO	AUTO PASSENGER	TRANSIT PATRON	OTHER (i.e. walk, bicycle, etc.)	TOTALS
Work-Based Trips	a	813	141	126	211	1291
	b	(63%)	(11%)	(10%)	(16%)	
	c	(35%)	(18%)	(48%)	(57%)	
	d	(22%)	(4%)	(3%)	(6%)	(35%)
Non-Work Based Trips	a	1500	635	137	156	2428
	b	(62%)	(26%)	(6%)	(6%)	
	c	(65%)	(82%)	(52%)	(43%)	
	d	(40%)	(17%)	(4%)	(4%)	(65%)
TOTALS	a	2313	776	263	367	3719
	d	(62%)	(21%)	(7%)	(10%)	(100%)

Legend

a - Count

b - Row Percentage

c - Column Percentage

d - Total Percentage

*The information in this table was extracted directly from the raw data base of the 1977 CRD Home Interview Survey.

Assumptions and Travel-Demand Theory

The basis of travel-demand theory as stated in Chapter I has its roots in both the economics of consumer choice behaviour and the psychology of choice. The behavioural models of modal choice support these theories by the use of an equation based upon explanatory variables which identify empirically determined decision variables in an actual travel-choice situation.[13] The expression of these in a stochastic model structure permits a strong basis for developing causal relationships on consumer choice.

The regression model, in contrast, must use larger samples to minimize the inefficient use of least squares to estimate the linear probability function. Other limitations include heteroskedasticity which biases the standard error of the coefficient estimates and prediction errors that are not normally distributed. These limitations combine to preclude a satisfactory test of significance and goodness-of-fit.

The stochastic disaggregate travel-demand models conform to the rules of probability such that:

$$0 \leqslant P_k^i \leqslant 1 \text{ for all i and k} \qquad (2.1)$$

$$\sum P_k^i = 1 \text{ for all i}$$

where P_k^i is the probability of the i-th individual choosing the k-th alternative given n available alternatives.[14] Thus the hypothesis on behaviour is evidently consistent with probability theory which in turn forms a basis for psychologic models of choice behaviour. In psychological research it has been found that every human behaviour decision can be imagined as a probability event given a minimum variance in discrimination and dynamic changes in preference.

Given these concepts of choice behaviour, Stopher draws two major conclusions that become important in developing models of this type.

"1. The number of variables required to predict probability of choice is finite and asymptotically approaches the limit of human discrimination.

2. As a set of alternative choices (or travel models) becomes equivalent in subjective characteristics, the probability of choice approaches a limit of 1/n, where n is the number of alternatives." 15

The approach taken by psychologists asserts that there is a direct correlation between probability of choice and a set of associated measurable attributes or utilities. These measurable utilities are composed of both attributes of the alternatives and the individual. The equation expressing this follows:

$$U_{ij} = U\ (X_j,\ S_i\ ) \qquad (2.2)$$

where for any alternative j there is a utility U_{ij} consisting of the attributes of the alternatives, S_j modified by the attributes of the individual, S_i.

Traditional economic theory takes the approach which postulates that individuals are deterministic utility maximizers. Put into a mathematical construct, we have the following equation.[16]

$$U_a^i = U'\ (S_a,\ S_i\ ) + (X'_a\ ,\ S_i) \qquad (2.3)$$

where $U'\ (S_a,\ S_i\ )$ is the common utility of alternative "a" for individual i, with socio-economic characteristics, S_i. (Epsilon) $\varepsilon\ [X_a^1\ ,\ S_i]$ is the individual utility of alternative "a" for individual i, with socio-economic characteristics, S_i.

Modern economic theory now adds that the individual element of utility cannot be observed by the analyst, at least in no way that is practical. To overcome this shortcoming, the economist assigns a

probability to any individual decision. In order to incorporate this probability transformation it is assumed that each individual utility (E_{ik}) is independent across a set of alternatives, thus the X_a 's must be specific to each mode and cannot be common. A second assumption is that the distributional characteristics of the independent variables are satisfactory. Generally, the normal distribution is selected; however, most model structures do not empirically support the normality construct for each of the independent variables. Empirically, a positive skewed distribution appears often. The Weibull distribution resembles this shape and is normalized by taking logarithms. The Weibull distribution is illustrated mathematically as:

$$\Pr \{ \varepsilon (X', S_i) \geqslant \varepsilon^* \} = e^{(-e^{\varepsilon^*})} \qquad (2.4)$$

and graphically in Figure 2.2. A significant property of the Weibull distribution is that the difference of Weibull distributed variables produces the same model form as the binary logit distribution. It can be seen from the foregoing descriptions that the theories of behaviour used by both economists and psychologists complement the statistical assumptions of the binary LOGIT model.

The assumptions that underlie the LOGIT model can be summarized as a set of assumed conditions about the individual and the alternatives that are the subject of choice.[18]

Rationality

Each decision made is natural inasmuch as an individual will choose comfort over discomfort, lower cost over higher, shorter time over longer, etc.

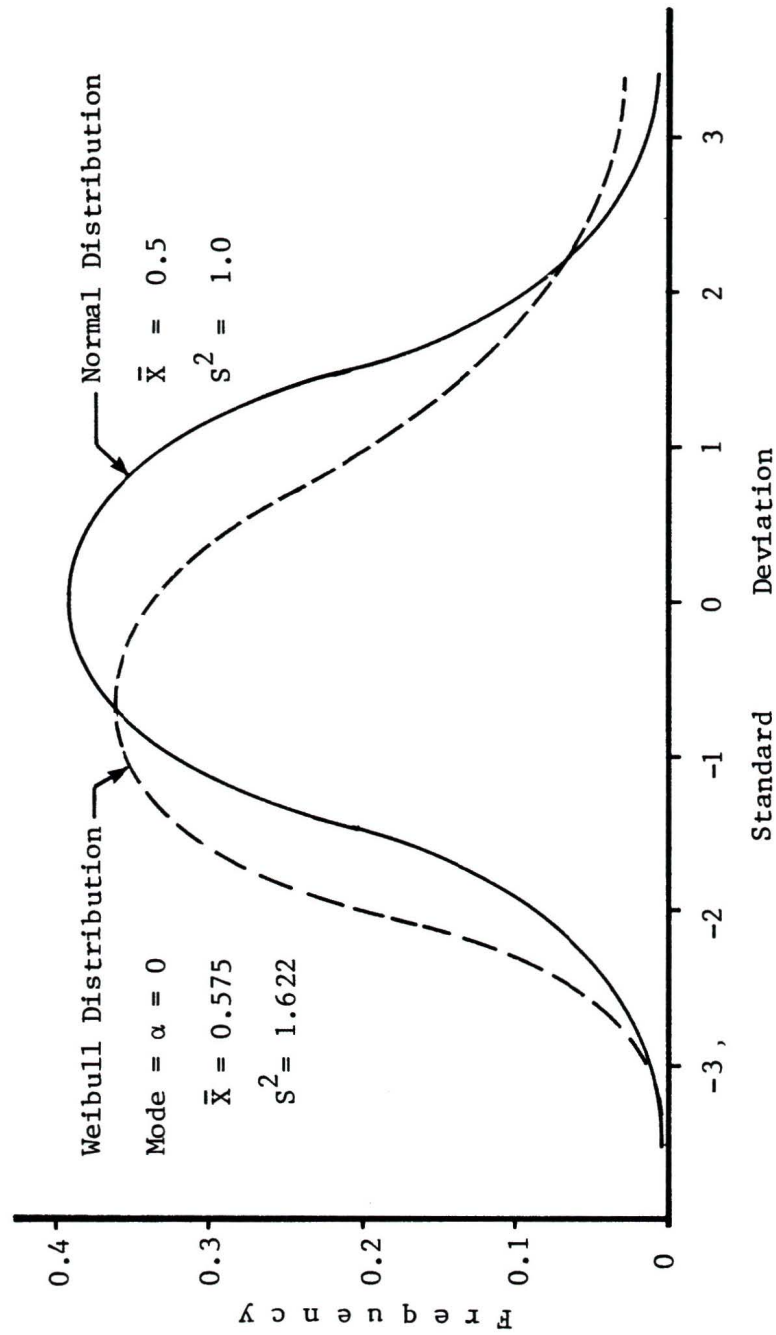


Figure 2.2 Standard Normal and Weibull Probability Distributions

Limited Resources

The choice option is assumed to be constrained by limited resources including time, money, income and travel modes.

Perfect Knowledge

The important assumption of practical knowledge about all competing modes is implicit in behavioural models. In the LOGIT model it is also implicit that all travel modes be available or reasonably accessible.

Preference Reflected in Behaviour

The choice of a mode is based on a preference for that mode given the situation surrounding the choice.

Two-Term Consistency

Given a set of circumstances, if an individual chooses mode A over B he will not choose B another time given the same circumstances. The circumstances so measured and associated with individual choice must show consistency.

The problem of relating the LOGIT model formulation to the specifics of modal variables and socio-economic variables is one of taking the theory of choice behaviour and applying it directly to the journey to work event. This has been the focus of this model and is the root to evaluating the central problems associated with both transit and more generally, transportation planning. Haney categorized four central problems in determining whether potential explanatory factors can be supported by travel demand theory:[19]

1. Determine factors that auto drivers consider in making highway decisions.
2. Develop a measure of the accuracy with which drivers are informed of these quantitative factors.

3. Assess the relation of the numeric value of a factor to its economic utility, i.e., the calibration problem.
4. Determine ways in which individual utilities are combined into a total utility for each alternative considered; that is, to avoid dependency between independent factors.

2.4 Choosing a Statistical Tool to Calibrate a Binary Choice Model

The disaggregate, stoachastic models of individual travel mode choice are dominated by three statistical techniques: discriminate analysis, probit analysis and LOGIT analysis.[20] The details of their mathematical derivation is beyond the scope of this work; however, the LOGIT model will be given more detailed description as the chosen statistical tool in this study. The importance in comparing the various techniques is to afford an understanding of the assumptions and advantages of each approach. The final justification for a study technique has been to illustrate the advantages of the LOGIT model as found in previous research.

Discriminant Analysis

In 1962 Warner used discriminant analysis as a probabilistic extension of the maximization of between-population variances. Simply stated the general form can be expressed as:

$$Z_{ij} = \lambda_1 X_{1ij} + \lambda_2 X_{2ij} + \ldots + \lambda_k X_{kij} \qquad (2.5)$$

where Z_{ij} is the discriminant score for the i-th mode of the j-th person, λ_p is the weighting coefficient and X_{pij} is the explanatory variable value for the p-th factor (p = 1..k) of the j-th person (j = 1..n) in the i-th mode (i = 1,2) in a binary formulation.

Discriminant analysis is a statistical approach first used in

biology to separate two populations based on discriminating criterion. This process takes the weights assigned by the λ_p coefficient such that the between-population variance is maximized relative to the within-population variance. This maximization function referred to by mathematicians as "G" is stated as follows:

$$G = \frac{\{ \Sigma_{p=1}^{k} \lambda(\bar{X}_{p1} - \bar{X}_{p2}) \}^2}{\Sigma_{p=1}^{k} \Sigma_{q=1}^{k} \lambda_p \lambda_q C_{pq}} \qquad (2.6)$$

The probabilistic extension transforms the discriminant Z^* scores into a probability statement. This form is not too unlike the logistic function and produces the following function:

$$P(2\backslash N) = \frac{\frac{N_1}{N_2} \; e^{(z+t)}}{1 + \left(\frac{N_2}{N_1} \right) \; e^{(z+t)}} \qquad (2.7)$$

where N_1 and N_2 are the two population sizes (see Figure 2.3), and $Z = z + t$ and $P(2\backslash N)$ is the probability of being classified from population 2 at Z^* (discriminant Z score).

Discriminant analysis addresses the problem of classification where discrete populations are defined by known classifiable characteristics. The problem with this approach is seen in Figure 2.3 where the intersection between population 1 and population 2, say transit patrons versus automobile drivers, is large, producing a high probability for misclassification by the model. In travel-demand studies it is generally accepted that any individual could with a calculable probability choose either one mode or another given the right circumstances. Thus, in mode choice, individuals in the population do not necessarily fit into one group or another. The results produced by discriminant analysis have been shown

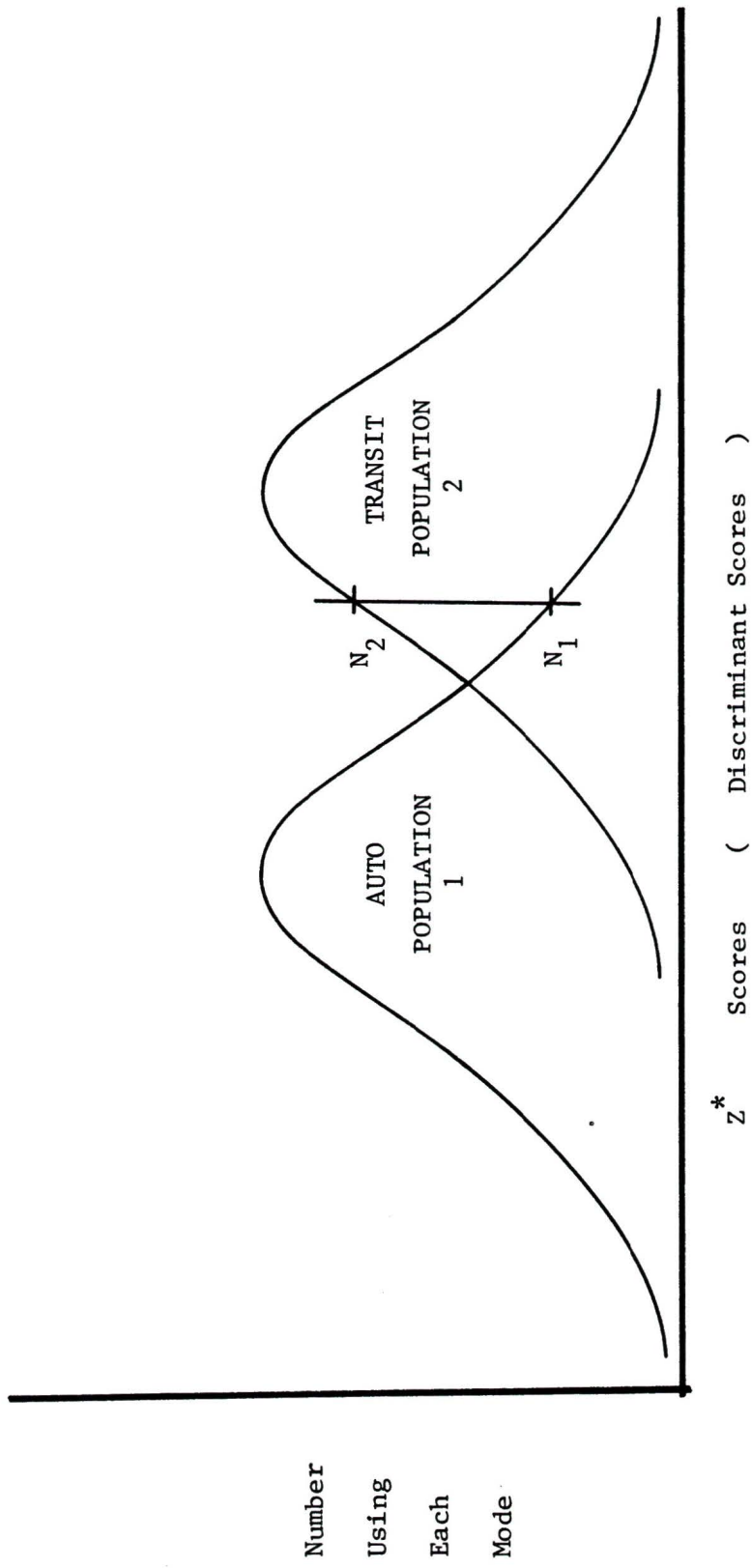


Figure 2.3 Distribution of Discriminant Function[23]

to produce poor results as a consequence of this limitation.[24]

Probit Analysis

Probit analytical techniques were first used in biological assay to determine the effects of various toxins on organisms. A typical dichotomous event would be death or non-death where probabilities would be given to various strengths of a given toxin. Similarly in mode choice studies, probit analysis can be thought of as a dichotomous event probability function that is dependent on some threshold value of a set of independent explanatory variables. The automobile versus transit choice is the dichotomous event whose probability is to be estimated.

The dependent variable, say "W" is postulated to take the values of the independent or explanatory variables. An index "I" is used to construct a linear combination of the independent variables. The following equation results:

$$I = \beta_o + \alpha_1 X_1 + \beta_2 X_2 + \ldots + \beta_m X_m \tag{2.8}$$

Non-linear transformations can be used as in regression analysis.

The form of the probit is the standard cumulative normal distribution. The probability that "I", where "W_i" is equal to 1 gives the function:

$$P(I) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{I} e^{(-.5u)} du \tag{2.9}$$

The competing alternative mode where W_i is equal to "0" gives the function:

$$Q(I) = \frac{1}{\sqrt{2\pi}} \int_{I}^{\infty} e^{(-.5u)} du \tag{2.10}$$

where Q (I) - 1 - P (I). Thus "I" is the probit of P (W) and is defined as the abscissa corresponding to P (W) in a normal distribution with mean of zero and variance of one.

The coefficients in equation (2.4) are arrived at using maximum likelihood estimation. Refer to Appendix H for an introductory explanation of the maximum likelihood estimation technique used in both probit and LOGIT (and others) models. In Figure 2.4, the general probit formulation is illustrated graphically.

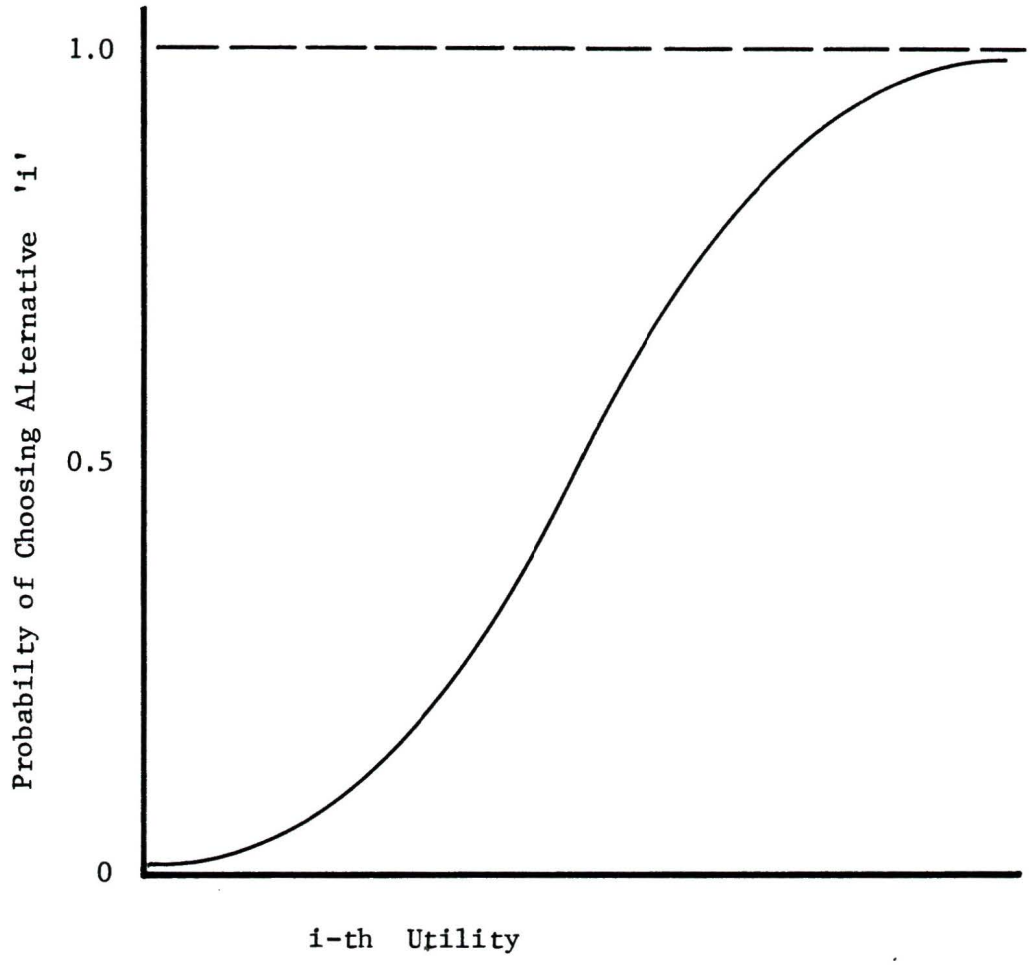


Figure 2.4 Cumulative Probability (P) Distribution

The advantage of the probit model is that it is not limited by unbounded predictions since it utilizes a transformation bounded by "0" and "1". There are a number of assumptions[25] that apply specifically to probit analysis.

1. The assumption that "each individual is characterized by a threshold value of the combination of the explanatory variables;"[26] thus a value of I (from equation 2.8) below a certain threshold yields a choice of one mode and where a value is above, a choice of the alternative mode is made.
2. "The threshold values are normally distributed over the population of tripmakers whose (travel mode) choice behaviour must be modelled."[27]

This last assumption combined with a relatively complicated formulation are the main drawbacks against the use of the probit model. It has been shown by Donnea (19), Domencich (18), Watson (56) and others that the results provided by both probit and LOGIT models are nearly indistinguishable within the middle range of values and P (I) differ only slightly as P (I) approaches 0 or 1. As stated by Domencich and McFadden (18) the probit converges to 0 and 1 more rapidly than the LOGIT model.

Logit Analysis

LOGIT analysis like the probit model falls into the groups of disaggregate binary modal choice models using a sigmoid shaped cumulative probability distribution. Thus the assumption of the LOGIT model for mode choice is that the relationship between an individual's choice of travel mode and the combination of a set of explanatory variables is a logistic sigmoid. The logistic probability function is a symmetrical

sigmoid curve similar to the cumulative normal (probit) curve. However, the probit assumption of normally distributed "threshold values" over the population of tripmakers is dropped. Moreover, the LOGIT formulation is clearly less complex and more easily extended beyond the classical binary choice approach to various multinomial formulations developed during the 1970's.[28] The standard LOGIT model like the probit model has bounded probabilities between 0 and 1 using a LOGIT transformation of the form:

$$G(\underline{X}) = \ln \left[\frac{P_1}{(1 - P_1)} \right] \tag{2.11}$$

where $G(\underline{X})$ is a linear combination of the explanatory variables affecting modal choice or of some non-linear transformation of these variables. P_1 is the probability that an individual will choose mode 1. Equation (2.11) can be re-expressed in the form used in Chapter I (1.1).[29]

$$e^{G(\underline{X})} = \frac{P_1}{1 - P_1} \tag{2.12}$$

becomes:

$$P_1 = \frac{e^{G(\underline{X})}}{1 - e^{G(\underline{X})}} \tag{2.13}$$

The $G(\underline{X})$ function is equivalent to the function used in probit analysis. Stopher and others have used stratified data sets and applied least squares to estimate model coefficients; however, such efforts require more data to "fill" the sub-samples and produce results which do not reflect the coefficients at the individuals' level.[30]

The model used in this study uses the maximum likelihood technique applied to a linear function of the form:

$$G(\underline{X}) = \alpha_0 + \sum_{a=1}^{n} \alpha_a (\Delta X_a) + \sum_{b=1}^{m} \alpha_b (\Delta X_b) \qquad (2.14)$$

where $G(\underline{X})$ is the unbounded value of the linear combination of explanatory factors.

α_o = the maximum likelihood constant term of the function $G(\underline{X})$.

α_a = the maximum likelihood estimated coefficients associated with individual or household characteristics

$\sum_{a=1}^{n} \Delta X_a$ i.e. $\alpha_{a1} \cdot\cdot \alpha_{an}$ for $\Delta X_{a1} \cdot\cdot \Delta X_{an}$

α_b = the maximum likelihood estimated coefficients associated with trip characteristics

$\sum_{b=1}^{m} \Delta X_b$ i.e. $\alpha_{b1} \cdot\cdot \alpha_{bm}$ for $\Delta X_{b1} \cdot\cdot \Delta X_{bm}$

It has been shown that LOGIT analysis uses Bernouill's approach with the dependent variable composed of an unobservable probability and an unobservable error term. The implication is that the LOGIT (and probit) model avoids using a stochastic error term and the need for assumptions about the distribution of that error term.

Maximum Likelihood Estimation

The utility function defined by the linear equation $G(\underline{X})$ is scaled by coefficients calculated by maximum likelihood estimation.[31] This technique while having a relatively involved mathematical derivation, can be described as an iterative maximization problem involving the solution of a series of partial derivatives.[32]

Given a sample of 623 individuals' trip records for Victoria, for each trip record or individual the following is known: the status of travel mode choice, i.e. auto driver or passenger and transit passenger, and the specific values of the explanatory variables for the individual's

trip. Using $\underline{X}_j$ as the value for the parameter $\underline{X}$ for the j-th individual, the likelihood function is arranged such that the observations (individuals) j for which j = 1, ..N_1, are the observations choosing transit, and for j = N_1 + 1, ..N are the observations choosing the auto driver/passenger mode. The Victoria survey reveals 95 transit choices and 528 auto choices.[33] Expressed mathematically, the likelihood function produces the following:

$$\Lambda = \prod_{j=1}^{95} P_1(\underline{X}_j) \prod_{j=96}^{623} \{1 - P_1(\underline{X}_j)\} \tag{2.15}$$

If the $\underline{X}$ values are set equal to 1 and a_1 equal to the constant term (α_0) from equation (2.14) then for the binary LOGIT analysis, the likelihood function becomes:

$$\Lambda = \prod_{j=1}^{95} \frac{e^{G(\underline{X}_j,\underline{a})}}{1 + e^{G(\underline{X}_j,\underline{a})}} \prod_{j=96}^{623} \frac{1}{1 + e^{G(\underline{X}_j,\underline{a})}} \tag{2.16}$$

This can be transformed to the log - likelihood function producing:

$$\ln \Lambda = \Lambda^* = \sum_{j=1}^{95} \{G(\underline{X}_j,\underline{a}) - \ln(1 + e^{G(\underline{X}_j,\underline{a})})\} + \sum_{j=96}^{623} - \ln(1 + e^{G(\underline{X}_j,\underline{a})}) \tag{2.17}$$

The maximum likelihood estimates are made for a_i as values of a_i produce a maximum for Λ^*. The conditions for a maximum of Λ^* are obtained by the partial derivatives as:

$$\Lambda^* = \frac{\partial \Lambda^*}{\partial a_i} = 0 \quad \text{for } i = 1 \ldots m \tag{2.18}$$

The solution of equation (2.18) follows an iterative process using trial values of the a_i's.

The estimation technique assumes that Λ^* are linear between the trial solution $\Lambda^*(\bar{a})$ and the actual solution, thus:

$$\Lambda_i^*(\bar{a} + \Delta a_i, \bar{a}_2 + \Delta a_2, \cdots, \bar{a}_m + \Delta a_m) = \Lambda_i^*(\bar{a}) + \sum_{k=1}^{m} \Lambda_{ik}^*(\bar{a}) \cdot \Delta a_k = 0 \tag{2.19}$$

The values of the adjustments to Δa_k are added to the trail value of each of the parameters a_k $(k = 1, ..m)$ thereby causing $\Lambda_i^*(\bar{a})$ to converge to zero.

Ultimately, equation (2.19) becomes:

$$0 = \sum_{j=1}^{m} X_{ij} - \sum_{j=1}^{623} X_{ij} P_1(\underline{X}_j, \bar{a}) - \sum_{k=1}^{m} \left\{ \sum_{j=1}^{623} X_{ij} X_{kj} P_1(\underline{X}_j, \bar{a}) \{ 1 - P_1(\underline{X}_j, \bar{a}) \} \right\} \Delta a_k \tag{2.20}$$

where m = number of parameters. A new trial value $\bar{\bar{a}} = (\sqrt{a} + \Delta a)$ is then returned to the process and repeated using $(\bar{a} + \Delta a)$ instead of the former $\bar{a}$ value until the Δa_i's converge to zero (actually become negligible). The final iteration designates $\underline{\alpha}$ as the estimate for $\underline{a}$.

2.5 Summary and Conclusions

The traditional techniques were described as aggregate models requiring larger data sets and employing assumptions that cannot easily apply to the smallest decision making unit, namely the individual.

Behavioural mode choice models developed during the 1960's and '70's, in contrast, have shown far stronger results using smaller data bases and employing a disaggregate, asymptotic stochastic model form. The favoured models developed during this period were the probit and LOGIT models and to a lesser extent, the discriminant model.

The traditional method of regression analysis using least squares in a binary choice model was noted to suffer from three major problems, that is, the problems of heteroskedasticity, non-normal distribution of the error term, and unbounded predictions. By comparison, the LOGIT model, as the selected model in this study, was found to have several desirable qualities. These qualities include the avoidance of using a stochastic error term and the assumptions about the distribution of that error term. Also desirable is the tendency of the LOGIT analysis in lowering both measurement and specification error with increasing variable complexity.

Overall, the LOGIT model was found to be best suited to mode choice studies. The assumptions of the LOGIT model noteably support the complementary assumptions and theory of both economic consumer choice behaviour and the psychology of choice. Although not discussed in this chapter, there is one issue that deserves an initial addressing; that is, what are the implications of adding a new travel mode alternative? It is generally agreed that if a new alternative provides competing service with substantially different comfort and convenience amenities that are not measured by any independent variable, then recalibration of the model using new data would probably be required. A more complete discussion of this issue and other enhancements and maintenance issues is presented in Chapters V and VI.

In Chapter III, the focus will be the data base itself. A detailed description and evaluation of all the useable variables will be made including the conditions under which the baseline survey was implemented.

References

1. RTAC (39) pp. 93-97. The two basic types of modal split models described in the RTAC guide are trip-end models, and trip-interchange models. In the former, mode split is estimated before trip distribution and in the latter, mode split is determined once trip distribution has been estimated.

2. Stopher (44) p. 26. Travel demand models which might be considered "behavioural models" predate the special group of behavioural models generally implied with the behavioural terminology. The key words "probabilistic" and "disaggregate" complete this narrow definition. Additional reading includes Domencich and McFadden (18) pp. 4-5.

3. RTAC (39) p. 93. One of the first large scale transportation studies using disaggregate data was the Chicago Area Transportation Study (1960). The trip distribution component proved difficult to calibrate and implement in other areas.

4. Examples of the use of category analysis (cross-classification) and regression techniques in transport studies for Victoria are found in Appendix E and F respectively.

5. The traditional focus of transport planning has been in the area of trip distribution and generation. The growth factor models and others which use regression analysis for calibration are not the focus of this study and lie outside the scope of this review. The reader can refer to bibliographic references listed in RTAC (39) p. 93, Morrall (32) p. 3, and Donnea (19) p. 32.

6. Stopher (44) p. 3, covers the subject of behavioural travel demand models noting them to be distinctly different from traditional methods because a disaggregate and probabilistic approach is used.

7. The "iron horse" technique of model calibration is least squares regression which produces a specific deterministic value or result with generally larger standard error and the interpretive difficulties associated with covariance and homoscedasticity.

8. Table 2.1 benefits from the descriptions contained in Donnea (19) pp. 32-38.

9. Donnea (19) p. 33.

10. Trip purposes can be sorted into easily interpreted categories such as work-based, home-based, shopping, social, entertainment, medical, business, etc. Chapter III elaborates on this.

11. Donnea (19) p. 42.

12. Watson (56) p. 16.

13. Stopher (44) p. 3.

14. Ibid., p. 4.

15. Ibid., p. 5.

16. Ibid., p. 9.

17. Domencich (18) p. 62.

18. Watson (56) pp. 16-18.

19. Watson (56) p. 31. Watson used Haney's problem statement taken from work undertaken at the Stanford Research Institute.

20. Donnea (19) ch. 4 and Watson (56) ch. 3 detail the characteristics, advantages and disadvantages with discriminant, probit and LOGIT analyses.

21. Donnea (19) p. 55. The key point stressed by Donnea and also Watson is that the model must share compatible assumptions with the travel-demand theory which underlies the selection of a priori variables.

22. Warner is referenced by Stopher (43, 44, & 46) as one of the first to use discriminant analysis in the Chicago Area Transportation Study.

23. Based on Donnea (19) p. 47 and Watson (56) p. 115.

24. Donnea (19) pp. 56-63 gives a detailed description of discriminant analysis including a derivation of the technique which reduces to:

$$P_1 \quad (\underline{X}) \quad = \quad \frac{e^z}{1 + e^z}$$

and becomes an exercise of estimating the parameters of z. This can be done by using maximum likelihood estimation which is used by both probit and LOGIT analyses.

25. Donnea (19) p. 69.

26. Ibid.

27. Ibid.

28. The multi-nomial LOGIT model while not used in this study, represents the present state-of-the-art in mode choice research. The following citations provide in-depth coverage of the multi-nomial approach: Peat, Marwick, Mitchell (35), Domencich (18), Watson (56), Stopher et al (44).

29. Equation (2.13) is also equivalent to:

$$P_1 = \frac{1}{1 + e^{-G(\underline{X})}}$$ used by some authors.

30. Stopher (46), 1969 and Bee (2), 1980.

31. Mathematicians will also refer to the coefficient as a vector of the parameter. Generally, the term "vector" implies a two-dimensional quality as with mass through distance being a force. In the discussions found in this chapter detailing the maximum likelihood technique, terms have been made consistent with statistical terminology to minimize confusion.

32. Watson (56) p. 118.

33. The Victoria model uses several stratifications. The full data set used for calibration comprises 623 observations. Other models were calibrated using subsets.

34. The derivation of the maximum likelihood technique is based on Donnea (19), pp. 220-222, and Dixon's BMDP (17), p. 315.

CHAPTER III

THE DATA

In Chapter I, an overview of the baseline information used in this study was presented. A considerable degree of detail will now be added. The full data set is contained in Appendix A. The model framework described in Chapter II now leads to a discussion of the essential variables which have a justifiable basis for inclusion in the model. This chapter will address all the useful data considerations encountered in the study and will also preview certain results found with those variables which showed themselves unsuitable despite initial expectations to the contrary.

The full data set was gathered in three parts and consists of two basic types of information. The first part of the data set was provided by the travel survey itself; the second part was taken from a variety of published sources, as well as a trip-by-trip map measurement exercise which will be explained later in this chapter. The third part was assembled by simple transformations of variables taken from the first two parts.

All three parts of the data set can be divided into two types of information. The first type provides data on the individual or household; the second type is trip specific, that is, information collected on reported trips taken by the survey respondents. Simply stated, there is trip maker data and trip specific data that combine to form a set of explanatory independent variables which can be modelled to predict a probability for travel mode choice.

The model uses independent variables which find support in the travel

research literature. Generally, variables used will have direct parallels in previous research studies; however, the treatment given to some of these will require experimentation. It is the intention of the study, therefore, to build onto the body of knowledge on travel behaviour and the use of the LOGIT model formulation.

In Table 3.1 a brief overview is given of the specifications of the data set used in this study. The details of this summary chart will be the subject of this chapter. Later in the chapter a comparison of independent variable classes used in previous studies is made to provide a useful overview of mode choice data that has been used successfully.

Table 3.1

Data Specifications

1. Records	
Survey sample program -	2000 households
Completed survey forms -	492 households
Completed trip records -	3665 trip records
Trips per household samples -	7.45 trips
Number of individuals' trip records -	1396 individuals
Trip Records selected for study	623 trip records or 17% of total
Households selected	215 households or 43.7% of total

continued...

continued...49

Table 3.1

Data Specifications

2. 1977 Travel Survey Data

29 Variables

1 dependent variable

9 essential variables

5 classification variables

1 identification variable

13 non-essential variables

3. Data from Other Sources

16 Variables

15 essential variables

1 classification variable

4. Generated Data based on the first two data groups

26 Variables

7 essential variables

19 dummy variables used for selection, classification and as special constants

5. A Priori Variables

7 variables developed for model calibration

6 successful variables used

3.1 1977 Travel Survey

The Capital Regional District undertook a home interview travel survey during the summer of 1977. The purpose of the survey was to collect origin and destination trip data for individual households for inclusion into the traffic survey completed in the same year and to eventually build a mode choice model. The first purpose was achieved by providing trip rate information by household as well as other descriptive data on trip generation by mode, purpose and time frame. The second purpose of the survey, for which the survey format was specifically designed, was a baseline data base to use in calibrating a mode choice model for Victoria.

The history of this data set is one of initial use to extract descriptive statistics followed by the discovery that certain inconsistencies and inaccuracies were resident in the data. These shortcomings were seen to preclude disaggregate analytical treatment. The result of this early fear was to "shelve" the data to pause for a future opportunity to carefully review and edit the entire data set. This opportunity was taken up by the author in 1979-80, at which time it was determined that the data was salvageable and capable of being edited with minimum loss of data records.

Survey Design

The survey design was inspired by a National Co-operative Housing Rehabilitation Program Report 167 which supported smaller sample sizes in transport research.[1] The CRD classified a twelve category household survey to obtain a 24 hour record of all trips taken by all members of a sampled household during a typical mid-week day.

The sample design was to collect at least 30 observations (households) from each of the twelve household categories. The categories were defined by a matrix of household size against household auto ownership. The twelve categories are shown in Table 3.2 below as 1 through 12:

Table 3.2

Household Categories

		Household Size				
		1	2	3	4+	
Household Automobile Ownership	0	1	2	3	4	Category Numbers
	1	5	6	7	8	
	2+	9	10	11	12	

The twelve household categories are by no means similar in size; on the contrary, cells 3, 4 and 9 represent a small fraction of households in Victoria. Using the 1971 census, the relative percentages in each category have been calculated and illustrated in Table 3.3.

The CRD survey design attempted to obtain samples of the smaller "cell sizes" and at the same time achieve a wide geographical distribution. To accomplish this the City Directory was used in conjunction with municipal information, the latter being required from Central and North Saanich. Stratified random sampling from these documents produced a list of 2000 households throughout the Capital Region.

The telephone interview format was chosen for its economy and its acceptable performance record in similar surveys. The telephone format consisted of an initial contact by phone to determine a willingness to

Table 3.3

Household Categories by Percentages[2]

		Household Population				
		1	2	3	4+	
Auto Ownership	0	11.8	6.1	1.4	1.7	21
	1	9.1	19.2	6.7	14.1	49.1
	2+	0.4	7.0	6.9	15.6	29.9
		21.3	32.3	15	31.4	100

participate. A questionnaire was then sent by mail to the willing households requesting respondents to record their travel movements for a 24 hour period, as well as various household information. A second phone call was made to record these responses. In many cases respondents were either unwilling to complete the survey form or were unavailable for the second telephone call. The survey allowed for up to three attempts to contact participants. The response rate was initially less than 50% of the 2000+ selected households. Of those households who agreed to participate, only 50% responded, giving a total sample of 492 or about 25% of the original 2000.[3]

Table 3.4 shows the actual response schedule as totals and percentages (brackets) for each household category. The differences between the sample distribution in Table 3.4 and the 1971 census distribution shown in Table 3.3 is partly due to changing population trends which includes smaller family size and increased car ownership.

Table 3.4

Interview Responses by Household Category (Percentages)

	1	2	3	4+	Totals	%
0	28 (5.7)	29 (5.8)	3 (0.6)	2 (0.4)	62	12.5
1	58 (11.6)	97 (19.4)	50 (10.0)	56 (11.3)	261	52.3
2+	1 (0.2)	38 (7.6)	40 (8.0)	97 (19.4)	176	35.2
	87 (17.5)	164 (32.8)	93 (18.6)	155 (31.1)	499	100

The sample selected in this study is actually a sub-sample of the 492 households based on trip records. This reduced the household representation to 215 households. The selection checks included home trip and household zone number verification, correct trip purpose, destination zone consistency, missing data corrections and other visual and computational examinations. An example might illustrate one such simple test of consistency. Given work trips from a household in zone A, these trips must start from zone A and end at zone B. For that same trip maker, the return journey must begin in zone B and end in zone A. Typical errors were transposed zone numbers which in most cases were easily corrected. Overall, the number of records needing some corrections were under 5%.

In Table 3.5 a full listing is shown of the information categories collected by the CRD survey. The actual survey form used to record

Table 3.5*

Information Categories

1977 Transportation Study/Home Interview Survey

No.	Information Category Name	Comment
1.	Sample Number	Household I.D.
2.	Sub-Region	e.g. Victoria, Saanich, etc.
3.	District	Aggregate of traffic/ transportation zones
4.	Transportation Zone	Zone location is the most disaggregate grouping of household locations
5.	Day of the Week	All samples taken during mid-week
6.	Structure Type	Dwelling type, i.e., SFD, apartment, converted house, etc.
7.	Total Household Population	
8.	Household Population 5 years and under	
9.	Motor Vehicle Availability for Household	The number of cars (includes pick-ups and light vehicles) connected with household
10.	Bicycle Availability for Household	
11.	Other Motor Vehicles Resident w/Household	Includes trucks, motor-homes, etc.
12.	Number of Employed Persons in Household	

*A computer file of the original raw data set resides with the Planning Department of the Capital Regional District, Victoria, B.C.

Table 3.5 (cont'd)

No	Information Category Name	Comment
13.	Household Income	Does not reflect individuals' income unless only one employed person is indicated
14.	Survey Completion Code Number	Status code for the data record
15.	Tripmaker Number	Each individual was assigned a number associated with household. Generally the head of the household was '01'.
16.	Sex	Coded as 1 or 2 for each individual tripmaker
17.	Age	A five level range was used to group age classes
18.	Trip Number	The number of trips made by each individual was ordered as 1, 2, 3 etc.
19.	Origin Zone	The traffic (Transportation) zone where a sampled trip originates. A four digit code.
20.	Destination Zone	Similar to origin for the zone of destination
21.	Trip Start Time	The specific time that a trip was made using the 24 hour clock
22.	Trip End Time	The speicifc time a sampled trip was completed using the 24 hr. clock
23.	Travel Mode	The study dependent variable expressed as a code for up to 11 modes

Table 3.5 continued...

24.	Trip Purpose From	Type of place from which trip was made, e.g., home, work, shopping, etc.
25.	Trip Purpose To	Type of place to which a trip is to be made (same as 24 above)
26.	Auto Driver Occupants	Number of passengers accompanying driver
27.	Parking Location Downtown by Traffic Zone	Included only downtown traffic zones
28.	Transit Passenger	Redundant with 23 mode classification for transit mode
29.	Park & Ride Mode Change Location	The zone location where park & ride interchange took place

responses (second telephone contact) is reproduced in Appendix B.

A great deal of information was made available by the survey; however, certain information gaps and insufficiencies necessitated the addition of several new variables. In the next three sections, details will be given on only those variables which were needed in the study.

3.2 Useable Survey Data

This section is intended to detail each variable or information class which was used in the study, either directly to build predictive independent variables, or indirectly to select, compare and review records in the data set. The discussion will first focus on those variables used indirectly in the model development.

Since variable names will be, in many cases, a longer name, a short name will be used occasionally in the text for brevity. Where necessary the short name is bracketed along side the heading for each variable.

3.2.1 Indirectly Used Data

Identification

The sample number identifies the original 2000+ households selected for the survey. The sub-region number corresponds with municipal boundaries and designated unorganized communities (e.g., View Royal).

Transportation Zone

The transportation zone (or traffic zone) serves as the smallest spatial unit in the location of each sampled household in the data base. The Capital Regional District divided the entire region into 362 such zones. The primary criteria for defining zone boundaries was homogeneous land use combined with approximate correspondence with Canada census tracts, as well as conformity to municipal boundaries. Figure 3.1 illustrates the larger grouping of zones into traffic super districts. As is evident from Figure 3.1, the level of disaggregation is very good for a metropolitan area of less than a quarter of a million population. Appendix C contains a fold-out map illustrating all traffic zones in the core urban area of the Capital Region.

Travel Mode

The travel mode variable was transformed into three dummy variables to permit their use as the dependent variable in the model. The survey provided for the choice of travel mode to be specified for each trip record. Eleven modes were identified:

1. Auto Driver	5. Truck Passenger	9. Walk to Work
2. Auto Passenger	6. Taxi Passenger	10. School Bus
3. Transit	7. Park and Ride	11. Other
4. Truck Driver	8. Bicycle	

The purpose of the model is to predict this dependent variable. Unfortunately, having eleven possible results in the dependent variable requires eleven sets of assumptions about each of them, along with a suitable sample of trip records for each "cell" in the travel mode matrix.

The survey data did not intend to cover this data-hungry requirement with only 492 households in the full raw data set, and less than 3700 actual trip records. On the positive side, it is recognized that the focus of any mode choice study is to predict the split between auto use and transit use, since they represent the primary modes in peak hour traffic.

In transport planning, it is generally understood that a focus on peak period travel will best serve to understanding regional transport needs. With this in mind, it can be seen that the survey can be maximized by extracting only those trip records which are key to peak traffic patterns and problems in the Victoria area, namely, the auto and transit modes. As a result, the data set is reduced in size by more than 80%. Nevertheless, it includes more consistently predictable groupings which can be handled by a relatively simple mode choice LOGIT model.

Trip Purpose

The trip purpose variable is a basic stratifying factor used initially to select the work-based trip records. Each individual trip record was identified with one of eight possible trip purposes:

Note: Each Super District is subdivided into Traffic or Transportation Zones

Source: CRD Regional Planning Depatment

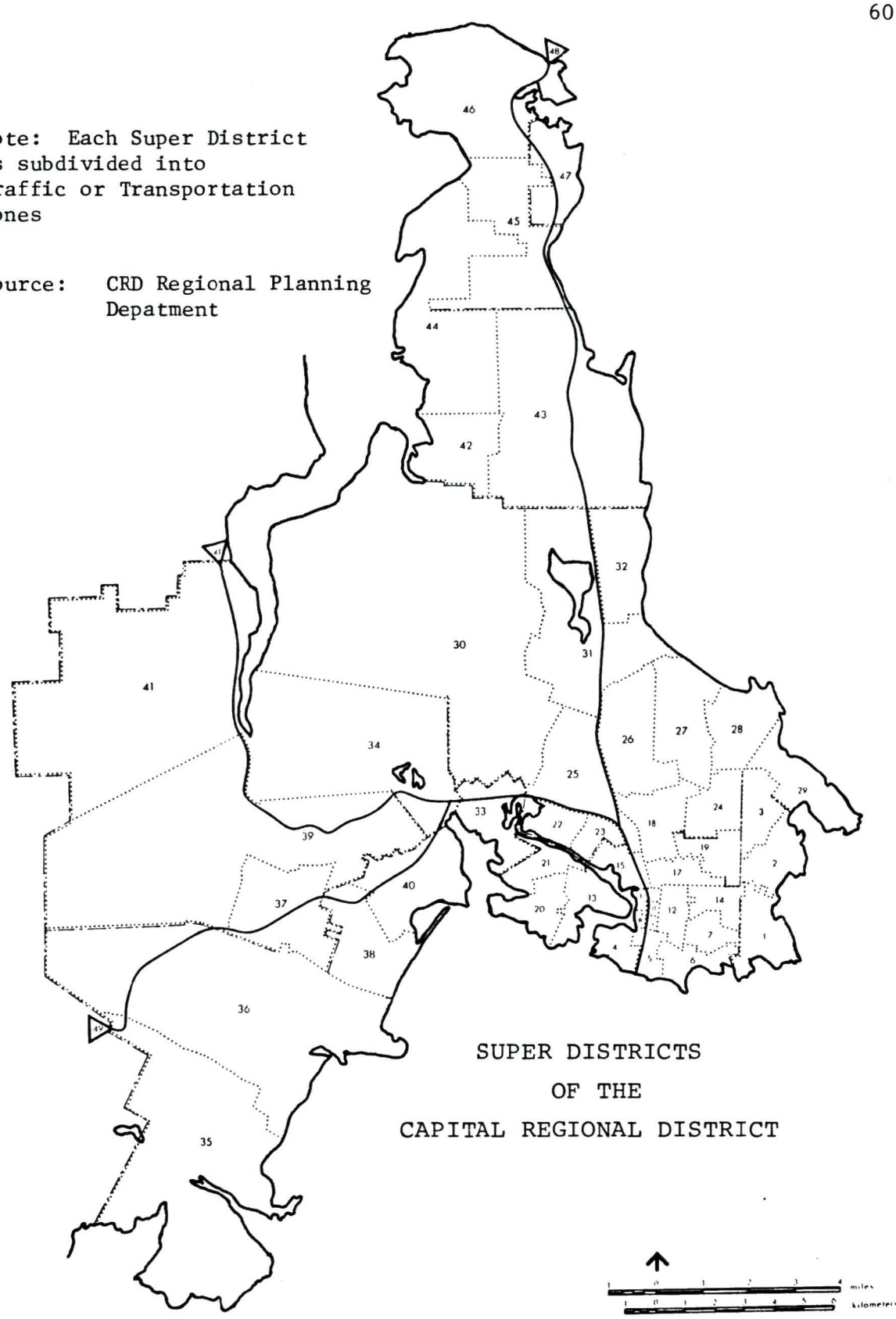


Figure 3.1 SUPER DISTRICTS

1. Work
2. Shopping
3. Business/Medical-Dental
4. Social/Recreational/Entertainment
5. School
6. Home
7. Serve Passenger (chauffeur)
8. Other

A similar problem of complexity found with the travel mode variable is also encountered with trip purpose. The trip purpose variable serves the study to enable a variety of models to be calibrated; however, the survey data and the focus of this study points toward only a single purpose, namely, the work-home trips (categories 1 and 6, respectively).

Neither the size of the survey data set nor the scope of this study permits a more comprehensive approach to modelling transport mode choice behaviour. In an effort to capture the important aspects of mode choice, though, it is possible to isolate only those trip records which best reflect the majority travel pattern. Not surprisingly, this has been found to be the journey to work travel pattern. The work-based journeys are for most individuals the only routine daily trips. It is this routine aspect that is important since such travel events require a reliable, economical, long-term solution leaving the individual worry-free in the area of transportation.

Research has found that being able to assess and predict journey to work travel behaviour offers a true baseline for all travel behaviour since the solutions to the journey to work problems are often solutions to most other travel requirements such as shopping, entertainment/social, business, etc. Using this set of assumptions the trip purpose variable was used to isolate work-home related trips (coded 1 and 6 respectively).

No direct use of this "variable" was made. Greater discussion on the assumptions in the model, particularly regarding trip purpose, has been made in Chapter IV.

3.2.2 Survey Variables Directly Used

The following four variables found direct use in the development of independent explanatory factors.

Household Population

The household population (size) variable on its own does not reveal a great deal about travel behaviour; however, its use to develop other variables has been considered in this study. It has been used to generate the income status variable with household income.

Car Ownership

The car ownership variable includes any automobile at the disposal of a sampled household. This variable has strong significance. Most LOGIT models, regression and cross-classification studies, etc. use car ownership as the measure of household mobility and is regarded as a major factor affecting public transit use. This study offers a refinement to this measure of mobility, namely, car availability which may be simplified as the ratio between car ownership and either household population (weaker) or household employment (better). This will be further discussed later on. This variable is used in the model with household employment to define car availability.

Household Employment

Household employment is the total number of persons employed outside of their place of residence. This variable is used with car ownership to derive an expression for car availability.

Many surveys do not obtain household employment data. Furthermore, much of the literature in mode choice does not stress its importance either directly or in variable generation. This study experiments with its use to better express car ownership as a measure of availability. It might be argued as the more appropriate utility expression for mode choice over the less useful expression of car ownership.

Household Income

The household income variable includes all incomes by all workers in the household, not just the principal income. The research in travel mode choice largely supports the income variable for use in many types of model calibrations. This study has set household income as an indicator of a socio-economic class variable. This will be discussed in detail later. Initial examination of this variable reveals one potentially confusing characteristic; that is, the distribution of incomes in a household may be asymmetrical with a very large standard deviation. In other words, the mean income per person for a sample household with two or more incomes may not represent any of the individual incomes in the household. This being the case, the income variable would produce a confusing logic to the utility theory about income and transit mode choice. This observation will be expanded later in this chapter and in Chapter IV. The income variable is used in the model for most of the initial experimentation.

Origin and Destination Zone

The origin and destination zone provide locational data that forms the baseline information in the study. Generally, such surveys use the "O" in Origin and the "D" in destination to identify an "O-D Survey", a

term most often used to describe this type of survey. Since the raw data only identifies specific zones in the region it is necessary to translate these figures into a travel pattern that can be described in terms of time and distance. Since the data set was also relatively small, it was practical to manually transform the O-D matrix into travel times using a most-likely-route scenario based on a known mode, the trip start time and origin/destination locations.[5] Specific addresses were not used in the survey so the origin "address" was redefined as the centroid of the transportation zone.[6] This method depends on the researcher's familiarity with the regional traffic network. One must, for example, identify populated areas in the geographically larger traffic zones located in the peripheries of the study area. Please refer to Appendix C which illustrates the transportation zones in the Greater Victoria area. Further discussion of travel times and distances is contained in Chapter IV.

Sex and Age

Each tripmaker is identified by sex and age. Only these two "status" variables are directly associated with the individual. The remaining trip specific data relate to the travel characteristics of the tripmaker's trip. The advantages and disadvantages of having much of the data set associated with the household and not the individual tripmaker raises many basic questions regarding the assumptions in the model and what results can be expected from it. This discussion has been reserved for section 3.3 when the a priori variables are introduced.

Time of Trip

The start and completion times of each trip were recorded using the

standard 24 hour clock. A sample of the selected trip records revealed that the trip times were only approximate and provided a poor statistic for trip time or duration. While it is not critical to know the exact time a particular trip started, it is, by contrast, critical that the reported travel times be calculated to better than the plus or minus 10 to 15 minutes that emerges in the editing of the survey. Remedial measures were carried out to improve on the errors in the reported travel times. This was accomplished manually by examining each and every trip record and scaling each trip on a large scale map and applying a most-likely average speed for the journey. For longer trips, the scaled distances were grouped by several speed zones to distinguish open highway travel from urban collectors, etc. This exercise was lengthy but extremely rewarding and suitably accurate.[7] Specifically, the start time was used to locate a trip in an hourly time window. For example, a trip which began at 0845 hrs. was located in the 0800 - 0900 hrs. time window.

The trip time variable was not directly used in the model. Experiments in grouping trip records by the time of day was disappointing when applied directly to the model. Descriptive statistics were made in the data set and assist in the interpretation and application of the model in planning. Figure 3.2 illustrates the hourly distribution of work-based trips used in the study.

3.3 Additional Data Appended

The purpose of the additional variables has been to transform trip record data, such as zone to zone trip information, into specific trip time and distance measures for both auto and transit modes. Other additions have been made to add greater geographical information to the household itself.

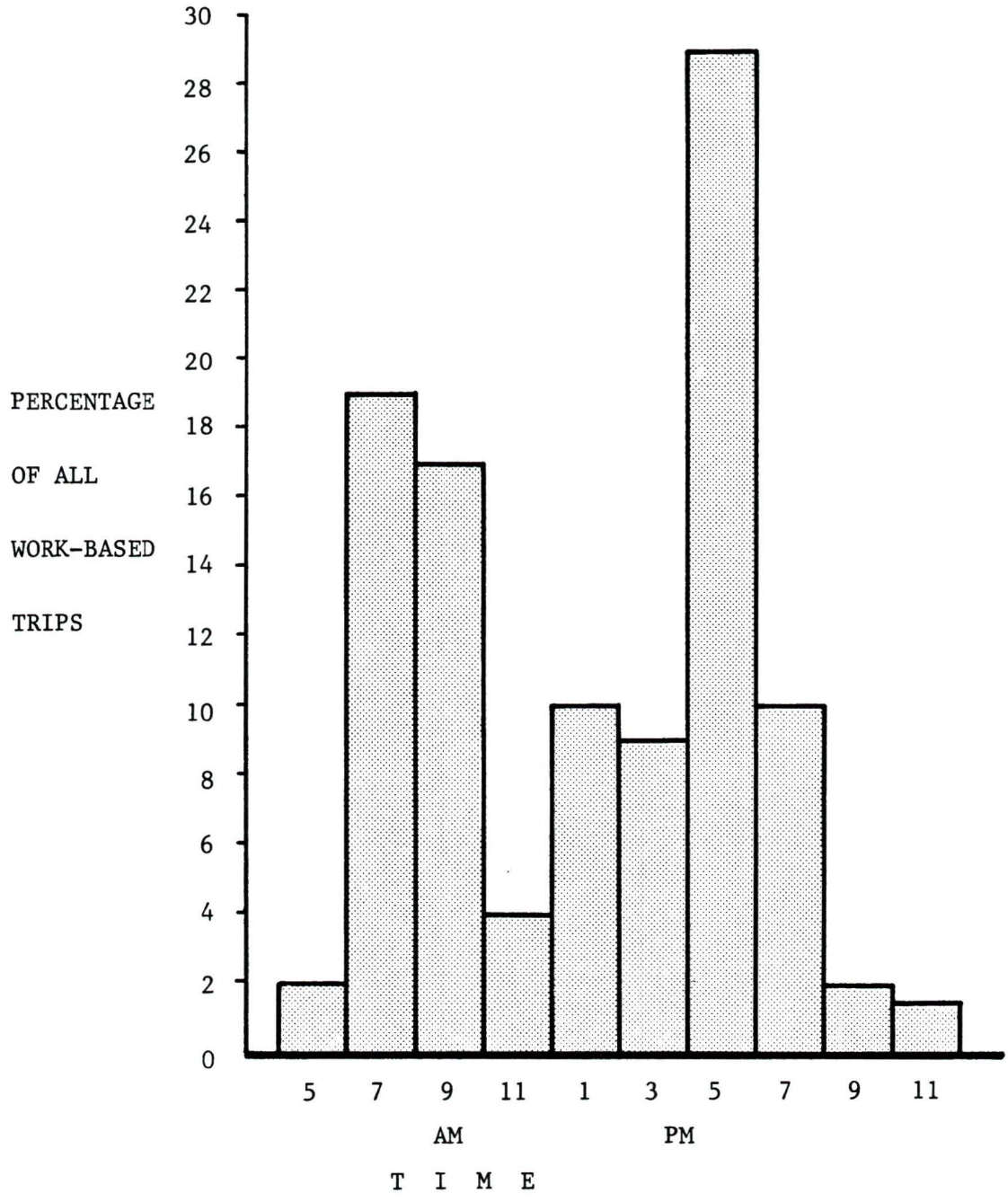


Figure 3.2 Bi-Hourly Trip Frequency

The process of adding new information to the data base came in a two-phase program. The first phase comprised a somewhat lengthy exercise of deriving zonal and trip specific data. The second phase expanded this base through programmed subroutines permitted by the model calibration software. As an example, given any calibration run of the model, it is possible to experiment with various associations between input variables by taking their ratios or their differences and using these new expressions as explanatory variables in the model calibration. Table 3.6 identifies all variables original or appended to the permanent or final data set. The second phase variables are generated by the calibration (LOGIT) software and have not been permanently stored on disk. Please refer to Table 3.6 when examining the raw data set in Appendix A.

The Dependent Variable - Transit

The dependent variable in the binary choice LOGIT model must be a dummy variable. The data set has provided for three separate dummy variables as described above, that is, the auto driver mode, the auto passenger mode and the transit patron mode. For the purpose of this study, the expression for the dependent is simply transit versus non-transit where the only competitive alternative mode is assumed to be the automobile.

The data set provides for a multinomial approach; however, as detailed in Chapter II, the favoured model formulation is a binary choice dependent variable. Dummy variables of 0 and 1 express the dependent variable of trip mode. Thus, an auto trip would be "1" in the column for "AUTO", otherwise it would be "0". Similarly, a transit trip would be coded "1" in the column for "TRANSIT" otherwise a "0" would be coded and

Table 3.6

Final Data Set

INDIRECTLY USED VARIABLES	
Variable Name	Key-Word Use
Household Number (code)	identification
Sub-Region Number (SUBREGN)	classification
Transportation Zone Number	location
Residence Type (RESTYPE)	NOT USED
Tripmaker Number	identification
Origin Zone (O)	location
Desitnation Zone (D)	location
Trip Start Time	classification
Trip Purpose (PURPOSE	stratification
DIRECTLY USED VARIABLES	
Car availability (CARAVAIL)	model calibration
SEX of Tripmaker	model calibration
AGE of Tripmaker	model calibration
Household Employment (EMPHSHLD)	in "CARAVAIL"
Transit Level of Service	in "SER"
Auto Mode Level of Service	in "SER"
Out-of-Vehicle Travel Time for Auto (OUTIMA)	in "OUT"
Out-of-Vehicle Travel Time for Transit (OUTIMT)	in "OUT"

Table 3.6 (cont'd)

DIRECTLY USED VARIABLES continued ...	
Total Transfers (TRNSFERS)	in "OUT"
Total Travel Costs for Trip Using Auto (COSTAUTO)	in "COST"
Total Travel Costs for Trip Using Transit (COSTTRAN)	in "COST"
Household Population (POPHSHLD)	NOT USED
Origin Zone Density (ORGDEN)	NOT USED
Destination Zone Employment (DESEMP)	NOT USED
Origin Zone Employment (ORGEMP)	NOT USED
Destination Zone Density (DESDEN)	NOT USED
Total Travel Time Using the Auto (TTIMAUT)	NOT USED
Total Travel Time Using Transit (TTIMTRN)	NOT USED
In-Vehicle Travel Time for Auto (INTIMA)	NOT USED
DEPENDENT VARIABLES	**(DUMMY VARIABLES)**
Transit Passenger Mode	(0,1)
Car Driver Mode	(0,1)
Car Passenger Mode	(0,1)

so on. Normally, two dummy variables can code three different items or classes. In this data set, three separate variables were used to make stratification and sorting of the data set easier. This presents a problem in the form of data "noise" since it is assumed that all car

passengers would otherwise drive a vehicle and not ever opt for transit. It could be presumed that such an assumption is overly biased against transit. The alternative is to delete all CARPASS records. This would in essence ignore the fact that some 14% of the vehicular based journeys to work do not happen.[8] It would also make the assumption that exactly half would otherwise take transit and the other half would drive a vehicle. But which half? Are they evenly distributed in each traffic zone? Unfortunately, this is not possible to determine. Nevertheless, by including all auto passenger trip records, more trip information is made available for model calibration.

The car availability factor was first introduced in section 3.2 under household employment. The employment and auto ownership factors were seen as possible factors to generate the car availability expression. The following ratio expression results:

$$Ca = H_{AO}/H_E \qquad (3.1)$$

where Ca = Car availability,

H_{AO} = Household auto ownership, and

H_E = Household employment.

This ratio expression has intuitive logic since the study is concerned with work related trips. Car ownership will most certainly relate to the size of the household and particularly the numbers of employed persons. A possible characteristic of travel behaviour that is assumed by the car availability expression (3.1) is that people own automobiles for mobility first and foremost and their most urgent need for mobility is their accessibility to their work place. The availability of an automobile for each working adult in a household given good access to a viable transit option

makes a statement about one's economic status, observing that having a vehicle at one's disposal will lead to its use unless other considerations preclude the auto amenity (i.e., parking costs, traffic volumes, etc.). The CARAVAIL variable was appended to the main data base as a key explanatory variable in the calibration process.

Trip Costs for Auto and Transit Modes

Both of these factors have been combined as a single out-of-pocket cost factor in the model (coded as COST, see section 3.2.2). The trip costs for the auto mode have units in cents. The formulation is based on the UMTA (U.S.) guidelines for determining the value of time in mode choice modelling. A factor of 30% is added to the U.S. statistic for 1977 to estimate the Canadian equivalent. This value is then converted from costs per mile to costs per minute which calculated to 3.79 cents per minute of travel time. The second step is to multiply this constant by the total travel time (auto mode) and then divide this by 1/3 of the household income expressed as cents/working minute.

$$\text{COSTAUTO} = \frac{3.79 * TT_A}{.33* \text{INCHSHLD}} \qquad (3.2)$$

where: COSTAUTO = trip travel costs in cents per working minute,

3.79 = travel costs per minute for auto mode (constant),

TT_A = travel time for trip by auto mode,

INCHSHLD = Household income, and

.33 = constant derived from travel demand research sponsored by the Urban Mass Transportation Administration (U.S.) Transit costs were also based on the UMTA formulation. The expression follows:

$$\text{COSTTRAN} = \frac{F_T}{.33*\text{INCHSHLD}} \qquad (3.3)$$

where: COSTTRAN = trip travel costs in cents per working minute,

F_T = transit fare constant which equaled \$0.50 per one way trip in 1977 (Victoria)

.33*INCHSHLD (See explanation for equation 3.2 above). The out-of-pocket travel costs is common to virtually all travel behaviour research.[9] Travel costs can be expressed in terms of distance or time. The value of time has been shown to increase for higher income individuals. The research in mode choice has found this to be true in both Europe and North America.[10] The time expression in travel costs also identifies slower trip paths from faster ones. The underlying assumptions with the travel costs factor is that given reasonable knowledge of relative costs, man, as a utility maximizer, will choose the most cost effective mode if the values for all other relevant factors are equal. Further details on travel cost factors are covered under the "COST" variable in section 3.4.

Total Travel Times

The trip specific travel times have been classified into three categories; total travel times for both auto and transit modes (TTMAUT, TTMTRN resp.), out-of-vehicle travel times for each mode (OUTIMA, OUTIMT). The travel time factor has strong support in travel research. The form it can take will generally have major bearing on how it performs in any mode choice model. Since the combination of an "in" and "out" times equal the total it is not acceptable that all three values are used as separate factors. Much of the literature supports either a total time expression or an out-of-vehicle time factor. Initial experiments in the model use both factors while excluding the in-time expression. The time formulations are expressed by contrasting the transit and auto modes.

These expressions use TTIMAUT, TTIMTRN, OUTIMA and OUTIMT to generate the time variables used directly in the model.

The eventual use of the travel time variables is to combine them in a single expression which is detailed in Chapter IV and introduced later in this chapter.

Bus Transfers

The bus transfers variable, "TRNSFERS" and its weighted derivative, "TRFRS" is a simple designation for the number of interchanges between two or more bus routes serving an individual's trip destination requirements. The weighted "TRFRS" variable is simply one-quarter the value of the actual number of transfers. Thus,

$$TRFRS = .25 * TRNSFERS \qquad (3.4)$$

The weighted transfers expression is used in the formulation of the out-of-vehicle travel time variable (see section 3.4).

The use of the transfers variable is well documented in transport research and receives serious consideration in this study. The interaction effects between key variables and the particular characteristics of the Victoria transit system offer a possible explanation of its rather poor performance in the model when used as a separate variable. First, the interaction effects between the out-of-vehicle travel time (i.e., wait and walk times associated with transit and parking) serve to mask the effects of the transfer event itself. The second point carries this further, and that is, that the radial or spoke pattern of the transit system produces poor cross-town transit opportunities due to higher total travel times in comparison with the auto option. It has been noted in mode choice studies that indirect routing through the city centre

discourages transit use. It is evident that the added inconvenience of a transfer event forms only a part of this negative utility. In Victoria, most transfers are associated with indirect routing through the downtown, thus, the transfer event plays a relatively minor role in transit ridership. This is not to say that such travel events can be discounted. Given two transit journies with equal out-of-vehicle travel times, it should be expected that if one of them requires a transfer (timed or otherwise) then such a route would attract less ridership, all other factors being equal. The use of the transfer variable in the out-of-vehicle travel time expression ("OUT") has been considered a possible and effective compromise. A discussion of the combined use of transfers with the out-of-vehicle travel time factor is made in Chapter IV.

Level of Service

The level-of-service factors are travel mode specific. In order to use these factors in the model, a relative or resultant level-of-service expression must be used which combines both factors. The final data set provides an estimate of the level of service for transit (LSERVT) and auto modes (SERVA). The combined relative estimate is short named SER and receives detailed discussion later on in this chapter. In this study, level of service is simply a measure of the relative convenience and reliability of the alternative travel modes. The transit mode is route-defined, therefore the characteristics of the route are a best measure for transit mode level of service (LSERVT). Specifically, route headway and the average speed for the route were used.

$$LSERVT = \frac{V_{Ti}}{F_{Ti}} \qquad (3.5)$$

where: LSERVT = level of service for transit,

V_{Ti} = average velocity (kmh) for transit trip "i", and

F_{Ti} = route frequency (headway) for transit trip "i" in minutes.

The level-of-service for the auto mode is more subjectively derived in this study. The auto level of service measure is based on the parking opportunity at the destination zone. A three point scale was selected and weighted to approximate an equivalency with the LSERVT measurement. The three-point scale is defined in Table 3.7 below:

Table 3.7

LSERVT measurement scale

Estimated Score	Description
2	destination inside the central urban core where parking costs are highest and the inconvenience of finding parking is greatest.
4	destination inside the pay parking core but outside the parkade dominant central core zones.
6	destination outside the pay parking urban core areas.

The rather subjective weighting was based on a review of the range of transit service indices and the relative convenience represented by the auto mode in the more congested city core where parking is a problem and carries a reasonable cost ($1 to $3 per day in 1977). As a comparative example, if one considers the auto in the city core at 6 (weighted), then it might be argued that a 7-10 minute transit service (headway) to within a block of your destination be considered an equal or better overall level of service. Considerations, such as the opportunity for a seat on the bus are not calculated, although the average speed for specific bus

service is, and it is reflected in the LSERVT estimate for transit level of service. The expression for LSERVT and LSERVA are intended to lead to a single expression for a trip specific level of service associated with the dependent variable, that is, a relative measure of the trip level of service. The single expression (SER) is defined as:

$$SER = LSERVT - LSERVA \quad \text{or} \quad SER = LSERVT/LSERVA \tag{3.6}$$

The SER expression is a relative transit utility expression taking into effect the relative impact of the auto mode option. This variable proved to be a very strong explanatory variable with equally strong support in travel demand modelling.[11] The SER variable is further detailed in section 3.4.

Relative Household Income (HINC)

The relative household income variable was coded as HINC. This variable was generally discussed in part in section 3.2.2 and needs only minor elaboration here. The various formulations of the income variable as represented by the HINC expression attempts to relate income to the employment and population in the household. The most conceptually suitable formulation took the following form:

$$HINC = \frac{INCHSHLD}{100} * \frac{EMPHSHLD}{POPHSHLD} \tag{3.7}$$

where: HINC = the index of household income,

INCHSHLD = mean income category for the household (total household income),

EMPHSHLD = household employment, and

POPHSHLD = household population. The larger the household population relative to its employment, the lower the index of household incomes

will be. This generated variable unfortunately does not untangle the individual incomes of the tripmaker. The income value has been shown to only confuse the relationship of the tripmaker with the ability to use an auto for the journey to work on an ongoing basis. The usefulness of HINC as mentioned earlier was poor, as was INCHSHLD and any formulation which used the INCHSHLD variable. The details of the performance of HINC are reserved for the next chapter.

Peak Travel Period (PEAK)

The peak variable shows an alternative temporal stratification which includes the a.m. peak (6-10 a.m.) and the p.m. peak (4-6 p.m.). The results of this stratification are to be detailed in Chapter IV.

Downtown Based (DTN)

The downtown variable stratifies the data set between trips destined for or coming from the downtown core area. The traffic zones included in the downtown variable are zone numbers 121, 122, 140-163 and 190-201. See Figure 3.3 for details of downtown traffic zones. The basis of this stratification is to better identify the variation between the relatively good transit routing within the central business area of Victoria and other major nodes of employment such as the Gorge Road industrial area, the military node in Esquimalt and the University of Victoria in North Oak Bay/S.E. Saanich. The downtown classification permitted a possible model stratification in addition to descriptive statistics on downtown specific travel behaviour. An analysis of this model stratification class is made in Chapter IV.

Trip Cost (COST)

The COST variable is defined as the relative out-of-pocket costs for

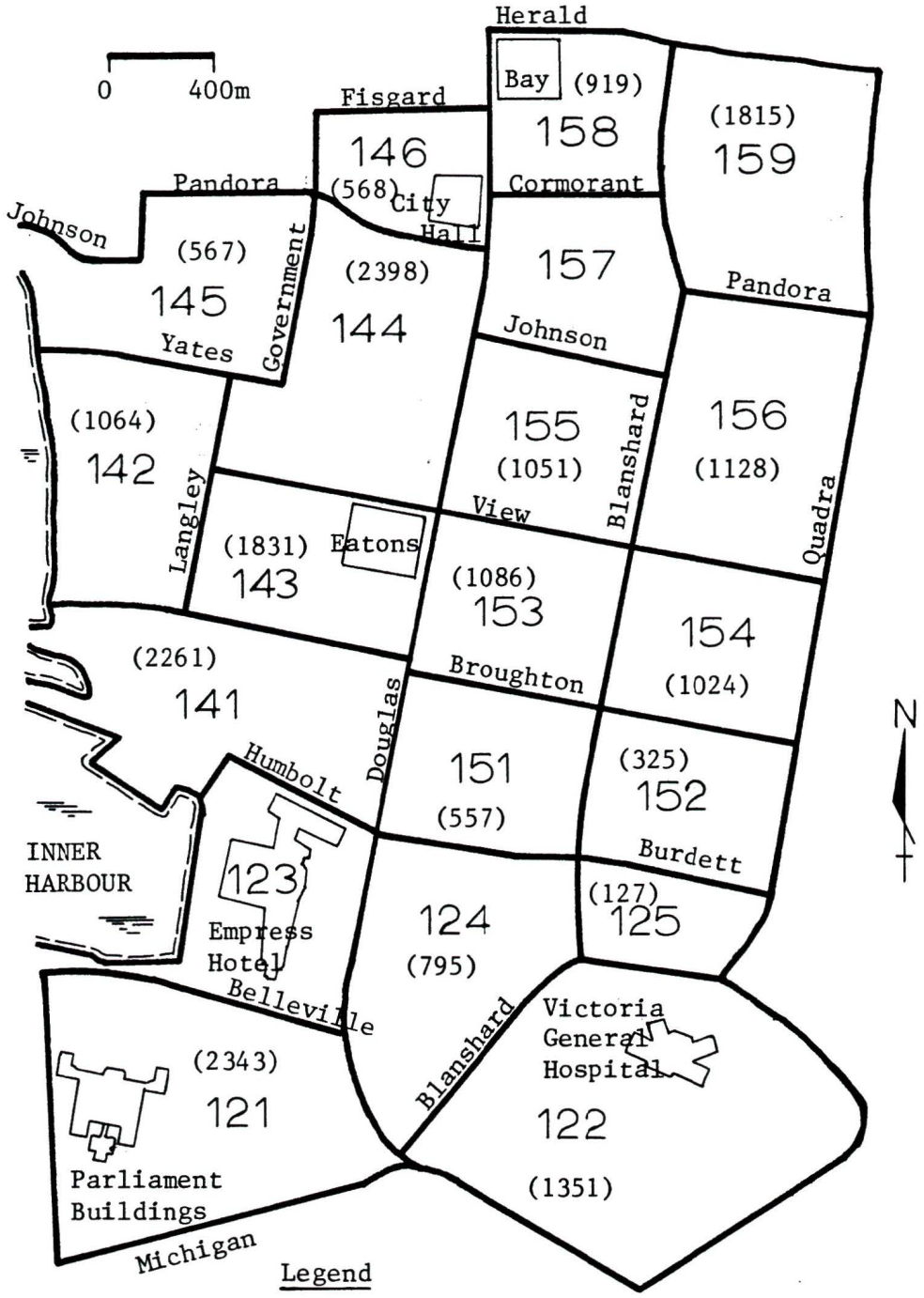


Figure 3.3 DOWNTOWN TRAFFIC ZONES - Victora CBD

a particular person-trip record (one-way trip to or from work). The formulation is simply the difference between the auto costs and transit costs for the same journey to work opportunity given a particular household income.

$$COST_{ij} = COSTAUTO_{ij} - COSTTRAN_{ij} \quad (3.8)$$

where: $COST_{ij}$ = relative out-of-pocket costs for person trip "i" with j-th household income,

$COSTAUTO_i$ = calculated relative auto costs for trip "i" with j-th household income, and

$COSTTRAN_i$ = calculated relative transit costs for trip "i" with j-th household income.

The strong support for the COST variable is found throughout the transport literature on mode choice research. Its performance in this study is satisfactory; however, it appears likely that the form of the income variable as household income and not tripmaker (individual) income weakens this factor. As will be shown in Chapter IV, the limitation of household income is identified in the calibration results for the "COST" factors. Greater detail will be made on the contribution of the COST variable following this chapter.

Relative Travel Time

The TIM variable is defined as the relative mean time of a given person-trip. It is formulated as the difference between the transit time and auto time (total trip times).

$$TIM_i = TTIMTRN_i - TTIMAUT_i \quad (3.9)$$

where: TIM_i = the relative or resultant total time for trip,

$TTIMTRN_i$ = manually calculated travel time for transit trip "i" (includes out-of-vehicle time), and

$TTIMAUT_1$ = manually calculated travel time for auto trip "i" (includes out-of-vehicle time and probably parking time).

Travel time is an important variable. The data set afforded three travel time statistics: total, in-vehicle, and out-of-vehicle travel times (in minutes). The obvious covariance between these three time factors necessitates that only a single expression be used to identify the travel time factor. While a total travel time factor may be important on its own, it offers little additional strength to the model when used alongside the out-of-vehicle variable, which is itself, contained in the total travel time. Further detail on the out-of-vehicle travel time variable follows. For this study the TIM variable is consequently not used directly in the final model's calibrations. The use of the TIM factor to produce an additional travel time factor was also made and with equally disappointing results. This additional time factor is described below.

Travel Time Index (TIMVAL)

The TIMVAL variable is a measure of transit utility on travel time. Several expressions were formulated using combinations of total travel time, and in- and out-of-vehicle travel time. The performance of this variable was found to be poor. The best formulation used TIM and OUT as a simple product:

$$TIMVAL_i = TIM_i * OUT_i * 10 \qquad (3.10)$$

where: $TIMVAL_i$ = index of travel values in minutes for trip "i",

OUT_i = relative mean out-of-vehicle travel time for trip "i",

10 = constant to keep typical values above 1.0 for easier examination.

The TIMVAL variable suffers from the same weakness as the TIM variable. That is, the out-of-vehicle travel time value (OUT) explains most of the

variation due to travel time differences. The TIM statistic only confused the relative strength of the OUT factor in the model. TIMVAL was the resultant formulation using the other travel time expressions. The results demonstrated clearly that, for Victoria, the travel time issue only relates to the relative inconvenience and discomfort associated with the journey to work which is appropriately estimated by the out-of-vehicle travel time statistic. Thus, TIMVAL like its relative, TIM, was removed from the final model's calibration.

Out-of-Vehicle Travel Time (OUT)

The OUT variable is defined as the relative mean out-of-vehicle travel time for a given person-trip. The formulation is simply the difference between the average out-of-vehicle travel time for the transit and auto modes. Thus,

$$OUT_i = OUTIMT_i - OUTIMA_i \tag{3.11}$$

where: OUT_i = the relative out-of-vehicle travel time (OVTT) for trip "i",

$OUTIMT_i$ = the estimated OVTT of transit for trip "i", and

$OUTIMA_i$ = the estimated OVTT for the auto mode for trip "i".

The OUT variable is a frequent topic in transit planning literature.[12] The strong performance observed by this factor in all but one of the models clearly supports the inclusion of this variable.[13]

The out-of-vehicle factor includes for transit: wait times, transfer times, and walk times to and from bus stops. The auto mode includes walk times from average parking situations downtown. The minimum OVTT for the auto mode was estimated to be approximately 3 min. This value is subjective since the variation is considerable. For example, in wintertime car owners who use a garage do not require frost removal or extended

warm-up periods, whereas many motorists may spend upwards of 10 minutes scraping windows and warming up cold motors (even in Victoria!) before leaving their home parking place.

The obvious correlation between the total travel time and the out-of-vehicle time required that only one be used or both combined to produce a third expression as described by the TIMVAL variable. Since the OUT factor was determined to be the most useful travel time variable, its use in all model stratifications is prominent.

Relative Level of Service (SER)

The SER variable like TIME, OUT, and COST, is a combination of associated factors which provides a relative measure of the difference between transit and auto travel characteristics. The SER variable combines LSERVT and LSERVA in the following simple formulations. The two versions of SER are more completely detailed in Chapter IV where performance comparisons are detailed.

$$SER_i = LSERVT - LSERVA*2 \quad \text{(version 1)}$$
$$SER_i = LSERVT/LSERVA \quad \text{(version 2)} \qquad (3.12)$$

where: SER_i = the relative mean level of service for trip "i",

$LSERVT_i$ = the mean estimate of the level of service for transit attributed to trip "i",

LSERVA = the mean estimate of the level of service for the auto mode attributed to trip "i", and

2 = constant or correction factor that serves to more realistically compare the LSERVA values with the LSERVT values in the difference version (version 1).

The study considered the SER variable as an important independent variable. The level of service concept is well known in mode choice

research; however, the specific formulations to estimate its value vary widely. Before any detailed description of the SER variable can be made, it is important to clarify the concept behind the level of service measurement.

The level of service expression is a measure of relative utility and suitability. It is important to note that several measures already defined in the study under the heading COST and TIM (OUT, etc.) contributes a sizeable portion to the overall service level factor. It is also noteworthy that cost and time factors do not explain all the variation that can be attributed to a broadly defined service level variable. Thus, the application of the more narrowly defined SER variable (including LSERVT and LSERVA) in this study has been to estimate the more subjective or indirect characteristics of a trip event.

As described in section 3.2.2, dealing with LSERVT and LSERVA the essential estimators for the SER factor are transit headway, transit route mean velocity and for the auto mode, relative parking difficulty. While these factors are outwardly objective measures, they actually serve to estimate subjective matters such as perceived convenience and reliability. The SER formulation logically translates into a transit mode utility function with a plus sign to the coefficient where a large value indicates an increase probability for transit use.

3.4 Conclusions

An examination of the computer printout of the LOGIT calibration reproduced in Appendix A reveals a set of non-specific socio-economic variables referred to generally as the travel propensity variables. Their use in the model though inappropriate to a disaggregate model, served to

point out the difficulty in using zonal averages to predict individuals' choice behaviour. These "macro" scaled variables used zonal employment and population to classify trip mode attractability by zone. In comparison to these, the variables which have the most useful application in the model are individual or household specific. They are summarized in Table 3.8 following. The six independent variables described in Table 3.8 combine both tripmaker characteristics and sampled trip characteristics to form the basis for calibrating a model of travel mode choice.

The LOGIT model has been used in several mode choice studies with success using a variety of variables. These studies generally used some formulation to estimate travel time and travel cost in conjunction with other key variables. Watson has compiled a list of noteable mode choice studies which effectively illustrate these key variables. This list is contained in Table 3.9 and compares these variable selections with the author's (Hogan).[14] The calibration of the key primary factors in the Victoria mode choice models, along with an analysis of the results, is made in Chapter IV.

Table 3.8

Calibration Variables

1. Car Availability (CARAVAIL)	- Combines household employment and car ownership.
2. Level-of-Service (SER)	- Relative measure of mode convenience and comfort. Composed of the individual service level estimates for transit and auto modes.
3. Out-of-Vehicle Travel Time (OUT)	- Combines the separate out-of-vehicle time estimates, OUTIMT and OUTIMA.
4. Relative Travel Costs (COST)	- Combines trip specific estimates of auto travel costs and transit travel costs (COSTAUTO, COSTTRAN, respectively).
5. SEX	- Tripmaker sex, taken from the 1977 survey.
6. AGE	- Tripmaker age (range), taken from the 1977 survey.

Table 3.9

Selected Explanatory Variables
In Mode Choice Studies

Variable Name	Authors						Hogan
	Lave	Lisco	Quarmby	Stopher	Thomas	Warner	
Time	*	*	*	*	*	*	*OUT
Cost	*	*	*	*	*	*	*COST
Comfort/ Convenience	*	-	-	-	*	-	*SER
Distance	#					*	#
Journey Purpose	N/A	N/A	N/A	N/A	N/A	X	X
Journey Frequency	-	-	-	-	-	-	-
Age/Sex	*	*	-	-	SEX	*	*AGE, SEX
Car Availability	-	*	*	-	-	*	*CARAVAIL
Car Ownership	N/A	N/A	-	-	N/A	N/A	#
No. of Travellers	-	-	-	-	-	-	-
Other	0	0	*	0	*	0	0

Legend

N/A	not applicable
*	used in model
X	used to stratify sample
#	indirectly used
-	not used
0	none

References

1. The documentation information on the CRD home interview transportation survey was obtained from a staff report to the Metropolitan Victoria Transportation Planning Committee, Wednesday, December 21, 1977.

2. Statistics on households grouped by census tract from the 1971 census.

3. The CRD survey actually produced 499 household-record sets; however, 7 household record sets contained irreconcilable errors and were deleted from the data set by the author.

4. Watson (56), Donnea (19), Stopher (43, 44) and others identify car ownership in most mode choice studies, particularly models of individual choice.

5. Computer programming routines can be used to compare each zone matrix of average distances between zones, given the road pattern and traffic opportunities. This study did not require such software development, since the data set was sufficiently small.

6. The author had access to the specific addresses for each household in the sample. This information, though, was not used, as this would have required far greater computational effort. Such effort would not be generally available in a typical transit planning environment. The standard practice in such O-D matrices is to make the traffic zone suitably small to enable practical programming and/or manual manipulation.

7. Mean vehicle speeds have been calculated by the transit operating company for all routes and by time periods, i.e., a.m. peak, mid-day, p.m. peak, evening, etc.

8. The CRD O-D survey indicated that on any given day, approximately 14% of trips will be as an auto passenger.

9. The bibliography includes several references on stochastic, disaggregate behavioural modelling where the theoretical framework embodies economic theory on the value of time in travel demand analysis. These include Dickey (19), Domencich (18), Donnea (19), Heggie (24), Hyman et al (27), Manning (31), Stopher et al (43, 44, 45, 46), Watson (56), Yeung et al (59).

10. Domencich and Donnea in Europe and Watson and Stopher in North America.

11. Watson (56) pp. 55-67. A comparison of several studies is tabled allowing comparison between variables used. Comfort/convenience variable was used by Lave and Thomas. See also Curtis (13.5).

12. The out-of-vehicle travel time variable is closely studied in transit planning and is considered the essential criterion for assessing overall service level; that is, the degree to which modern urban transit is provided. In British Columbia, papers by the Bureau of Transit Services (now B.C. Transit) make mention of the importance of minimizing on-curb patron waits in scheduled or unscheduled transfers. See Thompson (50) and Smith et al (40).

13. Details of each of the seven models calibrated for this study are found in Chapter IV. The "seventh" model is actually an "exceptional" stratification which produces noteablly different results from the other model stratifications.

14. Watson (56) p. 55.

CHAPTER IV

CALIBRATION OF THE VICTORIA MODEL

The foundation of any predictive model is the independent variable set. In Chapter III, the full array of possible independent variables has been detailed with a view of their importance to the model calibration process. In Chapter IV, the variables considered essential and usable in Chapter III will be scrutinized more closely for suitability directly in the model calibration. Aspects of the evolution of the various stratifications in the Victoria model will be described along with notes on the software used. Also included is a discussion of methods for producing variables where auto and transit travel characteristics are combined using their differences or their ratios to produce a relative trip characteristic measure. Finally, the resultant Victoria mode choice model will be described and assessed for statistical significance.

4.1 Model Stratification

One of the first steps in preparing the data for model calibration was to define the problem "area" and then select records from the main body of data that are associated with that particular problem area. In this study the "problem area" is defined as the most frequent trip purpose; that is, the journey to work (and back). The problem symptoms are peak traffic movement and its resultant congestion. Not surprisingly, it can be shown that the work-based journey is the primary trip purpose for those peak traffic times. Of additional interest is the general agreement that of all trip purposes, the journey to work is the one that is most habitual with the individual and therefore possesses the greatest propensity for prediction.[1] Having justified a limiting of the data set

to only 623 records by stratifying on the basis of work-based journeys in the core municipalities of Victoria, why then stratify further? To best answer this question one must consider the scope of the study and the problem area being addressed. If it is possible to develop a reliable model on the baseline data, that is, the 623 selected trip records, then is it also possible to base a model on a narrower problem area, while retaining the model's reliability? The answer is yes, providing the selection of records achieves a greater degree of homogeneity regarding the assumptions of travel mode behaviour. Naturally, with any sample stratification, what is gained in theory is partly taken away by the reduction in sample size and its corresponding reduction in statistical significance. As will be shown later in this chapter, such stratifications can be made with suitable statistical significance.

The Victoria mode choice model uses four stratifications. They are: 1) the general Victoria model, 2) the peak period model, 3) the downtown-based model, and 4) the suburban non-peak model. Before describing each of the model stratifications above it will be useful to detail the evolution of the general Victoria model. The final form of the general model came from numerous test runs of the SHAZAM calibration computer program which is to be discussed in section 4.2. The experimental period involved the testing of all possible variables. In this process some of these variables produced unacceptable results that required more detailed examination and explanation.

In Chapter II, assumptions regarding the data requirements of logistic analysis were introduced. To that discussion should be added that with any multivariate model there is the obvious necessity to show that the explanatory variables are not independent of the dependent variable

nor correlated amongst themselves. The question on model assumptions might now focus with the issue of independence between each dependent trip record's observation. It should be noted that the trip records used in the calibration include both journeys to work as well as the return journey home; in other words, all work-based trips. Thus, it is obvious that most trip records are in pairs representing an individual's (tripmaker's) journey to and from work, obviously, a kind of correlation exists; however, the assumptions of the model do not depend on this type of dependence for validity or significance. It should be further noted that the correlation coefficient is not suitable as a closeness-of-fit measurement for a non-normal binary dependent variable.[2] Moreover, the implications of not considering the round trip data creates some important limitations, namely, the absence of journey home characteristics which can vary in travel time, level of service for transit, and even travel distance, thereby removing a major part of the total work trip event for a given tripmaker. Clearly, the mode choice decision must take into account the daily round-trip journey to properly capture all trip-specific information for any sampled individual. Thus, in calibrating the model, the more information obtainable on the work-based journeys, the better the statistical reliability and the greater the opportunity for specialized model stratifications. An additional caution on the dependent variable assumptions is the requirement that no bias is introduced to the data records selection which conflicts with the intended selection stratification. For example, it would not be appropriate to select round-trip records for transit trips while limiting auto trips to a one-way trip to work selection. Such biases would generally create a major over-estimation of one of the binary choices.

4.1.1 General Work-Based Victoria Model

The general work-based Victoria model was calibrated successfully using four possible variable sets. In Table 4.1, descriptions of these are shown along with a variable listing.

4.1.2 Special Work-Based Victoria Models

The results of the general model calibration are fully described later in this chapter. The favoured general model is number four (FMIX2) and the variables used in this model are also used in all the special purpose models. In Table 4.2 a brief listing of general characteristics is shown for these special models which use a subset of the full data base.

4.2 A Note on Model Computer Software

The mathematical complexity of the LOGIT model or more specifically, the maximum likelihood estimation technique, combined with the size of the sample required that suitable computer software be used. The selected program is part of a package of econometric statistical models going by the name SHAZAM.[3] The latest release of SHAZAM is available at the University of Victoria computing centre and other selected major computing facilities in North America.

The selection of SHAZAM over competing software was based on the relative ease of use to both set up the program routine and to include variable generation subroutines. An alternative program is provided in the BMDP statistical program from the University of California.[4]

Throughout the study the use of computing facilities was important and invaluable; however, the model calibration phase was the only data processing activity requiring more specialized software generally found with larger computing installations. A microcomputer was used for much of the data preparation and editing during the later stages prior to

Table 4.1

General Work Based Victoria Model

(No. of individual trip records = 623)

Variables Used	Computer Name and Number			
	1 FDF1	2 FDF2	3 FMIX1	4 FMIX2
Car Availability (CARAVAIL)	R	R	R	R
SEX	*	*	*	*
Relative Level of Service (SER)	D	D	R	R
AGE	*	*	*	*
Relative Travel Costs (COST)	D	D	D	D
Relative Travel Time (TIM)	D	-	-	-
Out-of-Vehicle Travel Time (OUT)	D	D	D	D
Transfers (TRNSFERS)	T	-	-	-
Household Income Status (HINC)	-	-	*	-

Legend:
- D = Difference expression to express relative value between transit and auto modes. (See discussion in section 4.3).
- * = Individual or household data.
- R = Ratio expression to express relative value between transit and auto modes. (See discussion in section 4.3)
- - = Not used.
- T = Transit mode data.

Table 4.2

Special Work-Based Victoria Models

	Computer Name and Number		
	5 PKMIX	6 DTNMIX	7 NOPDMIX
Number of Records	416	216	153
Data Subset (Stratification)	Peak Periods Only, i.e. 5 a.m. to 10 a.m. and 4 p.m. to 6 p.m.	Downtown Based Journies Included Traffic Zones Downtown Are 121, 122 140 to 163 and 190 to 201 See Appendix C	Excludes Records in Model No. 5 and 6
Percentage Choosing Transit (Mode Split)	18%	29.2%	4.6%

the calibration phase of the study. As will be described in Chapter V, the use of a microcomputer to run the model itself in a scenario gaming exercise is an important aspect of the model's practicality in smaller scale planning environments. This study used a standard IBM PC using simple programs written in BASIC and FORTRAN to assist in the detection of measurement and coding errors. The final file preparation and much of the appended data entry and variable generation was completed using the LOTUS 1-2-3 program.[5] In general, the exclusive use of the microcomputer in many transport modelling studies is imminent, making computing tasks both cost effective and convenient.

4.3 Relative Variable Measurements - Some Considerations

Two variables used in all seven model calibrations need a special discussion to compare ways of formulating a value for a relative variable. They are the car availability variable designated as CARAVAIL and the relative service level variable designated as SER, both of which contribute much to the model. In the calibration experiments two basic ways of expressing these variables were considered, the first uses simple differences to combine contributing variables, the second takes the ratio between the contributing variables as the ratio of factors a and b. This ratio expression thereby represents a wholly new measurement. This distinction therefore must govern the development of secondary or combined variables.

The car availability expression was developed to improve the household car ownership variable by relating it to household employment. Taking their differences appears somewhat inappropriate since their units are unrelated. A better way to illustrate the distinction between the two approaches is to compare tables of values for car availability which

has been calculated using both methods. Thus we have

$$Ca_H = CO_H - E_H \quad \text{or}$$

$$Ca_H = CO_H / E_H$$

where Ca_H is car availability, CO_H is car ownership by household and E_H is household employment (labour force). In Table 4.3 typical values are shown.

4.3.1 Relative trip characteristics - Difference versus ratio approach

In the binary choice LOGIT model measures of trip characteristics are generally relative measures where the corresponding auto and transit characteristics are combined to form a single expression. The general method is to simply take the difference between the auto and transit values. In this model the approach has been, wherever possible, to use the differences of combined factors. The best examples are the relative out-of-vehicle travel time (OUT).

Two other variables have been used which do not find satisfactory results by taking differences between the contributing factors. These are the relative level-of-service factor and the car availability variable. Both of these have been expressed as a ratio of two contributing factors. Thus, there is need to make a distinction between these two approaches; differences and ratios.

Conceptually, differences imply a simple resultant affect where the value of variable "c" is given as the value of factor "a" less the influence of factor "b". In a ratio expression a variable "c" is created. The range of values between each method clearly reveals the problem of a differences expression. For example, does it follow that a household with no cars and two workers have the same relative car availability as a

Table 4.3

Comparison of Difference Versus Ratio Approach

for Car Availability (CARAVAIL)

		Difference	Ratio
CO_H	E_H	$CO_H - E_H$	CO_H / E_H
0	1	-1	0
0	2	-2	0
1	1	0	1
2	1	1	2
3	1	2	3
1	2	-1	.5
2	2	0	1
3	2	-1	1.33
2	5	-3	.40

household with three workers and one car? Probably not since the former has no car availability at all and the latter has at least some potential in a single vehicle. The ratio expression offers a more intuitive logic giving higher values to logically stronger levels of car availability without under or over emphasizing the value of this expression. Thus a new variable is created by a ratio expression that can be referred to as cars available per employed person.

The second variable which was generated as a ratio expression is the relative level-of-service factor which presents a different type of problem. This factor combines the level-of-service measures for each of the model's travel modes. This being so, the usual difference expression should follow; however, the actual method of measurement departs markedly presenting some logical problems regarding common units. Looking closer at the level-of-service for transit (LSERVT) and the level-of-service for auto (LSERVA) factors, we have for the former, bus route frequency and mean service velocity and to the latter, a three point scale for parking convenience. While it is reasonable to estimate parking opportunity by zone using a three point scale, it is somewhat less intuitive to equate this scale, weighted or not, to the transit service level measurement scale. To avoid this deficiency in logic it is proposed that a ratio be formed to calibrate a relative or resultant expression (SER) which combines the two service level measurements. The results of this reformulation of SER has significantly improved its performance. Since a ratio expression does not need scale equivalency it therefore becomes evident that an index for quality-of-service or level-of-service can be estimated as the ratio of transit service against auto service. Thus, if the

level-of-service for transit is low and the level-of-service for auto is high, their quotient would be a correspondingly small value indicating a weak preference for transit mode choice. In the opposite case, a strong preference would be observed for auto use.

In summary, variables combined to generate a new resultant value should be added or subtracted when units or scales are equivalent. When two differing measures are associated, their resultant is a wholly new expression that must contain within it a rational or substantial relationship that remains consistent or logical regardless of the range each component value has. An appropriate concluding remark on this general topic of generated variables might be that any proposed variable which is generated from raw data must be reasonably uncorrelated with the individual component parts, have consistent logic throughout the range of values it might take, including unbounded limits, and lastly, show clear results which uncovers a modal utility expression independently decisive when compared to its component parts. The SER expression has fulfilled these requirements and constitutes a major component in the Victoria LOGIT model.

4.4 The LOGIT Form

In Chapter II, detail was given on the derivation of the LOGIT model and its basic mathematical form. It will now be useful to illustrate this form before describing the model results and assessing their statistical performance.

The first task of predicting travel mode choice with a model relates back to the assumptions we have about what counts in making a choice decision and to what degree it counts. In the simplest form, a linear relationship might be imposed on the data such that for any change in a

mode's utility (ΔU) there is a linear change in the probability (P_i) that this mode will be chosen, as shown in Figure 4.1. The problem of unbounded limits is clearly evident as larger or smaller values produce impossible probabilities ($P_i \neq \{0 > P_i$; and $P_i > 1.0\}$) without suitable constraints applied to the model's range.

The sigmoid form in Figure 4.2 in contrast does not result in unbounded limits. As extreme values occur the sensitivity to changes in the utility function (ΔU) decreases in direct proportion, thus as ΔU approaches infinity the sensitivity of ΔU approaches zero. The LOGIT form thus reflects the economists' principle of diminishing returns which more realistically models choice behaviour.

The LOGIT model is a probability model which predicts a probability of a particular event happening consistently. Thus, the outputs of the model can be interpreted as a percentage split between the possible occurrences defined by the dependent variable. In the Victoria model the choices are two; transit and the automobile. The dependent variable is specifically expressed as the "yes" occurrence for transit, thus model results are probabilities for transit P(T). The probability for the alternative auto mode is therefore 1 - P(T).

4.5 A Methodology to Analyse Model Significance

The methods required to test the statistical significance of the overall model and its constituent components is different from the classical tests associated with multiple regression analysis. A covariance matrix of coefficients was made between each of the independent variables to test for independence. This is an unavoidable assumption in all mathematical models. In logistic analysis, though, it is not necessary

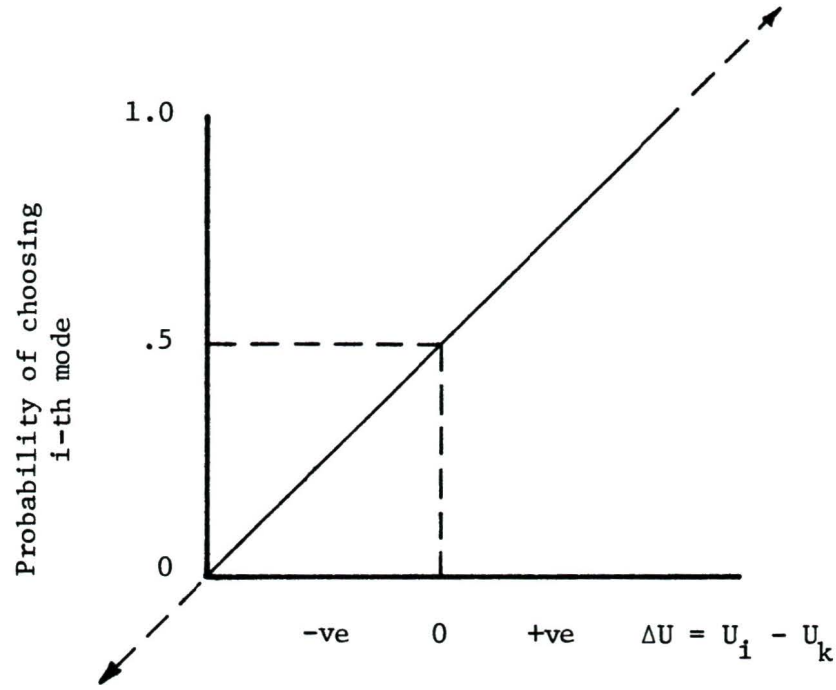


Figure 4.1 Linear Relationship for Mode Choice[6]

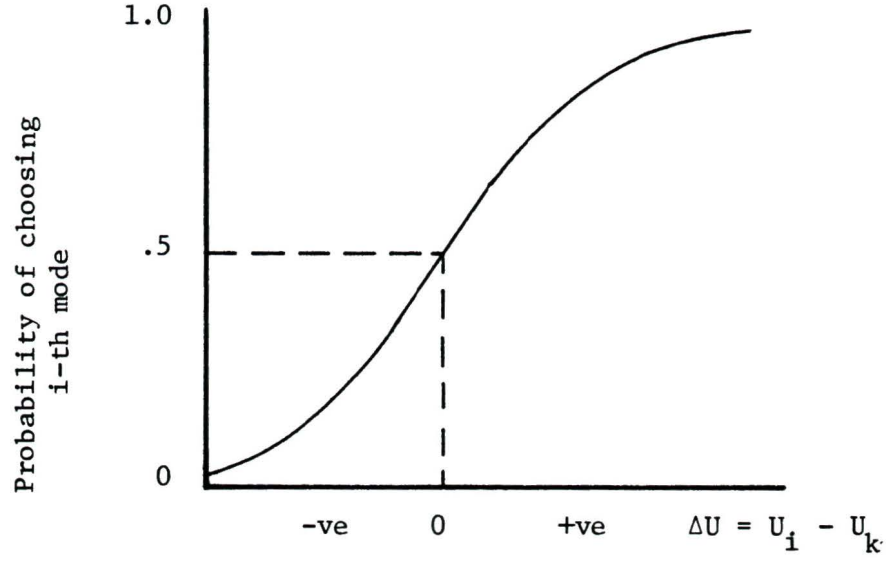


Figure 4.2 Logistic Relationship for Mode Choice
(A Sigmoid Form)

that each independent variable be normally distributed thus, the tests using the parametric correlation coefficient must be interpreted with some caution. See Table 4.4 for the covariance matrix of independent variables. This table supports the intuitive independence between the explanatory variables. The coefficients are very small indeed!

4.4.1 Likelihood Ratio Test

The LOGIT model as with its cousin, the probit model, must be assessed using the likelihood ratio test. It tests the hypothesis that the dependent variable (the probability of taking public transit in the work-based journey) is independent of the values of the explanatory variables of the model. Expressed mathematically we have the hypothesis of[7]

$$P_{Transit} = \frac{e^{\alpha_0}}{1 + e^{\alpha_0}} \tag{4.1}$$

where α_0= constant term when all values of the explanatory variables are 0. If this hypothesis cannot be rejected, then the maximum likelihood estimate of α_0 will be the value that maximizes the likelihood function of the sample. Going back to equation (2.12) we have for the dependent variable, 95 transit observations and 528 auto observations from a sample of 623. Thus,

$$\Lambda\ (\alpha_0\ ,\ 0,\ 0,\ \ldots\ ,\ 0) = \frac{e^{\alpha_0}}{1 + e^{\alpha_0}}^{95} \frac{1}{1 + e^{\alpha_0}}^{623-95} \tag{4.2}$$

This restated becomes a value a'_o producing

$$P_{Transit}(a'_o) = \frac{e^{a'_0}}{1 + e^{a'_0}} = \frac{95}{623} \tag{4.3}$$

It follows that the value of the logarithm of the likelihood function (4.2) evaluated with the maximum likelihood value of the parameter α_0 is:

Table 4.4

Covariance Matrix

No.	Variable Name	6	10	56	11	52	54	61
6	CARAVAIL	.113						
10	SEX	.007	.07					
56	SER	-.0004	-.0008	.0002				
11	AGE	-.006	.002	.0001	.020			
52	COST	-.0009	.0003	.00002	.00005	.0004		
54	OUT	.0006	-.0005	.0002	.00006	-.0002	.001	
61	CONSTANT	-.06	-.101	-.002	-.059	.0005	-.008	.458

$$\Lambda^*(a'_o, 0, 0, .., 0) = 95 \log \frac{95}{623} + (623-95) + \log \frac{623-95}{623} \quad (4.4)$$

if the probability of taking transit is not independent of the explanatory variables, the log of the likelihood function takes the form (from equation 2.10):

$$\Lambda^* (\alpha_0 , \sum^{n} \alpha_{a_n} , \sum^{n} \alpha_{b_n}) = \sum_{j=1}^{95} \log Pj (\alpha_0 , .. \sum^{n} \alpha_{b_n}) +$$

$$\sum_{j=96}^{623} \log [1 - Pj (\alpha_0 , .. \sum^{n} \alpha_{b_n})] \quad (4.5)$$

The maximum likelihood values of the parameters $\alpha_0 .., \sum^{n} \alpha_{b_n}$ is called $a_o .., \sum^{n} a_{b_n}$. Thus, the log likelihood ratio becomes

$$\log \lambda - \Lambda^* (a'_o, 0, .., 0) - \Lambda^* (a_o, a_a \ldots a_{b_n}) \quad (4.6)$$

The log of the likelihood ratio can be transformed to approximate the chi-square distribution using $-2 \log\lambda$ with m degrees of freedom (where m = number of independent variables).

4.6 Analysis of Model Performance

The two model cateogries including the general Victoria models' four separate formulations are to be described in detail. While only one general purpose model is favoured, the other three have been used to illustrate the development considerations and offer a means of comparing the key test models. Thus the first category serves as the testing ground for the entire model to which stratifications might be developed.

As mentioned previously, the seven models can be grouped into two categories. The first category includes the full data set models identified in Figure 4.1. The second cateogry includes the peak period and downtown based stratifications. These two models are intended to focus on the most homogeneous travel group. More will be said about this later.

The last model is really the "residual " or suburban work-based model identified as model 7 in Table 4.5. The "residual " model isolates non-peak and non-downtown based trips (remembering that even these trips must be accessible by transit in order to be kept in the data set). In a sense, model 7 represents the no group or seemingly "patternless" portion of the data which at first examination does not appear to follow any strong behavioural trend. As will be discussed later in this chapter, this residual model (seven) does reveal appropriate characteristics consistent with our assumptions about travel behaviour.

The test statistics that can be used to assess each independent variable is the standard error of the estimate which yields t-ratios that are easily interpreted using standard t-tables. In the next sub-sections each independent variable will be assessed with regard to its performance in each of the two model categories. A summary table of t-ratios and the chi-square tests of the likelihood ratio are shown for all seven model calibrations in Table 4.5. This table will be referred to throughout the remainder of this chapter.

4.6.1 The General Work-Based Victoria Model

The first independent variable is car availability identified as CARAVAIL (variable number 6). In Table 4.6 there is a summary of the t-ratios for the maximum likelihood estimate for the car availability coefficient (CARAVAIL). The car availability factor is quite strong as a predictor of transit mode choice. This variable is to be considered a key factor; however, it is a static variable that becomes out of date with the passage of time. Separate forecasting methods would normally be used to keep these variables current. Car ownership, though not collected by Statistics Canada since 1971 can be forecast from data made available

Table 4.5

Mode Choice Significance Test Results: T-Ratios and Chi Square

Variable No.	Variable Name	General Work Based Model (Full Data Set)				Special Work Based Models			Variable Type
Run Numbers and File Code Names*		1 FDIF1	2 FDIF2	3 FMIX1	4 FMIX2	Peak 5 PKMIX	Downtown 6 DTNMIX	Non-Peak Non-Dntn 7 NOPDMIX	
6	CARAVAIL	-5.38	-5.54	-5.64	-5.53	-5.42	-3.30	-1.76	Household
10	SEX	2.11	2.13	1.58	1.48	0.57	0.40	2.15	Tripmaker
56	SER	3.08	3.05	4.07	4.13	2.59	3.00	-0.64	Trip Characteristic
11	AGE	-2.16	-2.17	-1.96	-1.94	-1.73	-1.63	1.20	Tripmaker
52	COST	2.03	2.43	2.21	2.18	1.51	2.31	0.29	Trip Characteristic
53	TIM	0.34	n/a	n/a	n/a	n/a	n/a	n/a	Trip Characteristic
54	OUT	-2.70	-4.40	-3.56	-3.54	-3.46	-3.07	0.17	Trip Characteristic
31	TRNSFERS	0.38	n/a	n/a	n/a	n/a	n/a	n/a	Trip Characteristic
57	TPROP **	-0.27	n/a	0.58	n/a	n/a	n/a	n/a	Aggregate Demographic
35	HINC	n/a	n/a	-0.83	n/a	n/a	n/a	n/a	Household Tripmaker
61	CONSTANT	0.001	0.01	0.06	-0.24	1.14	0.41	-1.99	Constant
Chi-Square		410	410	402	403	289	204	43.9	
Degrees of Freedom		9	6	8	6	6	6	6	
Transit Mode Choice		15.2%	15.2%	15.2%	15.2%	18.0%	29.2%	4.6%	
Sample Size		623	623	623	623	416	216	153	

*See Appendix A for computer printouts of each run

**Not considered for the favoured models (i.e., models 4 to 7).

Table 4.6

General Work-Based Victoria Models

Significance of Car Availability (CARAVAIL)

Coefficient	Std. error	t-ratios	d.f.	Model	Significance (one tailed)
-1.84	.34	-5.38	9	I	.0005
-1.85	.33	-5.54	6	II	.005
-1.93	.34	-5.64	8	III	.0005
-1.86	.34	-5.53	6	IV	.005

Table 4.7

General Work-Based Victoria Models

Significance of SER

Coefficient	Std. error	t-ratios	d.f.	Model	Significance (one tailed)
.076	.025	3.08*	9	I	.01
.073	.024	3.05*	6	II	.015
.051	.012	4.07**	8	III	.003
.051	.012	4.13**	6	IV	.004

* SER = LSERVT - LSERVA*2

** SER = LSERVT/ LSERVA*2

from the provincial motor vehicle branch or from auto insurance companies. This issue will be looked at in more detail when future applications, improvements and recommendations are discussed in Chapter V.

The t-ratios in all four models are more or less equivalent in statistical significance. Car availability is also the most explanatory factor in the model based on its high t-ratios. The second independent variable is the mode level of service short-named SER (variable number 56). Table 4.7 contains the summary t-ratios. The level-of-service variable is a most interesting factor. Continuing from earlier discussions where the ratio versus differences approach was detailed, it is now appropriate to note the marked improvement in the ratio expression (model III & IV). While the multiplier factor of 2 which was used to equate scales was more or less successful (subjective trial and error) the valid ratio expression not surprisingly reveals the "real" explanatory strength of this factor as a major variable in transit service planning. The use of the SER variable in scenario analysis is critical to the use of the model in assessing various service level impacts on ridership and costing. The actual use of the model using a micro computer is the subject of Chapter V.

The third independent variable is the out-of-vehicle travel time factor designated as OUT (variable number 54). Table 4.8 contains the t-ratio summary. The expression measures out-of-vehicle time as a resultant between transit and auto "out" times; thus, a large value puts the transit option in a less favourable light.

In all four models the t-ratios show satisfactory or better significance. The marked difference between the t-ratios of Model I and II are

Table 4.8

General Work-Based Victoria Model

Significance of OUT

Coefficients	Std. Error	t-ratio	d.f.	Model	Significance (one tailed)
-.164	.061	-2.70	9	I	.015
-.138	.031	-4.40	6	II	.003
-.114	.032	-3.56	8	III	.005
-.112	.032	-3.54	6	IV	.008

due to the removal of the TIM and TRNSFERS variables in model II. The interaction of these explanatory factors has a defusing influence in their individual statistical significances. As a result the advantage of removing all such weak interacting factors becomes clearly apparent. The problems with removing particular factors from the model have been discussed previously in Chapter III.

The use of the out-of-vehicle travel time variable in planning is also very key to scenario analysis. Since this variable is specific to a given traffic zone or group of zones, it is possible to experiment with possible transit options to compare route design concepts such as timed-transfer feeder-bus routes versus longer direct trunk routes. Though not specifically illustrated in the example application in Chapter V, it nevertheless constitutes a potentially inelastic variable worthy of experiment.

The fourth independent variable is the relative travel costs of the person-trip. The short name is COST and its summary of t-ratios is found in Table 4.9. The relative or resultant out-of-pocket cost estimates for a specific person-trip is the fourth key variable in model use for scenario analysis. The obvious use in transit planning is to test various pricing policies to allow a potentially more reliable estimate of annual revenue from transit operations to be made and to also assess possible effects on the traffic network.

The fifth independent variable is the tripmaker's sex (designated SEX, variable number 10). Table 4.10 contains t-ratio summaries. Statistics Canada provides a male-female split by age group for each census tract. This permits an update on this "constant" every five years.

Table 4.9

General Work-Based Victoria Models

Significance of COST

Coefficients	Std. Error	t-ratios	d.f.	Model	Significance (one tailed)
.047	.023	2.03	9	I	.04
.050	.020	2.43	6	II	.04
.045	.020	2.21	8	III	.03
.045	.021	2.18	6	IV	.04

Table 4.10

General Work-Based Victoria Models

Significance of SEX

Coefficients	Std. Error	t-ratios	d.f.	Model	Significance (one tailed)
.55	.26	2.11	9	I	.03
.55	.26	2.13	6	II	.04
.42	.27	1.58	8	III	.08
.39	.27	1.48	6	IV	.095

While this factor is statistically significant its elasticity is moderately high; thus, a census tract (traffic zone equivalent) would have to show a marked difference in male-female population before a significant change in mode split would be reliably determined. This range of elasticity will be demonstrated later in this chapter. The plus sign (+) of the SEX factor indicates that women are more likely to take transit.

The sixth independent variable is the tripmaker's age (designated AGE, variable number 11). Table 4.11 contains the t-ratio summaries. The age factor is another given for the traffic zone or zones being studied. The greater the average age in an area the less likely that an individual will take transit. In real terms this relationship is partly false since the elderly very often take transit and do not own or operate a motor vehicle. The study data, however, restricts trip records to the journey to work. Thus, such travel behaviour remains undetected.

The remaining independent variables were found to be unsuitable to the model. These variables are the relative travel time factor (TIM, number 53), the bus transfer factor (TRNSFERS, number 31), and lastly, the relative household income variable (HINC, Number 35). In Table 4.12 a summary of t-ratios for total relative travel time, transfers required and travel propensity is made. A separate discussion of HINC follows. The bases for the inclusion of these factors in the model were to both experiment with their effects and to uncover their limitations. The significance of the t-ratios while quite low is <u>not</u> completely unacceptable when applied to the LOGIT model.

The total relative travel time (TIM) variable was noted to interact with the out-of-vehicle travel time factor. The strength of total travel

Table 4.11

General Work-Based Victoria Models

Significance of AGE

Coefficient	Std. Error	t-ratio	d.f.	Model	Significance (one tailed)
-.301	.139	-2.16	9	I	.03
-.303	.139	-2.17	6	II	.04
-.278	.142	-1.96	8	III	.04
-.275	.141	-1.94	6	IV	.05

Table 4.12

General Work-Based Victoria Model

Significance of TIM, TRNSFERS and TPROP

Variable Model No.	t-Ratios		d.f.		Significance	
	I	III	I	III	I	III
TIM	.34	-	9	-	.10	-
TRNSFERS	.38	-	9	-	.10	-

time lies in the "OUT" component of it; moreover, the in-vehicle-time component appears to be mostly residual characteristics that interact poorly, thus reducing the strong influence of the OUT component. The TIM factor is not used in the other models as a consequence.

The bus transfers factor is used in the out-of-vehicle travel time for models II through VIII. In model No. I, bus transfers has been used separately to reveal its own strength removed from its association with the out-of-vehicle inconvenience factor. The most noteable aspect of this factor besides its poor performance is the plus sign (+) of the coefficient. The only reasonable conclusion to this observation is that person-trips in the data set which require one or even two transfers were associated with a relatively close travel time difference between total transit and auto travel times. This observation can be supported by the Pat Bay Highway and Trans Canada transit services which were (in 1977) express services with the system's fastest average speeds. The plus sign (+) for total travel time also supports this possible explanation. The advantage of removing the transfers number from the model and combining it with the out-of-vehicle travel time expression can be readily seen in the other models' t-ratios.

The last variable considered in this study is the relative household income variable, designnated as HINC (variable number 35). Table 4.13 summarizes the t-ratio. The limitations of using household income as previously discussed in Chapter III are clearly seen in the above t-ratio statistic. The inclusion of HINC in model III has been to verify the functional and theoretical problems of using this ratio-expressed income variable. The negative sign on the t-ratio value is consistent with the

Table 4.13

General Work-Based Victoria Modes

Significance of HINC

t-ratio	d.f.	Model	Significance (one tailed)
-.83	8	III	> .10

a priori logic of income being inversely associated with transit mode choice. The HINC factor's statistical significance is unfortunately undermined by its rather indirect association with the tripmaker's actual personal income. As a result of this limitation with the household income statistic, the HINC factor has been deleted from the other models.

4.6.2 Special Work-Based Models

The special work-based models are designed to isolate the primary work trip events most associated with the problem of transport efficiency and particularly traffic congestion and optimum transit service. The first two special models are stratified by peak period travel connected with the morning and afternoon rush hours and the downtown based work trips. The third model is identified in Table 4.5 as model VII and is stratified by non-peak and non-downtown work-based trips, that is, the "residual" case model which will be discussed in this section as well. The specific application advantages of these special models are the subject of Chapter V. As with the general model it is important to separately review the performance of each independent variable in the light of the particular stratification and the assumptions that are connected with these three special case models.

Of special interest is the somewhat unexpected results of the non-peak/non-downtown model which, though statistically significant, appears to contradict the assumptions made on travel behaviour. This observation will be discussed later in this section where the noteable sign (+/-) changes to key variable coefficients is discussed in contrast to the other models.

The first variable is car availability and its performance is shown in Table 4.14 below. The car availability factor remains a very strong

Table 4.14

Special Work-Based Victoria Models

Significance of CARAVAIL

Stratification	Peak Period Trips	Stratification Downtown Based Trips	Stratification Non-Downtown Trips
coefficient	-2.21	-1.31	-2.69
Std. Error	0.409	.397	1.53
t-ratio	-5.42	-3.30	-1.76
d.f.	6	6	6
Model	V	VI	VII
Significance	.0008	.007	.07
Sample Size	416	216	153

factor in the first two models. The peak period work-trip is somewhat more strongly associated with transit mode choice than the downtown location stratification. This difference is not particularly surprising since peak period travel corresponds with peak transit headways (service frequencies) for all routes in the system. This difference also points to the study's most important travel behaviour stratification which is the journey to work stratification itself. The downtown work destination is important; however, the more important general travel factor is the response of the transit system to handling the peak traffic periods which are primarily work related.

The second variable to consider in the special models is the out-of-vehicle travel time variable (OUT). Table 4.15 summarizes the OUT variable. The out-of-vehicle travel time factor shows near equivalent strength between models V and VI. The higher t-ratio observed for model V is due probably to its larger sample size.

It is important to note that the OUT factor plays a key role for peak and downtown based trips but becomes insignificant in the "non-group" model which excludes the model V and VI stratifications. More will be said on this when the last model (VII) is discussed in conjunction with the SEX variable.

The overall good performance of the out-of-vehicle travel time factor is fundamental to the model's application to transport scenario analysis and general transit planning. The t-ratios indicate good statistical significance and places greater confidence in the potential strength of the model to solve practical planning problems. This latter note will be made more apparent in Chapter V.

Table 4.15

Special Work-Based Victoria Models

Significance of Out-of-Vehicle Travel Time (OUT)

Stratification	Peak Period Trips	Downtown Based Trips	Non-Peak Non-Downtown Trips
Coefficient	-.138	-.201	.015
Std. Error	.04	.065	.091
t-ratio	-3.46	-3.07	.17
d.f.	6	6	6
Model	V	VI	VII
Significance	.008	.012	> .20
Sample Size	416	216	153

The third variable in this category is the relative service level, SER, which like out-of-vehicle travel time is a very key factor. The t-ratio summaries are found in Table 4.6 following. The level-of-service factor is strongly associated with downtown destinations since they involve fewer and shorter transfer delays. This observation is noted by the stronger t-ratio scored in model VI. The SER factor is very similar to the OUT factor in relative performance and general importance to the application of the model. The noteable sign (+/-) change to the non-peak/non-downtown model as well as other marked differences in this model will be discussed separately later in this section.

The fourth variable is the relative out-of-pocket travel costs factor (COST) which is summarized in the following t-ratio Table 4.17. The out-of-pocket travel cost (COST) is an important issue for downtown based trips where pay parking significantly adds to the cost of using private automobiles. Clearly, such effects on mode choice can be seen by the relatively strong t-ratio scores in model VI compared to both the general model IV and model V. The overall importance of pay parking which is essentially downtown based (model VI) is a key characteristic to understanding mode choice behaviour by non-captive transit ridership.

The fifth variable in the special models is age (AGE). Please refer to Table 4.18 for the t-ratio summaries. The age factor appears unrelated to whether work trips are downtown based or taken during the peak period. The only factor that appears to account for the differences between the t-ratios in each of the models is the sample size. This consistent t-score for each of the models (except model VII) presents no apparent problems and is so considered a suitable factor for all the

Table 4.16

Special Work-Based Victoria Models

Significance of Relative Service Level (SER)

Stratification	Peak Period Trips	Downtown Based Trips	Non-Peak Non-Downtown Based Trips
Coefficient	.038	.049	-.159
Std. Error	.015	.016	.247
t-ratio	2.59	3.00	-.64
d.f.	6	6	6
Model	V	VI	VII
Significance	.02	.013	> .20
Sample Size	416	216	153

Table 4.17

Special Work-Based Victoria Models

Significance of COST

Stratification	Peak Period Trips	Downton Based Trips	Non-Peak Non-Downtown Based Trips
Coefficient	.038	.068	.026
Std. Error	.025	.028	.089
t-ratio	1.51	2.31	.29
d.f.	6	6	6
Model	V	VI	VII
Significance	.09	.03	> .20

Table 4.18

Special Work-Based Victoria Models

Significance of AGE

Stratification	Peak Period Trips	Downtown Based Trips	Non-Peak Non-Downtown Based Trips
Coefficients	-.289	-.318	.696
Std. Error	.167	.195	.579
t-ratios	-1.73	-1.63	1.20
d.f.	6	6	6
Model	V	VI	VII
Significance	.07	.06	.13
Sample Size	416	216	153

models. The sign change in the model VII coefficient is noteworthy and gets a separate discussion together with the other model VII variables.

The sex (SEX) variable is the last independent variable in the special models' stratifications. The t-ratio summaries are contained in Table 4.19. The SEX variable is somewhat associated with the propensity of women to take transit. This factor is also related to car availability and out-of-pocket costs which are primary indicators that distinguish the travel behaviour choices between men and women. As a result it has been observed that the sex variable in terms of personal preference or willingness to take transit is unlikely to be any different between men and women given their common prospects for getting to and from work in a reliable, convenient and cost effective fashion, all other factors being equal. This observation is not detected in the general (full data set) model and interestingly enough, is apparent between the low t-ratios in the special models of peak and downtown trips compared with the relatively high t-ratios in the non-peak, non-downtown trip model (model VII). A separate discussion of model VII follows below.

Model VII - Non-Peak and Non-Downtown Work Trips

The distinction between the performance of the SEX variable in all three special models is worthy of further exploration. The non-peak, non-downtown model (model VII) reveals only three reasonably significant t-ratios. The SEX factor has scored the highest t-ratio against very poor scores for the relative level of service factor, the out-of-pocket travel costs variable and the out-of-vehicle travel time variable. Moreover, all the transit versus auto type variables in model VII did poorly in contrast with the household and tripmaker factors which scored

Table 4.19

Special Work-Based Victoria Models

Significance of SEX

Stratification	Peak Period Trips	Downtown-Based Trips	Non-Peak Non-Downtown Based Trips
Coefficients	.182	.151	2.52
Std. Error	.318	.376	1.17
t-ratios	.57	.40	2.15
d.f.	6	6	6
Models	V	VI	VII
Significance	> .20	> .20	.035
Sample Size	416	216	153

relatively high. But most importantly, the SER and AGE coefficients were found to change signs!

What can be observed from this are the following interaction and association affects that can offer an explanation for the most striking differences between the non-peak, non-downtown model and all other models in this study.

1. Mode choice is not clearly a function of auto-transit characteristics. This is partly due to the relatively poor split in mode choice in favour of the automobile (95.4% in model VII). The relative sensitivity of the transit-auto trip characteristics seem to be lost given that the parking opportunities are greatest and transit opportunities are at their lowest.
2. Residual characteristics not measured (or even measureable) appear to determine a significant part of the travel behaviour. This is evidenced by a lower chi-square (χ^2) score in model VII. (See Table 4.4).
3. The essential factor in mode choice for the off-peak time periods not connected with the downtown area is observed to be car availability (CARAVAIL). In this situation parking is generally free and plentiful, whereas transit service is least frequent and less convenient.
4. The connection between women travelling in off-peak time periods to work destinations outside of the downtown area and the lack of car availability is noticeable in the model VII t-ratio. This observation is not surprising since transit service to regional employment nodes such as shopping centres is moderately good and corresponds with a higher proportion of female employment compared with the downtown area (e.g., retail sales employment, etc.). In other words, the

primary transit ridership during the off-peak periods to destinations outside the downtown area are typically captives to the system. A measure of transit captivity is car availability and it is more prevalent with women than men and with older persons than younger persons. Thus, we observe a strong influence from the sex variable and a reversal of the signs of the coefficient for both age and service level factors.

The usefulness of stratifying special models from the general model has been to uncover the marked differences between the influence of each independent variable on each of the model designs. The separate use of each special model, though more narrow in scope, makes it possible for their application to more specialized transit and transport problems. While the t-scores for model VII are lower than the other models, they are nevertheless statistically significant. As a consequence, the so called "residual" designation for the non-peak, non-downtown model (VII) has direct application in studying regional suburban scenarios for travel behaviour. Having assessed each variable in all seven models, it is now possible to consider the overall performance of the model.

4.6.3 Model Significance - A Chi-Square Analysis

The LOGIT model is a probability model based on a binary choice dependent variable. As with any non-normal distribution, non-parametric methods to test goodness-of-fit must be employed. While the computer software used in the model calibration includes an R-square (R^2) statistic, its value cannot be usefully interpreted given the distributional violation of this nominal-scale dependent variable.[8] The alternative is

to employ the chi-square distribution by converting the log likelihood function, formulated as the log likelihood ratio, to an approximate chi-square distribution. This can be accomplished by doubling (by-2) the value of the likelihood function and interpreting its value as a chi-square statistic with m degrees of freedom, where m is the number of independent variables in the calibration. Thus,

$$\chi^2 = -2 \log \lambda \qquad (4.7)$$

where χ^2 is the estimate of chi-square, -2 the conversion constant, and $\log \lambda$ the log likelihood function.[9] The chi-square distribution in this application tests the contribution made by the independent variables to predict a probability for the dependent variable mode choice. Thus, the null hypothesis (H_o) states that there is statistical independence between the dependent variable and the explanatory variables of each of the calibrated models. In Table 4.20 the entire set of models is compared with the chi-square test statistic. Table 4.20 clearly shows very strong levels of rejection for the null hypothesis, thus, it can be concluded that all seven models each contain a set of explanatory variables which are unquestionably associated with the value of the dependent variable.

The general characteristics of the LOGIT model and its usefulness in probability modelling is connected partly with its freedom from standard parametric assumptions on the error term. This point leads to a final note on assessing the significance of model results and particularly the interpretation of any R-square statistic.

Human travel behaviour is not so easily predicted since the myriad of considerations and preferences by individuals' travel choices preclude

Table 4.20

Chi-Square - Model Significance

Model No.	Chi-Square	d.f.	Significance	Chi-Square	Status of H_o
I	410	9	> .001	(27.88)	Rejected
II	410	6	> .001	(22.46)	Rejected
III	402	8	> .001	(26.13)	Rejected
IV	403	6	> .001	(22.46)	Rejected
V	289	6	> .001	(22.46)	Rejected
VI	204	6	> .001	(22.46)	Rejected
VII	43.9	6	> .001	(22.46)	Rejected

any constant type of determinism. Behavioural theory assumes that for any phenomenon to be modelled, a minimum unexplainable variance exists. While most model designs can decrease the specification error by adding more explanatory variables and approaching the threshold minimum error, it is also observed to increase the measurement error by in some cases an equal or greater extent.[10] The LOGIT model appears to avoid this compromising measurement error unlike the aggregate models generally used in transit studies. Overall, models depend on large samples to minimize measurement error, with numerous independent variables to minimize specification error, and a sound analytical technique to minimize calibration error.

Regression analysis when used in a binary choice model has certain theoretical shortcomings. The first one has already been described in Chapter II, the second is more serious; that is, probabilities cannot be observed; moreover, a binary dependent variable is by definition not normally distributed. Thus, the random, normal assumption on the error term of the regression is violated. Even using a LOGIT transformation of the regression equation, the underlying circumstance still remains unchanged with the produced coefficients left without a valid goodness-of-fit statistic. The regression coefficients, even in a LOGIT formulation, cannot be shown to be a best fit or to be linear unbiased estimates, nor even a maximum likelihood estimate. Thus using any regression goodness-of-fit statistic (R^2) is equally inappropriate in a binary LOGIT model that was calibrated using maximum likelihood estimation. In conclusion, the LOGIT model, using maximum likelihood estimation, can be tested by converting certain key statistics on the chi-square distribution. A

discussion of mode choice modelling techniques by Stopher and Meyburg concludes that the binary LOGIT model "has the property of reducing the measurement error of the original variables used in the model."[11] They further assert that the LOGIT model using maximum likelihood estimation is the most useful procedure for building travel choice models.

4.7 Conclusions

The purpose of Chapter IV has been to describe the variables which are best suited to the model, and to test their statistical significance. Also covered in this chapter has been the identification of key data stratifications which enable both a general modal split for Victoria and various model stratifications.

Seven models were calibrated, four of which were based on the entire data set, and the remaining three used the favoured independent variables to define a peak period model, a downtown trip based model and a suburban (non-downtown) non-peak model. It was shown that the relative level-of-service variable was best expressed using a ratio formulation (Model III and IV). The relative household income variable (HINC) was noted to possess specification error by confusing the real statistic required, namely, an individual income statistic. This limitation forced the removal of HINC from the model. Thus, model IV having the most workable variables, with the HINC variable removed, was selected as the favoured general work-based modal split model for Victoria.

The t-ratio was calcualted by the calibration program as a test of each independent variable's statistical significance. It was found that the most suitable variables were car availability, sex, relative level-of-service, age, relative travel costs and relative out-of-vehicle travel

time. Among these variables it was shown that no covariance existed, thus the assumption of independence between explanatory variables was met. In the chi-square test all favoured models showed good results which speaks well of the survey design and of the assumptions on travel behaviour.

Now, having described each model calibration and selected a favoured variable set, it is now possible to specify the linear utility function ($G(\underline{X})$) first introduced in Chapter I, equation 1.1. This equation ($G(\underline{X})$) is transformed using the LOGIT transformation; thus, for the probability of an individual choosing transit in Victoria we define the following:

$$P_{Transit} = \frac{e^{G(\underline{X}_{vt})}}{1 + e^{G(\underline{X}_{vt})}} \qquad (4.10)$$

where $P_{Transit}$ is the probability for choosing public transit and ($G(\underline{X}_{vt})$ is the transit (t) function calibrated for the Victoria (v) urban environment. In Table 4.21 a summary of each G(X) function is shown for both the favoured general model and the various special model stratifications. In Chapter V the task of applying these models to a scenario analysis of a hypothetical transit problem is to be undertaken.

Table 4.21

Transit Utility Functions - $G(\underline{X})$

Model IV - General Work-Based Victoria Model

$$G(\underline{X})_4 = -1.86X_6 + .39X_{10} + .051X_{56} + (-.275X_{11}) + .045X_{52} + (-.112X_{54}) - .163 \quad (4.11)$$

Model V - Peak Period Work-Based Stratification

$$G(\underline{X})_5 = -2.21X_6 + .18X_{10} + .0375X_{56} + (-.289X_{11}) + .383X_{52} + (-.138X_{54}) + .93 \quad (4.12)$$

Model VI - Downtown Work-Based Stratification

$$G(\underline{X})_6 = -.131X_6 + .151X_{10} + .049X_{56} + (-.318X_{11}) + .0658X_{52} + (-.201X_{54}) + 43 \quad (4.13)$$

Model VII - Non-Peak Non-Downtown Work-Based Stratification

$$G(\underline{X})_7 = -2.687X_6 + 2.52X_{10} + (-.159X_{56}) + .696X_{11} + .0256X_{52} + .155X_{54} - 6.94 \quad (4.14)$$

Where: $G(\underline{X})_n$ is the transit utility function for Victoria based models. X_6 is car availability (CARAVAIL), X_{10} is SEX, X_{56} is the relative level of service (SER), X_{11} is the AGE range, X_{52} is the relative travel costs (COST), and X_{54} is the relative out-of-vehicle travel time (OUT).

continued... 133

continued... Table 4.21

MODEL VARIABLE CHARACTERISTICS (General Model Only)

No.	Name	Mean	Standard Deviation
6	Car Availability	.892	.566
10	SEX	1.39	.49
56	Level-of-Service	13.4	10.8
11	AGE	3.2	.89
52	Out-of-Pocket COSTs	1.05	6.85
54	Out-of-Vehicle Travel Time	7.57	5.36

See APENDIX A5 - A7 for details of variable characteristics for the special Victoria models.

References

1. The theory of peak travel behaviour and the journey to work is discussed in Chapters I and II. Further reading on the state of the art in travel behaviour is contained in Stopher et al, (43 and 47), and Manning (31).

2. Donnea (19) p. 124. The likelihood ratio test is used in place of the multiple correlation coefficient.

3. SHAZAM was written by K.J. White of the Economics Department of the University of British Columbia.

4. BMDP is a major statistical analysis program from the University of California. See bibliography (17). Refer to Chapter 14, p. 315 and the programs referred to as "P3R" and "PAR".

5. LOTUS 1-2-3, is a specialized spreadsheet, graphics and data management program copyrighted by LOTUS Corporation (1982) for use on many microcomputer systems including the IBM PC, Apple MacIntosh, Tandy computers and others.

6. From Watson (56), p. 21-22.

7. Donnea (19), p. 124-125. This section is based on Donnea's derivation of the likelihood ratio test.

8. The authors of the computer software which was used in this study caution users in the use of $\bar{R}^2$ to interpret results.

9. The conversion of $\log\lambda$ to a chi-square statistic was proven by T. Tobin and documented in his 1955 work "The Application of Multivariate Probit Analysis to Economic Survey Data", Cowles Foundation Discussion Paper No. 1, pp. 9-11.

10. A discussion of three types of modelling errors is found in most good statistical manuals. An excellent transportation specific test on errors in modelling behaviour is found in Stopher and Meyburg (46) pp. 33-44 and 295-297 (LOGIT model error analysis).

11. Stopher and Meyburg (46), p. 297.

CHAPTER V

APPLICATION OF THE MODEL

The process of developing a practical mode choice model for Victoria has been carried out as one important piece in the transport modelling process. In Chapter II the four part process of transportation modelling was introduced. This introduction described the first step as trip generation which involves the prediction of all person trips produced in a given area, i.e., traffic zone, on a daily basis by time of day and by trip purpose. This is generally accomplished by developing household-based equations to estimate trip generation for local neighbourhoods as defined by traffic zones. This level of disaggregation is generally a major task, consequently, few urban areas attempt modelling trip generation for small areas such as the traffic zones defined for the region of greater Victoria. The second process in the transportation model is to distribute the predicted person-trips between the areas defined for trip generation. This task relies on the relative attractions within and between the various trip generation areas (zones). Once this step is completed, it is possible to engage the mode choice component (also referred to as modal split model) to predict the split between transit and auto modes.

In this chapter the application of the mode choice model involves these first three steps of the transport modelling process and uses these results to address transit policy issues. It is also possible to apply the model to urban traffic investigations and more general urban transport studies. Since the information that is required to fully employ the

mode choice model goes beyond the scope of this work, it will not be possible to specify the reliability of those modelling components which are not specific to the development of the LOGIT mode choice model. These components include trip generation and distribution estimations. Despite this limitation it has been possible to develop respectable estimates for one selected area in the Victoria region and to conduct a hypothetical analysis of the transit market by testing a variety of transit options which can represent key policies on public transit.

This chapter will proceed with a step-by-step description of the scenario analysis following from the development of the data matrix through the trip generation/distribution procedure, to the computation of transit ridership and other transit information useful to assessing cost and efficiency issues. Once this is complete it will be possible to look back at the data which was specified for the model and evaluate the range of problems which can be reviewed by this type of transport modelling package. While only the General Work-Based Victoria Model will be specifically illustrated, a discussion of the practical uses of the special models (peak, downtown, etc.) will be made. The final part of this chapter will include a review of possible enhancements of and limitations to the mode choice modelling component. Also included is a prescription for the management and operation of a small scale transport model for use in a typical transit planning environment.

5.1 Hypothetical Case Study of Transit Options Using a Victoria Transit Planning Area

The following case study will be a scenario analysis of a transit planning area formerly used by the Captial Region planning department.

It is located in the north-east quadrant of the core urban area of Victoria and is referred to as the Gordon Head-Mount Douglas area. This part of the region is connected to the inner core of the city by what can be described as the Shelbourne Street corridor. The study area is outlined on a map in Figure 5.1. The data used in this exercise is as accurate as the author can provide given the scope of this work; however, it has been possible to be detailed, thus providing a degree of practical realism to the procedure. The case study will be discussed in six parts:

1. Statement of problem and study area;
2. Development of data matrix;
3. Trip generation procedure;
4. Trip distribution procedure;
5. Mode split and transit ridership; and
6. Scenario experiments: service levels, transit fare levels, and implications on fleet size and operating costs.

Statement of Problem and Study Area

The objective of this study is not to develop a complete transporation model for Victoria nor to produce a computer program to analyse all 35+ transit routes in the Capital Region. This task involves far greater effort and resources than is possible in this work. It is possible, though, to illustrate one part of this total transport model framework and demonstrate its wider application to all of the Victoria region by sampling one small sector.

The Gordon Head area was selected because it comprises a reasonably homogeneous community of middle class families that reside in predominantly single family dwellings. The area has good transit ridership

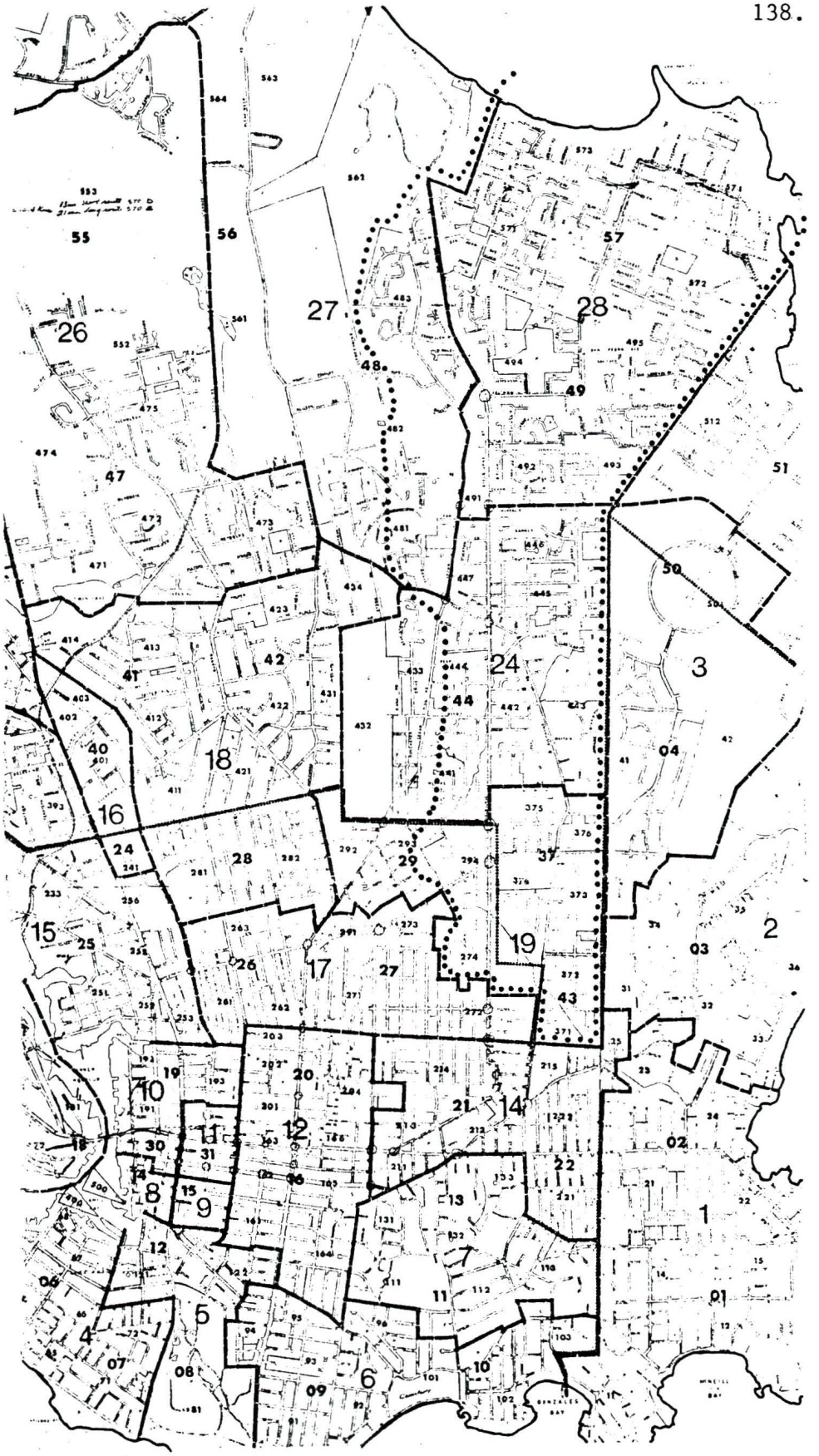


Figure 5.1 Study Area of Scenario Analysis

(comparatively) for Victoria; however, since the area has higher income groups, only a small fraction of this ridership would be considered strictly captive to transit. In all likelihood this community exemplifies a very modern suburban phenomenon whereby the primary breadwinner leaves the family car at home with his/her spouse and children for their use and enjoyment while the household worker "tolerates" the public transit experience. In this type of neighbourhood realistic scenarios are possible to test various transit service levels and fare options.

The analysis is to be set up as a gaming exercise using a data matrix and the various transport models that form the transport planning process. The example in this study will focus on three input variables, 1) transit headways (i.e., frequency of service) in minutes, 2) full load options (average numbers of standees plus total seats per bus), and 3) transit fare in cents. The outputs of the gaming exercise are diagrammed in Figure 5.2 following. This simplification of the transit planning scenario model illustrates the components in the analysis and their functional purpose in producing the desirable outputs. The outputs in this exercise focus on transit costs contrasted with transit service levels. It is the task of the planner to compare these in an effort to balance bus fleet constraints, ridership goals, and a politically acceptable fare charge that can produce a desirable compromise. As will be seen in the analysis of the hypothetical results, certain compromises can be arrived at given a degree of knowledge of their probable impacts.

Development of the Data Matrix

The most useful data matrix sets out model information at the smallest unit of enumeration that can be made possible by available data.

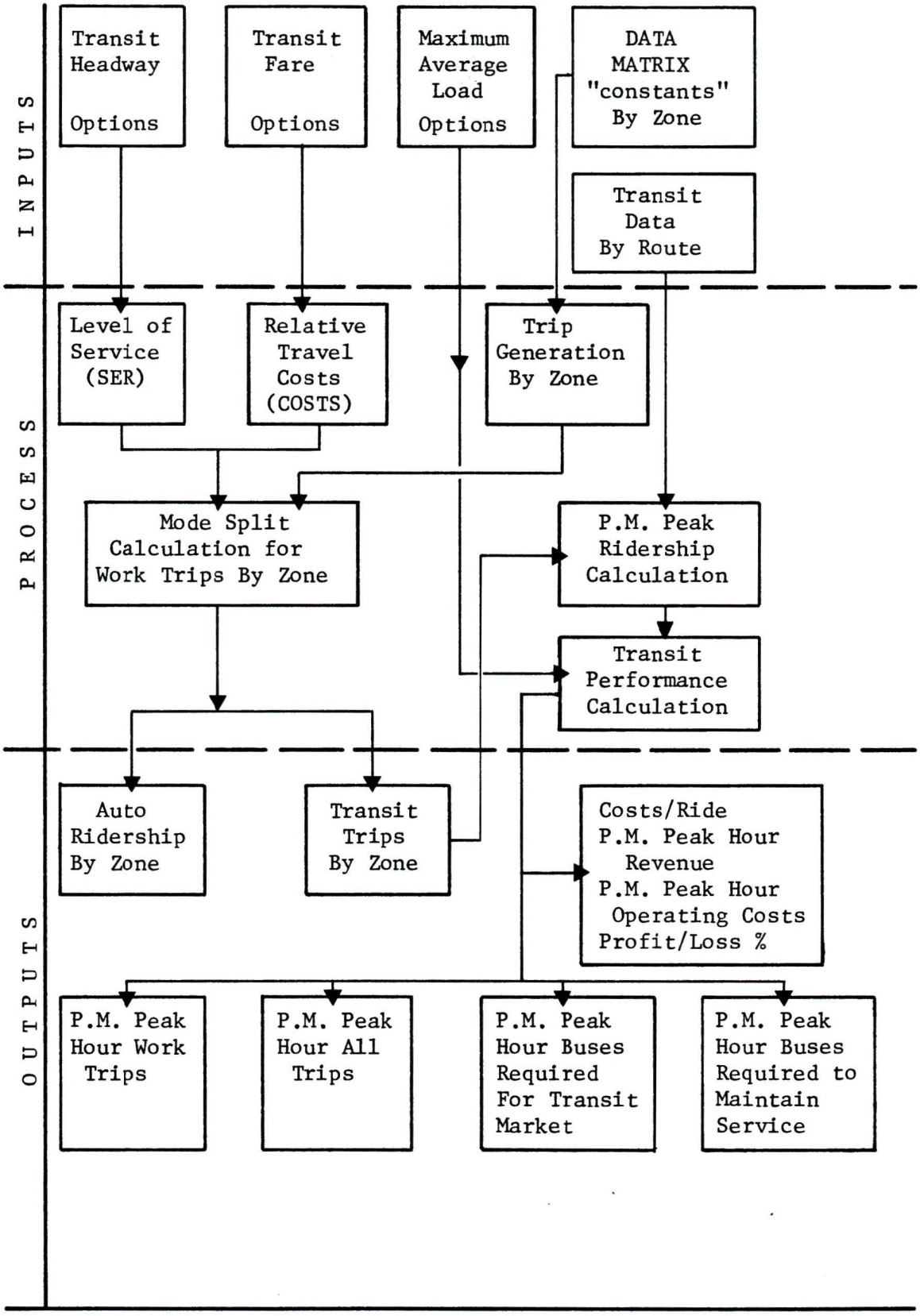


Figure 5.2 Scenario Model Inputs and Outputs

In this scenario exercise the traffic zone is used which constitutes the smallest geographical unit possible in the Victoria region made possible by the 1977 survey and the transportation planning data framework developed by the Capital Regional District Planning Department in 1976.

The study area comprises 23 traffic zones with an estimated 1981 population of 29,000 residents who are within walking distance (400-500 m) of the main trunk bus route serving this area. The matrix is contained in Table 5.1 and represents the generalized status of the Gordon Head transit services as they existed in the 1981-82 fiscal year. The first group of data added to the matrix is information which was obtained for population, household number, employment (labour force), income, sex and age based on the 1981 census. In all, nine census tracts are located in the study area which permitted subdivision of these statistics into the 23 traffic zones. Population density and land use maps served to make this subdivision as accurate as possible.

Car availability was the only information not available in both the 1976 and 1981 census. The 1971 figures were therefore used and estimates made from a comparison of population, labour force and household size. The car ownership data was listed by households owning no cars, one car and two or more cars. Separate multipliers were developed for each of these three ownership groups in order to obtain total car ownership by zone.

The second data group was trip and mode specific data calculated for each zone. These included time and distance parameters, costs, fares and other information specific to the mode choice model. A reference work journey was used to estimate the typical work journey. This work

journey connected the centroids of the study area zones to the downtown centroid set at the Yates and Douglas Streets intersection in Victoria's central business district (CBD). While this is a fairly crude generalization, it was considered a practical estimate for the purpose of this study. A more complex matrix could include trip distribution data connecting each zone in the study area with all the major employment nodes of the region that are connected by transit service. More will be said about this more complex enhancement later in this chapter.

The final array of zone based data is generated from the first two groups to produce trip generation estimates by zone.

Trip Generation Procedure

The trip generation process can be a much more complex procedure than has been used in this scenario exercise. Two separate quick procedures were used to estimate zonal work-based trips. The first estimate used the cross-classification curves developed in the trip generation analysis (see Appendix E) where trip generation by household is estimated on the basis of car ownership (0, 1, and 2 or more) against mean household income. The second used a simpler formulation by using zonal labour force (employed persons) within the study area, and multiplying by the proportion of workers working outside the local area and then multiplying by 2.05 work trips (round trip). The ".05" of 2.05 was added as an estimate of those employed persons who returned home for lunch during the work day in the study area. The rather independent procedures produced estimates that typically varied 13% where the second estimate generally exceeded the former.

It was observed that the car ownership rates (1971 census) employed

Figure 5.1 Case Study Data Matrix

FULL TRANSPORT MATRIX - TRANSIT PLANNING AREA "GORDON HEAD AND AREA" file page 1

	SUPER DISTRICT NUMBER	TRAFFIC ZONE NUMBER	CENSUS TRACT NUMBER	ZONE POP AS % of C.T.	CENSUS TRACT POP	POPULATION BY ZONE	HOUSE-HOLDS IN CEN TRCT	HSHLDS BY TRAFFIC ZONE)	EMPLOYED IN CENSUS TRACT	EMPLOYED BY TRAFFIC ZONE	MEAN INCOME	SEX M=1, F=2 (SEX)
1	19	274	14	17%	7048	1198	2825	480	3445	586	21,852	1.54
2	19	293	14	14%	7048	987	2825	396	3445	482	21,852	1.54
3	19	371	123.01	20%	2643	529	985	197	1035	207	23,253	1.52
4	19	372	123.01	40%	2643	1057	985	394	1035	414	23,253	1.52
5	19	375	123.02	22%	2905	639	1265	278	1325	292	24,791	1.55
6	24	443	123.02	42%	2905	1220	1265	531	1325	557	24,791	1.55
7	24	442	123.02	36%	2905	1046	1265	455	1325	477	24,791	1.55
8	24	441	124	30%	4004	1201	1500	450	1830	549	26,546	1.53
9	24	444	124	21%	4004	841	1500	315	1830	384	26,546	1.53
10	24	445	122	40%	2867	1147	1500	600	1540	616	23,094	1.53
11	24	446	122	35%	2867	1003	1200	420	1540	539	23,094	1.53
12	24	447	122	25%	2867	717	1200	300	1540	385	23,094	1.53
13	27	481	131	30%	4040	1212	1405	422	2035	611	32,106	1.52
14	27	482	131	20%	4040	808	1405	281	2035	407	32,106	1.52
15	27	483	131	35%	4040	1414	1405	492	2035	712	32,106	1.52
16	28	492	121.01	55%	4923	2708	1525	839	2550	1403	30,807	1.53
17	28	493	121.01	45%	4923	2215	1525	686	2550	1148	30,807	1.53
18	28	494	121.03	25%	6574	1644	1910	478	3200	800	34,884	1.50
19	28	495	121.03	30%	6574	1972	1910	573	3200	960	34,884	1.50
20	28	571	121.03	45%	6574	2958	1910	860	3200	1440	34,884	1.50
21	28	572	121.02	38%	2546	967	805	306	1255	477	43,599	1.49
22	28	573	121.02	24%	2546	611	805	193	1255	301	43,599	1.49
23	28	574	121.02	38%	2546	967	805	306	1255	477	43,599	1.49
					TOTALS>	29,062		10,251		14,222		

Total population served by routes in area A 29,062

FULL TRANSPORT MATRIX - TRANSIT PLANNING AREA "GORDON HEAD AND AREA" file page 2

	SUPER DISTRICT NUMBER	TRAFFIC ZONE NUMBER	AGE 1-5 Rg (AGE)	AUTO OWNER-SHIP	CAR AVAILABILITY (CARAVAIL)	TRAVEL TIME AUTO -TTIMAUT-	TRAVEL DISTANCE AUTO	STOP LIGHTS ENROUTE	REL TRAVEL COSTS (COST)	TRANSIT FARE	MEAN SPEED TRANSIT PM PEAK	ROUTE FREQUENCY -HEADWAY-
1	19	274	3.00	610	1.04	6.79	4.20	12	($4.05)	80	20.66	7.5
2	19	293	3.00	503	1.04	5.19	3.80	8	($5.85)	80	20.66	7.5
3	19	371	3.07	269	1.30	5.41	3.62	9	($5.27)	80	20.66	7.5
4	19	372	3.07	537	1.30	5.65	3.99	9	($5.01)	80	20.66	7.5
5	19	375	3.22	377	1.29	6.37	4.57	10	($3.99)	80	20.66	7.5
6	24	443	3.22	719	1.29	7.33	6.00	10	($3.05)	80	20.66	7.5
7	24	442	3.22	617	1.29	7.67	5.52	12	($2.70)	80	20.66	7.5
8	24	441	3.13	578	1.05	6.53	4.31	11	($3.58)	80	20.66	7.5
9	24	444	3.13	405	1.05	7.00	5.01	11	($3.15)	80	20.66	7.5
10	24	445	2.98	712	1.16	8.80	6.72	13	($1.70)	80	20.66	7.5
11	24	446	2.98	623	1.16	8.67	7.02	12	($1.84)	80	20.66	7.5
12	24	447	2.98	445	1.16	7.65	5.48	12	($2.93)	80	20.66	7.5
13	27	481	3.08	660	1.08	7.75	5.63	12	($2.03)	80	20.66	7.5
14	27	482	3.08	440	1.08	8.31	6.47	12	($1.60)	80	20.66	7.5
15	27	483	3.08	770	1.08	10.84	8.77	15	$0.33	80	20.66	7.5
16	28	492	3.04	1392	0.99	9.52	7.30	14	($0.70)	80	20.66	15
17	28	493	3.04	1139	0.99	10.10	8.16	14	($0.24)	80	20.66	15
18	28	494	3.04	785	0.98	10.54	8.33	15	$0.10	80	20.66	15
19	28	495	3.04	942	0.98	11.16	9.25	15	$0.53	80	20.66	15
20	28	571	3.04	1412	0.98	11.26	9.40	15	$0.60	80	20.66	15
21	28	572	3.11	515	1.08	11.69	10.05	15	$0.72	80	20.66	15
22	28	573	3.11	325	1.08	11.96	10.46	15	$0.88	80	20.66	15
23	28	574	3.11	515	1.08	12.05	10.60	15	$0.93	80	20.66	15
	Total population served by routes in area A 29,062			MEAN> VALUES	1.11	8.62	6.72	12.43	-1.90	80.00	<	

Figure 5.1 Case Study Data Matrix (continued)

FULL TRANSPORT MATRIX - TRANSIT PLANNING AREA "GORDON HEAD AND AREA"

	SUPER DISTRICT NUMBER	TRAFFIC ZONE NUMBER	SERV LEVEL TRANSIT -LSERVT-	SERV LEVEL AUTO -LSERVA-	RELATIVE SERV LEVEL (SER)	OUTSIDE TRANSIT TIME -OUTIMT-	OUTSIDE AUTO TIME -OUTIMA-	TRANSIT TRANSFERS -TRNSFERS-	REL OUTSIDE TRAVEL TIME (OUT)	
1	19	274	27.55	3	18.364	5	3	0	2	
2	19	293	27.55	3	18.364	5	3	0	2	
3	19	371	27.55	3	18.364	5	3	0	2	
4	19	372	27.55	3	18.364	5	3	0	2	
5	19	375	27.55	3	18.364	5	3	0	2	
6	24	443	27.55	3	18.364	5	3	0	2	
7	24	442	27.55	3	18.364	5	3	0	2	
8	24	441	27.55	3	18.364	5	3	0	2	
9	24	444	27.55	3	18.364	5	3	0	2	
10	24	445	27.55	3	18.364	5	3	0	2	
11	24	446	27.55	3	18.364	5	3	0	2	
12	24	447	27.55	3	18.364	5	3	0	2	
13	27	481	27.55	3	18.364	7	3	0	4	
14	27	482	27.55	3	18.364	6	3	0	3	
15	27	483	27.55	3	18.364	5	3	0	2	
16	28	492	13.77	3	9.182	5	3	0	2	
17	28	493	13.77	3	9.182	5	3	0	2	
18	28	494	13.77	3	9.182	5	3	0	2	
19	28	495	13.77	3	9.182	5	3	0	2	
20	28	571	13.77	3	9.182	5	3	0	2	
21	28	572	13.77	3	9.182	5	3	0	2	
22	28	573	13.77	3	9.182	5	3	0	2	
23	28	574	13.77	3	9.182	5	3	0	2	
	Total population served by routes in area A 29,062		22.76	3.00	15.17	5.13	3.00		2.13	< MEAN VALUES

in the cross-classification analysis somewhat underestimates current trends; consequently, the simpler estimate produced by the alternative procedure (i.e., labour force based) was used to produce transit ridership estimates. Both procedures are summarized in the following equations:

Procedure One:

$$WT_i^1 = TT_i * WC_i \qquad (5.1)$$

where WT_i^1 is the estimated work-based trips generated from zone "i"; TT_i is the total trips generated by zone "i" and WC_i is the "work constant", that is, the percentage of trips estimated to be work-based for zone "i". TT_i is estimated as follows:

$$TT_i = \{ PC_i \ (H_i^o * HC_i^o + H_i^1 * HC_i^1 + H_i^{2+} * HC_i^{2+}) \} \qquad (5.2)$$

where PC_i is the proportion of the census tract population in zone "i"; $H_i^o \sim H_i^{2+}$ are the estimated number of households with 0, 1 or 2 or more automobiles in zone "i"; and $HC_i^o \sim HC_i^{2+}$ are the estimated household trip generation multipliers taken from the cross-classification curves found in Appendix E. Each multiplier is specific to household car ownership, i.e., 0, 1, 2+. The WC_i constant (equation 5.1) was also estimated using income based trip purpose curves developed in the cross-classification analysis (Appendix E). Income data was provided by the 1981 Census of Canada and rationalized for each traffic zone.

Procedure Two

$$WT_i^2 = E_i * WCnl_i * 2.05 \qquad (5.3)$$

where WT_i^2 is the estimated work-based trips generated from zone "i"; E_i is the estimated employment or labour force in zone "i"; $WCnl_i$ is the

work-based constant for non-local trips in zone "i" expressed as a percentage of total employment (labour force) in zone "i". The constant as stated above equates to the return trip home from work. The final estimates for each procedure are contained in Table 5.2 following. The next step in the analysis is to distribute work-based trips by time period and by downtown-non-downtown categories.

Trip Distribution Procedure

The standard trip distribution process apportions trips between each traffic zone or trip generation "unit". For the purpose of this analysis the study area is viewed as one distributional unit connected to the downtown via a trunk transit service corridor. The distribution is thus defined by a two-by-two distribution matrix depicted in Table 5.3 for peak period trips.

The variance error on any given zone for trip distribution is likely high; however, the error is probably randomly above and below the actual value and in this aggregate form the order of magnitude is likely to be correct and serves to illustrate the use of the mode choice component. A comparison to actual ridership estimates produced by on-bus surveys validate the relative magnitudes of the estimates.[1]

Mode Split and Transit Ridership

The general work-based G($\underline{X}$) equations (equation 4.11) as listed in Table 4.22 in Chapter IV have been used to produce a transit ridership estimate using the LOGIT transformation (equation 4.10). The mode choice calculation is employed on a zone by zone basis producing a mode split multiplier that combines with zone work-based trip generation to give an estimate of transit work-based ridership. At this stage, it is necessary

Table 5.2

Work-Based Trip Generation Estimates

Zone	Procedure One	Procedure Two
274	817	1008
293	673	831
371	375	378
372	750	755
375	526	514
443	1005	981
442	861	841
441	828	979
444	580	685
445	941	1174
446	824	1028
447	588	734
481	964	1076
482	643	718
483	1125	1256
492	2034	2358
493	1664	1929
494	1154	1410
495	1385	1692
571	2077	2539
572	741	851
573	468	537
574	741	851
Totals	21,763	25,125

Table 5.3

Trip Distribution Matrix

P.M. Peak Hour Trips

For Study Area "A"	Downtown Trips	Non-Downton Trips	Totals
Work-Based	27% (1933)	63% (4511)	90% (6444)
Non-Work Based	3% (215)	7% (501)	10% (716)
Totals	30% (2148)	70% (5012)	100% (7160)*

*Total estimated P.M. peak work trips using CRD trip rates (10% of total trips are P.M. peak hour trips).

to distribute work-based trips by time period. In the scenario analysis the focus has been to estimate P.M. peak ridership since it corresponds with peak diurnal ridership. This narrowing of the study focus offers the following baseline planning information: 1) a good representative sample of the overall transit market by zone, 2) the maximum vehicle requirement to operate the transit system, and 3) the opportunity to balance vehicular deployment between routes in an optimum fashion.

Given this scenario framework, that is, the work-based trips of the P.M. peak period, it is now possible to compare possible planning options using the microcomputer as a gaming tool.

Scenario Experiments

The data matrix which includes a zonal trip generation and mode split calculation allows a variety of output "forms" to be set up. Each form sets out specific input variables to be examined and allows for a specialized output. In this type of computer programming framework it has been possible to customize a special input/output form to look at transit service options. In Figure 5.3 is a typical printout of the computer display screen. The "screen" contains four blocks of information. The three left-hand columns reference all the traffic zones contained in the study area along with the corresponding Super District numbers (refer to Figure 3.1 for map overview of Victoria by Super Districts). The columns next to the zone reference enumerate the trip generation and modal split results including key trip generation multipliers. The final column contains the total work-based transit rides by zone, thus forming the key input variable to the scenario output block. The "input block" is located next to the transit ridership column. The input variables have

Figure 5.3 INPUT / OUTPUT SCREEN FORM

FULL TRANSPORT MATRIX - TRANSIT PLANNING AREA " A "

	SUPER DISTRICT NUMBER	TRAFFIC ZONE NUMBER	TRIP_GEN % Rate work trips	EMP OUT OF AREA % OUTSIDE	TRIP GENERATED TOTAL	TOT_WORK TRIPS EST #1	TOT_WORK TRIPS EST #2	MODAL SPLIT MODEL 4	TRANSIT RIDERSHIP (WORK TRIPS)
1	19	274	27.8	84%	2938	817	1008	0.191	193
2	19	293	27.8	84%	2419	673	831	0.179	148
3	19	371	28.9	89%	1298	375	378	0.120	45
4	19	372	28.9	89%	2597	750	755	0.121	92
5	19	375	28.9	86%	1821	526	514	0.125	64
6	24	443	28.9	86%	3477	1005	981	0.130	127
7	24	442	28.9	86%	2981	861	841	0.131	111
8	24	441	30.0	87%	2761	828	979	0.189	185
9	24	444	30.0	87%	1933	580	685	0.192	132
10	24	445	27.9	93%	3373	941	1174	0.176	207
11	24	446	27.9	93%	2952	824	1028	0.175	180
12	24	447	27.9	93%	2108	588	734	0.168	124
13	27	481	31.5	86%	3060	964	1076	0.163	175
14	27	482	31.5	86%	2040	643	718	0.181	130
15	27	483	31.5	86%	3570	1125	1256	0.213	267
16	28	492	31.8	82%	6396	2034	2358	0.132	311
17	28	493	31.8	82%	5233	1664	1929	0.134	259
18	28	494	31.8	86%	3629	1154	1410	0.139	196
19	28	495	31.8	86%	4354	1385	1692	0.141	239
20	28	571	31.8	86%	6532	2077	2539	0.142	360
21	28	572	31.8	87%	2330	741	851	0.120	102
22	28	573	31.8	87%	1472	468	537	0.121	65
23	28	574	31.8	87%	2330	741	851	0.121	103
				TOTALS	71,604	21,763	25,125		3,817 TRANSIT RIDES

Total population served by routes in area A 29,062

* * * P O L I C Y * * *
* * * S T A T U S * * *

		ANY(Y/N) CHANGES? 1=Y,0=N
Statement on policy:		
HEADWAYS:	5	1
	10	1
FULL LOAD:	52	0
TRANSIT FARE: (cents)	100	1

Enter Policy Values then press key "F9"

COMMENTS ? :

(1)	TRANSIT MODE SPLIT FOR TRANSIT PLANNING AREA "A" WORK-BASED TRIPS (APPROX. 90% OF PM PEAK TRIPS)	15.25%	
(2)	PM PEAK TRANSIT RIDERSHIP(4-6 PM) 30% (77 SURVEY)	1145	WORK-BASED RIDES
(3)	PM PEAK HOUR RIDERSHIP (60% of PM Peak Period)	687	WORK-BASED RIDES
(4)	TOTAL PM PEAK TRANSIT RDRSHP TO AREA "A" (APPROX. AS WORK-BASED +10% -5% FROM AREA "A")	718	RIDES
(5)	PEAK HOUR BUSES REQUIRED	17.3	BUSES
		18	BUSES (ROUNDED UP)
(6)	PEAK HOUR BUSES REQUIRED TO MAINTAIN HEADWAY (FULL LOAD POLICY IS 52 PASSENGERS / BUS) (ROUND TRIP TIME IS 75 MINUTES) (NOMINAL HEADWAY OF 5 MINUTES FOR AREA)	16	BUSES
(7)	COST PER PASSENGER RIDE FOR PEAK HOUR (1981-82 Bus operating costs $40.00 / bus hour)	$0.95	
(8)	PEAK HOUR REVENUE (fare profile constant)	$700.00	
(9)	PEAK HOUR OPERATING COSTS (includes fixed overhead)	$710.33	
(10)	PROFIT OR LOSS MARGIN IN PERCENT OF OPERATING COSTS	-1.45%	

been restricted to three datum specific to the scenario gaming design. Of special note is the transit frequency variable which is referred to as the "headway". Since the study area is serviced by a dual outer loop network served by two separate bus routes operating in opposite directions within their respective loops, it is necessary to input two separate headways. Thus in the area of the two loops, headways are half that of the common route path taken along the Shelbourne corridor. Figure 5.4 illustrates the study area transit network.

The output block occupies the bottom third of the game screen. The ten computations are straightforward data conversions based on empirical data from the 1977 home interview survey, the 1977 transit rider survey and metro transit costing and fare profiles.[2] Sample screen printouts have been arranged in Appendix D to allow a detailed look at the elasticities of both the transit service frequency variable (headway) and the fare charge variable.

The sample computer runs in Appendix D allowed a set of bar charts to be constructed which illustrate the usefulness and ease by which key policy changes can be tested and compared with competing options. This first graph appears in Figure 5.5 and compares various peak period route headway options given no changes to the route path and travel time characteristics.

The service level option ranges between a rather extreme headway of 2.5/5 minutes to a more evening or week-end styled headway of 15/30 minutes. The variation in ridership through this range indicates a relatively inelastic character to the level-of-service factor. The information in Figure 5.5 can only reveal half of the transit efficiency

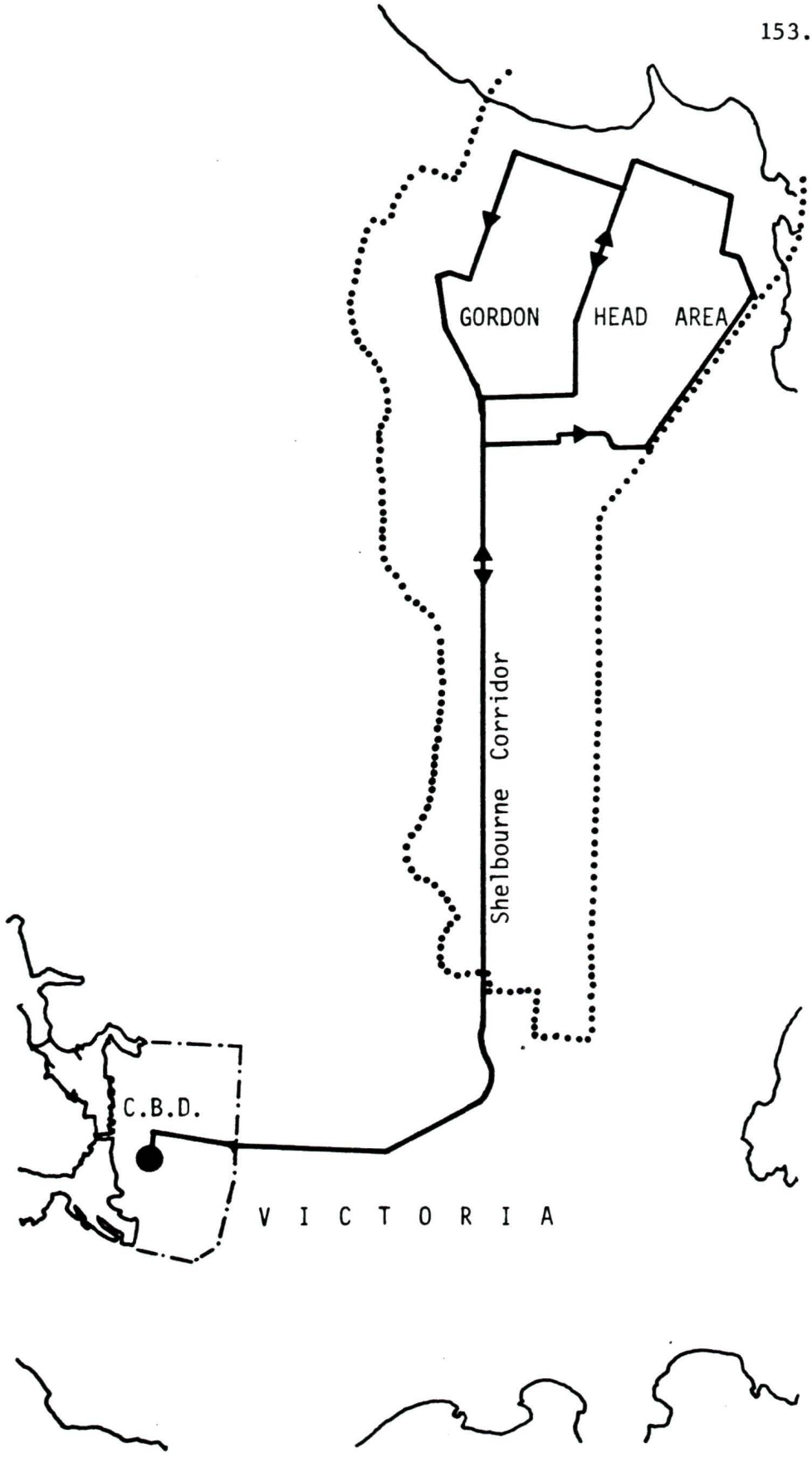


Figure 5.4 Study Area Bus Routes

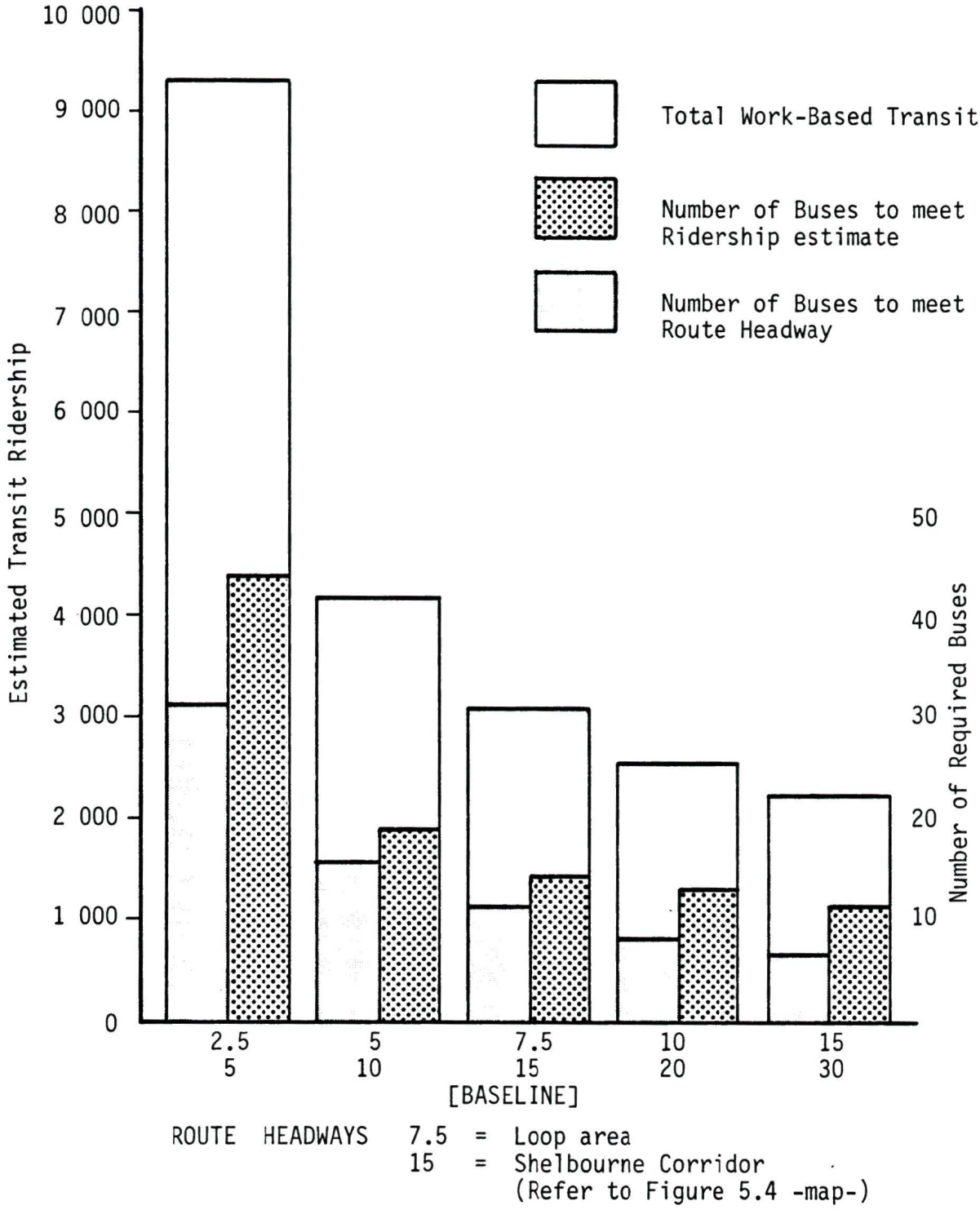


Figure 5.5 SERVICE LEVEL OPTIONS

picture. The cost and revenue considerations enable the completion of this picture. The revenue options in transit demand can be assessed by substituting the existing fare charge with various fare options. An illustration of possible fare options is contained in Figure 5.6. This figure reveals a somewhat contrasting picture of the influences on ridership. The range of fare charges runs from the old rate of the mid-seventies ($.50) to a somewhat extreme rate ($1.50) given the relative operating costs and the public's perception of an equitable fare charge. Figure 5.6 illustrates the change in the profit/loss margin, i.e., the percent revenue of total operating costs, which is offset by the change in transit's modal share. In this instance the fare charge shows up as a relatively elastic variable regarding transit ridership whereas the impact increased fares has on the transit deficit is striking indeed. Clearly, the combination of the service and fare options enables a balance to be made which can combine policy positions regarding responsible management of the costs of transit services offset by the mandate to provide an attractive quality service to as many citizens as possible. Fine-tuning the system on a route-by-route basis using this type of model framework can effectively enable policy optimization.

The information available from the various scenarios can also point towards specific solutions. In this example it is observed that the required buses to serve the estimated market exceeds the number of buses needed to maintain the service headways. This is even the case for the baseline service. In fact, transit systems often respond to such unserviced latent ridership by adding overload buses which run in tandem with the regular service.[3] The Gordon Head bus services in the study

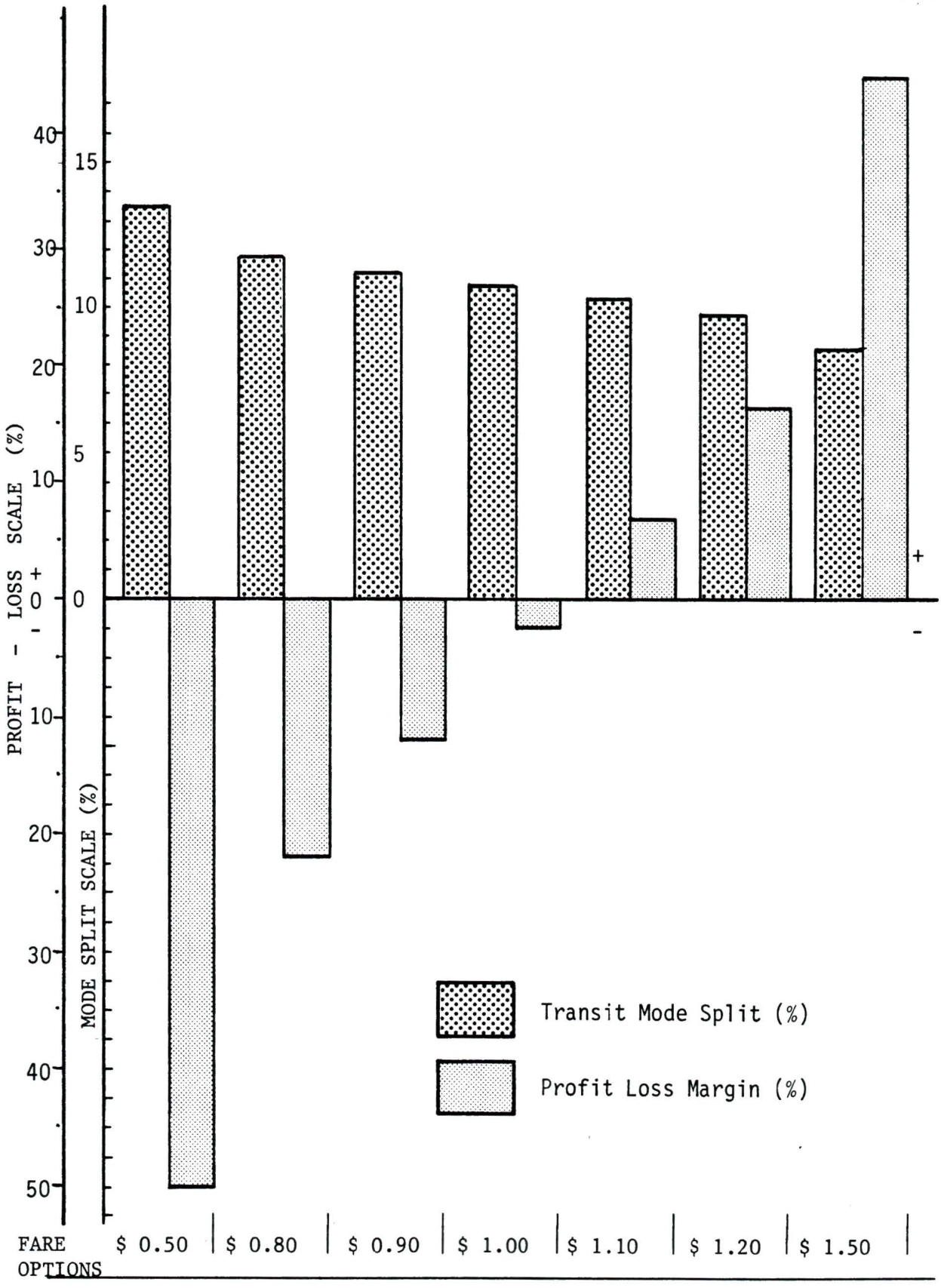


Figure 5.6 TRANSIT FARE OPTIONS

area actually do operate several overload buses. The results of this practice, though, raises some questions of efficiency and optimum service potential given the resources being made available. A re-examination of both Figures 5.5 and 5.6 suggests that an increase in service headway combined with a moderate increase in the fares would produce a marked improvement in ridership while lowering the total deficit all by using the same vehicular resources (approximately 16-17 buses) for improved headways to 5 and 10 minutes.

How is such an improvement possible? The likely key to the inefficiency of the system stems from the overuse of overload buses and a marked undervaluation of the fare charge which has fallen behind all other public or private commodities during the past decade. While this specific exercise looks at reducing overload buses to fine-tune the system, other avenues can be likewise examined, with their impacts reasonably estimated and "packaged". Such packaging of information affords decision makers and planners alike the opportunity to work together in relative ease using a straightforward approach made possible by computer models born from relatively small, quality information bases.

In Figure 5.7 a possible scenario is tested which might be considered to balance the farebox charge limits with fleet size constraints while achieving a respectable level-of-service. One possible justification for the increase would be the "increase in service", even though no additional buses were required to achieve this! In the next section, attention is to be given to the limitations and possible enhancements of the model.

	SUPER DISTRICT NUMBER	TRAFFIC ZONE NUMBER	TRIP_GEN % Rate work trips	EMP OUT OF AREA % OUTSIDE	TRIP GENERATED TOTAL	TOT_WORK TRIPS EST #1	TOT_WORK TRIPS EST #2	MODAL SPLIT MODEL 4	TRANSIT RIDERSHIP (WORK TRIPS)
1	19	274	27.8	84%	2938	817	1008	0.191	193
2	19	293	27.8	84%	2419	673	831	0.179	148
3	19	371	28.9	89%	1298	375	378	0.120	45
4	19	372	28.9	89%	2597	750	755	0.121	92
5	19	375	28.9	86%	1821	526	514	0.125	64
6	24	443	28.9	86%	3477	1005	981	0.130	127
7	24	442	28.9	86%	2981	861	841	0.131	111
8	24	441	30.0	87%	2761	828	979	0.189	185
9	24	444	30.0	87%	1933	580	685	0.192	132
10	24	445	27.9	93%	3373	941	1174	0.176	207
11	24	446	27.9	93%	2952	824	1028	0.175	180
12	24	447	27.9	93%	2108	588	734	0.168	124
13	27	481	31.5	86%	3060	964	1076	0.163	175
14	27	482	31.5	86%	2040	643	718	0.181	130
15	27	483	31.5	86%	3570	1125	1256	0.213	267
16	28	492	31.8	82%	6396	2034	2358	0.132	311
17	28	493	31.8	82%	5233	1664	1929	0.134	259
18	28	494	31.8	86%	3629	1154	1410	0.139	196
19	28	495	31.8	86%	4354	1385	1692	0.141	239
20	28	571	31.8	86%	6532	2077	2539	0.142	360
21	28	572	31.8	87%	2330	741	851	0.120	102
22	28	573	31.8	87%	1472	468	537	0.121	65
23	28	574	31.8	87%	2330	741	851	0.121	103
	TOTALS >				71,604	21,763	25,125		3,817

* * * P O L I C Y * * * * * * S T A T U S * * *	
Statement on policy:	ANY(Y/N) CHANGES? 1=Y, 0=N
HEADWAYS: 5	1
10	1
FULL LOAD: 52	0
TRANSIT FARE: 100 (cents)	1
Enter Policy Values then press key "F9"	
COMMENTS ? :	

Total population served by routes in area A 29,062

TRANSIT RIDES

(1) TRANSIT MODE SPLIT FOR TRANSIT PLANNING AREA "A"
WORK-BASED TRIPS (APPROX. 90% OF PM PEAK TRIPS) 15.25%

(2) PM PEAK TRANSIT RIDERSHIP(4-6 PM) 30% (77 SURVEY) 1145 WORK-BASED RIDES
(3) PM PEAK HOUR RIDERSHIP (60% of PM Peak Period) 687 WORK-BASED RIDES
(4) TOTAL PM PEAK TRANSIT RDRSHP TO AREA "A" 718 RIDES
(APPROX. AS WORK-BASED +10% -5% FROM AREA "A")
(5) PEAK HOUR BUSES REQUIRED 17.3 BUSES
18 BUSES (ROUNDED UP)
(6) PEAK HOUR BUSES REQUIRED TO MAINTAIN HEADWAY 16 BUSES
(FULL LOAD POLICY IS 52 PASSENGERS / BUS)
(ROUND TRIP TIME IS 75 MINUTES)
(NOMINAL HEADWAY OF 5 MINUTES FOR AREA)
(7) COST PER PASSENGER RIDE FOR PEAK HOUR $0.95
(1981-82 Bus operating costs $40.00 / bus hour)
(8) PEAK HOUR REVENUE (fare profile constant) $700.00
(9) PEAK HOUR OPERATING COSTS (includes fixed overhead) $710.33
(10) PROFIT OR LOSS MARGIN IN PERCENT OF OPERATING COSTS -1.45%

PAT HOGAN INPUT-OUTPUT FORM SCENARIO ANALYSIS

Figure 5.7 INPUT - OUTPUT FORM : Using 5/10 min headway and $1.00 Fare

5.2 Special Model Applications

This study is not intended to demonstrate the special work-based models; however, it is important to note their possible application to transit planning. The three special models were calibrated which took a sub-set of the full work-trip data base and recalibrated it taking into consideration the possible peculiarities associated with these three stratifications.

The first special model considers peak period work-trips. With this model it is possible to develop transit mode choice from a peak period trip generation model. Like the narrow focus of the general work-based mode choice model developed in this study, it is also possible to restrict the trip generation procedure to data that demonstrates greater homogeneity of behaviour, thereby permitting a more accurate trip generation estimate for the primary travel period, that is, the peak periods of the A.M. and P.M. rush hours. In this manner the peak period mode choice model can take advantage of such a specific trip generation procedure thereby preserving the integrity of the entire transport modelling process.

The second special model uses only downtown-based work trips. This stratification again assumes that the trip generation model has specialized on the downtown trip production component. Similarly, to the peak period model the problem focus has been narrowed and so the trip generation procedure must also produce a specific downtown-based trip production estimate.

The third special model, perhaps the least useful in the more general transportation area, can find use in transit planning. Most transit

properties focus on the need to connect the residential area with the central business core of the city; however, in smaller urban areas, the model may find use in estimating transit ridership for various cross-town route options. The key application is then both a route path exercise, where directness can be compromised by the need to penetrate as large a transit market as possible, and also a service and cost efficiency exercise similar to the scenario analysis detailed in section 5.1.

Clearly, the more specific and specialized the transit/transport problem is, the more likely such special purpose models will better serve the analysis.

5.3 Limitations to the Model

A tendency by many who use any of a variety of computer models is to let the machine's computations preclude careful interpretation and assessment of the results. This is like the "magic black box" which produces an assumed "total answer" for its user. All planning models by their nature must simplify the real world and in so doing can miss the special cases or the peculiar circumstances that are not measured or available to the model calculations. More importantly, the planning model can only be a powerful tool if the planner himself becomes acquainted with the limitations of this electronic tool and develops a keen understanding of the complexity of other information that further describes the problems and the study area but which cannot be directly used in the model computations.

The urban transport planning function is really a sub-set of the regional and community planning process where each functional part must allow their "micro" scaled considerations to be overlaid with the larger

considerations of the entire socioeconomic development of the region and its component communities. In general terms the use of planning models allows a scenario type analysis to be made whereby variables can be tested at their extremes; however, such extreme scenarios test the assumptions and rationale of the logistic probability function by predicting well outside the range of variable values found in the calibration data base.

In an ideal modelling framework, all components that are major influences on the outputs must share equal levels of integrity and reliability. This then requires that the trip generation and distribution procedures be undertaken with the same attention to detail and thoroughness as has been made for the mode choice model in this study.

Referring back to the scenario exercise, it is worthy to note that when any variable is selected as an input for evaluation, that its variables' range be accounted for within the model design and its assumptions. The maximum or full load variable which can range from a seated load of 46 seats (typically) to a maximum "crush" load of 70+ passengers violates this condition. The original trip characteristics used to distinguish each trip record did not determine whether a given transit journey was likely to have been made seated, standing or a combination of both. This limitation then raises the question, what effect do large standing loads have on ridership? what is the effect on ridership of such conditions as longer transit trips? In fact, no information can easily document this situation. However, it is clear that where there are consistently large standing loads for a given bus route, there is evidence that a substantial latent ridership exists given the prevailing service level and fare.

As in the case of the Gordon Head service, frequent large standing loads are observed for both peak periods. Has this not caused planners to wonder whether an increase in peak period service can "pay off"? Such questions are difficult to answer even with the model framework described in this study. An approach that minimizes such unknown influences as large standing loads is to plan a system which does not use extreme load limits as a criteria to determine fleet size. To illustrate, a transit property which calculates peak hour resources around standing loads over 60 will obviously require fewer buses than a system that plans for 52. For the former, though, the mode split estimates for transit can be expected to be inflated since it is assumed that large standing loads are looked upon by patrons as unfavourable. The problem still remains, by how much has the mode split calculation overestimated transit use? For the latter, the "load" policy of 52 patrons, though slightly more than a seated load, more realistically approximates the conditions under which the calibration was made and therefore it can be expected that mode split estimates will be more realistic.

In conclusion, the use of the mode split model can only be made where a very specific task has been identified and the nature of the limitations scrutinized. It cannot be a "fishing exercise" that attempts to draw blank conclusions from the model results in the absence of a clear idea of the type of results one might expect, and the reasons why. This point might remind us of the first pitfall that was taught us about using computers: "garbage in gives garbage out"!

5.4 Model and Data Matrix Management

One of the original goals of this thesis is to demonstrate the

usefulness of a mode split model in transit planning. Part of this task, if the operative word "useful" is to be validated, is to outline the requirements for the operation and maintenance for this type of model and its matrix of required data. Figure 5.8 illustrates this data management flow chart. Though somewhat simplified, this management process considers the very necessary verification step each time a new scenario test form is developed for addressing a new set of policies and options. It will be useful to briefly overview the resources and data management considerations.

5.4.1 Required Resources

The planning agency undertaking this general type of transport model requires at least a micro computer with a large random access memory and a moderate sized on-line storage unit. The specific requirements would depend on the number of transportation zones to be used and the size of the urban area. Using the Victoria example, a large micro computer of the IBM PC class would suffice if equipped with at least 512K of ramdom access memory and a 10 gegabyte hard disk drive currently available in the "XT" version of the IBM PC or its many fully compatible competitors.

Staff requirements can be restricted to one planner possessing moderate skills in both statistics and the use of computers.

5.4.2 Data Management

The heart of the model is really the transportation zone-based data. In order to ensure that it contains the complete and latest information it is necessary to review the matrix yearly as a necessary part of the work program. New information should be thoroughly verified for consistency and reliability before appending to the main data. The data bases

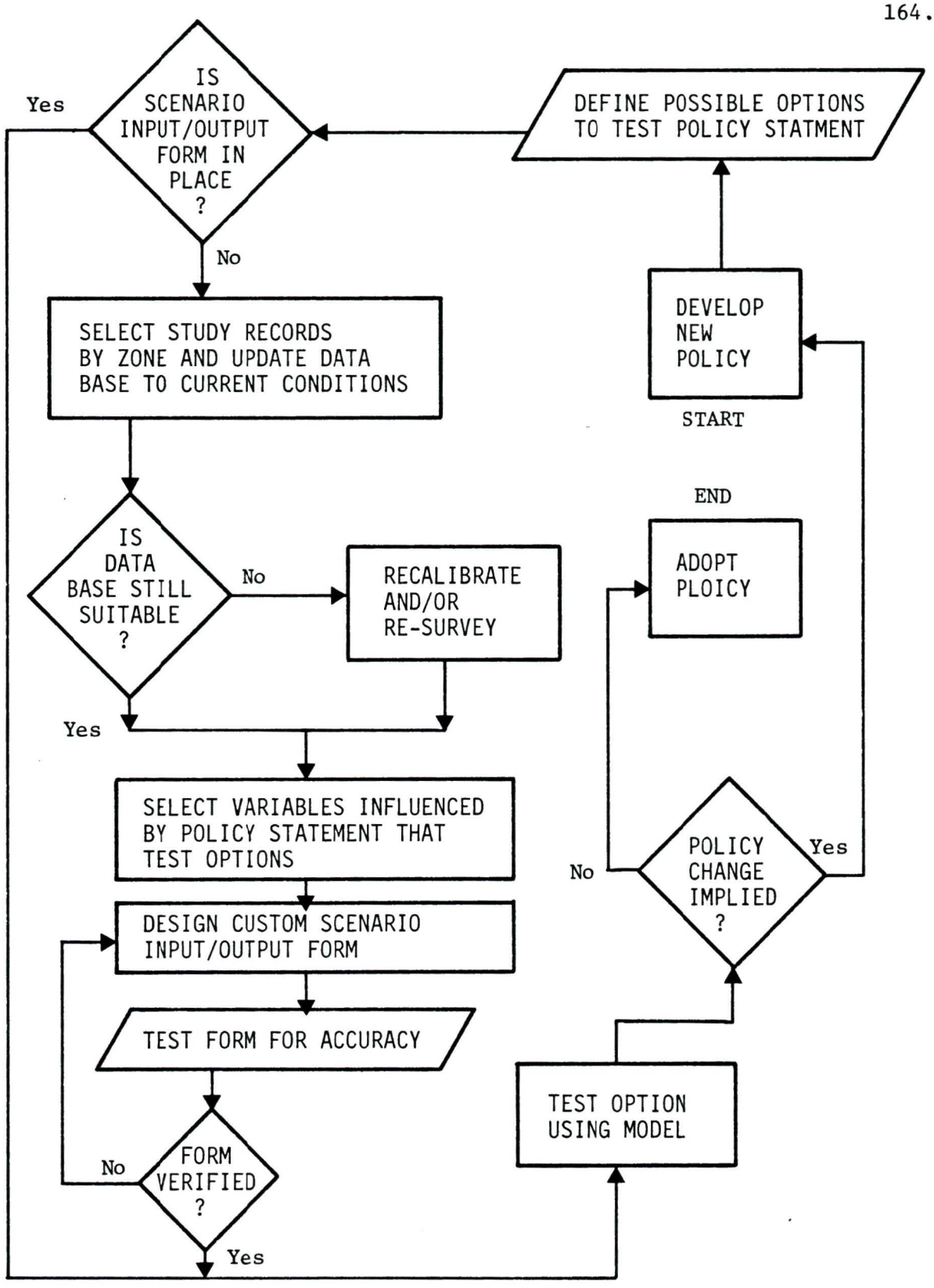


Figure 5.8 Model and Data management FLOW CHART

appended to a copy of the old file. In this fashion it is possible to map the changes over the years for all variables on an annual basis as well as verify the newly updated data files using the older files as a comparison.

In general, it is important to keep abreast of the latest statistics routinely collected by national, provincial and local agencies. Within the planning agency it is likely that certain information is only made available by initiating "in-house" data collection programs. In the transit planning area such additional information might include small surveys to capture car ownership, local area employment and other statistics related to producing reliable mode choice estimates. It is assumed that regular bus and route information would continue to be routinely collected by the transit property in a fashion that facilitates both long range planning and short term scheduling. With the management of any system, it depends on readily accessible information and in this area the full transit/transport model demonstrates its greatest asset by providing an organized data matrix capable of being quickly and easily programmed to address a multitude of transit demand issues.

5.5 Summary

Chapter V has given context to the mode choice model described in previous chapters. This context is one of transforming trip generation and trip distribution estimates to transit and auto mode trip estimates. This information is important to developing or fine-tuning transit services. The specific application illustrated in this chapter contrasted the impact of various service level options on ridership with various fare charges. It was possible to assess thier elasticities and show

their application to transit and transport demand studies. This was made possible by staging a transit related scenario analysis using a computer software package and comparing a series of planning options. A variety of options can be tested in an effort to optimize transit demand and balance the goals connected with transit planning policies.

References

1. The transit planning department independently estimated weekday peak hour ridership for the Gordon Head area to be 578. The study estimates ridership to be 572. ("Transit System Evaluation Report, 1981-82", Capital Regional District Transit Planning Department, June 1982, Table 2).

2. The following Capital Regional District (CRD) Reports contain survey information used to develop trip generation and distributional estimates:
   1) "Goals, Objectives and Formulation of a Conceptual Transit Plan", CRD, Dec. 1979.
   2) "Conceptual Plan--A Five-Year Strategy for Transit" (Technical Report), CRD, 1981.
   3) "Transit System Evaluation Report, 1981-82", CRD, June 1982.
   4) "Annual Operating Agreement, 1982-83", CRD/BCT, 1982.
   5) "Transit Planning Program, Evaluation of Population and Land Use Trends, 1980-85", CRD, 1981.
   6) "A Five Year Transit Strategy--Update 1983-87", Oct. 1982.
   7) "Victoria Metropolitan Area--Existing and Future Employment Estimates for Transportation Demand Modelling", CRD, May 1979.
   8) "Assessment of Transit Service Coverage in Downtown Victoria", Technical Report 3, Sept. 1979.

3. Transit overloads are employed during the peak periods as a response to extreme "crush" loads. Thus, two buses operate as one running head-to-toe enroute.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The process of developing a transport mode choice model for Victoria has been a general study in the transport planning process. In doing the study it has been necessary to detail the context for the model not only for Victoria transit planning, but more generally as a key component to transport system evaluation. In this chapter a brief summary of each of the key points in this work will be made; however, it will be instructive to complete this study with a brief discussion on the impact of changing lifestyles, technologies and particularly changed transport technologies on the model's future usefulness.

In the introduction eight specific goals were outlined. A re-examination of these goals will now serve as both a completion and a summary to this study and reiterate the conclusions that have come from this work.

The first goal was to bring together available data and prepare it for use in this study. The 1977 home interview survey afforded this opportunity. This survey data base, though incomplete in itself, supplied the baseline information for the entire study including the trip generation report contained in Appendix E. The data contained essentially two types of information; the first type gathered data on the sampled tripmaker and his/her household. This included age and sex along with household size, status and income. The second type of data was specific to the actual trips taken during the 24-hour sampling period set aside for each household in the survey. The entire information base

was organized by individual trips or person-trips. The initial use of the survey was restricted to the assemblage of descriptive statistics; however, its design was for far more rigorous analysis which this study has attempted to undertake.

The second goal was to develop a set of explanatory (independent) variables for use in the model. From a relatively voluminous array of information that was assembled for each trip record the final matrix of data was reduced to six strong independent variables. Only two variables were taken, unchanged, from the original 1977 survey; they were: the tripmaker's sex and age class. The other four were generated from other variables in the data set. These included the car availability variable which took the ratio of household car ownership with household employment (labour force). The next variable was an estimate of the relative level-of-service. This combined the individual levels-of-service for auto and transit modes again using a simple ratio. The relative travel costs were also computed by combining the separate measures for auto and transit modes. The travel costs factor considered household income with travel time and for the auto, unit costs per minute and for transit, the single trip fare. The last variable found to be useful was an estimate for the relative out-of-vehicle travel time. As with the other trip specific measures the out-of-vehicle travel time factor combined, in this case, the differences between the out-of-vehicle times for auto and transit modes. All of these selected variables for the model calibration produced a substantive level of statistical significance while showing acceptability low correlations amongst all six emplanatory factors.

Goal number three required that available software be used to calibrate the model. It was shown that this type of study does not use obscure techniques or require difficult-to-use computer software. At the present time most practical programs that perform a LOGIT calibration are available only at mainframe computer installations. The two specific programs cited are SHAZAM and BMDP statistical programming packages. Other LOGIT software has been developed for mini and "super-micro" computers.[1] While the author has not had the opportunity to examine these small computer statistical packages, it is nevertheless clear that future small sized computers will be equal to the task of handling the larger data bases and more complex statistical techniques such as LOGIT and PROBIT analyses and typically large urban transport data bases.

The fourth goal was to develop useful model designs which can be applied to practical transport problems. In this study the focus has been on transit planning problems. Chapter V described a scenario analysis which attempted to predict the impact of various transit levels-of-service options against various fare charges. The computational format selected in this work was the popular computer spreadsheet framework. This approach offers good flexibility in the creation of specific input-output forms as well as easily programmed routines which can conveniently handle the update and management of complex data bases.

A variety of extensions to the general work-based modal split model were developed. These extensions referred to as the special work-based models allow for the more specific problem areas to be studied. These involved separate model calibrations on a sub-set of the full work-trip

file. The sub-sets chosen were the downtown-based trips, the peak period trips and the non-peak, non-downtown trips. All three special models can take advantage of specialized trip generation and trip distribution models which predict using these narrower model designs that use far more homogeneous data sets.

The discussion of the fourth goal has really provided the introduction to goal number five. This goal is intended to demonstrate the use of the model with a practical example. Chapter V provides this example by describing the transit problem of fine tuning bus routes in a "business" which functions on deficit financing. Certainly, over the years (early to mid 1960's) the fare box revenues of most North American transit companies have seen an increasing undervaluation of the real costs of operating the system.[2] A multifaceted transport system comprising numerous bus routes that serve many types of urban enighbourhoods will always have some routes that are "winners" and others that incur large losses. The planner's job is to assess the transit market for all the region's neighbourhoods and fine tune each bus route component so that service to each area is equitably provided. This can be a difficult task if all the planner has to work with is hindsight information (e.g., typically ridership data by route). The example in Chapter V, though restricted to one sector of the city and only one bus route. corridor, clearly serves to illustrate both the flexibility and ease by which service planning options can be examined with consistency and a known level of reliability.[3] The example showed that with a moderate increase in fares and service headways (without overload buses), a net improvement results in both ridership and the deficit and all this can be achieved without the need to increase the size of the bus fleet!

The next goal was to document the model and its rationale. This task was accomplished in two phases, the first looked at the development of explanatory variables that took advantage of the disaggregate model design. The second phase tested these variables working together in the model calibration. The first phase has already been reviewed where it was shown that only a few select variables are necessary to calibrate a rather powerful behavioural model. The second phase produced a testable model. Two significance tests have been shown to test the goodness-of-fit of the models' components. The first test is the t-ratio for each independent variable coefficient. It was found that the t-ratios confirmed the remarkably low variation on favoured variables on all but one of the model calibrations. The second test employed a chi-square test using the log likelihood function. All seven models were found to easily reject the null hypothesis of independence between the dependent variables and the set of explanatory variables. Thus, the model calibration phase demonstrated that a relatively small data base can produce surprisingly strong model significance.

The seventh goal was to discuss and recommend possible improvements to the model and the data base. This study was a mode choice model-building effort. In order to properly apply this model to the transportation forecasting process it is necessary to have the other forecasting components in place and developed to an equivalent level of reliability and statistical rigor. Unfortunately this is not the case at present for the Victoria region; however, much information has been assembled by the Capital Regional District and with suitable resources the trip generation and distribution components already developed could be reactivated and updated.[4] Other possible improvements would be the calibration of a

modified sub-set of the original 1977 survey which would include more than just home-to-work and work-to-home work-based trips. The 1977 survey (3700 trip records) contains both trip purposes from an origin, to a destination; consequently, trips from a place of shopping to work or work to social or business-medical to work can be added to the work-home trip file to expand the baseline data. This baseline data then could be calibrated and a revised model created.

The last goal was to discuss maintenance implications and model re-calibration considerations. In Chapter V a discussion was made of the model's maintenance needs and a general procedure for creating and managing the data matrix was illustrated in Figure 5.8. In this discussion the issue of recalibration was suggested to be necessary if the baseline data was considered obsolete or out of date to a degree where reliable estimates were no longer possible. The question remains, what would make the data base obsolete or "out of date"? An earlier discussion drew a distinction between aggregate and disaggregate data by noting that disaggregate information on the individual relates more directly to human choice behaviour which is assumed to be unchanging through time. This assumption is only true to some extent; however, the unmeasured characteristics influencing mode choice also includes the social status society attaches to the private automobile and public transit. In recent years, more aggressive marketing of public transit has tried to produce a shift in this status without really changing the physical amenities associated with bus transport. It must be recognized that through time such shifts in the status of either the private auto or the transit bus will change the elasticities of the model's explanatory

variables. The only remedy to such changes would then be a new survey and model recalibration program.

We have discussed shifts in status as a cause for model obsolescence; what if the physical amenities of either modes changes or a new competing mode(s) is introduced? Here again, a fundamental change in mode would be present which is not detected entirely by the model variables. Thus, a mode change in effect carries its own specific social status. This status cannot be expected to be the same as traditional modes. Generally, mode changes have been created by the introduction of rail-based rapid transit systems. Though rapid transit is not usually in competition with bus services, the physical amenities do change marking a possible shift in mode status.[5] These mode changes whether they are competing or more often complementary to traditional modes creates uncertainty in the model's ability to reliably estimate modal split. In such cases, a new survey and model calibration is a practical and cautious approach. It also points towards a multinomial model approach where more than two choices require modelling.

As a last note, the author would like to restate in more general terms the need and practicality of computer modelling in transit and transport planning. Now, more than ever before, the tools to analyse larger data bases are readily available and accessible to the small city planning environment. No longer is it necessary to employ specialized computer programmers with many years of advanced programming on mainframe computers. The modern planners from geography, economics, engineering and other disciplines can use and manage a complex transport data base using relatively inexpensive computer hardware with convenience and

reliability. In the years to come, the ease with which information is processed and collected may transform all planning endeavours and re-kindle confidence in transportation and urban planning.

References

1. The University of Montreal has used the VAX mini computer (DIGITAL) and the PIXEL super micro computers to develop large scale transportation forecasting programs.

2. Transit fare box revenue in Victoria is intended to only recover 35% of the total operating costs. Large urban areas such as Toronto, Ontario plan their system around a 60-70% cost recovery.

3. Reliability in a model goes beyond the model calibration tests of significance, that is, whenever new data is added to the information base in the production of new estimates, the reliability of this new data must be known.

4. The transportation section of the Planning Department of the Capital Regional District was deactivated in January 1984. The Victoria area transportation information base and the associated models which have already been developed are, as a consequence, no longer accessible.

5. The Bay Area Rapid Transit (BART) system in San Francisco is one example where rapid transit competes directly with conventional bus services that serve the same transit market. Such competition is atypical and counterproductive to cost effective transit.

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CONTENTS OF APPENDIX A

	Page
A1 - FDIF1 (General Model) with TIM, OUT, TRNSFERS, TPROP	182
A2 - FDIF2 (General Model) with SER - LSERVT - LSERVA * 2	187
A3 - FMIX1 (General Model) with TPROP	192
A4 - FMIX4 (General Model) with SER - LSERVT / LSERVA * 2	197
A5 - PKMIX (Peak Period Model)	202
A6 - DNTMIX (Downtown-Based Model)	206
A7 -NOPDMIX (Non-Peak & Non-Downtown Based Model)	210

APPENDIX A1 FDIF1 (General Model)

```
 TYPE MSLOG FDIF1
TYPE MSLOG FDIF1


 WORKSPACE IS  503K
 SHAZAM (VERSION 3.1.1 - JULY 1980)    SOLOMON 33 623 TEST RUN CRD MODE CHOICE
 NAME 2 SUBREGN 4 RESTYPE 5 POPHSHLD 6 CARAVAIL 7 EMPHSHLD 8 INCHSHLD 14 T
      15 AUTO 16 CARPASS 19 ORGDEN 20 DESEMP 21 ORGEMP 22 DESDEN 23 COSTAUTO
      24 COSTTRAN 25 TTIMAUT 26 TTIMTRN 27 OUTIMA 28 OUTIMT 29 INTIMA 30 INTIMT
      32 LSERVT 33 LSERVA 31 TRNSFERS 17 TRANSIT 10 SEX 11 AGE 18 PURPOSE
      12 O 13 D
 GENR TRFRS=(TRNSFERS*.25)
 GENR HINC=0
 GENR V=(SUBREGN.EQ.1)
 GENR S=(SUBREGN.EQ.2)
 GENR OB=(SUBREGN.EQ.3)
 GENR EV=(SUBREGN.EQ.4).OR.(SUBREGN.EQ.7)
 GENR ST23=0
 GENR ST21=0
 GENR ST19=0
 GENR ST17=0
 GENR ST15=0
 GENR ST13=0
 GENR ST11=0
 GENR ST9=0
 GENR ST7=0
 GENR ST5=0
 GENR X=(T.GE.2200).AND.(T.LT.2500)
 IF(X.EQ.1)ST23=1
 GENR X=  (T.GE.2000).AND.(T.LT.2200)
 IF(X.EQ.1)ST21=1
 GENR X=  (T.GE.1800).AND.(T.LT.2000)
 IF(X.EQ.1)ST19=1
 GENR X=  (T.GE.1600).AND.(T.LT.1800)
 IF(X.EQ.1)ST17=1
 GENR X=  (T.GE.1400).AND.(T.LT.1600)
 IF(X.EQ.1)ST15=1
 GENR X=  (T.GE.1200).AND.(T.LT.1400)
 IF(X.EQ.1)ST13=1
 GENR X=  (T.GE.1000).AND.(T.LT.1200)
 IF(X.EQ.1)ST11=1
 GENR X=  (T.GE.800).AND.(T.LT.1000)
 IF(X.EQ.1)ST9=1
 GENR X=  (T.GE.600).AND.(T.LT.800)
 IF(X.EQ.1)ST7=1
 GENR X=  (T.GE.400).AND.(T.LT.600)
 IF(X.EQ.1)ST5=1
 GENR PEAK=(ST5.EQ.1).OR.(ST7.EQ.1).OR.(ST9.EQ.1).OR.(ST17.EQ.1)
 SKIP IF(PEAK.EQ.3)
 GENR COST=COSTAUTO-COSTTRAN
 GENR TIM=TTIMTRN-TTIMAUT
 GENR OUT=OUTIMT-OUTIMA
 GENR TIMVAL=TIM*OUT*10
 GENR SER=LSERVT-LSERVA*2
 GENR TPROP=0
 IF(DESEMP.EQ.0)DESEMP=0
 IF(ORGEMP.EQ.0)ORGEMP=0
 IF(PURPOSE.EQ.1)TPROP=(DESDEN-ORGDEN)+(ORGEMP-DESEMP)
 IF(PURPOSE.EQ.6)TPROP=(ORGDEN-DESDEN)+(DESEMP-ORGEMP)
 GENR Y=(O.GE.140).AND.(O.LE.163).OR.(O.EQ.121).OR.(O.EQ.122).OR.
       (O.GE.190).AND.(O.LE.201)
 GENR Z=(D.GE.140).AND.(D.LE.163).OR.(D.EQ.121).OR.(D.EQ.122).OR.
      (D.GE.190).AND.(D.LE.201)
 GENR DTN=Y+Z
 IF(DTN.EQ.2)DTN=1
 SKIP IF(DTN.EQ.3)
 DATA COMMAND = DATA FILE
      .EFFICIENT REGION SET TO  60 VARIABLES AND       2030 OBSERVATIONS
```

```
 FIRST FIVE INCLUDED AND LAST OBSERVATION
     1  4.0000      2.0000      475.00      1.0000      4.0000      2.0000      1.0000      4.0000      1.0000      1.0000
        4.0000      475.00      255.00      830.00      1.0000      .0          .0          6.0000      1010.0      817.00
        524.00      2026.0      17.750      15.610      15.000      25.000      3.0000      12.000      12.000      12.000
        .0          21.500      3.0000      .0          .0          .0          1.0000      .0          .0          .0
        .0          .0          .0          .0          .0          .0          1.0000      .0          .0          .0
        1.0000      2.1400      10.000      9.0000      900.00      15.500      -723.00     .0          .0          .0
     2  4.0000      2.0000      475.00      1.0000      4.0000      2.0000      1.0000      4.0000      1.0000      1.0000
        3.0000      255.00      475.00      1300.0      1.0000      .0          .0          1.0000      2026.0      524.00
        817.00      1010.0      17.750      15.610      15.000      25.000      3.0000      12.000      12.000      14.000
        .0          11.400      3.0000      .0          .0          .0          1.0000      .0          .0          .0
        .0          .0          .0          .0          1.0000      .0          .0          .0          .0          .0
        .0          2.1400      10.000      9.0000      900.00      5.4000      -723.00     .0          .0          .0
     3  4.0000      2.0000      475.00      1.0000      4.0000      2.0000      1.0000      4.0000      1.0000      1.0000
        4.0000      255.00      475.00      1730.0      1.0000      .0          .0          1.0000      2026.0      524.00
        817.00      1010.0      23.670      15.610      20.000      26.000      3.0000      12.000      12.000      14.000
        .0          15.400      3.0000      .0          .0          .0          1.0000      .0          .0          .0
        .0          .0          1.0000      .0          .0          .0          .0          .0          .0          .0
        1.0000      8.0600      6.0000      9.0000      540.00      9.4000      -723.00     .0          .0          .0
     4  7.0000      2.0000      475.00      1.0000      6.0000      1.0000      1.0000      4.0000      1.0000      1.0000
        4.0000      475.00      321.00      645.00      .0          1.0000      .0          6.0000      1010.0      4982.0
        524.00      2110.0      23.670      15.610      20.000      38.000      3.0000      10.000      17.000      28.000
        1.0000      7.1000      3.0000      .25000      .0          .0          1.0000      .0          .0          .0
        .0          .0          .0          .0          .0          .0          .0          1.0000      .0          .0
        1.0000      8.0600      18.000      7.0000      1260.0      1.1000      3358.0      .0          .0          .0
     5  10.000      2.0000      475.00      1.0000      5.0000      .33000      3.0000      6.0000      1.0000      1.0000
        2.0000      475.00      422.00      1345.0      1.0000      .0          .0          6.0000      1010.0      202.00
        524.00      2364.0      5.6810      7.4950      10.000      13.000      1.0000      5.0000      9.0000      8.0000
        .0          11.400      3.0000      .0          .0          .0          1.0000      .0          .0          .0
        .0          .0          .0          .0          1.0000      .0          .0          .0          .0          .0
        .0          -1.8140     3.0000      4.0000      120.00      5.4000      -1676.0     .0          .0          .0
   623  2232.0      2.0000      392.00      3.0000      3.0000      1.0000      1.0000      5.0000      1.0000      1.0000
        4.0000      392.00      233.00      800.00      1.0000      .0          .0          6.0000      2487.0      244.00
        680.00      2026.0      3.3420      11.020      4.0000      8.0000      2.0000      5.0000      2.0000      3.0000
        .0          10.500      3.0000      .0          .0          .0          1.0000      .0          .0          .0
        .0          .0          .0          .0          .0          .0          1.0000      .0          .0          .0
        1.0000      -7.6780     4.0000      3.0000      120.00      4.5000      25.000      .0          .0          .0
 ...YOUR LARGE AMOUNT OF DATA USES LOTS OF MEMORY
 ...IF POSSIBLE USE THE NOHD OR DP OPTIONS TO REDUCE MEMORY REQUIRED
 SHAZAM (VERSION 3.1.1 - JULY 1980)  SOLOMON 33 623 TEST RUN CRD MODE CHOICE

 NUMBER OF OBSERVATIONS=   623
 NUMBER OF INPUT VARIABLES= 33
 USING OBSERVATIONS    1 THRU    623
 NUMBER OF VARIABLES AFTER TRANSFORMATION = 60
```

VARIABLE NAME	NO.	MEAN	STANDARD DEVIATION	VARIANCE	MINIMUM	MAXIMUM
	1	923.68	596.01	.35523D+06	4.0000	2232.0
SUBREGN	2	1.9374	1.0352	1.0716	1.0000	7.0000
	3	304.61	173.57	30127	4.0000	671.00
RESTYPE	4	1.5843	1.1836	1.4008	1.0000	5.0000
POPHSHLD	5	3.4414	1.3607	1.8515	1.0000	7.0000
CARAVAIL	6	.87165	.55573	.30884	.0	4.0000
EMPHSHLD	7	2.1413	1.1437	1.3080	1.0000	6.0000
INCHSHLD	8	5.2343	1.2792	1.6363	1.0000	7.0000
	9	1.6019	.85555	.73196	1.0000	5.0000
SEX	10	1.3933	.48887	.23899	1.0000	2.0000
AGE	11	3.1429	.89863	.80753	1.0000	5.0000
O	12	286.23	182.78	33407.	11.000	991.00
D	13	280.80	177.67	31568.	11.000	991.00
T	14	1278.1	455.37	.20736D+06	400.00	2530.0
AUTO	15	.69663	.46008	.21168	.0	1.0000
CARPASS	16	.14928	.35665	.12720	.0	1.0000
TRANSIT	17	.15249	.35978	.12944	.0	1.0000
PURPOSE	18	3.5522	2.5015	6.2573	1.0000	6.0000
ORGDEN	19	2357.5	1297.8	.16842D+07	124.00	6455.0
DESEMP	20	673.43	922.94	.85181D+06	.0	4982.0
ORGEMP	21	688.21	935.01	.87425D+06	.0	4982.0
DESDEN	22	2358.3	1289.4	.16625D+07	124.00	6455.0
COSTAUTO	23	11.662	9.6383	92.896	2.0290	94.680
COSTTRAN	24	11.195	6.2848	39.499	5.3530	41.630
TTIMAUT	25	13.774	6.8236	46.561	3.0000	45.000
TTIMTRN	26	27.528	14.814	219.44	5.0000	105.00
OUTIMA	27	2.6934	.94923	.90103	1.0000	7.0000
OUTIMT	28	10.393	5.0890	25.898	3.0000	25.000
INTIMA	29	11.021	6.6833	44.667	1.0000	42.000
INTIMT	30	17.173	11.915	141.97	1.0000	80.000
TRNSFERS	31	.43820	.50935	.25944	.0	2.0000
LSERVT	32	10.561	4.6520	21.642	3.3000	26.100
LSERVA	33	2.3515	.89120	.79424	1.0000	3.0000
TRFRS	34	.10955	.12734	.16215D-01	.0	.50000
HINC	35	.0	.0	.0	.0	.0
V	36	.39647	.48956	.23967	.0	1.0000
S	37	.39326	.48887	.23899	.0	1.0000
OB	38	.11075	.31408	.98646D-01	.0	1.0000
EV	39	.99518D-01	.29960	.89759D-01	.0	1.0000
ST23	40	.17657D-01	.13181	.17373D-01	.0	1.0000
ST21	41	.22472D-01	.14833	.22002D-01	.0	1.0000
ST19	42	.57785D-01	.23352	.54533D-01	.0	1.0000
ST17	43	.29374	.45584	.20779	.0	1.0000
ST15	44	.93098D-01	.29080	.84566D-01	.0	1.0000
ST13	45	.10112	.30173	.91044D-01	.0	1.0000
ST11	46	.38523D-01	.19261	.37099D-01	.0	1.0000
ST9	47	.17175	.37747	.14248	.0	1.0000
ST7	48	.18941	.39215	.15378	.0	1.0000
ST5	49	.12841D-01	.11268	.12697D-01	.0	1.0000
X	50	.12841D-01	.11268	.12697D-01	.0	1.0000
PEAK	51	.66774	.47140	.22222	.0	1.0000
COST	52	.46625	6.5731	43.206	-19.390	53.050
TIM	53	13.754	9.7642	95.340	-5.0000	73.000
OUT	54	7.6998	5.2397	27.455	-1.0000	23.000
TIMVAL	55	1462.7	1875.5	.35176D+07	-200.00	16790.
SER	56	5.8579	5.3422	28.539	-2.7000	24.100
TPROP	57	-436.87	2142.3	.45894D+07	-6415.0	5656.0
Y	58	.16533	.37178	.13822	.0	1.0000
Z	59	.18459	.38828	.15076	.0	1.0000
DTN	60	.34671	.47630	.22687	.0	1.0000

```
SUBPROBLEM NO.   1          SOLOMON 33 623 TEST RUN CRD MODE CHUICE
LOGIT TRANSIT CARAVAIL SEX SER AGE COST TIM OUT TRNSFERS TPROP / RS
THIS PROBLEM USES  221K
 LOGIT ANALYSIS     DEPENDENT VARIABLE =  17  TRANSIT
       623 TOTAL OBSERVATIONS
        95 OBSERVATIONS AT ONE
       528 OBSERVATIONS AT ZERO
  25 MAXIMUM ITERATIONS
CONVERGENCE TOLERANCE =0.00100

LOG OF LIKELIHOOD FOR BINOMIAL MODEL =    -266.02
BINOMIAL  ESTIMATE =0.1525
ITERATION  0      LOG OF LIKELIHOOD FUNCTION =     -266.02
ITERATION  1 ESTIMATES
-1.1189      .52241      .87889D-01 -.34228      .39009D-01  .61498D-02 -.12838     .26449     -.11549D-04 -.14210
ITERATION  1      LOG OF LIKELIHOOD FUNCTION =     -214.63
ITERATION  2 ESTIMATES
-1.5730      .52805      .75863D-01 -.30190      .43734D-01  .87231D-02 -.15349     .21616     -.12825D-04 -.10416
ITERATION  2      LOG OF LIKELIHOOD FUNCTION =     -205.70
ITERATION  3 ESTIMATES
-1.8110      .54986      .75897D-01 -.30102      .46952D-01  .99773D-02 -.16374     .18769     -.16930D-04 -.37845D-02
ITERATION  3      LOG OF LIKELIHOOD FUNCTION =     -205.17
ITERATION  4 ESTIMATES
-1.8370      .55216      .75956D-01 -.30121      .47297D-01  .10092D-01 -.16437     .18187     -.17709D-04  .65444D-02
ITERATION  4      LOG OF LIKELIHOOD FUNCTION =     -205.17
ITERATION  5 ESTIMATES
-1.8372      .55218      .75957D-01 -.30121      .47301D-01  .10093D-01 -.16437     .18179     -.17720D-04  .66418D-02

    MAXIMUM LIKELIHOOD ESTIMATES
                    ESTIMATES       STANDARD ERRORS    T-RATIOS
  6 CARAVAIL         -1.8372          .34132          -5.3828
 10 SEX               .55218          .26121           2.1140
 56 SER              .75957D-01       .24647D-01       3.0818
 11 AGE              -.30121          .13948          -2.1595
 52 COST             .47301D-01       .23294D-01       2.0306
 53 TIM              .10093D-01       .28980D-01       .34828
 54 OUT              -.16437          .60813D-01      -2.7029
 31 TRNSFERS          .18179          .48287           .37648
 57 TPROP           -.17720D-04       .65434D-04      -.27080
 61 CONSTANT         .66418D-02       .67529           .98355D-02

     LIKELIHOOD RATIO  TEST      121.712      WITH       9  D.F.
DURBIN-WATSON = 1.2463     VON NEUMAN RATIO = 1.2483     FIRST-ORDER RHO =  0.3769
RESIDUAL SUM =  -.30106D-06  RESIDUAL VARIANCE =    .95240D-01
SUM OF ABSOLUTE ERRORS=    121.82
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.2662
LOG-LIKELIHOOD FUNCTION =    -205.1655
 END OF SUBPROBLEM  1
      3.123 SEC. CPU TIME
     END OF SUBPROBLEMS
SINCE 84.090 YOU HAVE USED:     962.96 CPU SECONDS IN     86 RUNS OF SHAZAM CMS.

R, T=0.09/0.52 21:11:31
```

APPENDIX A2 FDIF2 (General Model)

```
TYPE MSLOG FDIF2
TYPE MSLOG FDIF2


WORKSPACE IS  503K
SHAZAM (VERSION 3.1.1 - JULY 1980)     SOLOMON 33 623 TEST RUN CRD MODE CHOICE
NAME 2 SUBREGN 4 RESTYPE 5 POPHSHLD 6 CARAVAIL 7 EMPHSHLD 8 INCHSHLD 14 T
     15 AUTO 16 CARPASS 19 ORGDEN 20 DESEMP 21 ORGEMP 22 DESDEN 23 COSTAUTO
     24 COSTTRAN 25 TTIMAUT 26 TTIMTRN 27 OUTIMA 28 OUTIMT 29 INTIMA 30 INTIMT
     32 LSERVT 33 LSERVA 31 TRNSFERS 17 TRANSIT 10 SEX 11 AGE 18 PURPOSE
     12 O 13 D
GENR TRFRS=(TRNSFERS*.25)
GENR HINC=0
GENR V=(SUBREGN.EQ.1)
GENR S=(SUBREGN.EQ.2)
GENR OB=(SUBREGN.EQ.3)
GENR EV=(SUBREGN.EQ.4).OR.(SUBREGN.EQ.7)
GENR ST23=0
GENR ST21=0
GENR ST19=0
GENR ST17=0
GENR ST15=0
GENR ST13=0
GENR ST11=0
GENR ST9=0
GENR ST7=0
GENR ST5=0
GENR X=(T.GE.2200).AND.(T.LT.2500)
IF(X.EQ.1)ST23=1
GENR X=  (T.GE.2000).AND.(T.LT.2200)
IF(X.EQ.1)ST21=1
GENR X=  (T.GE.1800).AND.(T.LT.2000)
IF(X.EQ.1)ST19=1
GENR X=  (T.GE.1600).AND.(T.LT.1800)
IF(X.EQ.1)ST17=1
GENR X=  (T.GE.1400).AND.(T.LT.1600)
IF(X.EQ.1)ST15=1
GENR X=  (T.GE.1200).AND.(T.LT.1400)
IF(X.EQ.1)ST13=1
GENR X=  (T.GE.1000).AND.(T.LT.1200)
IF(X.EQ.1)ST11=1
GENR X=  (T.GE.800).AND.(T.LT.1000)
IF(X.EQ.1)ST9=1
GENR X=  (T.GE.600).AND.(T.LT.800)
IF(X.EQ.1)ST7=1
GENR X=  (T.GE.400).AND.(T.LT.600)
IF(X.EQ.1)ST5=1
GENR PEAK=(ST5.EQ.1).OR.(ST7.EQ.1).OR.(ST9.EQ.1).OR.(ST17.EQ.1)
SKIP IF(PEAK.EQ.3)
GENR COST=COSTAUTO-COSTTRAN
GENR TIM=TTIMTRN-TTIMAUT
GENR OUT=OUTIMT-OUTIMA
GENR TIMVAL=TIM*OUT*10
GENR SER=LSERVT-LSERVA*2
GENR TPROP=0
IF(DESEMP.EQ.0)DESEMP=0
IF(ORGEMP.EQ.0)ORGEMP=0
IF(PURPOSE.EQ.1)TPROP=(DESDEN-ORGDEN)+(ORGEMP-DESEMP)
IF(PURPOSE.EQ.6)TPROP=(ORGDEN-DESDEN)+(DESEMP-ORGEMP)
GENR Y=(O.GE.140).AND.(O.LE.163).OR.(O.EQ.121).OR.(O.EQ.122).OR.
      (O.GE.190).AND.(O.LE.201)
GENR Z=(D.GE.140).AND.(D.LE.163).OR.(D.EQ.121).OR.(D.EQ.122).OR.
     (D.GE.190).AND.(D.LE.201)
GENR DTN=Y+Z
IF(DTN.EQ.2)DTN=1
SKIP IF(DTN.EQ.3)
DATA COMMAND = DATA FILE
......EFFICIENT REGION SET TO  60 VARIABLES AND       2030 OBSERVATIONS
```

APPENDIX A2 - 1

```
FIRST FIVE INCLUDED AND LAST OBSERVATION
  1  4.0000      2.0000      475.00      1.0000      4.0000      2.0000      1.0000      4.0000      1.0000      1.0000
     4.0000      475.00      255.00      830.00      1.0000      .0          .0          6.0000      1010.0      817.00
     524.00      2026.0      17.750      15.610      15.000      25.000      3.0000      12.000      12.000      12.000
     .0          21.500      3.0000      .0          .0          .0          1.0000      .0          .0          .0
     .0          .0          .0          .0          .0          .0          1.0000      .0          .0          .0
     1.0000      2.1400      10.000      9.0000      900.00      15.500      -723.00     .0          .0          .0
  2  4.0000      2.0000      475.00      1.0000      4.0000      2.0000      1.0000      4.0000      1.0000      1.0000
     3.0000      255.00      475.00      1300.0      1.0000      .0          .0          1.0000      2026.0      524.00
     817.00      1010.0      17.750      15.610      15.000      25.000      3.0000      12.000      12.000      14.000
     .0          11.400      3.0000      .0          .0          .0          1.0000      .0          .0          .0
     .0          .0          .0          .0          1.0000      .0          .0          .0          .0          .0
     .0          2.1400      10.000      9.0000      900.00      5.4000      -723.00     .0          .0          .0
  3  4.0000      2.0000      475.00      1.0000      4.0000      2.0000      1.0000      4.0000      1.0000      1.0000
     4.0000      255.00      475.00      1730.0      1.0000      .0          .0          1.0000      2026.0      524.00
     817.00      1010.0      23.670      15.610      20.000      26.000      3.0000      12.000      12.000      14.000
     .0          15.400      3.0000      .0          .0          .0          1.0000      .0          .0          .0
     .0          .0          1.0000      .0          .0          .0          .0          .0          .0          .0
     1.0000      8.0600      6.0000      9.0000      540.00      9.4000      -723.00     .0          .0          .0
  4  7.0000      2.0000      475.00      1.0000      6.0000      1.0000      1.0000      4.0000      1.0000      1.0000
     4.0000      475.00      321.00      645.00      .0          1.0000      .0          6.0000      1010.0      4982.0
     524.00      2110.0      23.670      15.610      20.000      38.000      3.0000      10.000      17.000      28.000
     1.0000      7.1000      3.0000      .25000      .0          .0          1.0000      .0          .0          .0
     .0          .0          .0          .0          .0          .0          .0          1.0000      .0          .0
     1.0000      8.0600      18.000      7.0000      1260.0      1.1000      3358.0      .0          .0          .0
  5  10.000      2.0000      475.00      1.0000      5.0000      .33000      3.0000      6.0000      1.0000      1.0000
     2.0000      475.00      422.00      1345.0      1.0000      .0          .0          6.0000      1010.0      202.00
     524.00      2364.0      5.6810      7.4950      10.000      13.000      1.0000      5.0000      9.0000      8.0000
     .0          11.400      3.0000      .0          .0          .0          1.0000      .0          .0          .0
     .0          .0          .0          .0          1.0000      .0          .0          .0          .0          .0
     .0          -1.8140     3.0000      4.0000      120.00      5.4000      -1676.0     .0          .0          .0
623  2232.0      2.0000      392.00      3.0000      3.0000      1.0000      1.0000      5.0000      1.0000      1.0000
     4.0000      392.00      233.00      800.00      1.0000      .0          .0          6.0000      2487.0      244.00
     680.00      2026.0      3.3420      11.020      4.0000      8.0000      2.0000      5.0000      2.0000      3.0000
     .0          10.500      3.0000      .0          .0          .0          1.0000      .0          .0          .0
     .0          .0          .0          .0          .0          .0          1.0000      .0          .0          .0
     1.0000      -7.6780     4.0000      3.0000      120.00      4.5000      25.000      .0          .0          .0
... YOUR LARGE AMOUNT OF DATA USES LOTS OF MEMORY
... IF POSSIBLE USE THE NOHD OR DP OPTIONS TO REDUCE MEMORY REQUIRED
SHAZAM (VERSION 3.1.1 - JULY 1980)     SOLOMON 33 623 TEST RUN CRD MODE CHOICE

NUMBER OF OBSERVATIONS=    623
NUMBER OF INPUT VARIABLES= 33
USING OBSERVATIONS     1 THRU    623
NUMBER OF VARIABLES AFTER TRANSFORMATION = 60
```

VARIABLE NAME	NO.	MEAN	STANDARD DEVIATION	VARIANCE	MINIMUM	MAXIMUM
	1	923.68	596.01	.35523D+06	4.0000	2232.0
SUBREGN	2	1.9374	1.0352	1.0716	1.0000	7.0000
	3	304.61	173.57	30127.	4.0000	671.00
RESTYPE	4	1.5843	1.1836	1.4008	1.0000	5.0000
POPHSHLD	5	3.4414	1.3607	1.8515	1.0000	7.0000
CARAVAIL	6	.87165	.55573	.30884	.0	4.0000
EMPHSHLD	7	2.1413	1.1437	1.3080	1.0000	6.0000
INCHSHLD	8	5.2343	1.2792	1.6363	1.0000	7.0000
	9	1.6019	.85555	.73196	1.0000	5.0000
SEX	10	1.3933	.48887	.23899	1.0000	2.0000
AGE	11	3.1429	.89863	.80753	1.0000	5.0000
O	12	286.23	182.78	33407.	11.000	991.00
D	13	280.80	177.67	31568.	11.000	991.00
T	14	1278.1	455.37	.20736D+06	400.00	2530.0
AUTO	15	.69663	.46008	.21168	.0	1.0000
CARPASS	16	.14928	.35665	.12720	.0	1.0000
TRANSIT	17	.15249	.35978	.12944	.0	1.0000
PURPOSE	18	3.5522	2.5015	6.2573	1.0000	6.0000
ORGDEN	19	2357.5	1297.8	.16842D+07	124.00	6455.0
DESEMP	20	673.43	922.94	.85181D+06	.0	4982.0
ORGEMP	21	688.21	935.01	.87425D+06	.0	4982.0
DESDEN	22	2358.3	1289.4	.16625D+07	124.00	6455.0
COSTAUTO	23	11.662	9.6383	92.896	2.0290	94.680
COSTTRAN	24	11.195	6.2848	39.499	5.3530	41.630
TTIMAUT	25	13.774	6.8236	46.561	3.0000	45.000
TTIMTRN	26	27.528	14.814	219.44	5.0000	105.00
OUTIMA	27	2.6934	.94923	.90103	1.0000	7.0000
OUTIMT	28	10.393	5.0890	25.898	3.0000	25.000
INTIMA	29	11.021	6.6833	44.667	1.0000	42.000
INTIMT	30	17.173	11.915	141.97	1.0000	80.000
TRNSFERS	31	.43820	.50935	.25944	.0	2.0000
LSERVT	32	10.561	4.6520	21.642	3.3000	26.100
LSERVA	33	2.3515	.89120	.79424	1.0000	3.0000
TRFRS	34	.10955	.12734	.16215D-01	.0	.50000
HINC	35	.0	.0	.0	.0	.0
V	36	.39647	.48956	.23967	.0	1.0000
S	37	.39326	.48887	.23899	.0	1.0000
OB	38	.11075	.31408	.98646D-01	.0	1.0000
EV	39	.99518D-01	.29960	.89759D-01	.0	1.0000
ST23	40	.17657D-01	.13181	.17373D-01	.0	1.0000
ST21	41	.22472D-01	.14833	.22002D-01	.0	1.0000
ST19	42	.57785D-01	.23352	.54533D-01	.0	1.0000
ST17	43	.29374	.45584	.20779	.0	1.0000
ST15	44	.93098D-01	.29080	.84566D-01	.0	1.0000
ST13	45	.10112	.30173	.91044D-01	.0	1.0000
ST11	46	.38523D-01	.19261	.37099D-01	.0	1.0000
ST9	47	.17175	.37747	.14248	.0	1.0000
ST7	48	.18941	.39215	.15378	.0	1.0000
ST5	49	.12841D-01	.11268	.12697D-01	.0	1.0000
X	50	.12841D-01	.11268	.12697D-01	.0	1.0000
PEAK	51	.66774	.47140	.22222	.0	1.0000
COST	52	.46625	6.5731	43.206	-19.390	53.050
TIM	53	13.754	9.7642	95.340	-5.0000	73.000
OUT	54	7.6998	5.2397	27.455	-1.0000	23.000
TIMVAL	55	1462.7	1875.5	.35176D+07	-200.00	16790.
GER	56	5.8579	5.3422	28.539	-2.7000	24.100
TPROP	57	-436.87	2142.3	.45894D+07	-6415.0	5656.0
Y	58	.16533	.37178	.13822	.0	1.0000
Z	59	.18459	.38828	.15076	.0	1.0000
DTN	60	.34671	.47630	.22687	.0	1.0000

```
SUBPROBLEM NO.  1          SOLOMON 33 623 TEST RUN CRD MODE CHOICE
LOGIT TRANSIT CARAVAIL SEX SER AGE COST  OUT  / RS CV
THIS PROBLEM USES  205K
 LOGIT ANALYSIS     DEPENDENT VARIABLE =  17  TRANSIT
      623 TOTAL OBSERVATIONS
       95 OBSERVATIONS AT ONE
      528 OBSERVATIONS AT ZERO
   25 MAXIMUM ITERATIONS
CONVERGENCE TOLERANCE =0.00100

LOG OF LIKELIHOOD FOR BINOMIAL MODEL =    -266.02
BINOMIAL  ESTIMATE =0.1525
ITERATION  0      LOG OF LIKELIHOOD FUNCTION =     -266.02
ITERATION  1 ESTIMATES
-1.1367      .51557      .84954D-01 -.33044      .41205D-01 -.10145     -.13999
ITERATION  1      LOG OF LIKELIHOOD FUNCTION =     -214.77
ITERATION  2 ESTIMATES
-1.5926      .52150      .73554D-01 -.30069      .46153D-01 -.12605     -.61528D-01
ITERATION  2      LOG OF LIKELIHOOD FUNCTION =     -205.87
ITERATION  3 ESTIMATES
-1.8267      .54584      .73272D-01 -.30221      .49358D-01 -.13678      .51365D-01
ITERATION  3      LOG OF LIKELIHOOD FUNCTION =     -205.34
ITERATION  4 ESTIMATES
-1.8510      .54885      .73294D-01 -.30257      .49662D-01 -.13770      .62026D-01
ITERATION  4      LOG OF LIKELIHOOD FUNCTION =     -205.34
ITERATION  5 ESTIMATES
-1.8512      .54888      .73294D-01 -.30258      .49665D-01 -.13771      .62111D-01

   MAXIMUM LIKELIHOOD ESTIMATES
                ESTIMATES       STANDARD ERRORS     T-RATIOS
 6 CARAVAIL      -1.8512          .33384          -5.5453
10 SEX            .54888          .25786           2.1286
56 SER            .73294D-01      .24017D-01       3.0517
11 AGE           -.30258          .13917          -2.1742
52 COST           .49665D-01      .20451D-01       2.4285
54 OUT           -.13771          .31332D-01      -4.3951
61 CONSTANT       .62111D-01      .65948           .94181D-01

     LIKELIHOOD RATIO  TEST    121.365    WITH     6  D.F.
ITERATION  5 ASYM. COVARIANCE MATRIX
   .11145
   .50600D-02   .66493D-01
  -.71647D-03  -.96203D-03   .57684D-03
  -.67653D-02   .12264D-02   .21260D-03   .19367D-01
  -.93187D-03   .27254D-03   .71264D-04   .51376D-04   .41823D-03
   .47236D-03  -.28791D-03   .23788D-03   .44032D-04  -.13642D-03   .98172D-03
  -.53021D-01  -.99571D-01  -.44257D-02  -.55728D-01   .89850D-04  -.71316D-02   .43492
DURBIN-WATSON = 1.2421    VON NEUMAN RATIO = 1.2441    FIRST-ORDER RHO =  0.3789
RESIDUAL SUM =  -.23345D-06  RESIDUAL VARIANCE =   .95359D-01
SUM OF ABSOLUTE ERRORS=   121.98
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.2653
LOG-LIKELIHOOD FUNCTION =   -205.3390
 END OF SUBPROBLEM  1
      1.823 SEC.  CPU TIME
    END OF SUBPROBLEMS
SINCE 84.090 YOU HAVE USED:     971.78 CPU SECONDS IN     87 RUNS OF SHAZAM CMS.

R; T=0.09/0.54 21:31:16
```

APPENDIX A3 FMIX1 (General Model)

```
TYPE MSLOG FMIX1
TYPE MSLOG FMIX1


WORKSPACE IS  503K
SHAZAM (VERSION 3.1.1 - JULY 1980)     SOLOMON 33 623 TEST RUN CRD MODE CHOICE
NAME 2 SUBREGN 4 RESTYPE 5 POPHOUSE 6 CARAVAIL 7 EMPHOUSE 8 INCHOUSE 14 T
     15 AUTO 16 CARPASS 19 ORGDEN 20 DESEMP 21 ORGEMP 22 DESDEN 23 COSTAUTO
     24 COSTTRAN 25 TTIMAUT 26 TTIMTRN 27 OUTIMA 28 OUTIMT 29 INTIMA 30 INTIMT
     32 LSERVT 33 LSERVA 31 TRNSFERS 17 TRANSIT 10 SEX 11 AGE 18 PURPOSE
     12 O 13 D
GENR TRFRS=(TRNSFERS*.25)
GENR HINC=0
GENR V=(SUBREGN.EQ.1)
GENR S=(SUBREGN.EQ.2)
GENR OB=(SUBREGN.EQ.3)
GENR EV=(SUBREGN.EQ.4).OR.(SUBREGN.EQ.7)
GENR ST23=0
GENR ST21=0
GENR ST19=0
GENR ST17=0
GENR ST15=0
GENR ST13=0
GENR ST11=0
GENR ST9=0
GENR ST7=0
GENR ST5=0
GENR X=(T.GE.2200).AND.(T.LT.2500)
IF(X.EQ.1)ST23=1
GENR X=  (T.GE.2000).AND.(T.LT.2200)
IF(X.EQ.1)ST21=1
GENR X=  (T.GE.1800).AND.(T.LT.2000)
IF(X.EQ.1)ST19=1
GENR X=  (T.GE.1600).AND.(T.LT.1800)
IF(X.EQ.1)ST17=1
GENR X=  (T.GE.1400).AND.(T.LT.1600)
IF(X.EQ.1)ST15=1
GENR X=  (T.GE.1200).AND.(T.LT.1400)
IF(X.EQ.1)ST13=1
GENR X=  (T.GE.1000).AND.(T.LT.1200)
IF(X.EQ.1)ST11=1
GENR X=  (T.GE.800).AND.(T.LT.1000)
IF(X.EQ.1)ST9=1
GENR X=  (T.GE.600).AND.(T.LT.800)
IF(X.EQ.1)ST7=1
GENR X=  (T.GE.400).AND.(T.LT.600)
IF(X.EQ.1)ST5=1
IF(INCHOUSE .EQ. 1) HINC=( 4000/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 2) HINC=( 6000/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 3) HINC=( 8500/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 4) HINC=(12000/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 5) HINC=(17000/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 6) HINC=(25000/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 7) HINC=(35000/100*EMPHOUSE/POPHOUSE)
GENR PEAK=(ST5.EQ.1).OR.(ST7.EQ.1).OR.(ST9.EQ.1).OR.(ST17.EQ.1)
SKIP IF(PEAK.EQ.3)
GENR COST=COSTAUTO-COSTTRAN
GENR TIM=TTIMTRN-TTIMAUT
GENR OUT=OUTIMT-OUTIMA+TRFRS
GENR TIMVAL=TIM*OUT*10
GENR SER=LSERVT/LSERVA*2
GENR TPROP=0
IF(DESEMP.EQ.0)DESEMP=0
IF(ORGEMP.EQ.0)ORGEMP=0
IF(PURPOSE.EQ.1)TPROP=(DESDEN/ORGDEN)+(ORGEMP/DESEMP)
IF(PURPOSE.EQ.6)TPROP=(ORGDEN/DESDEN)+(DESEMP/ORGEMP)
GENR Y=(O.GE.140).AND.(O.LE.163).OR.(O.EQ.121).OR.(O.EQ.122).OR.
     (O.GE.190).AND.(O.LE.201)
GENR Z=(D.GE.140).AND.(D.LE.163).OR.(D.EQ.121).OR.(D.EQ.122).OR.
     (D.GE.190).AND.(D.LE.201)
GENR DTN=Y+Z
IF(DTN.EQ.2)DTN=1
SKIP IF(DTN.EQ.3)
DATA COMMAND = DATA FILE
.....EFFICIENT REGION SET TO  60 VARIABLES AND      2030 OBSERVATIONS
```

APPENDIX A3 - 1

FIRST FIVE INCLUDED AND LAST OBSERVATION

1	4.0000	2.0000	475.00	1.0000	4.0000	2.0000	1.0000	4.0000	1.0000	1.0000
	4.0000	475.00	255.00	830.00	1.0000	.0	.0	6.0000	1010.0	817.00
	524.00	2026.0	17.750	15.610	15.000	25.000	3.0000	12.000	12.000	12.000
	.0	21.500	3.0000	.0	30.000	.0	1.0000	.0	.0	.0
	.0	.0	.0	.0	.0	.0	1.0000	.0	.0	.0
	1.0000	2.1400	10.000	9.0000	900.00	14.333	2.0577	.0	.0	.0
2	4.0000	2.0000	475.00	1.0000	4.0000	2.0000	1.0000	4.0000	1.0000	1.0000
	3.0000	255.00	475.00	1300.0	1.0000	.0	.0	1.0000	2026.0	524.00
	817.00	1010.0	17.750	15.610	15.000	25.000	3.0000	12.000	12.000	14.000
	.0	11.400	3.0000	.0	30.000	.0	1.0000	.0	.0	.0
	.0	.0	.0	.0	1.0000	.0	.0	.0	.0	.0
	.0	2.1400	10.000	9.0000	900.00	7.6000	2.0577	.0	.0	.0
3	4.0000	2.0000	475.00	1.0000	4.0000	2.0000	1.0000	4.0000	1.0000	1.0000
	4.0000	255.00	475.00	1730.0	1.0000	.0	.0	1.0000	2026.0	524.00
	817.00	1010.0	23.670	15.610	20.000	26.000	3.0000	12.000	12.000	14.000
	.0	15.400	3.0000	.0	30.000	.0	1.0000	.0	.0	.0
	.0	.0	1.0000	.0	.0	.0	.0	.0	.0	.0
	1.0000	8.0600	6.0000	9.0000	540.00	10.267	2.0577	.0	.0	.0
4	7.0000	2.0000	475.00	1.0000	6.0000	1.0000	1.0000	4.0000	1.0000	1.0000
	4.0000	475.00	321.00	645.00	.0	1.0000	.0	6.0000	1010.0	4982.0
	524.00	2110.0	23.670	15.610	20.000	38.000	3.0000	10.000	17.000	28.000
	1.0000	7.1000	3.0000	.25000	20.000	.0	1.0000	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	1.0000	.0	.0
	1.0000	8.0600	18.000	7.2500	1305.0	4.7333	9.9863	.0	.0	.0
5	10.000	2.0000	475.00	1.0000	5.0000	.33000	3.0000	6.0000	1.0000	1.0000
	2.0000	475.00	422.00	1345.0	1.0000	.0	.0	6.0000	1010.0	202.00
	524.00	2364.0	5.6810	7.4950	10.000	13.000	1.0000	5.0000	9.0000	8.0000
	.0	11.400	3.0000	.0	150.00	.0	1.0000	.0	.0	.0
	.0	.0	.0	.0	1.0000	.0	.0	.0	.0	.0
	.0	-1.8140	3.0000	4.0000	120.00	7.6000	.81274	.0	.0	.0
623	2232.0	2.0000	392.00	3.0000	3.0000	1.0000	1.0000	5.0000	1.0000	1.0000
	4.0000	392.00	233.00	800.00	1.0000	.0	.0	6.0000	2487.0	244.00
	680.00	2026.0	3.3420	11.020	4.0000	8.0000	2.0000	5.0000	2.0000	3.0000
	.0	10.500	3.0000	.0	56.667	.0	1.0000	.0	.0	.0
	.0	.0	.0	.0	.0	.0	1.0000	.0	.0	.0
	1.0000	-7.6780	4.0000	3.0000	120.00	7.0000	1.5864	.0	.0	.0

...YOUR LARGE AMOUNT OF DATA USES LOTS OF MEMORY
...IF POSSIBLE USE THE NOHD OR DP OPTIONS TO REDUCE MEMORY REQUIRED
SHAZAM (VERSION 3.1.1 - JULY 1980) SOLOMON 33 623 TEST RUN CRD MODE CHOICE

NUMBER OF OBSERVATIONS= 623
NUMBER OF INPUT VARIABLES= 33
USING OBSERVATIONS 1 THRU 623
NUMBER OF VARIABLES AFTER TRANSFORMATION = 60

VARIABLE NAME	NO.	MEAN	STANDARD DEVIATION	VARIANCE	MINIMUM	MAXIMUM
	1	921.38	605.65	.36681D+06	4.0000	2232.0
SUBREGN	2	1.9639	1.0533	1.1095	1.0000	7.0000
	3	314.93	174.86	30577.	12.000	671.00
RESTYPE	4	1.6611	1.2352	1.5258	1.0000	5.0000
POPHOUSE	5	3.3365	1.3541	1.8335	1.0000	7.0000
CARAVAIL	6	.89173	.56635	.32075	.0	4.0000
EMPHOUSE	7	2.0793	1.0892	1.1865	1.0000	6.0000
INCHOUSE	8	5.1707	1.2884	1.6600	1.0000	7.0000
	9	1.5721	.85000	.72250	1.0000	5.0000
SEX	10	1.3870	.48765	.23781	1.0000	2.0000
AGE	11	3.1587	.89109	.79405	1.0000	5.0000
O	12	297.35	183.58	33703.	11.000	991.00
D	13	285.26	179.77	32317.	11.000	982.00
T	14	1157.5	450.90	.20331D+06	400.00	1750.0
AUTO	15	.67308	.46965	.22057	.0	1.0000
CARPASS	16	.14423	.35175	.12373	.0	1.0000
TRANSIT	17	.18029	.38489	.14814	.0	1.0000
PURPOSE	18	3.9087	2.4693	6.0977	1.0000	6.0000
ORGDEN	19	2293.6	1277.9	.16329D+07	124.00	6455.0
DESEMP	20	694.37	945.85	.89462D+06	1.0000	4982.0
ORGEMP	21	728.75	957.75	.91729D+06	1.0000	4982.0
DESDEN	22	2323.9	1319.6	.17413D+07	124.00	6455.0
COSTAUTO	23	12.514	10.245	104.95	2.2720	94.680
COSTTRAN	24	11.464	6.4374	41.440	5.3530	41.630
TTIMAUT	25	14.385	6.7700	45.832	3.0000	42.000
TTIMTRN	26	27.752	14.294	204.31	7.0000	98.000
OUTIMA	27	2.7620	.99085	.98178	1.0000	7.0000
OUTIMT	28	10.228	5.0989	25.998	3.0000	25.000
INTIMA	29	11.565	6.6525	44.256	2.0000	39.000
INTIMT	30	17.570	11.422	130.45	2.0000	73.000
TRNSFERS	31	.41587	.50790	.25796	.0	2.0000
LSERVT	32	11.345	4.9288	24.293	4.6000	26.100
LSERVA	33	2.2716	.91875	.84411	1.0000	3.0000
TRFRS	34	.10397	.12698	.16123D-01	.0	.50000
HINC	35	138.55	84.945	7215.6	12.143	350.00
V	36	.37981	.48592	.23612	.0	1.0000
S	37	.41106	.49262	.24267	.0	1.0000
OB	38	.10337	.30480	.92904D-01	.0	1.0000
EV	39	.10577	.30791	.94810D-01	.0	1.0000
ST23	40	.0	.0	.0	.0	.0
ST21	41	.0	.0	.0	.0	.0
ST19	42	.0	.0	.0	.0	.0
ST17	43	.43990	.49697	.24698	.0	1.0000
ST15	44	.0	.0	.0	.0	.0
ST13	45	.0	.0	.0	.0	.0
ST11	46	.0	.0	.0	.0	.0
ST9	47	.25721	.43762	.19151	.0	1.0000
ST7	48	.28365	.45131	.20368	.0	1.0000
ST5	49	.19231D-01	.13750	.18906D-01	.0	1.0000
X	50	.19231D-01	.13750	.18906D-01	.0	1.0000
PEAK	51	1.0000	.0	.0	1.0000	1.0000
COST	52	1.0508	6.8505	46.930	-19.390	53.050
TIM	53	13.368	9.2997	86.484	-5.0000	66.000
OUT	54	7.5703	5.3634	28.766	-1.0000	23.500
TIMVAL	55	1413.0	1845.0	.34041D+07	-200.00	15510.
SER	56	13.401	10.831	117.31	3.0667	52.200
TPROP	57	37.700	175.36	30751.	.11204	2392.2
Y	58	.17308	.37877	.14347	.0	1.0000
Z	59	.21875	.41390	.17131	.0	1.0000
DTN	60	.38942	.48821	.23835	.0	1.0000

```
1SUBPROBLEM NO.   1          SOLOMON 33 623 TEST RUN CRD MODE CHOICE
 LOGIT TRANSIT CARAVAIL SEX SER AGE COST OUT   / RS CV
 THIS PROBLEM USES  192K
  LOGIT ANALYSIS     DEPENDENT VARIABLE =  17  TRANSIT
       416 TOTAL OBSERVATIONS
        75 OBSERVATIONS AT ONE
       341 OBSERVATIONS AT ZERO
   25 MAXIMUM ITERATIONS
 CONVERGENCE TOLERANCE =0.00100

 LOG OF LIKELIHOOD FOR BINOMIAL MODEL =     -196.28
 BINOMIAL  ESTIMATE =0.1803
 ITERATION  0       LOG OF LIKELIHOOD FUNCTION =      -196.28
 ITERATION  1 ESTIMATES
-1.2257       .23478       .51649D-01 -.30827       .24970D-01 -.77279D-01  .93324D-01
 ITERATION  1       LOG OF LIKELIHOOD FUNCTION =      -152.94
 ITERATION  2 ESTIMATES
-1.8535       .17741       .37965D-01 -.28497       .34555D-01 -.12025       .66698
 ITERATION  2       LOG OF LIKELIHOOD FUNCTION =      -144.87
 ITERATION  3 ESTIMATES
-2.1754       .18037       .37524D-01 -.28862       .38033D-01 -.13612       .90632
 ITERATION  3       LOG OF LIKELIHOOD FUNCTION =      -144.25
 ITERATION  4 ESTIMATES
-2.2138       .18219       .37516D-01 -.28911       .38276D-01 -.13794       .93105
 ITERATION  4       LOG OF LIKELIHOOD FUNCTION =      -144.25
 ITERATION  5 ESTIMATES
-2.2143       .18223       .37516D-01 -.28912       .38277D-01 -.13796       .93132
```

```
     MAXIMUM LIKELIHOOD ESTIMATES
                      ESTIMATES       STANDARD ERRORS     T-RATIOS
     6 CARAVAIL        -1.9340          .34291           -5.6399
    10 SEX              .42465          .26955            1.5754
    56 SER              .50761D-01      .12472D-01        4.0699
    11 AGE             -.27808          .14183           -1.9606
    52 COST             .44863D-01      .20290D-01        2.2111
    54 OUT             -.11360          .31908D-01       -3.5604
    57 TPROP            .27678D-02      .47518D-02         .58247
    35 HINC            -.13583D-02      .16380D-02       -.82922
    61 CONSTANT         .46235D-01      .73349           .63034D-01

        LIKELIHOOD RATIO  TEST      130.335      WITH       8  D.F.
   ITERATION  5 ASYM. COVARIANCE MATRIX
      .11758
      .37643D-02    .72658D-01
     -.34854D-03   -.81563D-03    .15555D-03
     -.54316D-02    .13152D-02    .12599D-03    .20117D-01
     -.89441D-03    .30172D-03    .14209D-04    .51664D-04    .41167D-03
      .71255D-03   -.59239D-03    .16106D-03    .58568D-04   -.15168D-03    .10181D-02
     -.18590D-03   -.23531D-04   -.70951D-06    .40531D-04   -.15530D-05   -.48456D-05    .22580D-04
      .11881D-03   -.62063D-04    .63881D-06    .16633D-04   -.43483D-06    .23183D-05   -.42091D-07    .26830D-05
     -.76724D-01   -.90578D-01   -.24105D-02   -.62309D-01    .50802D-03   -.83207D-02   -.13364D-03   -.45589D-03    .53801
   DURBIN-WATSON = 1.2555     VON NEUMAN RATIO = 1.2575     FIRST-ORDER RHO =  0.3722
   RESIDUAL SUM =  -.27206D-06  RESIDUAL VARIANCE =    .93966D-01
   SUM OF ABSOLUTE ERRORS=   119.19
   R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.2749
   LOG-LIKELIHOOD FUNCTION =   -200.8537
    END OF SUBPROBLEM  1
         2.630 SEC.  CPU TIME
        END OF SUBPROBLEMS
   SINCE 84.090 YOU HAVE USED:     982.05 CPU SECONDS IN     90 RUNS OF SHAZAM CMS.

  R; T=0.10/0.63 22:21:47
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APPENDIX A4 FMIX2 (General Model and Favoured Calibration)

```
TYPE MSLOG FMIX2
TYPE MSLOG FMIX2

WORKSPACE IS 503K
SHAZAM (VERSION 3.1.1 - JULY 1980)     SOLOMON 33 623 TEST RUN CRD MODE CHOICE
NAME 2 SUBREGN 4 RESTYPE 5 POPHOUSE 6 CARAVAIL 7 EMPHOUSE 8 INCHOUSE 14 T
     15 AUTO 16 CARPASS 19 ORGDEN 20 DESEMP 21 ORGEMP 22 DESDEN 23 COSTAUTO
     24 COSTTRAN 25 TTIMAUT 26 TTIMTRN 27 OUTIMA 28 OUTIMT 29 INTIMA 30 INTIMT
     32 LSERVT 33 LSERVA 31 TRNSFERS 17 TRANSIT 10 SEX 11 AGE 18 PURPOSE
     12 O 13 D
GENR TRFRS=(TRNSFERS*.25)
GENR HINC=0
GENR V=(SUBREGN.EQ.1)
GENR S=(SUBREGN.EQ.2)
GENR OB=(SUBREGN.EQ.3)
GENR EV=(SUBREGN.EQ.4).OR.(SUBREGN.EQ.7)
GENR ST23=0
GENR ST21=0
GENR ST19=0
GENR ST17=0
GENR ST15=0
GENR ST13=0
GENR ST11=0
GENR ST9=0
GENR ST7=0
GENR ST5=0
GENR X=(T.GE.2200).AND.(T.LT.2500)
IF(X.EQ.1)ST23=1
GENR X=  (T.GE.2000).AND.(T.LT.2200)
IF(X.EQ.1)ST21=1
GENR X=  (T.GE.1800).AND.(T.LT.2000)
IF(X.EQ.1)ST19=1
GENR X=  (T.GE.1600).AND.(T.LT.1800)
IF(X.EQ.1)ST17=1
GENR X=  (T.GE.1400).AND.(T.LT.1600)
IF(X.EQ.1)ST15=1
GENR X=  (T.GE.1200).AND.(T.LT.1400)
IF(X.EQ.1)ST13=1
GENR X=  (T.GE.1000).AND.(T.LT.1200)
IF(X.EQ.1)ST11=1
GENR X=  (T.GE.800).AND.(T.LT.1000)
IF(X.EQ.1)ST9=1
GENR X=  (T.GE.600).AND.(T.LT.800)
IF(X.EQ.1)ST7=1
GENR X=  (T.GE.400).AND.(T.LT.600)
IF(X.EQ.1)ST5=1
IF(INCHOUSE .EQ. 1) HINC=( 4000/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 2) HINC=( 6000/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 3) HINC=( 8500/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 4) HINC=(12000/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 5) HINC=(17000/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 6) HINC=(25000/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 7) HINC=(35000/100*EMPHOUSE/POPHOUSE)
GENR PEAK=(ST5.EQ.1).OR.(ST7.EQ.1).OR.(ST9.EQ.1).OR.(ST17.EQ.1)
SKIP IF(PEAK.EQ.3)
GENR COST=COSTAUTO-COSTTRAN
GENR TIM=TTIMTRN-TTIMAUT
GENR OUT=OUTIMT-OUTIMA+TRFRS
GENR TIMVAL=TIM*OUT*10
GENR SER=LSERVT/LSERVA*2
GENR TPROP=0
IF(DESEMP.EQ.0)DESEMP=1
IF(ORGEMP.EQ.0)ORGEMP=1
IF(PURPOSE.EQ.1)TPROP=(DESDEN/ORGDEN)+(ORGEMP/DESEMP)
IF(PURPOSE.EQ.6)TPROP=(ORGDEN/DESDEN)+(DESEMP/ORGEMP)
GENR Y=(O.GE.140).AND.(O.LE.163).OR.(O.EQ.121).OR.(O.EQ.122).OR.
     (O.GE.190).AND.(O.LE.201)
GENR Z=(D.GE.140).AND.(D.LE.163).OR.(D.EQ.121).OR.(D.EQ.122).OR.
     (D.GE.190).AND.(D.LE.201)
GENR DTN=Y+Z
IF(DTN.EQ.2)DTN=1
SKIP IF(DTN.EQ.3)
```

APPENDIX A4 - 1

```
 DATA COMMAND = DATA FILE
 ......EFFICIENT REGION SET TO  60 VARIABLES AND      2030 OBSERVATIONS
 OFIRST FIVE INCLUDED AND LAST OBSERVATION
   1  4.0000     2.0000     475.00     1.0000     4.0000     2.0000     1.0000     4.0000     1.0000     1.0000
      4.0000     475.00     255.00     830.00     1.0000     .0         .0         6.0000     1010.0     817.00
      524.00     2026.0     17.750     15.610     15.000     25.000     3.0000     12.000     12.000     12.000
      .0         21.500     3.0000     .0         30.000     .0         1.0000     .0         .0         .0
      .0         .0         .0         .0         .0         .0         1.0000     .0         .0         .0
      1.0000     2.1400     10.000     9.0000     900.00     14.333     2.0577     .0         .0         .0
   2  4.0000     2.0000     475.00     1.0000     4.0000     2.0000     1.0000     4.0000     1.0000     1.0000
      3.0000     255.00     475.00     1300.0     1.0000     .0         .0         1.0000     2026.0     524.00
      817.00     1010.0     17.750     15.610     15.000     25.000     3.0000     12.000     12.000     14.000
      .0         11.400     3.0000     .0         30.000     .0         1.0000     .0         .0         .0
      .0         .0         .0         .0         1.0000     .0         .0         .0         .0         .0
      .0         2.1400     10.000     9.0000     900.00     7.6000     2.0577     .0         .0         .0
   3  4.0000     2.0000     475.00     1.0000     4.0000     2.0000     1.0000     4.0000     1.0000     1.0000
      4.0000     255.00     475.00     1730.0     1.0000     .0         .0         1.0000     2026.0     524.00
      817.00     1010.0     23.670     15.610     20.000     26.000     3.0000     12.000     12.000     14.000
      .0         15.400     3.0000     .0         30.000     .0         1.0000     .0         .0         .0
      .0         .0         1.0000     .0         .0         .0         .0         .0         .0         .0
      1.0000     8.0600     6.0000     9.0000     540.00     10.267     2.0577     .0         .0         .0
   4  7.0000     2.0000     475.00     1.0000     6.0000     1.0000     1.0000     4.0000     1.0000     1.0000
      4.0000     475.00     321.00     645.00     .0         1.0000     .0         6.0000     1010.0     4982.0
      524.00     2110.0     23.670     15.610     20.000     38.000     3.0000     10.000     17.000     28.000
      1.0000     7.1000     3.0000     .25000     20.000     .0         1.0000     .0         .0         .0
      .0         .0         .0         .0         .0         .0         .0         1.0000     .0         .0
      1.0000     8.0600     18.000     7.2500     1305.0     4.7333     9.9863     .0         .0         .0
   5  10.000     2.0000     475.00     1.0000     5.0000     .33000     3.0000     6.0000     1.0000     1.0000
      2.0000     475.00     422.00     1345.0     1.0000     .0         .0         6.0000     1010.0     202.00
      524.00     2364.0     5.6810     7.4950     10.000     13.000     1.0000     5.0000     9.0000     8.0000
      .0         11.400     3.0000     .0         150.00     .0         1.0000     .0         .0         .0
      .0         .0         .0         .0         1.0000     .0         .0         .0         .0         .0
      .0         -1.8140    3.0000     4.0000     120.00     7.6000     .81274     .0         .0         .0
 623  2232.0     2.0000     392.00     3.0000     3.0000     1.0000     1.0000     5.0000     1.0000     1.0000
      4.0000     392.00     233.00     800.00     1.0000     .0         .0         6.0000     2487.0     244.00
      680.00     2026.0     3.3420     11.020     4.0000     8.0000     2.0000     5.0000     2.0000     3.0000
      .0         10.500     3.0000     .0         56.667     .0         1.0000     .0         .0         .0
      .0         .0         .0         .0         .0         .0         1.0000     .0         .0         .0
      1.0000     -7.6780    4.0000     3.0000     120.00     7.0000     1.5864     .0         .0         .0
 ...YOUR LARGE AMOUNT OF DATA USES LOTS OF MEMORY
 ...IF POSSIBLE USE THE NOHD OR DP OPTIONS TO REDUCE MEMORY REQUIRED
 SHAZAM (VERSION 3.1.1 - JULY 1980)     SOLOMON 33 623 TEST RUN CRD MODE CHOICE

 NUMBER OF OBSERVATIONS=   623
 NUMBER OF INPUT VARIABLES= 33
 USING OBSERVATIONS    1 THRU   623
 NUMBER OF VARIABLES AFTER TRANSFORMATION = 60
```

VARIABLE NAME	NO.	MEAN	STANDARD DEVIATION	VARIANCE	MINIMUM	MAXIMUM
	1	923.68	596.01	.35523D+06	4.0000	2232.0
SUBREGN	2	1.9374	1.0352	1.0716	1.0000	7.0000
	3	304.61	173.57	30127.	4.0000	671.00
RESTYPE	4	1.5843	1.1836	1.4008	1.0000	5.0000
POPHOUSE	5	3.4414	1.3607	1.8515	1.0000	7.0000
CARAVAIL	6	.87165	.55573	.30884	.0	4.0000
EMPHOUSE	7	2.1413	1.1437	1.3080	1.0000	6.0000
INCHOUSE	8	5.2343	1.2792	1.6363	1.0000	7.0000
	9	1.6019	.85555	.73196	1.0000	5.0000
SEX	10	1.3933	.48887	.23899	1.0000	2.0000
AGE	11	3.1429	.89863	.80753	1.0000	5.0000
O	12	286.23	182.78	33407.	11.000	991.00
D	13	280.80	177.67	31568.	11.000	991.00
T	14	1278.1	455.37	.20736D+06	400.00	2530.0
AUTO	15	.69663	.46008	.21168	.0	1.0000
CARPASS	16	.14928	.35665	.12720	.0	1.0000
TRANSIT	17	.15249	.35978	.12944	.0	1.0000
PURPOSE	18	3.5522	2.5015	6.2573	1.0000	6.0000
ORGDEN	19	2357.5	1297.8	.16842D+07	124.00	6455.0
DESEMP	20	673.47	922.91	.85176D+06	1.0000	4982.0
ORGEMP	21	688.25	934.99	.87420D+06	1.0000	4982.0
DESDEN	22	2358.3	1289.4	.16625D+07	124.00	6455.0
COSTAUTO	23	11.662	9.6383	92.896	2.0290	94.680
COSTTRAN	24	11.195	6.2848	39.499	5.3530	41.630
TTIMAUT	25	13.774	6.8236	46.561	3.0000	45.000
TTIMTRN	26	27.528	14.814	219.44	5.0000	105.00
OUTIMA	27	2.6934	.94923	.90103	1.0000	7.0000
OUTIMT	28	10.393	5.0890	25.898	3.0000	25.000
INTIMA	29	11.021	6.6833	44.667	1.0000	42.000
INTIMT	30	17.173	11.915	141.97	1.0000	80.000
TRNSFERS	31	.43820	.50935	.25944	.0	2.0000
LSERVT	32	10.561	4.6520	21.642	3.3000	26.100
LSERVA	33	2.3515	.89120	.79424	1.0000	3.0000
TRFRS	34	.10955	.12734	.16215D-01	.0	.50000
HINC	35	139.98	83.749	7013.8	12.143	350.00
V	36	.39647	.48956	.23967	.0	1.0000
S	37	.39326	.48887	.23899	.0	1.0000
OB	38	.11075	.31408	.98646D-01	.0	1.0000
EV	39	.99518D-01	.29960	.89759D-01	.0	1.0000
ST23	40	.17657D-01	.13181	.17373D-01	.0	1.0000
ST21	41	.22472D-01	.14833	.22002D-01	.0	1.0000
ST19	42	.57785D-01	.23352	.54533D-01	.0	1.0000
ST17	43	.29374	.45584	.20779	.0	1.0000
ST15	44	.93098D-01	.29080	.84566D-01	.0	1.0000
ST13	45	.10112	.30173	.91044D-01	.0	1.0000
ST11	46	.38523D-01	.19261	.37099D-01	.0	1.0000
ST9	47	.17175	.37747	.14248	.0	1.0000
ST7	48	.18941	.39215	.15378	.0	1.0000
ST5	49	.12841D-01	.11268	.12697D-01	.0	1.0000
X	50	.12841D-01	.11268	.12697D-01	.0	1.0000
PEAK	51	.66774	.47140	.22222	.0	1.0000
COST	52	.46625	6.5731	43.206	-19.390	53.050
TIM	53	13.754	9.7642	95.340	-5.0000	73.000
OUT	54	7.8094	5.3402	28.518	-1.0000	23.500
TIMVAL	55	1485.7	1908.4	.36418D+07	-200.00	17155.
SER	56	11.943	10.001	100.01	2.2000	52.200
TPROP	57	37.491	168.95	28546.	.11204	2392.2
Y	58	.16533	.37178	.13822	.0	1.0000
Z	59	.18459	.38828	.15076	.0	1.0000
DTN	60	.34671	.47630	.22687	.0	1.0000

SUBPROBLEM NO. 1 SOLOMON 33 623 TEST RUN CRD MODE CHOICE
LOGIT TRANSIT CARAVAIL SEX SER AGE COST OUT / RS CV
THIS PROBLEM USES 205K

LOGIT ANALYSIS DEPENDENT VARIABLE = 17 TRANSIT
623 TOTAL OBSERVATIONS
95 OBSERVATIONS AT ONE
528 OBSERVATIONS AT ZERO
25 MAXIMUM ITERATIONS
CONVERGENCE TOLERANCE =0.00100

```
MAXIMUM LIKELIHOOD ESTIMATES
                    ESTIMATES        STANDARD ERRORS      T-RATIOS
 6 CARAVAIL          -2.2143           .40068            -5.4182
10 SEX                .18223           .31815             .57276
56 SER                .37516D-01       .14511D-01        2.5854
11 AGE               -.28912           .16724            -1.7288
52 COST               .38277D-01       .25353D-01        1.5098
54 OUT               -.13796           .39868D-01        -3.4605
61 CONSTANT           .93132           .81155            1.1476

      LIKELIHOOD RATIO  TEST      104.069      WITH       6  D.F.
 ITERATION  5 ASYM. COVARIANCE MATRIX
   .16702
   .12916D-01    .10122
  -.34929D-03   -.13896D-02    .21056D-03
  -.93411D-02    .10064D-02    .27782D-03    .27969D-01
  -.92522D-03   -.55467D-05    .43365D-04    .81294D-04    .64277D-03
   .13744D-02   -.26820D-03    .21673D-03    .17037D-03   -.25335D-03    .15894D-02
  -.96350D-01   -.13722       -.32861D-02   -.83661D-01    .53818D-03   -.13009D-01    .65861
 DURBIN-WATSON = 1.3298     VON NEUMAN RATIO = 1.3330     FIRST-ORDER RHO =  0.3351
 RESIDUAL SUM =  -.73079D-06  RESIDUAL VARIANCE =    .10186
 SUM OF ABSOLUTE ERRORS=    86.936
 R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.3138
 LOG-LIKELIHOOD FUNCTION =    -144.2468
  END OF SUBPROBLEM  1
       1.200 SEC. CPU TIME
     END OF SUBPROBLEMS
 SINCE 84.090 YOU HAVE USED:     998.05 CPU SECONDS IN     92 RUNS OF SHAZAM CMS.

R;  T=0.08/0.45 22:08:33
```

APPENDIX A5 PKMIX (Peak Period Model)

```
TYPE MSLOG PKMIX
TYPE MSLOG PKMIX


 WORKSPACE IS  503K
 SHAZAM (VERSION 3.1.1 - JULY 1980)    SOLOMON 33 623 TEST RUN CRD MODE CHOICE
 NAME 2 SUBREGN 4 RESTYPE 5 POPHOUSE 6 CARAVAIL 7 EMPHOUSE 8 INCHOUSE 14 T
      15 AUTO 16 CARPASS 19 ORGDEN 20 DESEMP 21 ORGEMP 22 DESDEN 23 COSTAUTO
      24 COSTTRAN 25 TTIMAUT 26 TTIMTRN 27 OUTIMA 28 OUTIMT 29 INTIMA 30 INTIMT
      32 LSERVT 33 LSERVA 31 TRNSFERS 17 TRANSIT 10 SEX 11 AGE 18 PURPOSE
      12 O 13 D
 GENR TRFRS=(TRNSFERS*.25)
 GENR HINC=0
 GENR V=(SUBREGN.EQ.1)
 GENR S=(SUBREGN.EQ.2)
 GENR OB=(SUBREGN.EQ.3)
 GENR EV=(SUBREGN.EQ.4).OR.(SUBREGN.EQ.7)
 GENR ST23=0
 GENR ST21=0
 GENR ST19=0
 GENR ST17=0
 GENR ST15=0
 GENR ST13=0
 GENR ST11=0
 GENR ST9=0
 GENR ST7=0
 GENR ST5=0
 GENR X=(T.GE.2200).AND.(T.LT.2500)
 IF(X.EQ.1)ST23=1
 GENR X=  (T.GE.2000).AND.(T.LT.2200)
 IF(X.EQ.1)ST21=1
 GENR X=  (T.GE.1800).AND.(T.LT.2000)
 IF(X.EQ.1)ST19=1
 GENR X=  (T.GE.1600).AND.(T.LT.1800)
 IF(X.EQ.1)ST17=1
 GENR X=  (T.GE.1400).AND.(T.LT.1600)
 IF(X.EQ.1)ST15=1
 GENR X=  (T.GE.1200).AND.(T.LT.1400)
 IF(X.EQ.1)ST13=1
 GENR X=  (T.GE.1000).AND.(T.LT.1200)
 IF(X.EQ.1)ST11=1
 GENR X=  (T.GE.800).AND.(T.LT.1000)
 IF(X.EQ.1)ST9=1
 GENR X=  (T.GE.600).AND.(T.LT.800)
 IF(X.EQ.1)ST7=1
 GENR X=  (T.GE.400).AND.(T.LT.600)
 IF(X.EQ.1)ST5=1
 IF(INCHOUSE .EQ. 1) HINC=( 4000/100*EMPHOUSE/POPHOUSE)
 IF(INCHOUSE .EQ. 2) HINC=( 6000/100*EMPHOUSE/POPHOUSE)
 IF(INCHOUSE .EQ. 3) HINC=( 8500/100*EMPHOUSE/POPHOUSE)
 IF(INCHOUSE .EQ. 4) HINC=(12000/100*EMPHOUSE/POPHOUSE)
 IF(INCHOUSE .EQ. 5) HINC=(17000/100*EMPHOUSE/POPHOUSE)
 IF(INCHOUSE .EQ. 6) HINC=(25000/100*EMPHOUSE/POPHOUSE)
 IF(INCHOUSE .EQ. 7) HINC=(35000/100*EMPHOUSE/POPHOUSE)
 GENR PEAK=(ST5.EQ.1).OR.(ST7.EQ.1).OR.(ST9.EQ.1).OR.(ST17.EQ.1)
 SKIP IF(PEAK.EQ.0)
 GENR COST=COSTAUTO-COSTTRAN
 GENR TIM=TTIMTRN-TTIMAUT
 GENR OUT=OUTIMT-OUTIMA+TRFRS
 GENR TIMVAL=TIM*OUT*10
 GENR SER=LSERVT/LSERVA*2
 GENR TPROP=0
 IF(DESEMP.EQ.0)DESEMP=1
 IF(ORGEMP.EQ.0)ORGEMP=1
 IF(PURPOSE.EQ.1)TPROP=(DESDEN/ORGDEN)+(ORGEMP/DESEMP)
 IF(PURPOSE.EQ.6)TPROP=(ORGDEN/DESDEN)+(DESEMP/ORGEMP)
 GENR Y=(O.GE.140).AND.(O.LE.163).OR.(O.EQ.121).OR.(O.EQ.122).OR.
       (O.GE.190).AND.(O.LE.201)
 GENR Z=(D.GE.140).AND.(D.LE.163).OR.(D.EQ.121).OR.(D.EQ.122).OR.
      (D.GE.190).AND.(D.LE.201)
 GENR DTN=Y+Z
 IF(DTN.EQ.2)DTN=1
 SKIP IF(DTN.EQ.3)
 DATA COMMAND = DATA FILE
 .....EFFICIENT REGION SET TO  60 VARIABLES AND      2030 OBSERVATIONS
    THE LISTING OF SKIPPED OBSERVATIONS HAS BEEN DELETED FROM THIS PRINT OUT..
 ...YOUR LARGE AMOUNT OF DATA USES LOTS OF MEMORY
 ...IF POSSIBLE USE THE NOHD OR DP OPTIONS TO REDUCE MEMORY REQUIRED
 SHAZAM (VERSION 3.1.1 - JULY 1980)    SOLOMON 33 623 TEST RUN CRD MODE CHOICE

 NUMBER OF OBSERVATIONS=   416
 NUMBER OF INPUT VARIABLES= 33
 USING OBSERVATIONS    1 THRU   623
 NUMBER OF VARIABLES AFTER TRANSFORMATION = 60
```

VARIABLE NAME	NO.	MEAN	STANDARD DEVIATION	VARIANCE	MINIMUM	MAXIMUM
	1	923.68	596.01	.35523D+06	4.0000	2232.0
SUBREGN	2	1.9374	1.0352	1.0716	1.0000	7.0000
	3	304.61	173.57	30127.	4.0000	671.00
RESTYPE	4	1.5843	1.1836	1.4008	1.0000	5.0000
POPHOUSE	5	3.4414	1.3607	1.8515	1.0000	7.0000
CARAVAIL	6	.87165	.55573	.30884	.0	4.0000
EMPHOUSE	7	2.1413	1.1437	1.3080	1.0000	6.0000
INCHOUSE	8	5.2343	1.2792	1.6363	1.0000	7.0000
	9	1.6019	.85555	.73196	1.0000	5.0000
SEX	10	1.3933	.48887	.23899	1.0000	2.0000
AGE	11	3.1429	.89863	.80753	1.0000	5.0000
O	12	286.23	182.78	33407.	11.000	991.00
D	13	280.80	177.67	31568.	11.000	991.00
T	14	1278.1	455.37	.20736D+06	400.00	2530.0
AUTO	15	.69663	.46008	.21168	.0	1.0000
CARPASS	16	.14928	.35665	.12720	.0	1.0000
TRANSIT	17	.15249	.35978	.12944	.0	1.0000
PURPOSE	18	3.5522	2.5015	6.2573	1.0000	6.0000
ORGDEN	19	2357.5	1297.8	.16842D+07	124.00	6455.0
DESEMP	20	673.43	922.94	.85181D+06	.0	4982.0
ORGEMP	21	688.21	935.01	.87425D+06	.0	4982.0
DESDEN	22	2358.3	1289.4	.16625D+07	124.00	6455.0
COSTAUTO	23	11.662	9.6383	92.896	2.0290	94.680
COSTTRAN	24	11.195	6.2848	39.499	5.3530	41.630
TTIMAUT	25	13.774	6.8236	46.561	3.0000	45.000
TTIMTRN	26	27.528	14.814	219.44	5.0000	105.00
OUTIMA	27	2.6934	.94923	.90103	1.0000	7.0000
OUTIMT	28	10.393	5.0890	25.898	3.0000	25.000
INTIMA	29	11.021	6.6833	44.667	1.0000	42.000
INTIMT	30	17.173	11.915	141.97	1.0000	80.000
TRNSFERS	31	.43820	.50935	.25944	.0	2.0000
LSERVT	32	10.561	4.6520	21.642	3.3000	26.100
LSERVA	33	2.3515	.89120	.79424	1.0000	3.0000
TRFRS	34	.10955	.12734	.16215D-01	.0	.50000
HINC	35	139.98	83.749	7013.8	12.143	350.00
V	36	.39647	.48956	.23967	.0	1.0000
S	37	.39326	.48887	.23899	.0	1.0000
OB	38	.11075	.31408	.98646D-01	.0	1.0000
EV	39	.99518D-01	.29960	.89759D-01	.0	1.0000
ST23	40	.17657D-01	.13181	.17373D-01	.0	1.0000
ST21	41	.22472D-01	.14833	.22002D-01	.0	1.0000
ST19	42	.57785D-01	.23352	.54533D-01	.0	1.0000
ST17	43	.29374	.45584	.20779	.0	1.0000
ST15	44	.93098D-01	.29080	.84566D-01	.0	1.0000
ST13	45	.10112	.30173	.91044D-01	.0	1.0000
ST11	46	.38523D-01	.19261	.37099D-01	.0	1.0000
ST9	47	.17175	.37747	.14248	.0	1.0000
ST7	48	.18941	.39215	.15378	.0	1.0000
ST5	49	.12841D-01	.11268	.12697D-01	.0	1.0000
X	50	.12841D-01	.11268	.12697D-01	.0	1.0000
PEAK	51	.66774	.47140	.22222	.0	1.0000
COST	52	.46625	6.5731	43.206	-19.390	53.050
TIM	53	13.754	9.7642	95.340	-5.0000	73.000
OUT	54	7.8094	5.3402	28.518	-1.0000	23.500
TIMVAL	55	1485.7	1908.4	.36418D+07	-200.00	17155.
SER	56	11.943	10.001	100.01	2.2000	52.200
TPROP	57	9.8256	31.826	1012.9	.11204	340.66
Y	58	.16533	.37178	.13822	.0	1.0000
Z	59	.18459	.38828	.15076	.0	1.0000
DTN	60	.34671	.47630	.22687	.0	1.0000

```
SUBPROBLEM NO.  1          SOLOMON 33 623 TEST RUN CRD MODE CHOICE
LOGIT TRANSIT CARAVAIL SEX SER AGE COST OUT TPROP HINC  / RS CV
THIS PROBLEM USES  216K
 LOGIT ANALYSIS     DEPENDENT VARIABLE =  17  TRANSIT
      623 TOTAL OBSERVATIONS
       95 OBSERVATIONS AT ONE
      528 OBSERVATIONS AT ZERO
   25 MAXIMUM ITERATIONS
CONVERGENCE TOLERANCE =0.00100
```

```
LOG OF LIKELIHOOD FOR BINOMIAL MODEL =     -266.02
BINOMIAL  ESTIMATE =0.1525
ITERATION  0       LOG OF LIKELIHOOD FUNCTION =      -266.02
ITERATION  1 ESTIMATES
-1.1316        .37386        .70901D-01 -.28007        .34218D-01 -.71888D-01 -.67088
ITERATION  1       LOG OF LIKELIHOOD FUNCTION =      -212.88
ITERATION  2 ESTIMATES
-1.5710        .36737        .49830D-01 -.26620        .41010D-01 -.10279     -.30296
ITERATION  2       LOG OF LIKELIHOOD FUNCTION =      -201.92
ITERATION  3 ESTIMATES
-1.8317        .39156        .51193D-01 -.27403        .44730D-01 -.11165     -.17429
ITERATION  3       LOG OF LIKELIHOOD FUNCTION =      -201.36
ITERATION  4 ESTIMATES
-1.8589        .39424        .51312D-01 -.27473        .45056D-01 -.11243     -.16279
ITERATION  4       LOG OF LIKELIHOOD FUNCTION =      -201.35
ITERATION  5 ESTIMATES
-1.8591        .39427        .51313D-01 -.27473        .45059D-01 -.11244     -.16270

    MAXIMUM LIKELIHOOD ESTIMATES
                    ESTIMATES       STANDARD ERRORS     T-RATIOS
  6 CARAVAIL         -1.8591           .33607          -5.5320
 10 SEX               .39427           .26662           1.4788
 56 SER               .51313D-01       .12428D-01       4.1290
 11 AGE              -.27473           .14135          -1.9436
 52 COST              .45059D-01       .20716D-01       2.1750
 54 OUT              -.11244           .31738D-01      -3.5426
 61 CONSTANT         -.16270           .67640          -.24053

     LIKELIHOOD RATIO  TEST      129.335      WITH       6  D.F.
ITERATION  5 ASYM. COVARIANCE MATRIX
   .11294
   .71027D-02    .71085D-01
  -.39149D-03   -.80925D-03    .15445D-03
  -.63227D-02    .16841D-02    .12544D-03    .19981D-01
  -.94991D-03    .25385D-03    .15270D-04    .50039D-04    .42917D-03
   .57272D-03   -.54397D-03    .15662D-03    .61198D-04   -.15558D-03    .10073D-02
  -.58242D-01   -.10130       -.22474D-02   -.59071D-01    .53802D-03   -.78524D-02    .45752
DURBIN-WATSON = 1.2578    VON NEUMAN RATIO = 1.2598    FIRST-ORDER RHO =  0.3711
RESIDUAL SUM =  -.31290D-06  RESIDUAL VARIANCE =   .94117D-01
SUM OF ABSOLUTE ERRORS=   119.46
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.2738
LOG-LIKELIHOOD FUNCTION =   -201.3541
 END OF SUBPROBLEM  1
      1.787 SEC.  CPU TIME
    END OF SUBPROBLEMS
SINCE 84.090 YOU HAVE USED     990.90 CPU SECONDS IN    91 RUNS OF SHAZAM CMS.

R; T=0.09/0.54 22:31:07
```

APPENDIX A6 DTNMIX (Downtown-Based Model)

```
TYPE MSLOG DTNMIX
TYPE MSLOG DTNMIX


WORKSPACE IS  503K
SHAZAM (VERSION 3.1.1 - JULY 1980)    SOLOMON 33 623 TEST RUN CRD MODE CHOICE
NAME 2 SUBREGN 4 RESTYPE 5 POPHOUSE 6 CARAVAIL 7 EMPHOUSE 8 INCHOUSE 14 T
     15 AUTO 16 CARPASS 19 ORGDEN 20 DESEMP 21 ORGEMP 22 DESDEN 23 COSTAUTO
     24 COSTTRAN 25 TTIMAUT 26 TTIMTRN 27 OUTIMA 28 OUTIMT 29 INTIMA 30 INTIMT
     32 LSERVT 33 LSERVA 31 TRNSFERS 17 TRANSIT 10 SEX 11 AGE 18 PURPOSE
     12 O 13 D
GENR TRFRS=(TRNSFERS*.25)
GENR HINC=0
GENR V=(SUBREGN.EQ.1)
GENR S=(SUBREGN.EQ.2)
GENR OB=(SUBREGN.EQ.3)
GENR EV=(SUBREGN.EQ.4).OR.(SUBREGN.EQ.7)
GENR ST23=0
GENR ST21=0
GENR ST19=0
GENR ST17=0
GENR ST15=0
GENR ST13=0
GENR ST11=0
GENR ST9=0
GENR ST7=0
GENR ST5=0
GENR X=(T.GE.2200).AND.(T.LT.2500)
IF(X.EQ.1)ST23=1
GENR X=  (T.GE.2000).AND.(T.LT.2200)
IF(X.EQ.1)ST21=1
GENR X=  (T.GE.1800).AND.(T.LT.2000)
IF(X.EQ.1)ST19=1
GENR X=  (T.GE.1600).AND.(T.LT.1800)
IF(X.EQ.1)ST17=1
GENR X=  (T.GE.1400).AND.(T.LT.1600)
IF(X.EQ.1)ST15=1
GENR X=  (T.GE.1200).AND.(T.LT.1400)
IF(X.EQ.1)ST13=1
GENR X=  (T.GE 1000).AND.(T.LT.1200)
IF(X.EQ.1)ST11=1
GENR X=  (T.GE 800).AND.(T.LT.1000)
IF(X.EQ.1)ST9=1
GENR X=  (T.GE.600).AND.(T.LT.800)
IF(X.EQ.1)ST7=1
GENR X=  (T.GE.400).AND.(T.LT.600)
IF(X.EQ.1)ST5=1
IF(INCHOUSE .EQ. 1) HINC=( 4000/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 2) HINC=( 6000/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 3) HINC=( 8500/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 4) HINC=(12000/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 5) HINC=(17000/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 6) HINC=(25000/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 7) HINC=(35000/100*EMPHOUSE/POPHOUSE)
GENR PEAK=(ST5.EQ.1).OR.(ST7.EQ.1).OR.(ST9.EQ.1).OR.(ST17.EQ.1)
SKIP IF(PEAK.EQ.3)
GENR COST=COSTAUTO-COSTTRAN
GENR TIM=TTIMTRN-TTIMAUT
GENR OUT=OUTIMT-OUTIMA+TRFRS
GENR TIMVAL=TIM*OUT*10
GENR SER=LSERVT/LSERVA*2
GENR TPROP=0
IF(DESEMP.EQ.0)DESEMP=1
IF(ORGEMP.EQ.0)ORGEMP=1
IF(PURPOSE.EQ.1)TPROP=(DESDEN/ORGDEN)+(ORGEMP/DESEMP)
IF(PURPOSE.EQ.6)TPROP=(ORGDEN/DESDEN)+(DESEMP/ORGEMP)
GENR Y=(O.GE.140).AND.(O.LE.163).OR.(O.EQ.121).OR.(O.EQ.122).OR.
      (O.GE.190).AND.(O.LE.201)
GENR Z=(D.GE.140).AND.(D.LE.163).OR.(D.EQ.121).OR.(D.EQ.122).OR.
     (D.GE.190).AND.(D.LE.201)
GENR DTN=Y+Z
IF(DTN.EQ.2)DTN=1
SKIP IF(DTN.EQ.0)
DATA COMMAND = DATA FILE
......EFFICIENT REGION SET TO  60 VARIABLES AND      2030 OBSERVATIONS
  THE LISTING OF SKIPPED OBSERVATIONS HAS BEEN DELETED FROM THIS PRINT OUT...
...YOUR LARGE AMOUNT OF DATA USES LOTS OF MEMORY
...IF POSSIBLE USE THE NOHD OR DP OPTIONS TO REDUCE MEMORY REQUIRED
SHAZAM (VERSION 3.1.1 - JULY 1980)    SOLOMON 33 623 TEST RUN CRD MODE CHOICE

NUMBER OF OBSERVATIONS=   216
NUMBER OF INPUT VARIABLES= 33
USING OBSERVATIONS    1 THRU   612
NUMBER OF VARIABLES AFTER TRANSFORMATION = 60
```

APPENDIX A6 - 1

VARIABLE NAME	NO.	MEAN	STANDARD DEVIATION	VARIANCE	MINIMUM	MAXIMUM
	1	889.88	605.90	.36711D+06	22.000	2026.0
SUBREGN	2	1.9907	1.1412	1.3022	1.0000	7.0000
	3	296.94	179.12	32083.	4.0000	671.00
RESTYPE	4	1.6898	1.2616	1.5917	1.0000	5.0000
POPHOUSE	5	3.4583	1.4103	1.9890	1.0000	7.0000
CARAVAIL	6	.83148	.58894	.34685	.0	4.0000
EMPHOUSE	7	2.1713	1.1547	1.3333	1.0000	5.0000
INCHOUSE	8	5.2222	1.2856	1.6527	1.0000	7.0000
	9	1.7685	.95583	.91361	1.0000	5.0000
SEX	10	1.5139	.50097	.25097	1.0000	2.0000
AGE	11	3.0509	.93122	.86716	1.0000	5.0000
O	12	236.05	164.26	26980.	12.000	961.00
D	13	223.62	149.83	22450.	12.000	891.00
T	14	1265.3	457.59	.20939D+06	500.00	2400.0
AUTO	15	.51852	.50082	.25082	.0	1.0000
CARPASS	16	.18981	.39307	.15450	.0	1.0000
TRANSIT	17	.29167	.45559	.20756	.0	1.0000
PURPOSE	18	3.6389	2.5019	6.2597	1.0000	6.0000
ORGDEN	19	2269.2	1273.6	.16220D+07	124.00	6455.0
DESEMP	20	818.91	754.28	.56893D+06	1.0000	2398.0
ORGEMP	21	804.63	759.69	.57713D+06	1.0000	3261.0
DESDEN	22	2292.4	1279.1	.16361D+07	129.00	6455.0
COSTAUTO	23	11.161	9.3367	87.174	2.5060	94.680
COSTTRAN	24	11.236	6.1995	38.434	5.3530	41.630
TTIMAUT	25	13.361	5.2242	27.292	3.0000	30.000
TTIMTRN	26	22.389	9.8253	96.536	5.0000	61.000
OUTIMA	27	3.0278	1.1449	1.3109	1.0000	7.0000
OUTIMT	28	7.3426	3.5872	12.868	3.0000	23.000
INTIMA	29	10.306	5.1344	26.362	2.0000	28.000
INTIMT	30	15.037	8.0751	65.208	1.0000	38.000
TRNSFERS	31	.11111	.31500	.99225D-01	.0	1.0000
LSERVT	32	11.787	5.0712	25.717	4.4000	26.100
LSERVA	33	1.2130	.43243	.18699	1.0000	3.0000
TRFRS	34	.27778D-01	.78750D-01	.62016D-02	.0	.25000
HINC	35	143.99	87.765	7702.7	12.143	350.00
V	36	.41204	.49335	.24339	.0	1.0000
S	37	.34259	.47568	.22627	.0	1.0000
OB	38	.12963	.33668	.11335	.0	1.0000
EV	39	.11574	.32066	.10282	.0	1.0000
ST23	40	.23148D-01	.15072	.22717D-01	.0	1.0000
ST21	41	.13889D-01	.11730	.13760D-01	.0	1.0000
ST19	42	.37037D-01	.18929	.35831D-01	.0	1.0000
ST17	43	.33796	.47411	.22478	.0	1.0000
ST15	44	.87963D-01	.28390	.80599D-01	.0	1.0000
ST13	45	.41667D-01	.20029	.40116D-01	.0	1.0000
ST11	46	.46296D-01	.21061	.44358D-01	.0	1.0000
ST9	47	.22685	.41977	.17621	.0	1.0000
ST7	48	.18056	.38554	.14864	.0	1.0000
ST5	49	.46296D-02	.68041D-01	.46296D-02	.0	1.0000
X	50	.46296D-02	.68041D-01	.46296D-02	.0	1.0000
PEAK	51	.75000	.43402	.18837	.0	1.0000
COST	52	-.74384D-01	6.3408	40.206	-17.027	53.050
TIM	53	9.0278	6.3429	40.232	-1.0000	41.000
OUT	54	4.3426	3.7036	13.717	-1.0000	19.000
TIMVAL	55	584.34	1029.5	.10598D+07	-50.000	7790.0
SER	56	21.553	11.233	126.17	4.4000	52.200
TPROP	57	33.425	124.91	15603	.24711	1051.5
Y	58	.47685	.50062	.25062	.0	1.0000
Z	59	.53241	.50011	.25011	.0	1.0000
DTN	60	1.0000	.0	.0	1.0000	1.0000

1SUBPROBLEM NO. 1 SOLOMON 33 623 TEST RUN CRD MODE CHOICE
LOGIT TRANSIT CARAVAIL SEX SER AGE COST OUT / RS CV
THIS PROBLEM USES 180K
LOGIT ANALYSIS DEPENDENT VARIABLE = 17 TRANSIT
216 TOTAL OBSERVATIONS
63 OBSERVATIONS AT ONE
153 OBSERVATIONS AT ZERO
25 MAXIMUM ITERATIONS
CONVERGENCE TOLERANCE =0.00100

LOG OF LIKELIHOOD FOR BINOMIAL MODEL = -130.39
BINOMIAL ESTIMATE =0.2917
ITERATION 0 LOG OF LIKELIHOOD FUNCTION = -130.39
ITERATION 1 ESTIMATES
-.93889 .15416 .46457D-01 -.24795 .48996D-01 -.11708 -.72741D-01
ITERATION 1 LOG OF LIKELIHOOD FUNCTION = -104.55
ITERATION 2 ESTIMATES
-1.2439 .14584 .48024D-01 -.30521 .61953D-01 -.18246 .34718
ITERATION 2 LOG OF LIKELIHOOD FUNCTION = -102.29
ITERATION 3 ESTIMATES
-1.3083 .15055 .48920D-01 -.31793 .65613D-01 -.19987 .42884
ITERATION 3 LOG OF LIKELIHOOD FUNCTION = -102.21
ITERATION 4 ESTIMATES
-1.3104 .15112 .48967D-01 -.31848 .65788D-01 -.20081 .43151

```
     MAXIMUM LIKELIHOOD ESTIMATES
                      ESTIMATES        STANDARD ERRORS     T-RATIOS
      6 CARAVAIL       -1.3104           .39670           -3.3032
     10 SEX             .15112           .37562            .40231
     56 SER             .48967D-01       .16315D-01       3.0013
     11 AGE            -.31848           .19530           -1.6307
     52 COST            .65788D-01       .28462D-01       2.3114
     54 OUT            -.20081           .65340D-01       -3.0732
     61 CONSTANT        .43151          1.0630             .40593

         LIKELIHOOD RATIO  TEST      56.3475      WITH       6  D.F.
    ITERATION  4 ASYM. COVARIANCE MATRIX
       .15737
      .34003D-01    .14109
     -.10209D-02   -.93334D-03    .26619D-03
     -.82844D-02    .97602D-02    .42148D-03    .38141D-01
     -.36010D-02   -.34469D-05    .84492D-04    .50865D-03    .81007D-03
     -.25290D-03    .14710D-02    .16197D-03    .78939D-03   -.38708D-03    .42694D-02
     -.11526       -.26152       -.58624D-02   -.13318        .27591D-03   -.22405D-01    1.1300
    DURBIN-WATSON = 1.2702    VON NEUMAN RATIO = 1.2761    FIRST-ORDER RHO =  0.3647
    RESIDUAL SUM =  -.10579D-03  RESIDUAL VARIANCE =    .15099
    SUM OF ABSOLUTE ERRORS=    65.918
    R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.2730
    LOG-LIKELIHOOD FUNCTION =    -102.2117
     END OF SUBPROBLEM  1
          0.480 SEC.  CPU TIME
         END OF SUBPROBLEMS
    SINCE 84.090 YOU HAVE USED:    1003.48 CPU SECONDS IN     93 RUNS OF SHAZAM CMS.

R; T=0.07/0.44 22:02:31
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APPENDIX A7 NOPDMIX (Non-Peak and Non-Downtown Based Model)

```
MSLOG NOPDMIX
TYPE MSLOG NOPDMIX


WORKSPACE IS  503K
SHAZAM (VERSION 3.1.1 - JULY 1980)    SOLOMON 33 623 TEST RUN CRD MODE CHOICE
NAME 2 SUBREGN 4 RESTYPE 5 POPHOUSE 6 CARAVAIL 7 EMPHOUSE 8 INCHOUSE 14 T
     15 AUTO 16 CARPASS 19 ORGDEN 20 DESEMP 21 ORGEMP 22 DESDEN 23 COSTAUTO
     24 COSTTRAN 25 TTIMAUT 26 TTIMTRN 27 OUTIMA 28 OUTIMT 29 INTIMA 30 INTIMT
     32 LSERVT 33 LSERVA 31 TRNSFERS 17 TRANSIT 10 SEX 11 AGE 18 PURPOSE
     12 O 13 D
GENR TRFRS=(TRNSFERS*.25)
GENR HINC=0
GENR V=(SUBREGN.EQ.1)
GENR S=(SUBREGN.EQ.2)
GENR OB=(SUBREGN.EQ.3)
GENR EV=(SUBREGN.EQ.4).OR.(SUBREGN.EQ.7)
GENR ST23=0
GENR ST21=0
GENR ST19=0
GENR ST17=0
GENR ST15=0
GENR ST13=0
GENR ST11=0
GENR ST9=0
GENR ST7=0
GENR ST5=0
GENR X=(T.GE.2200).AND.(T.LT.2500)
IF(X.EQ.1)ST23=1
GENR X=  (T.GE.2000).AND.(T.LT.2200)
IF(X.EQ.1)ST21=1
GENR X=  (T.GE.1800).AND.(T.LT.2000)
IF(X.EQ.1)ST19=1
GENR X=  (T.GE.1600).AND.(T.LT.1800)
IF(X.EQ.1)ST17=1
GENR X=  (T.GE.1400).AND.(T.LT.1600)
IF(X.EQ.1)ST15=1
GENR X=  (T.GE.1200).AND.(T.LT.1400)
IF(X.EQ.1)ST13=1
GENR X=  (T.GE.1000).AND.(T.LT.1200)
IF(X.EQ.1)ST11=1
GENR X=  (T.GE.800).AND.(T.LT.1000)
IF(X.EQ.1)ST9=1
GENR X=  (T.GE.600).AND.(T.LT.800)
IF(X.EQ.1)ST7=1
GENR X=  (T.GE.400).AND.(T.LT.600)
IF(X.EQ.1)ST5=1
IF(INCHOUSE .EQ. 1) HINC=( 4000/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 2) HINC=( 6000/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 3) HINC=( 8500/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 4) HINC=(12000/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 5) HINC=(17000/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 6) HINC=(25000/100*EMPHOUSE/POPHOUSE)
IF(INCHOUSE .EQ. 7) HINC=(35000/100*EMPHOUSE/POPHOUSE)
GENR PEAK=(ST5.EQ.1).OR.(ST7.EQ.1).OR.(ST9.EQ.1).OR.(ST17.EQ.1)
SKIP IF(PEAK.EQ.1)
GENR COST=COSTAUTO-COSTTRAN
GENR TIM=TTIMTRN-TTIMAUT
GENR OUT=OUTIMT-OUTIMA+TRFRS
GENR TIMVAL=TIM*OUT*10
```

```
GENR SER=LSERVT/LSERVA*2
GENR TPROP=0
IF(DESEMP.EQ.0)DESEMP=1
IF(ORGEMP.EQ.0)ORGEMP=1
IF(PURPOSE.EQ.1)TPROP=(DESDEN/ORGDEN)+(ORGEMP/DESEMP)
IF(PURPOSE.EQ.6)TPROP=(ORGDEN/DESDEN)+(DESEMP/ORGEMP)
GENR Y=(O.GE.140).AND.(O.LE.163).OR.(O.EQ.121).OR.(O.EQ.122).OR.
     (O.GE.190).AND.(O.LE.201)
GENR Z=(D.GE.140).AND.(D.LE.163).OR.(D.EQ.121).OR.(D.EQ.122).OR.
     (D.GE.190).AND.(D.LE.201)
GENR DTN=Y+Z
IF(DTN.EQ.2)DTN=1
SKIP IF(DTN.EQ.1)
DATA COMMAND = DATA FILE
......EFFICIENT REGION SET TO  60 VARIABLES AND      2030 OBSERVATIONS
FIRST FIVE INCLUDED AND LAST OBSERVATION                    LISTING OF SKIPPED OBS HAS BEEN DELETED FROM
 623  2232.0      2.0000      392.00      3.0000      3.0000      1.0000      1.0000      5.0000      1.0000      1.0000
      4.0000      392.00      233.00      800.00      1.0000      .0          .0          6.0000      2487.0      244.00
      680.00      2026.0      3.3420      11.020      4.0000      8.0000      2.0000      5.0000      2.0000      3.0000
      .0          10.500      3.0000      .0          56.667      .0          1.0000      .0          .0          .0
      .0          .0          .0          .0          .0          .0          1.0000      .0          .0          .0
      1.0000      -7.6780     4.0000      3.0000      120.00      7.0000      1.5864      .0          .0          .0
SHAZAM (VERSION 3.1.1 - JULY 1980)    SOLOMON 33 623 TEST RUN CRD MODE CHOICE

NUMBER OF OBSERVATIONS=   153
NUMBER OF INPUT VARIABLES= 33
USING OBSERVATIONS    1 THRU   622
NUMBER OF VARIABLES AFTER TRANSFORMATION = 60
VARIABLE                MEAN        STANDARD      VARIANCE     MINIMUM      MAXIMUM
   NAME     NO.                     DEVIATION
            1    957.56             557.25       .31053D+06    4.0000       2166.0
SUBREGN     2    1.9085             1.0219       1.0442        1.0000       7.0000
            3    293.36             167.15       27940.        12.000       662.00
RESTYPE     4    1.4052             1.0159       1.0321        1.0000       5.0000
POPHOUSE    5    3.5817             1.3747       1.8897        1.0000       6.0000
CARAVAIL    6    .87536             .53560       .28687        .0           3.0000
EMPHOUSE    7    2.2353             1.2658       1.6022        1.0000       6.0000
INCHOUSE    8    5.3922             1.2682       1.6084        1.0000       7.0000
            9    1.6144             .84390       .71216        1.0000       5.0000
SEX        10    1.3922             .48983       .23994        1.0000       2.0000
AGE        11    3.1765             .88197       .77786        1.0000       5.0000
O          12    283.56             182.85       33433.        11.000       982.00
D          13    292.37             178.28       31784.        11.000       991.00
T          14    1517.2             347.26       .12059D+06    1000.0       2530.0
AUTO       15    .80392             .39833       .15867        .0           1.0000
CARPASS    16    .15033             .35857       .12857        .0           1.0000
TRANSIT    17    .45752D-01         .20963       .43946D-01    .0           1.0000
PURPOSE    18    2.7974             2.4071       5.7942        1.0000       6.0000
ORGDEN     19    2551.9             1348.2       .18176D+07    124.00       6455.0
DESEMP     20    544.67             893.21       .79783D+06    1.0000       4982.0
ORGEMP     21    536.29             899.33       .80880D+06    1.0000       4982.0
DESDEN     22    2427.5             1155.7       .13357D+07    124.00       6455.0
COSTAUTO   23    10.065             8.9189       79.547        2.0290       59.170
COSTTRAN   24    10.593             6.2630       39.225        5.3530       41.630
TTIMAUT    25    12.582             7.3392       53.863        4.0000       45.000
TTIMTRN    26    29.046             17.255       297.73        6.0000       105.00
OUTIMA     27    2.4183             .65509       .42914        1.0000       5.0000
OUTIMT     28    11.758             5.0511       25.514        3.0000       25.000
INTIMA     29    10.170             7.2636       52.760        1.0000       42.000
INTIMT     30    17.320             14.245       202.92        1.0000       80.000
TRNSFERS   31    .59477             .50573       .25576        .0           2.0000
```

```
LSERVT      32    8.6856        3.3398        11.154        3.3000        21.000
LSERVA      33    2.9673        .17838        .31820D-01    2.0000        3.0000
TRFRS       34    .14869        .12643        .15985D-01    .0            .50000
HINC        35    143.71        79.775        6364.1        20.000        350.00
V           36    .41176        .49377        .24381        .0            1.0000
S           37    .38562        .48834        .23848        .0            1.0000
OB          38    .10458        .30701        .94255D-01    .0            1.0000
EV          39    .98039D-01    .29834        .89009D-01    .0            1.0000
ST23        40    .39216D-01    .19475        .37926D-01    .0            1.0000
ST21        41    .71895D-01    .25916        .67165D-01    .0            1.0000
ST19        42    .18301        .38794        .15050        .0            1.0000
ST17        43    .0            .0            .0            .0            .0
ST15        44    .25490        .43724        .19118        .0            1.0000
ST13        45    .35294        .47945        .22988        .0            1.0000
ST11        46    .91503D-01    .28927        .83677D-01    .0            1.0000
ST9         47    .0            .0            .0            .0            .0
ST7         48    .0            .0            .0            .0            .0
ST5         49    .0            .0            .0            .0            .0
X           50    .0            .0            .0            .0            .0
PEAK        51    .0            .0            .0            .0            .0
COST        52    -.52728       6.1989        38.426        -14.650       27.950
TIM         53    16.464        11.190        125.21        1.0000        73.000
OUT         54    9.4886        5.1269        26.285        1.0000        23.500
TIMVAL      55    1981.5        2203.5        .48556D+07    10.000        17155.
SER         56    5.9118        2.4196        5.8545        2.2000        14.500
TPROP       57    29.991        149.32        22295.        .11204        1298.8
Y           58    .0            .0            .0            .0            .0
Z           59    .0            .0            .0            .0            .0
DTN         60    .0            .0            .0            .0            .0
SUBPROBLEM NO.   1          SOLOMON 33 623 TEST RUN CRD MODE CHOICE
LOGIT TRANSIT CARAVAIL SEX SER AGE COST OUT   / RS CV
THIS PROBLEM USES  176K
 LOGIT ANALYSIS     DEPENDENT VARIABLE =  17  TRANSIT
      153 TOTAL OBSERVATIONS
        7 OBSERVATIONS AT ONE
      146 OBSERVATIONS AT ZERO
  25 MAXIMUM ITERATIONS
CONVERGENCE TOLERANCE =0.00100

LOG OF LIKELIHOOD FOR BINOMIAL MODEL =    -28.429
BINOMIAL  ESTIMATE =0.0458
ITERATION  0       LOG OF LIKELIHOOD FUNCTION =     -28.429
ITERATION  1 ESTIMATES
-.99950       2.0643      -.16100       .35021       .20118D-01   .76573D-02 -5.2593
ITERATION  1       LOG OF LIKELIHOOD FUNCTION =     -24.317
ITERATION  2 ESTIMATES
-1.7174       2.1822      -.16043       .48766       .21176D-01   .11617D-01 -5.9857
ITERATION  2       LOG OF LIKELIHOOD FUNCTION =     -22.310
ITERATION  3 ESTIMATES
-2.4353       2.4064      -.16135       .63985       .23923D-01   .15039D-01 -6.6364
ITERATION  3       LOG OF LIKELIHOOD FUNCTION =     -21.989
ITERATION  4 ESTIMATES
-2.6695       2.5095      -.15914       .69216       .25423D-01   .15482D-01 -6.9144
ITERATION  4       LOG OF LIKELIHOOD FUNCTION =     -21.968
ITERATION  5 ESTIMATES
-2.6870       2.5194      -.15875       .69616       .25566D-01   .15485D-01 -6.9407
```

```
     MAXIMUM LIKELIHOOD ESTIMATES
                        ESTIMATES          STANDARD ERRORS      T-RATIOS
      6 CARAVAIL        -2.6870             1.5306             -1.7555
     10 SEX              2.5194             1.1726              2.1485
     56 SER             -.15875             .24650             -.64402
     11 AGE              .69616             .57864              1.2031
     52 COST             .25566D-01         .88742D-01          .28810
     54 OUT              .15485D-01         .91475D-01          .16928
     61 CONSTANT       -6.9407              3.4823             -1.9932


       LIKELIHOOD RATIO  TEST      12.9212      WITH       6  D.F.
   ITERATION  5 ASYM.  COVARIANCE MATRIX
      2.3423
     -.35175          1.3751
     -.66207D-01      .95009D-02    .60761D-01
     -.38183          .17561        .17928D-02    .33482
     -.14834D-01      .12723D-01    .24128D-02   -.83101D-02    .78752D-02
      .57895D-02     -.10137D-01    .21235D-02    .12730D-01   -.37319D-02    .83677D-02
      .88766        -2.8250        -.32042       -1.3258        .41029D-01   -.12912        12.126
   DURBIN-WATSON = 2.0310     VON NEUMAN RATIO = 2.0444     FIRST-ORDER RHO = -0.0155
   RESIDUAL SUM =  -.10071D-03  RESIDUAL VARIANCE =    .41125D-01
   SUM OF ABSOLUTE ERRORS=    12.178
   R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.0694
   LOG-LIKELIHOOD FUNCTION =    -21.96838
    END OF SUBPROBLEM  1
         0.500 SEC.  CPU TIME
       END OF SUBPROBLEMS
   SINCE 84.090 YOU HAVE USED:    1013.85 CPU SECONDS IN     95 RUNS OF SHAZAM CMS.

R;  T=0.08/0.46 21:52:20
```

APPENDIX B SAMPLE SURVEY FORM (1977 Home Interview Survey - CRD)

CAPITAL REGIONAL DISTRICT
1977 TRANSPORTATION STUDY / HOME INTERVIEW SURVEY

DWELLING UNIT SUMMARY

C

C1	C2	C3	C4	C5
Sample Number	Sub - Region 1. Victoria 2. Saanich 3. Oak Bay 4. Esquimalt 5. Langford 6. Metchosin 7. View Royal 8. Central Saanich 9. Sidney 10. N. Saanich	District	Transportation Zone	Day 1. Mon. 2. Tues. 3. Wed. 4. Thur. 5. Fri. 6. Sat. 7. Sun.
1 2 3 4 5 6		7 8 9	10 11 12 13	14

D

D1	D2	D3	D4	D5	D6	D7	D8
Structure Type 1. Single Family 2. Duplex 3. Converted Structure 4. Apartment 5. Row House 6. Mobile Home 7. Institutional, Rooming House other	Total No. of persons in premises.	No. of persons less than five years old.	No. of passenger vehicles owned or available for use in premises.	No. of bikes owned or available for use.	Other vehicles (pick-up, trucks, Motorbike, etc.)	No. of employed persons	Total Household Income (Annual) 1. Under 5,000 2. 5,000 - 6,999 3. 7,000 - 9,999 4. 10,000-18,999 5. 14,000-19,999 6. Over 20,000
15	16 17	18	19 20	21	22	23	24

ADMINISTRATIVE RECORD

E

E1

Interviewer:
Contact Record:

Date	Time	Comment

Report Submitted
Date: Complete Incomplete
Reasons for Incomplete Report:
Interviewer's initials:

E2

Date:
Supervisor's comment:

Date:
Interviews checked by:

Date coded:
Coder:

Date:
Coding checked by:

E3

Remarks:

Interview Code:
1. Complete
2. Sickness
3. No one at home
4. Refused
5. Partial
6. Other
25

INTERNAL TRIP REPORT

A

A1	A2	A3
Trip-maker Number	SEX 1. Male 2. Female	AGE 1. 5-15 2. 16-25 3. 26-40 4. 41-65 5. 66 & over
26 27	28	29

B

B1	B2	B3	B4		B5	B6		B7	B8	B9	B10
Trip Number	Origin (Where does this trip begin?)	Destination (Where does this trip end?)	Time of Trip		Mode of Travel	Purpose		Auto Driver – No. of Occupants	Parking Location (If trip begins or ends in downtown)	Transit Passenger – Transfer YES or NO	If mode of Travel is 7(B5), location of mode change
			START	END	1. Auto Driver 2. Auto Passenger 3. Transit 4. Truck Driver 5. Truck Passenger 6. Taxi Passenger 7. Park and Ride 8. Bike 9. Walk to work 10. School bus 11. Other	1. Work 2. Shop 3. Business/Medical-Dental 4. Social/Recreational/Entertainment 5. School 6. Home 7. Serve Passenger 8. Other					
30 31	32 33 34 35	36 37 38 39	40 41 42 43	44 45 46 47	48	FROM 49	TO 50	51	52 53 54 55	56	57 58 59 60
30 31	32 33 34 35	36 37 38 39	40 41 42 43	44 45 46 47	48	49	50	51	52 53 54 55	56	57 58 59 60
30 31	32 33 34 35	36 37 38 39	40 41 42 43	44 45 46 47	48	49	50	51	52 53 54 55	56	57 58 59 60
30 31	32 33 34 35	36 37 38 39	40 41 42 43	44 45 46 47	48	49	50	51	52 53 54 55	56	57 58 59 60
30 31	32 33 34 35	36 37 38 39	40 41 42 43	44 45 46 47	48	49	50	51	52 53 54 55	56	57 58 59 60

APPENDIX C TRAFFIC ZONES (Core Urban Area of Greater Victoria)



APPENDIX C. TRAFFIC ZONE MAP (Core Urban Area Of Greater Victoria Only)

APPENDIX D STUDY SCENARIO COMPUTER OUTPUT FORMS (Example Options)

	SUPER DISTRICT NUMBER	TRAFFIC ZONE NUMBER	TRIP_GEN % Rate work trips	EMP OUT OF AREA % OUTSIDE	TRIP GENERATED TOTAL	TOT_WORK TRIPS EST #1	TOT_WORK TRIPS EST #2	MODAL SPLIT MODEL 4	TRANSIT RIDERSHIP (WORK TRIPS)
1	19	274	27.8	84%	2938	817	1008	0.525	530
2	19	293	27.8	84%	2419	673	831	0.505	419
3	19	371	28.9	89%	1298	375	378	0.388	147
4	19	372	28.9	89%	2597	750	755	0.391	295
5	19	375	28.9	86%	1821	526	514	0.397	204
6	24	443	28.9	86%	3477	1005	981	0.408	400
7	24	442	28.9	86%	2981	861	841	0.411	346
8	24	441	30.0	87%	2761	828	979	0.516	506
9	24	444	30.0	87%	1933	580	685	0.521	357
10	24	445	27.9	93%	3373	941	1174	0.499	586
11	24	446	27.9	93%	2952	824	1028	0.498	511
12	24	447	27.9	93%	2108	588	734	0.485	356
13	27	481	31.5	86%	3060	964	1076	0.466	502
14	27	482	31.5	86%	2040	643	718	0.499	358
15	27	483	31.5	86%	3570	1125	1256	0.549	689
16	28	492	31.8	82%	6396	2034	2358	0.253	596
17	28	493	31.8	82%	5233	1664	1929	0.257	496
18	28	494	31.8	86%	3629	1154	1410	0.262	370
19	28	495	31.8	86%	4354	1385	1692	0.266	450
20	28	571	31.8	86%	6532	2077	2539	0.267	677
21	28	572	31.8	87%	2330	741	851	0.229	194
22	28	573	31.8	87%	1472	468	537	0.230	123
23	28	574	31.8	87%	2330	741	851	0.230	196
				TOTALS >	71,604	21,763	25,125		9,309 TRANSIT RIDES

* * * P O L I C Y * * * S T A T U S * * *	
Statement on policy:	ANY(Y/N) CHANGES? 1=Y, 0=N
HEADWAYS: 2.5	1
5	1
FULL LOAD: 52	0
TRANSIT FARE: 80	0
(cents)	
Enter Policy Values then press key "F9"	
COMMENTS ? :	

Total population served by routes in area A 29,062

(1)	TRANSIT MODE SPLIT FOR TRANSIT PLANNING AREA "A" WORK-BASED TRIPS (APPROX. 90% OF PM PEAK TRIPS)	39.36%	
(2)	PM PEAK TRANSIT RIDERSHIP(4-6 PM) 30% (77 SURVEY)	2793	WORK-BASED RIDES
(3)	PM PEAK HOUR RIDERSHIP (60% of PM Peak Period)	1676	WORK-BASED RIDES
(4)	TOTAL PM PEAK TRANSIT RDRSHP TO AREA "A" (APPROX. AS WORK-BASED +10% -5% FROM AREA "A")	1751	RIDES
(5)	PEAK HOUR BUSES REQUIRED	42.1	BUSES
		43	BUSES (ROUNDED UP)
(6)	PEAK HOUR BUSES REQUIRED TO MAINTAIN HEADWAY	31	BUSES
	(FULL LOAD POLICY IS 52 PASSENGERS / BUS)		
	(ROUND TRIP TIME IS 75 MINUTES)		
	(NOMINAL HEADWAY OF 2.5 MINUTES FOR AREA)		
(7)	COST PER PASSENGER RIDE FOR PEAK HOUR	$0.96	
	(1981-82 Bus operating costs $40.00 / bus hour)		
(8)	PEAK HOUR REVENUE (fare profile constant)	$1,365.81	
(9)	PEAK HOUR OPERATING COSTS (includes fixed overhead)	$1,703.70	
(10)	PROFIT OR LOSS MARGIN IN PERCENT OF OPERATING COSTS	-19.83%	

	SUPER DISTRICT NUMBER	TRAFFIC ZONE NUMBER	TRIP_GEN % Rate work trips	EMP OUT OF AREA % OUTSIDE	TRIP GENERATED TOTAL	TOT_WORK TRIPS EST #1	TOT_WORK TRIPS EST #2	MODAL SPLIT MODEL 4	TRANSIT RIDERSHIP (WORK TRIPS)
1	19	274	27.8	84%	2938	817	1008	0.212	214
2	19	293	27.8	84%	2419	673	831	0.199	165
3	19	371	28.9	89%	1298	375	378	0.134	51
4	19	372	28.9	89%	2597	750	755	0.135	102
5	19	375	28.9	86%	1821	526	514	0.138	71
6	24	443	28.9	86%	3477	1005	981	0.143	141
7	24	442	28.9	86%	2981	861	841	0.145	122
8	24	441	30.0	87%	2761	828	979	0.206	202
9	24	444	30.0	87%	1933	580	685	0.209	144
10	24	445	27.9	93%	3373	941	1174	0.195	229
11	24	446	27.9	93%	2952	824	1028	0.194	200
12	24	447	27.9	93%	2108	588	734	0.187	137
13	27	481	31.5	86%	3060	964	1076	0.175	189
14	27	482	31.5	86%	2040	643	718	0.195	140
15	27	483	31.5	86%	3570	1125	1256	0.228	287
16	28	492	31.8	82%	6396	2034	2358	0.143	337
17	28	493	31.8	82%	5233	1664	1929	0.146	281
18	28	494	31.8	86%	3629	1154	1410	0.149	211
19	28	495	31.8	86%	4354	1385	1692	0.152	257
20	28	571	31.8	86%	6532	2077	2539	0.152	386
21	28	572	31.8	87%	2330	741	851	0.128	108
22	28	573	31.8	87%	1472	468	537	0.128	69
23	28	574	31.8	87%	2330	741	851	0.129	109
	Total population served by routes in area A 29,062		TOTALS >		71,604	21,763	25,125		4,150 TRANSIT RIDES

* * * P O L I C Y * * * * * * S T A T U S * * *		ANY(Y/N) CHANGES? 1=Y, 0=N
Statement on policy:		
HEADWAYS:	5	1
	10	1
FULL LOAD:	52	0
TRANSIT FARE: (cents)	80	0

Enter Policy Values
then press key "F9"

COMMENTS ? :

(1)	TRANSIT MODE SPLIT FOR TRANSIT PLANNING AREA "A" WORK-BASED TRIPS (APPROX. 90% OF PM PEAK TRIPS)	16.62%	
(2)	PM PEAK TRANSIT RIDERSHIP(4-6 PM) 30% (77 SURVEY)	1245	WORK-BASED RIDES
(3)	PM PEAK HOUR RIDERSHIP (60% of PM Peak Period)	747	WORK-BASED RIDES
(4)	TOTAL PM PEAK TRANSIT RDRSHP TO AREA "A" (APPROX. AS WORK-BASED +10% -5% FROM AREA "A")	781	RIDES
(5)	PEAK HOUR BUSES REQUIRED	18.8	BUSES
		19	BUSES (ROUNDED UP)
(6)	PEAK HOUR BUSES REQUIRED TO MAINTAIN HEADWAY (FULL LOAD POLICY IS 52 PASSENGERS / BUS) (ROUND TRIP TIME IS 75 MINUTES) (NOMINAL HEADWAY OF 5 MINUTES FOR AREA)	16	BUSES
(7)	COST PER PASSENGER RIDE FOR PEAK HOUR (1981-82 Bus operating costs $40.00 / bus hour)	$0.97	
(8)	PEAK HOUR REVENUE (fare profile constant)	$608.92	
(9)	PEAK HOUR OPERATING COSTS (includes fixed overhead)	$770.65	
(10)	PROFIT OR LOSS MARGIN IN PERCENT OF OPERATING COSTS	-20.99%	

	SUPER DISTRICT NUMBER	TRAFFIC ZONE NUMBER	TRIP_GEN % Rate work trips	EMP OUT OF AREA % OUTSIDE	TRIP GENERATED TOTAL	TOT_WORK TRIPS EST #1	TOT_WORK TRIPS EST #2	MODAL SPLIT MODEL 4	TRANSIT RIDERSHIP (WORK TRIPS)
1	19	274	27.8	84%	2938	817	1008	0.144	145
2	19	293	27.8	84%	2419	673	831	0.134	111
3	19	371	28.9	89%	1298	375	378	0.088	33
4	19	372	28.9	89%	2597	750	755	0.089	67
5	19	375	28.9	86%	1821	526	514	0.091	47
6	24	443	28.9	86%	3477	1005	981	0.095	93
7	24	442	28.9	86%	2981	861	841	0.096	81
8	24	441	30.0	87%	2761	828	979	0.140	137
9	24	444	30.0	87%	1933	580	685	0.142	97
10	24	445	27.9	93%	3373	941	1174	0.131	154
11	24	446	27.9	93%	2952	824	1028	0.131	134
12	24	447	27.9	93%	2108	588	734	0.125	92
13	27	481	31.5	86%	3060	964	1076	0.117	126
14	27	482	31.5	86%	2040	643	718	0.131	94
15	27	483	31.5	86%	3570	1125	1256	0.156	196
16	28	492	31.8	82%	6396	2034	2358	0.117	275
17	28	493	31.8	82%	5233	1664	1929	0.119	229
18	28	494	31.8	86%	3629	1154	1410	0.122	172
19	28	495	31.8	86%	4354	1385	1692	0.124	210
20	28	571	31.8	86%	6532	2077	2539	0.124	315
21	28	572	31.8	87%	2330	741	851	0.104	88
22	28	573	31.8	87%	1472	468	537	0.104	56
23	28	574	31.8	87%	2330	741	851	0.104	89
				TOTALS >	71,604	21,763	25,125		3,041 TRANSIT RIDES

* * * P O L I C Y * * * * * * S T A T U S * * *	ANY(Y/N) CHANGES? 1=Y, 0=N
Statement on policy:	
BASELINE	
HEADWAYS: 7.5	0
15	0
FULL LOAD: 52	0
TRANSIT FARE: 80 (cents)	0

Enter Policy Values then press key "F9"

COMMENTS ? :

Total population served by routes in area A 29,062

(1)	TRANSIT MODE SPLIT FOR TRANSIT PLANNING AREA "A" WORK-BASED TRIPS (APPROX. 90% OF PM PEAK TRIPS)	11.85%
(2)	PM PEAK TRANSIT RIDERSHIP(4-6 PM) 30% (77 SURVEY)	912 WORK-BASED RIDES
(3)	PM PEAK HOUR RIDERSHIP (60% of PM Peak Period)	547 WORK-BASED RIDES
(4)	TOTAL PM PEAK TRANSIT RDRSHP TO AREA "A" (APPROX. AS WORK-BASED +10% -5% FROM AREA "A")	572 RIDES
(5)	PEAK HOUR BUSES REQUIRED	13.7 BUSES
		14 BUSES (ROUNDED UP)
(6)	PEAK HOUR BUSES REQUIRED TO MAINTAIN HEADWAY	11 BUSES
	(FULL LOAD POLICY IS 52 PASSENGERS / BUS)	
	(ROUND TRIP TIME IS 75 MINUTES)	
	(NOMINAL HEADWAY OF 7.5 MINUTES FOR AREA)	
(7)	COST PER PASSENGER RIDE FOR PEAK HOUR	$0.98
	(1981-82 Bus operating costs $40.00 / bus hour)	
(8)	PEAK HOUR REVENUE (fare profile constant)	$446.15
(9)	PEAK HOUR OPERATING COSTS (includes fixed overhead)	$569.99
(10)	PROFIT OR LOSS MARGIN IN PERCENT OF OPERATING COSTS	-21.73%

	SUPER DISTRICT NUMBER	TRAFFIC ZONE NUMBER	TRIP_GEN % Rate work trips	EMP OUT OF AREA % OUTSIDE	TRIP GENERATED TOTAL	TOT_WORK TRIPS EST #1	TOT_WORK TRIPS EST #2	MODAL SPLIT MODEL 4	TRANSIT RIDERSHIP (WORK TRIPS)
1	19	274	27.8	84%	2938	817	1008	0.117	118
2	19	293	27.8	84%	2419	673	831	0.109	91
3	19	371	28.9	89%	1298	375	378	0.071	27
4	19	372	28.9	89%	2597	750	755	0.072	54
5	19	375	28.9	86%	1821	526	514	0.073	38
6	24	443	28.9	86%	3477	1005	981	0.076	75
7	24	442	28.9	86%	2981	861	841	0.077	65
8	24	441	30.0	87%	2761	828	979	0.114	111
9	24	444	30.0	87%	1933	580	685	0.116	79
10	24	445	27.9	93%	3373	941	1174	0.107	125
11	24	446	27.9	93%	2952	824	1028	0.106	109
12	24	447	27.9	93%	2108	588	734	0.102	75
13	27	481	31.5	86%	3060	964	1076	0.095	102
14	27	482	31.5	86%	2040	643	718	0.107	77
15	27	483	31.5	86%	3570	1125	1256	0.127	160
16	28	492	31.8	82%	6396	2034	2358	0.117	275
17	28	493	31.8	82%	5233	1664	1929	0.119	229
18	28	494	31.8	86%	3629	1154	1410	0.122	172
19	28	495	31.8	86%	4354	1385	1692	0.124	210
20	28	571	31.8	86%	6532	2077	2539	0.124	315
21	28	572	31.8	87%	2330	741	851	0.104	88
22	28	573	31.8	87%	1472	468	537	0.104	56
23	28	574	31.8	87%	2330	741	851	0.104	89
	Total population served by routes in area A 29,062		TOTALS >		71,604	21,763	25,125		2,738 TRANSIT RIDES

* * * P O L I C Y * * * * * * S T A T U S * * *	
Statement on policy:	ANY(Y/N) CHANGES? 1=Y, 0=N
HEADWAYS: 10	1
15	0
FULL LOAD: 52	0
TRANSIT FARE: 80 (cents)	0
Enter Policy Values then press key "F9"	
COMMENTS ? :	

(1)	TRANSIT MODE SPLIT FOR TRANSIT PLANNING AREA "A" WORK-BASED TRIPS (APPROX. 90% OF PM PEAK TRIPS)	10.37%
(2)	PM PEAK TRANSIT RIDERSHIP(4-6 PM) 30% (77 SURVEY)	822 WORK-BASED RIDES
(3)	PM PEAK HOUR RIDERSHIP (60% of PM Peak Period)	493 WORK-BASED RIDES
(4)	TOTAL PM PEAK TRANSIT RDRSHP TO AREA "A" (APPROX. AS WORK-BASED +10% -5% FROM AREA "A")	515 RIDES
(5)	PEAK HOUR BUSES REQUIRED	12.4 BUSES
		13 BUSES (ROUNDED UP)
(6)	PEAK HOUR BUSES REQUIRED TO MAINTAIN HEADWAY	8 BUSES
	(FULL LOAD POLICY IS 52 PASSENGERS / BUS)	
	(ROUND TRIP TIME IS 75 MINUTES)	
	(NOMINAL HEADWAY OF 10 MINUTES FOR AREA)	
(7)	COST PER PASSENGER RIDE FOR PEAK HOUR	$0.93
	(1981-82 Bus operating costs $40.00 / bus hour)	
(8)	PEAK HOUR REVENUE (fare profile constant)	$401.78
(9)	PEAK HOUR OPERATING COSTS (includes fixed overhead)	$515.30
(10)	PROFIT OR LOSS MARGIN IN PERCENT OF OPERATING COSTS	-22.03%

	SUPER DISTRICT NUMBER	TRAFFIC ZONE NUMBER	TRIP_GEN % Rate work trips	EMP OUT OF AREA % OUTSIDE	TRIP GENERATED TOTAL	TOT_WORK TRIPS EST #1	TOT_WORK TRIPS EST #2	MODAL SPLIT MODEL 4	TRANSIT RIDERSHIP (WORK TRIPS)
1	19	274	27.8	84%	2938	817	1008	0.095	96
2	19	293	27.8	84%	2419	673	831	0.088	73
3	19	371	28.9	89%	1298	375	378	0.057	21
4	19	372	28.9	89%	2597	750	755	0.057	43
5	19	375	28.9	86%	1821	526	514	0.059	30
6	24	443	28.9	86%	3477	1005	981	0.061	60
7	24	442	28.9	86%	2981	861	841	0.062	52
8	24	441	30.0	87%	2761	828	979	0.092	90
9	24	444	30.0	87%	1933	580	685	0.094	64
10	24	445	27.9	93%	3373	941	1174	0.086	101
11	24	446	27.9	93%	2952	824	1028	0.086	88
12	24	447	27.9	93%	2108	588	734	0.082	60
13	27	481	31.5	86%	3060	964	1076	0.076	82
14	27	482	31.5	86%	2040	643	718	0.086	62
15	27	483	31.5	86%	3570	1125	1256	0.103	130
16	28	492	31.8	82%	6396	2034	2358	0.094	223
17	28	493	31.8	82%	5233	1664	1929	0.096	186
18	28	494	31.8	86%	3629	1154	1410	0.099	139
19	28	495	31.8	86%	4354	1385	1692	0.100	170
20	28	571	31.8	86%	6532	2077	2539	0.101	256
21	28	572	31.8	87%	2330	741	851	0.084	71
22	28	573	31.8	87%	1472	468	537	0.084	45
23	28	574	31.8	87%	2330	741	851	0.084	72
	TOTALS >				71,604	21,763	25,125		2,216 TRANSIT RIDES

* * * P O L I C Y * * * * * * S T A T U S * * *		
Statement on policy:		ANY(Y/N) CHANGES? 1=Y, 0=N
HEADWAYS:	15	1
	30	1
FULL LOAD:	52	0
TRANSIT FARE: (cents)	80	0

Enter Policy Values then press key "F9"

COMMENTS ? :

Total population served by routes in area A 29,062

(1) TRANSIT MODE SPLIT FOR TRANSIT PLANNING AREA "A"
WORK-BASED TRIPS (APPROX. 90% OF PM PEAK TRIPS) 8.38%

(2) PM PEAK TRANSIT RIDERSHIP(4-6 PM) 30% (77 SURVEY) 665 WORK-BASED RIDES
(3) PM PEAK HOUR RIDERSHIP (60% of PM Peak Period) 399 WORK-BASED RIDES
(4) TOTAL PM PEAK TRANSIT RDRSHP TO AREA "A" 417 RIDES
(APPROX. AS WORK-BASED +10% -5% FROM AREA "A")
(5) PEAK HOUR BUSES REQUIRED 10.0 BUSES
11 BUSES (ROUNDED UP)
(6) PEAK HOUR BUSES REQUIRED TO MAINTAIN HEADWAY 6 BUSES
(FULL LOAD POLICY IS 52 PASSENGERS / BUS)
(ROUND TRIP TIME IS 75 MINUTES)
(NOMINAL HEADWAY OF 15 MINUTES FOR AREA)
(7) COST PER PASSENGER RIDE FOR PEAK HOUR $0.96
(1981-82 Bus operating costs $40.00 / bus hour)
(8) PEAK HOUR REVENUE (fare profile constant) $325.06
(9) PEAK HOUR OPERATING COSTS (includes fixed overhead) $420.71
(10) PROFIT OR LOSS MARGIN IN PERCENT OF OPERATING COSTS -22.74%

FULL TRANSPORT MATRIX - TRANSIT PLANNING AREA "A

	SUPER DISTRICT NUMBER	TRAFFIC ZONE NUMBER	TRIP_GEN % Rate work trips	EMP OUT OF AREA % OUTSIDE	TRIP GENERATED TOTAL	TOT_WORK TRIPS EST #1	TOT_WORK TRIPS EST #2	MODAL SPLIT MODEL 4	TRANSIT RIDERSHIP (WORK TRIPS)
1	19	274	27.8	84%	2938	817	1008	0.247	249
2	19	293	27.8	84%	2419	673	831	0.232	193
3	19	371	28.9	89%	1298	375	378	0.157	59
4	19	372	28.9	89%	2597	750	755	0.158	120
5	19	375	28.9	86%	1821	526	514	0.160	82
6	24	443	28.9	86%	3477	1005	981	0.166	163
7	24	442	28.9	86%	2981	861	841	0.168	141
8	24	441	30.0	87%	2761	828	979	0.234	229
9	24	444	30.0	87%	1933	580	685	0.238	163
10	24	445	27.9	93%	3373	941	1174	0.226	266
11	24	446	27.9	93%	2952	824	1028	0.225	231
12	24	447	27.9	93%	2108	588	734	0.217	159
13	27	481	31.5	86%	3060	964	1076	0.195	210
14	27	482	31.5	86%	2040	643	718	0.217	156
15	27	483	31.5	86%	3570	1125	1256	0.253	317
16	28	492	31.8	82%	6396	2034	2358	0.161	380
17	28	493	31.8	82%	5233	1664	1929	0.164	316
18	28	494	31.8	86%	3629	1154	1410	0.166	234
19	28	495	31.8	86%	4354	1385	1692	0.168	285
20	28	571	31.8	86%	6532	2077	2539	0.169	429
21	28	572	31.8	87%	2330	741	851	0.139	118
22	28	573	31.8	87%	1472	468	537	0.140	75
23	28	574	31.8	87%	2330	741	851	0.140	119
	TOTALS >				71,604	21,763	25,125		4,694 TRANSIT RIDES

* * * P O L I C Y * * * * * * S T A T U S * * *	
Statement on policy: FARE OPTIONS with hw=5/10	ANY(Y/N) CHANGES? 1=Y, 0=N
HEADWAYS: 5	1
10	1
FULL LOAD: 52	0
TRANSIT FARE: 50 (cents)	1
Enter Policy Values then press key "F9"	
COMMENTS ? :	

Total population served by routes in area A 29,062

(1) TRANSIT MODE SPLIT FOR TRANSIT PLANNING AREA "A"
WORK-BASED TRIPS (APPROX. 90% OF PM PEAK TRIPS) 18.87%

(2) PM PEAK TRANSIT RIDERSHIP(4-6 PM) 30% (77 SURVEY) 1408 WORK-BASED RIDES
(3) PM PEAK HOUR RIDERSHIP (60% of PM Peak Period) 845 WORK-BASED RIDES
(4) TOTAL PM PEAK TRANSIT RDRSHP TO AREA "A" 883 RIDES
(APPROX. AS WORK-BASED +10% -5% FROM AREA "A")
(5) PEAK HOUR BUSES REQUIRED 21.2 BUSES
22 BUSES (ROUNDED UP)
(6) PEAK HOUR BUSES REQUIRED TO MAINTAIN HEADWAY 16 BUSES
(FULL LOAD POLICY IS 52 PASSENGERS / BUS)
(ROUND TRIP TIME IS 75 MINUTES)
(NOMINAL HEADWAY OF 5 MINUTES FOR AREA)
(7) COST PER PASSENGER RIDE FOR PEAK HOUR $0.95
(1981-82 Bus operating costs $40.00 / bus hour)
(8) PEAK HOUR REVENUE (fare profile constant) $430.47
(9) PEAK HOUR OPERATING COSTS (includes fixed overhead) $869.05
(10) PROFIT OR LOSS MARGIN IN PERCENT OF OPERATING COSTS -50.47%

PAT HOGAN

EXAMPLE INPUT/OUTPUT FORM

02-Apr-85 DATE

	SUPER DISTRICT NUMBER	TRAFFIC ZONE NUMBER	TRIP_GEN % Rate work trips	EMP OUT OF AREA % OUTSIDE	TRIP GENERATED TOTAL	TOT_WORK TRIPS EST #1	TOT_WORK TRIPS EST #2	MODAL SPLIT MODEL 4	TRANSIT RIDERSHIP (WORK TRIPS)
1	19	274	27.8	84%	2938	817	1008	0.212	214
2	19	293	27.8	84%	2419	673	831	0.199	165
3	19	371	28.9	89%	1298	375	378	0.134	51
4	19	372	28.9	89%	2597	750	755	0.135	102
5	19	375	28.9	86%	1821	526	514	0.138	71
6	24	443	28.9	86%	3477	1005	981	0.143	141
7	24	442	28.9	86%	2981	861	841	0.145	122
8	24	441	30.0	87%	2761	828	979	0.206	202
9	24	444	30.0	87%	1933	580	685	0.209	144
10	24	445	27.9	93%	3373	941	1174	0.195	229
11	24	446	27.9	93%	2952	824	1028	0.194	200
12	24	447	27.9	93%	2108	588	734	0.187	137
13	27	481	31.5	86%	3060	964	1076	0.175	189
14	27	482	31.5	86%	2040	643	718	0.195	140
15	27	483	31.5	86%	3570	1125	1256	0.228	287
16	28	492	31.8	82%	6396	2034	2358	0.143	337
17	28	493	31.8	82%	5233	1664	1929	0.146	281
18	28	494	31.8	86%	3629	1154	1410	0.149	211
19	28	495	31.8	86%	4354	1385	1692	0.152	257
20	28	571	31.8	86%	6532	2077	2539	0.152	386
21	28	572	31.8	87%	2330	741	851	0.128	108
22	28	573	31.8	87%	1472	468	537	0.128	69
23	28	574	31.8	87%	2330	741	851	0.129	109
	Total population served by routes in area A 29,062			TOTALS >	71,604	21,763	25,125		4,150 TRANSIT RIDES

* * * P O L I C Y * * * * * * S T A T U S * * *	
Statement on policy:	ANY(Y/N)
FARE OPTIONS	CHANGES?
with hw=5/10	1=Y, 0=N
HEADWAYS: 5	1
10	1
FULL LOAD: 52	0
TRANSIT FARE: 80	0
(cents)	
Enter Policy Values	
then press key "F9"	
COMMENTS ? :	

(1)	TRANSIT MODE SPLIT FOR TRANSIT PLANNING AREA "A" WORK-BASED TRIPS (APPROX. 90% OF PM PEAK TRIPS)	16.62%
(2)	PM PEAK TRANSIT RIDERSHIP(4-6 PM) 30% (77 SURVEY)	1245 WORK-BASED RIDES
(3)	PM PEAK HOUR RIDERSHIP (60% of PM Peak Period)	747 WORK-BASED RIDES
(4)	TOTAL PM PEAK TRANSIT RDRSHP TO AREA "A" (APPROX. AS WORK-BASED +10% -5% FROM AREA "A")	781 RIDES
(5)	PEAK HOUR BUSES REQUIRED	18.8 BUSES
		19 BUSES (ROUNDED UP)
(6)	PEAK HOUR BUSES REQUIRED TO MAINTAIN HEADWAY (FULL LOAD POLICY IS 52 PASSENGERS / BUS) (ROUND TRIP TIME IS 75 MINUTES) (NOMINAL HEADWAY OF 5 MINUTES FOR AREA)	16 BUSES
(7)	COST PER PASSENGER RIDE FOR PEAK HOUR (1981-82 Bus operating costs $40.00 / bus hour)	$0.97
(8)	PEAK HOUR REVENUE (fare profile constant)	$608.92
(9)	PEAK HOUR OPERATING COSTS (includes fixed overhead)	$770.65
(10)	PROFIT OR LOSS MARGIN IN PERCENT OF OPERATING COSTS	-20.99%

	SUPER DISTRICT NUMBER	TRAFFIC ZONE NUMBER	TRIP_GEN % Rate work trips	EMP OUT OF AREA % OUTSIDE	TRIP GENERATED TOTAL	TOT_WORK TRIPS EST #1	TOT_WORK TRIPS EST #2	MODAL SPLIT MODEL 4	TRANSIT RIDERSHIP (WORK TRIPS)
1	19	274	27.8	84%	2938	817	1008	0.201	203
2	19	293	27.8	84%	2419	673	831	0.189	157
3	19	371	28.9	89%	1298	375	378	0.127	48
4	19	372	28.9	89%	2597	750	755	0.128	97
5	19	375	28.9	86%	1821	526	514	0.131	68
6	24	443	28.9	86%	3477	1005	981	0.136	134
7	24	442	28.9	86%	2981	861	841	0.138	116
8	24	441	30.0	87%	2761	828	979	0.197	193
9	24	444	30.0	87%	1933	580	685	0.201	137
10	24	445	27.9	93%	3373	941	1174	0.186	218
11	24	446	27.9	93%	2952	824	1028	0.185	190
12	24	447	27.9	93%	2108	588	734	0.177	130
13	27	481	31.5	86%	3060	964	1076	0.169	182
14	27	482	31.5	86%	2040	643	718	0.188	135
15	27	483	31.5	86%	3570	1125	1256	0.220	277
16	28	492	31.8	82%	6396	2034	2358	0.138	324
17	28	493	31.8	82%	5233	1664	1929	0.140	270
18	28	494	31.8	86%	3629	1154	1410	0.144	203
19	28	495	31.8	86%	4354	1385	1692	0.147	248
20	28	571	31.8	86%	6532	2077	2539	0.147	373
21	28	572	31.8	87%	2330	741	851	0.124	105
22	28	573	31.8	87%	1472	468	537	0.125	67
23	28	574	31.8	87%	2330	741	851	0.125	106
	TOTALS >				71,604	21,763	25,125		3,981 TRANSIT RIDES

* * * P O L I C Y * * * * * * S T A T U S * * *		
Statement on policy:		ANY(Y/N) CHANGES? 1=Y, 0=N
FARE OPTIONS		
with hw=5/10		
HEADWAYS:	5	1
	10	1
FULL LOAD:	52	0
TRANSIT FARE:	90	1
(cents)		
Enter Policy Values then press key "F9"		
COMMENTS ? :		

Total population served by routes in area A 29,062

(1)	TRANSIT MODE SPLIT FOR TRANSIT PLANNING AREA "A" WORK-BASED TRIPS (APPROX. 90% OF PM PEAK TRIPS)	15.92%	
(2)	PM PEAK TRANSIT RIDERSHIP(4-6 PM) 30% (77 SURVEY)	1194	WORK-BASED RIDES
(3)	PM PEAK HOUR RIDERSHIP (60% of PM Peak Period)	717	WORK-BASED RIDES
(4)	TOTAL PM PEAK TRANSIT RDRSHP TO AREA "A" (APPROX. AS WORK-BASED +10% -5% FROM AREA "A")	749	RIDES
(5)	PEAK HOUR BUSES REQUIRED	18.0	BUSES
		18	BUSES (ROUNDED UP)
(6)	PEAK HOUR BUSES REQUIRED TO MAINTAIN HEADWAY (FULL LOAD POLICY IS 52 PASSENGERS / BUS) (ROUND TRIP TIME IS 75 MINUTES) (NOMINAL HEADWAY OF 5 MINUTES FOR AREA)	16	BUSES
(7)	COST PER PASSENGER RIDE FOR PEAK HOUR (1981-82 Bus operating costs $40.00 / bus hour)	$0.96	
(8)	PEAK HOUR REVENUE (fare profile constant)	$657.04	
(9)	PEAK HOUR OPERATING COSTS (includes fixed overhead)	$739.97	
(10)	PROFIT OR LOSS MARGIN IN PERCENT OF OPERATING COSTS	-11.21%	

FULL TRANSPORT MATRIX - TRANSIT PLANNING AREA "A

	SUPER DISTRICT NUMBER	TRAFFIC ZONE NUMBER	TRIP_GEN % Rate work trips	EMP OUT OF AREA % OUTSIDE	TRIP GENERATED TOTAL	TOT_WORK TRIPS EST #1	TOT_WORK TRIPS EST #2	MODAL SPLIT MODEL 4	TRANSIT RIDERSHIP (WORK TRIPS)
1	19	274	27.8	84%	2938	817	1008	0.191	193
2	19	293	27.8	84%	2419	673	831	0.179	148
3	19	371	28.9	89%	1298	375	378	0.120	45
4	19	372	28.9	89%	2597	750	755	0.121	92
5	19	375	28.9	86%	1821	526	514	0.125	64
6	24	443	28.9	86%	3477	1005	981	0.130	127
7	24	442	28.9	86%	2981	861	841	0.131	111
8	24	441	30.0	87%	2761	828	979	0.189	185
9	24	444	30.0	87%	1933	580	685	0.192	132
10	24	445	27.9	93%	3373	941	1174	0.176	207
11	24	446	27.9	93%	2952	824	1028	0.175	180
12	24	447	27.9	93%	2108	588	734	0.168	124
13	27	481	31.5	86%	3060	964	1076	0.163	175
14	27	482	31.5	86%	2040	643	718	0.181	130
15	27	483	31.5	86%	3570	1125	1256	0.213	267
16	28	492	31.8	82%	6396	2034	2358	0.132	311
17	28	493	31.8	82%	5233	1664	1929	0.134	259
18	28	494	31.8	86%	3629	1154	1410	0.139	196
19	28	495	31.8	86%	4354	1385	1692	0.141	239
20	28	571	31.8	86%	6532	2077	2539	0.142	360
21	28	572	31.8	87%	2330	741	851	0.120	102
22	28	573	31.8	87%	1472	468	537	0.121	65
23	28	574	31.8	87%	2330	741	851	0.121	103
			TOTALS >		71,604	21,763	25,125		3,817 TRANSIT RIDES

* * * P O L I C Y * * * * * * S T A T U S * * *	
Statement on policy:	ANY(Y/N)
FARE OPTIONS	CHANGES?
with hw=5/10	1=Y, 0=N
HEADWAYS: 5	1
10	1
FULL LOAD: 52	0
TRANSIT FARE: 100	1
(cents)	
Enter Policy Values	
then press key "F9"	
COMMENTS ? :	

Total population served by routes in area A 29,062

(1)	TRANSIT MODE SPLIT FOR TRANSIT PLANNING AREA "A" WORK-BASED TRIPS (APPROX. 90% OF PM PEAK TRIPS)	15.25%
(2)	PM PEAK TRANSIT RIDERSHIP(4-6 PM) 30% (77 SURVEY)	1145 WORK-BASED RIDES
(3)	PM PEAK HOUR RIDERSHIP (60% of PM Peak Period)	687 WORK-BASED RIDES
(4)	TOTAL PM PEAK TRANSIT RDRSHP TO AREA "A" (APPROX. AS WORK-BASED +10% -5% FROM AREA "A")	718 RIDES
(5)	PEAK HOUR BUSES REQUIRED	17.3 BUSES
		18 BUSES (ROUNDED UP)
(6)	PEAK HOUR BUSES REQUIRED TO MAINTAIN HEADWAY	16 BUSES
	(FULL LOAD POLICY IS 52 PASSENGERS / BUS)	
	(ROUND TRIP TIME IS 75 MINUTES)	
	(NOMINAL HEADWAY OF 5 MINUTES FOR AREA)	
(7)	COST PER PASSENGER RIDE FOR PEAK HOUR	$0.95
	(1981-82 Bus operating costs $40.00 / bus hour)	
(8)	PEAK HOUR REVENUE (fare profile constant)	$700.00
(9)	PEAK HOUR OPERATING COSTS (includes fixed overhead)	$710.33
(10)	PROFIT OR LOSS MARGIN IN PERCENT OF OPERATING COSTS	-1.45%

	SUPER DISTRICT NUMBER	TRAFFIC ZONE NUMBER	TRIP_GEN % Rate work trips	EMP OUT OF AREA % OUTSIDE	TRIP GENERATED TOTAL	TOT_WORK TRIPS EST #1	TOT_WORK TRIPS EST #2	MODAL SPLIT MODEL 4	TRANSIT RIDERSHIP (WORK TRIPS)
1	19	274	27.8	84%	2938	817	1008	0.181	182
2	19	293	27.8	84%	2419	673	831	0.169	141
3	19	371	28.9	89%	1298	375	378	0.114	43
4	19	372	28.9	89%	2597	750	755	0.115	87
5	19	375	28.9	86%	1821	526	514	0.119	61
6	24	443	28.9	86%	3477	1005	981	0.123	121
7	24	442	28.9	86%	2981	861	841	0.125	105
8	24	441	30.0	87%	2761	828	979	0.181	177
9	24	444	30.0	87%	1933	580	685	0.184	126
10	24	445	27.9	93%	3373	941	1174	0.167	197
11	24	446	27.9	93%	2952	824	1028	0.167	171
12	24	447	27.9	93%	2108	588	734	0.160	117
13	27	481	31.5	86%	3060	964	1076	0.157	169
14	27	482	31.5	86%	2040	643	718	0.175	125
15	27	483	31.5	86%	3570	1125	1256	0.205	258
16	28	492	31.8	82%	6396	2034	2358	0.127	299
17	28	493	31.8	82%	5233	1664	1929	0.129	249
18	28	494	31.8	86%	3629	1154	1410	0.134	189
19	28	495	31.8	86%	4354	1385	1692	0.137	231
20	28	571	31.8	86%	6532	2077	2539	0.137	347
21	28	572	31.8	87%	2330	741	851	0.117	99
22	28	573	31.8	87%	1472	468	537	0.118	63
23	28	574	31.8	87%	2330	741	851	0.118	100
	TOTALS >				71,604	21,763	25,125		3,659

* * * P O L I C Y * * * S T A T U S * * *		ANY(Y/N) CHANGES? 1=Y, 0=N
Statement on policy:		
FARE OPTIONS		
with hw=5/10		
HEADWAYS:	5	1
	10	1
FULL LOAD:	52	0
TRANSIT FARE:	110	1
(cents)		

Enter Policy Values
then press key "F9"

COMMENTS ? :

Total population served by routes in area A 29,062

TRANSIT RIDES

(1)	TRANSIT MODE SPLIT FOR TRANSIT PLANNING AREA "A" WORK-BASED TRIPS (APPROX. 90% OF PM PEAK TRIPS)	14.60%	
(2)	PM PEAK TRANSIT RIDERSHIP(4-6 PM) 30% (77 SURVEY)	1098	WORK-BASED RIDES
(3)	PM PEAK HOUR RIDERSHIP (60% of PM Peak Period)	659	WORK-BASED RIDES
(4)	TOTAL PM PEAK TRANSIT RDRSHP TO AREA "A" (APPROX. AS WORK-BASED +10% -5% FROM AREA "A")	688	RIDES
(5)	PEAK HOUR BUSES REQUIRED	16.5	BUSES
		17	BUSES (ROUNDED UP)
(6)	PEAK HOUR BUSES REQUIRED TO MAINTAIN HEADWAY	16	BUSES
	(FULL LOAD POLICY IS 52 PASSENGERS / BUS)		
	(ROUND TRIP TIME IS 75 MINUTES)		
	(NOMINAL HEADWAY OF 5 MINUTES FOR AREA)		
(7)	COST PER PASSENGER RIDE FOR PEAK HOUR (1981-82 Bus operating costs $40.00 / bus hour)	$0.99	
(8)	PEAK HOUR REVENUE (fare profile constant)	$738.09	
(9)	PEAK HOUR OPERATING COSTS (includes fixed overhead)	$681.73	
(10)	PROFIT OR LOSS MARGIN IN PERCENT OF OPERATING COSTS	8.27%	

FULL TRANSPORT MATRIX - TRANSIT PLANNING AREA "A

	SUPER DISTRICT NUMBER	TRAFFIC ZONE NUMBER	TRIP_GEN % Rate work trips	EMP OUT OF AREA % OUTSIDE	TRIP GENERATED TOTAL	TOT_WORK TRIPS EST #1	TOT_WORK TRIPS EST #2	MODAL SPLIT MODEL 4	TRANSIT RIDERSHIP (WORK TRIPS)
1	19	274	27.8	84%	2938	817	1008	0.171	173
2	19	293	27.8	84%	2419	673	831	0.160	133
3	19	371	28.9	89%	1298	375	378	0.108	41
4	19	372	28.9	89%	2597	750	755	0.109	82
5	19	375	28.9	86%	1821	526	514	0.113	58
6	24	443	28.9	86%	3477	1005	981	0.117	115
7	24	442	28.9	86%	2981	861	841	0.119	100
8	24	441	30.0	87%	2761	828	979	0.173	169
9	24	444	30.0	87%	1933	580	685	0.176	120
10	24	445	27.9	93%	3373	941	1174	0.159	187
11	24	446	27.9	93%	2952	824	1028	0.158	162
12	24	447	27.9	93%	2108	588	734	0.152	111
13	27	481	31.5	86%	3060	964	1076	0.151	162
14	27	482	31.5	86%	2040	643	718	0.168	121
15	27	483	31.5	86%	3570	1125	1256	0.198	249
16	28	492	31.8	82%	6396	2034	2358	0.122	287
17	28	493	31.8	82%	5233	1664	1929	0.124	239
18	28	494	31.8	86%	3629	1154	1410	0.130	183
19	28	495	31.8	86%	4354	1385	1692	0.132	223
20	28	571	31.8	86%	6532	2077	2539	0.132	335
21	28	572	31.8	87%	2330	741	851	0.114	97
22	28	573	31.8	87%	1472	468	537	0.114	61
23	28	574	31.8	87%	2330	741	851	0.114	97
	TOTALS >				71,604	21,763	25,125		3,506 TRANSIT RIDES

* * * P O L I C Y * * * * * * S T A T U S * * *	
Statement on policy:	ANY(Y/N) CHANGES? 1=Y, 0=N
FARE OPTIONS	
with hw=5/10	
HEADWAYS: 5	1
10	1
FULL LOAD: 52	0
TRANSIT FARE: 120	1
(cents)	

Enter Policy Values
then press key "F9"

COMMENTS ? :

Total population served by routes in area A 29,062

(1)	TRANSIT MODE SPLIT FOR TRANSIT PLANNING AREA "A" WORK-BASED TRIPS (APPROX. 90% OF PM PEAK TRIPS)	13.97%
(2)	PM PEAK TRANSIT RIDERSHIP(4-6 PM) 30% (77 SURVEY)	1052 WORK-BASED RIDES
(3)	PM PEAK HOUR RIDERSHIP (60% of PM Peak Period)	631 WORK-BASED RIDES
(4)	TOTAL PM-PEAK TRANSIT RDRSHP TO AREA "A" (APPROX. AS WORK-BASED +10% -5% FROM AREA "A")	660 RIDES
(5)	PEAK HOUR BUSES REQUIRED	15.9 BUSES
		16 BUSES (ROUNDED UP)
(6)	PEAK HOUR BUSES REQUIRED TO MAINTAIN HEADWAY (FULL LOAD POLICY IS 52 PASSENGERS / BUS) (ROUND TRIP TIME IS 75 MINUTES) (NOMINAL HEADWAY OF 5 MINUTES FOR AREA)	16 BUSES
(7)	COST PER PASSENGER RIDE FOR PEAK HOUR (1981-82 Bus operating costs $40.00 / bus hour)	$0.97
(8)	PEAK HOUR REVENUE (fare profile constant)	$771.62
(9)	PEAK HOUR OPERATING COSTS (includes fixed overhead)	$654.14
(10)	PROFIT OR LOSS MARGIN IN PERCENT OF OPERATING COSTS	17.96%

PAT HOGAN

EXAMPLE INPUT/OUTPUT FORM

02-Apr-85 DATE

FULL TRANSPORT MATRIX - TRANSIT PLANNING AREA "A

	SUPER DISTRICT NUMBER	TRAFFIC ZONE NUMBER	TRIP_GEN % Rate work trips	EMP OUT OF AREA % OUTSIDE	TRIP GENERATED TOTAL	TOT_WORK TRIPS EST #1	TOT_WORK TRIPS EST #2	MODAL SPLIT MODEL 4	TRANSIT RIDERSHIP (WORK TRIPS)
1	19	274	27.8	84%	2938	817	1008	0.162	164
2	19	293	27.8	84%	2419	673	831	0.152	126
3	19	371	28.9	89%	1298	375	378	0.102	38
4	19	372	28.9	89%	2597	750	755	0.103	78
5	19	375	28.9	86%	1821	526	514	0.107	55
6	24	443	28.9	86%	3477	1005	981	0.111	109
7	24	442	28.9	86%	2981	861	841	0.113	95
8	24	441	30.0	87%	2761	828	979	0.165	162
9	24	444	30.0	87%	1933	580	685	0.168	115
10	24	445	27.9	93%	3373	941	1174	0.151	177
11	24	446	27.9	93%	2952	824	1028	0.150	154
12	24	447	27.9	93%	2108	588	734	0.144	106
13	27	481	31.5	86%	3060	964	1076	0.145	156
14	27	482	31.5	86%	2040	643	718	0.162	116
15	27	483	31.5	86%	3570	1125	1256	0.191	240
16	28	492	31.8	82%	6396	2034	2358	0.117	275
17	28	493	31.8	82%	5233	1664	1929	0.119	229
18	28	494	31.8	86%	3629	1154	1410	0.125	176
19	28	495	31.8	86%	4354	1385	1692	0.127	215
20	28	571	31.8	86%	6532	2077	2539	0.127	324
21	28	572	31.8	87%	2330	741	851	0.110	94
22	28	573	31.8	87%	1472	468	537	0.111	60
23	28	574	31.8	87%	2330	741	851	0.111	95
	Total population served by routes in area A 29,062		TOTALS >		71,604	21,763	25,125		3,359 TRANSIT RIDES

* * * P O L I C Y * * * * * * S T A T U S * * *	
Statement on policy:	ANY(Y/N)
FARE OPTIONS	CHANGES?
with hw=5/10	1=Y, 0=N
HEADWAYS: 5	1
10	1
FULL LOAD: 52	0
TRANSIT FARE: 130	1
(cents)	
Enter Policy Values	
then press key "F9"	
COMMENTS ? :	

(1)	TRANSIT MODE SPLIT FOR TRANSIT PLANNING AREA "A" WORK-BASED TRIPS (APPROX. 90% OF PM PEAK TRIPS)	13.37%	
(2)	PM PEAK TRANSIT RIDERSHIP(4-6 PM) 30% (77 SURVEY)	1008	WORK-BASED RIDES
(3)	PM PEAK HOUR RIDERSHIP (60% of PM Peak Period)	605	WORK-BASED RIDES
(4)	TOTAL PM PEAK TRANSIT RDRSHP TO AREA "A" (APPROX. AS WORK-BASED +10% -5% FROM AREA "A")	632	RIDES
(5)	PEAK HOUR BUSES REQUIRED	15.2	BUSES
		16	BUSES (ROUNDED UP)
(6)	PEAK HOUR BUSES REQUIRED TO MAINTAIN HEADWAY (FULL LOAD POLICY IS 52 PASSENGERS / BUS) (ROUND TRIP TIME IS 75 MINUTES) (NOMINAL HEADWAY OF 5 MINUTES FOR AREA)	16	BUSES
(7)	COST PER PASSENGER RIDE FOR PEAK HOUR (1981-82 Bus operating costs $40.00 / bus hour)	$0.95	
(8)	PEAK HOUR REVENUE (fare profile constant)	$800.86	
(9)	PEAK HOUR OPERATING COSTS (includes fixed overhead)	$627.54	
(10)	PROFIT OR LOSS MARGIN IN PERCENT OF OPERATING COSTS	27.62%	

	SUPER DISTRICT NUMBER	TRAFFIC ZONE NUMBER	TRIP_GEN % Rate work trips	EMP OUT OF AREA % OUTSIDE	TRIP GENERATED TOTAL	TOT_WORK TRIPS EST #1	TOT_WORK TRIPS EST #2	MODAL SPLIT MODEL 4	TRANSIT RIDERSHIP (WORK TRIPS)
1	19	274	27.8	84%	2938	817	1008	0.145	146
2	19	293	27.8	84%	2419	673	831	0.135	112
3	19	371	28.9	89%	1298	375	378	0.091	34
4	19	372	28.9	89%	2597	750	755	0.092	69
5	19	375	28.9	86%	1821	526	514	0.097	50
6	24	443	28.9	86%	3477	1005	981	0.100	98
7	24	442	28.9	86%	2981	861	841	0.102	86
8	24	441	30.0	87%	2761	828	979	0.151	148
9	24	444	30.0	87%	1933	580	685	0.153	105
10	24	445	27.9	93%	3373	941	1174	0.136	159
11	24	446	27.9	93%	2952	824	1028	0.135	139
12	24	447	27.9	93%	2108	588	734	0.129	95
13	27	481	31.5	86%	3060	964	1076	0.134	145
14	27	482	31.5	86%	2040	643	718	0.150	108
15	27	483	31.5	86%	3570	1125	1256	0.178	223
16	28	492	31.8	82%	6396	2034	2358	0.108	254
17	28	493	31.8	82%	5233	1664	1929	0.110	211
18	28	494	31.8	86%	3629	1154	1410	0.116	164
19	28	495	31.8	86%	4354	1385	1692	0.118	200
20	28	571	31.8	86%	6532	2077	2539	0.119	301
21	28	572	31.8	87%	2330	741	851	0.104	88
22	28	573	31.8	87%	1472	468	537	0.105	56
23	28	574	31.8	87%	2330	741	851	0.105	89
	Total population served by routes in area A 29,062			TOTALS >	71,604	21,763	25,125		3,081 TRANSIT RIDES

* * * P O L I C Y * * * * * * S T A T U S * * *	
Statement on policy:	ANY(Y/N)
FARE OPTIONS	CHANGES?
with hw=5/10	1=Y, 0=N
HEADWAYS: 5	1
10	1
FULL LOAD: 52	0
TRANSIT FARE: 150	1
(cents)	
Enter Policy Values	
then press key "F9"	
COMMENTS ? :	

(1)	TRANSIT MODE SPLIT FOR TRANSIT PLANNING AREA "A" WORK-BASED TRIPS (APPROX. 90% OF PM PEAK TRIPS)	12.23%
(2)	PM PEAK TRANSIT RIDERSHIP(4-6 PM) 30% (77 SURVEY)	924 WORK-BASED RIDES
(3)	PM PEAK HOUR RIDERSHIP (60% of PM Peak Period)	555 WORK-BASED RIDES
(4)	TOTAL PM PEAK TRANSIT RDRSHP TO AREA "A" (APPROX. AS WORK-BASED +10% -5% FROM AREA "A")	580 RIDES
(5)	PEAK HOUR BUSES REQUIRED	13.9 BUSES
		14 BUSES (ROUNDED UP)
(6)	PEAK HOUR BUSES REQUIRED TO MAINTAIN HEADWAY	16 BUSES
	(FULL LOAD POLICY IS 52 PASSENGERS / BUS)	
	(ROUND TRIP TIME IS 75 MINUTES)	
	(NOMINAL HEADWAY OF 5 MINUTES FOR AREA)	
(7)	COST PER PASSENGER RIDE FOR PEAK HOUR	$0.97
	(1981-82 Bus operating costs $40.00 / bus hour)	
(8)	PEAK HOUR REVENUE (fare profile constant)	$847.57
(9)	PEAK HOUR OPERATING COSTS (includes fixed overhead)	$577.25
(10)	PROFIT OR LOSS MARGIN IN PERCENT OF OPERATING COSTS	46.83%

FULL TRANSPORT MATRIX - TRANSIT PLANNING AREA "A

	SUPER DISTRICT NUMBER	TRAFFIC ZONE NUMBER	TRIP_GEN % Rate work trips	EMP OUT OF AREA % OUTSIDE	TRIP GENERATED TOTAL	TOT_WORK TRIPS EST #1	TOT_WORK TRIPS EST #2	MODAL SPLIT MODEL 4	TRANSIT RIDERSHIP (WORK TRIPS)
1	19	274	27.8	84%	2938	817	1008	0.126	127
2	19	293	27.8	84%	2419	673	831	0.117	97
3	19	371	28.9	89%	1298	375	378	0.079	30
4	19	372	28.9	89%	2597	750	755	0.080	60
5	19	375	28.9	86%	1821	526	514	0.085	43
6	24	443	28.9	86%	3477	1005	981	0.088	86
7	24	442	28.9	86%	2981	861	841	0.089	75
8	24	441	30.0	87%	2761	828	979	0.134	132
9	24	444	30.0	87%	1933	580	685	0.137	94
10	24	445	27.9	93%	3373	941	1174	0.118	139
11	24	446	27.9	93%	2952	824	1028	0.118	121
12	24	447	27.9	93%	2108	588	734	0.113	83
13	27	481	31.5	86%	3060	964	1076	0.122	131
14	27	482	31.5	86%	2040	643	718	0.137	98
15	27	483	31.5	86%	3570	1125	1256	0.162	203
16	28	492	31.8	82%	6396	2034	2358	0.097	228
17	28	493	31.8	82%	5233	1664	1929	0.099	190
18	28	494	31.8	86%	3629	1154	1410	0.106	150
19	28	495	31.8	86%	4354	1385	1692	0.108	183
20	28	571	31.8	86%	6532	2077	2539	0.108	275
21	28	572	31.8	87%	2330	741	851	0.097	82
22	28	573	31.8	87%	1472	468	537	0.097	52
23	28	574	31.8	87%	2330	741	851	0.097	83
	Total population served by routes in area A 29,062		TOTALS >		71,604	21,763	25,125		2,762 TRANSIT RIDES

	* * * P O L I C Y * * *		
	* * * S T A T U S * * *		ANY(Y/N)
Statement on policy:			CHANGES?
FARE OPTIONS			1=Y, 0=N
with hw=5/10			
HEADWAYS:	5		1
	10		1
FULL LOAD:	52		0
TRANSIT FARE:	175		1
(cents)			
Enter Policy Values			
then press key "F9"			
COMMENTS ? :			

(1)	TRANSIT MODE SPLIT FOR TRANSIT PLANNING AREA "A" WORK-BASED TRIPS (APPROX. 90% OF PM PEAK TRIPS)	10.92%	
(2)	PM PEAK TRANSIT RIDERSHIP(4-6 PM) 30% (77 SURVEY)	829	WORK-BASED RIDES
(3)	PM PEAK HOUR RIDERSHIP (60% of PM Peak Period)	497	WORK-BASED RIDES
(4)	TOTAL PM PEAK TRANSIT RDRSHP TO AREA "A" (APPROX. AS WORK-BASED +10% -5% FROM AREA "A")	520	RIDES
(5)	PEAK HOUR BUSES REQUIRED	12.5	BUSES
		13	BUSES (ROUNDED UP)
(6)	PEAK HOUR BUSES REQUIRED TO MAINTAIN HEADWAY	16	BUSES
	(FULL LOAD POLICY IS 52 PASSENGERS / BUS)		
	(ROUND TRIP TIME IS 75 MINUTES)		
	(NOMINAL HEADWAY OF 5 MINUTES FOR AREA)		
(7)	COST PER PASSENGER RIDE FOR PEAK HOUR (1981-82 Bus operating costs $40.00 / bus hour)	$0.92	
(8)	PEAK HOUR REVENUE (fare profile constant)	$886.54	
(9)	PEAK HOUR OPERATING COSTS (includes fixed overhead)	$519.60	
(10)	PROFIT OR LOSS MARGIN IN PERCENT OF OPERATING COSTS	70.62%	

APPENDIX E TRIP GENERATION IN VICTORIA USING CROSS-CLASSIFICATION

Trip Generation Analysis

The Application of Cross-Classification Techniques

Introduction

The purpose of this short paper is to apply currently accepted trip generation techniques to the Greater Victoria area. The main source document is: "Trip Generation Analysis--August 1975" issued by the U.S. Dept. of Transportation, Federal Highway Administration.

Most small cities' transportation studies have found that practical, simple and straightforward cross-classification techniques can utilize disaggregate data at the household level to derive reasonable relationships between person-trip generation and key socio-economic variables such as income and car ownership rates per household (dwelling unit).

Cross classification involves a quantitative ordering of variables into a matrix to reveal relationships between pairs or triads of independent variables to the dependent person-trips per household variable. Goodness-of-fit checks may be made on the classifications by two common statistical techniques: 1) Analysis of variance, and 2) linear regression analysis.

The former is intended to determine the main effects and the interactions of variables in a cross-classification analysis. The latter technique attempts to equate the variation of independent variables to a predicted value of the dependent variable. In other words, to model trip generation. The resulting regression equation hopes to explain an acceptable percentage of the variation.

The author began working with home interview origin-destination data collected bt the Capital Regional District during the summer of 1977.

The data was first tested for continuity and completeness using various editing techniques made possible by on-line computing facilities. Editing was also carried out throughout the analysis as inconsistencies came up. The first step in the analysis was to attempt a regression analysis. All nominal and ordinal measures were converted to dummy variables producing a 48 variable step-wise multiple regression (least squares method). See Attachment B.

The sample produced 494 completed interviews representing only about 45% of the attempted sample schedule. Since this sample comprises less than 1% of 80,000 households in the region, problems of cell size in various categories make interpretation difficult in those near empty cells. This problem is difficult to reconcile in regression analysis and invariably produces a large standard error.

Trip generation theory supports strong relationships between trip rates, income, car ownership and household population (size). But theory also indicates that non-linear relationships exist and the large standard error in the regression equation appears to support this view. The regression equates is as follows:

$$PT. = -.643 + 1.64\ X_p + .13\ X_I + 1.09_c \pm 5$$

where: PT. = person trips, X_p = household population (size), X_I = household income and X_c = car ownership in household.

An alternative to the regression model is cross-classification techniques which have certain advantages over the linear regression model:

1. Cross-classification makes no linear assumptions.
2. Cross-classification enables smaller data sets to be used.
3. Cross-classification allows easier treatment of the data at the disaggregate household level.

4. Cross-classification uses a simple straightforward quantitative and non-statistical approach.

The disadvantages of cross-classification are:

1. It does not produce exact statistical error coefficients.
2. It requires careful checks using less powerful statistical testing of assumed relationships.
3. It requires an established theoretical base to verify the reasonableness of relationships. Such a theoretical base is born partly from careful non-linear regression models taken from very large data bases.

Cross-Classification Technique

The cross-classifications in this exercise were taken from two data files. Both files are based on the information collected in the interview. See Attachment A for an example interview form.

Simple fortran programs were used to produce a series of cross-classifications. See computer printouts of matrices and programs in Attachment F.

Since the graph plots of these tables indicate the resultant relationships deduced from the matrices and their respective manipulations, only the curves are to be formally presented. The source tables are roughed in on the computer printouts by appropriate labelling.

Objective: To identify and rationalize trip generation characteristics from the following levels.

1. Trip generation as a function of income and car ownership (Curve B). Two interval variables obtained in origin-destination survey.
2. Car ownership as a function of income (Curve A).

3. Trip generation as a function of trip purpose and income (trip purpose obtained in O-D survey). See Curve C and Attachments C and D.
4. Trip generation as a function of trip mode (trip mode obtained in O-D survey). See Curve D.

Although each relationship is seen as a two dimensional relationship, the blend of each curve in building block fashion allows a straightforward interpretation of the relationships associated with trip rates, modal splits and trip purpose problems. In the next section, the results of a series of cross-classifications are detailed.

PROBLEM SAMPLE:

1. GIVEN: VICTORIA REGION

TOTAL DWELLING UNITS 80,000 approximately

BROKEN DOWN INTO 4 INCOME GROUPS*

(000's $)

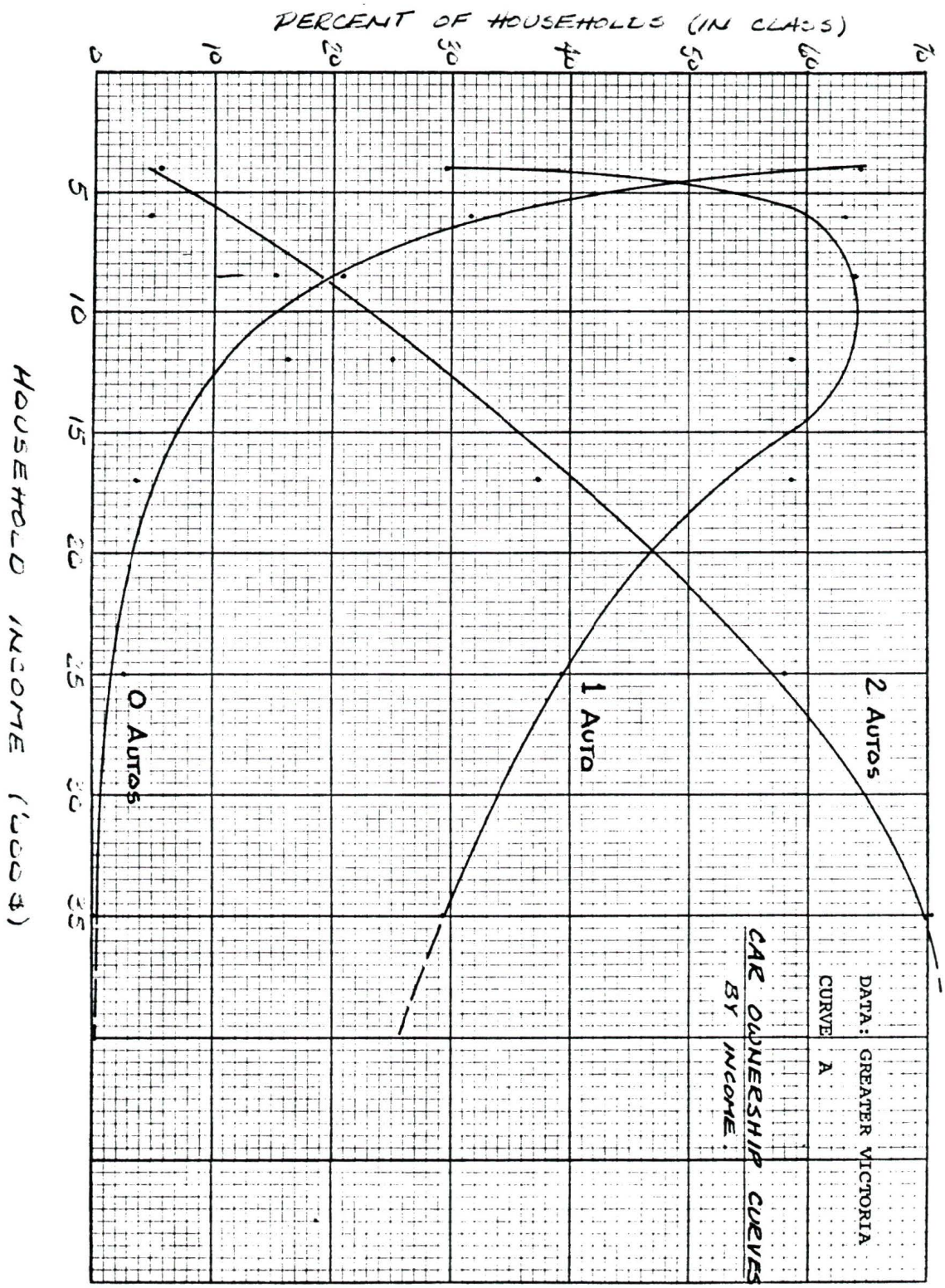
low income	($5)	=	6.9%	= 5520 units
lower middle income	($5-10)	=	19.0%	= 15200 units
upper middle income	($10-20)	=	43.1%	= 34480 units
higher income	($20)	=	31.0%	= 24800 units
				80,000 units

Solution: from Curve A

low income	0 Auto	= .61 x P_1	= 3367 = P_{10}
P_1 = (5520 units)	1 Auto	= .34 x P_1	= 1877 = P_{11}
	2+ Auto	= .05 x P_1	= 276 = P_{12}
lower middle income	0 Auto	= .62 x P_2	= 9424 = P_{20}
P_2 = (15200 units)	1 Auto	= .23 x P_2	= 3496 = P_{21}
	2+ Auto	= .15 x P_2	= 2280 = P_{22}
upper middle income	0 Auto	= .07 x P_3	= 2414 = P_{30}
P_3 = (34480 units)	1 Auto	= .58 x P_3	=19998 = P_{31}
	2+ Auto	= .35 x P_3	=12068 = P_{32}
higher income	0 Auto	= .02 x P_4	= 496 = P_{40}
P_4 = (24,800 units)	1 Auto	= .40 x P_4	= 9920 = P_{41}
	2+ Auto	= .58 x P_4	=14384 = P_{42}
		GRAND TOTAL	80,000

*Estimates from 500 household sample.

CURVE A


PERCENT OF HOUSEHOLDS (IN CLASS)
0
10
20
30
40
50
60
70
HOUSEHOLD INCOME ('000 $)
5
10
15
20
25
30
35
0 AUTOS
1 AUTO
2 AUTOS
DATA: GREATER VICTORIA
CURVE A
CAR OWNERSHIP CURVES
BY INCOME.

2 TOTAL PRODUCTION FOR EACH HOUSEHOLD IN PERSON TRIPS (See Curve B)

Low Income (5520)

TRIPS from 0 auto household = 2.9 x P_{10} = 9764

1 auto household = 4.8 x P_{11} = 9010

2+ auto household = 8.2 x P_{12} = 2263

$T._1$ = 21037 p.t.

Lower Middle Income (15200)

TRIPS from 0 auto household = 3.0 x P_{20} = 28272

1 auto household = 5.1 x P_{21} = 17830

2+ auto household = 8.4 x P_{22} = 19152

$T._2$ = 65254 p.t.

Upper Middle Income (34480)

TRIPS FROM 0 auto household = 4.5 x P_{30} = 10863

1 auto household = 6.5 x P_{31} = 129987

2+ auto household = 9.2 x P_{32} = 111026

$T._3$ = 251876

Higher Income (24800)

TRIPS FROM 0 auto household = 8.6 x P_{40} = 4266

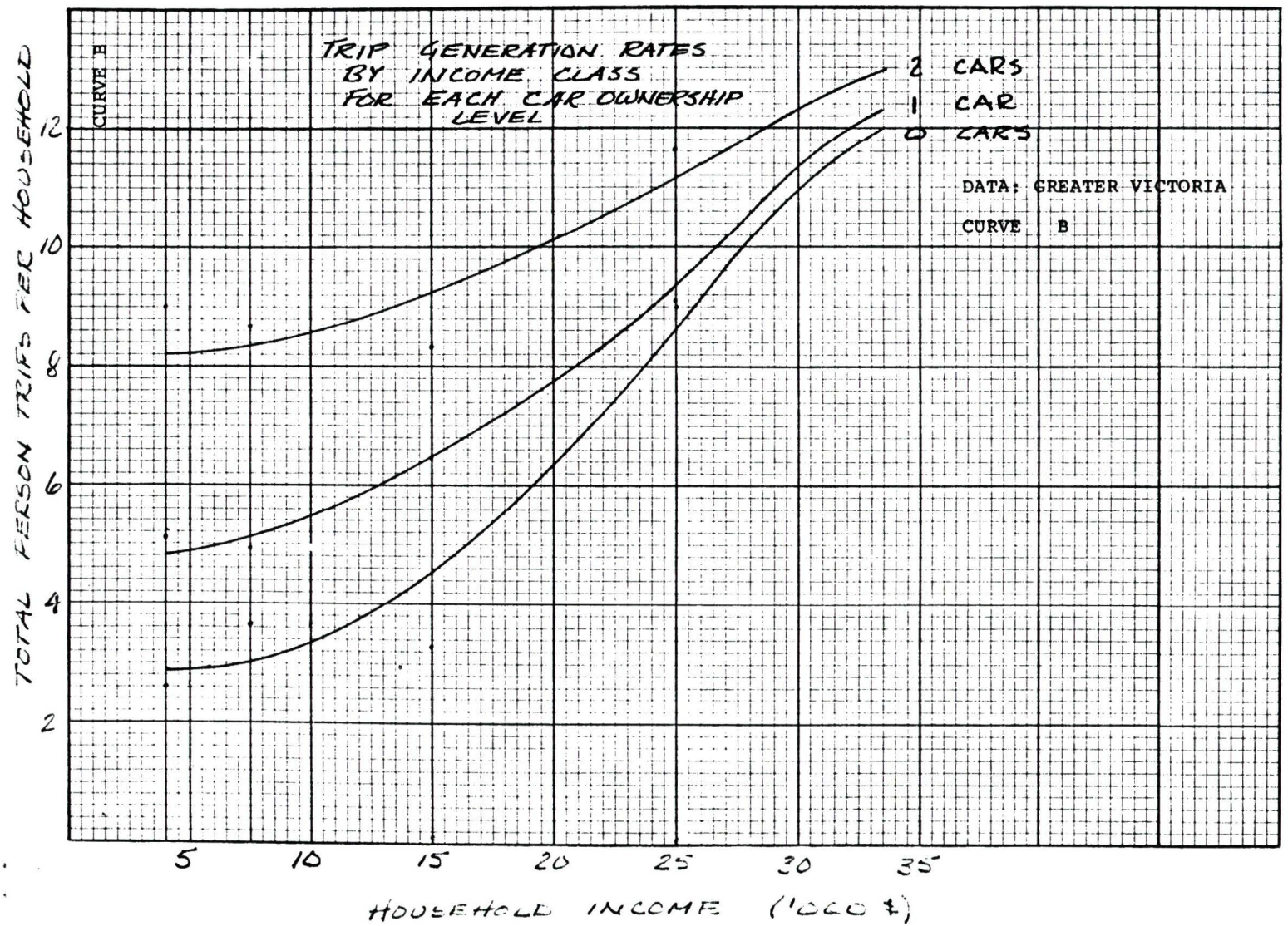
1 auto household = 9.4 x P_{41} = 93248

2+ auto household = 11.2 x P_{42} = 161101

$T._4$ = 258615

GRAND TOTAL = 596782

AVERAGE TRIPS/ D. U. = 7.0 trips


CURVE B
TRIP GENERATION RATES
BY INCOME CLASS
FOR EACH CAR OWNERSHIP
LEVEL
2 CARS
1 CAR
0 CARS
DATA: GREATER VICTORIA
CURVE B
TOTAL PERSON TRIPS PER HOUSEHOLD
2
4
6
8
10
12
5
10
15
20
25
30
35
HOUSEHOLD INCOME ('000 $)

CURVE B

3 TOTAL TRIPS PRODUCED BY PURPOSE (See Curves C & C')

Low Income $T._1$ = 21037 person trips (p.t.)

Home to Work trips	= 7%	x $T._1$	=	1473
Home to Shop trips	= 21%	x $T._1$	=	4418
Home to School trips	= 1%	x $T._1$	=	210
Home to Other trips	= 22%	x $T._1$	=	4628
Non-Home Based trips	= 49%	x $T._1$	=	10308
				21037 p.t.

Lower Middle Income $T._2$ = 65254 person trips

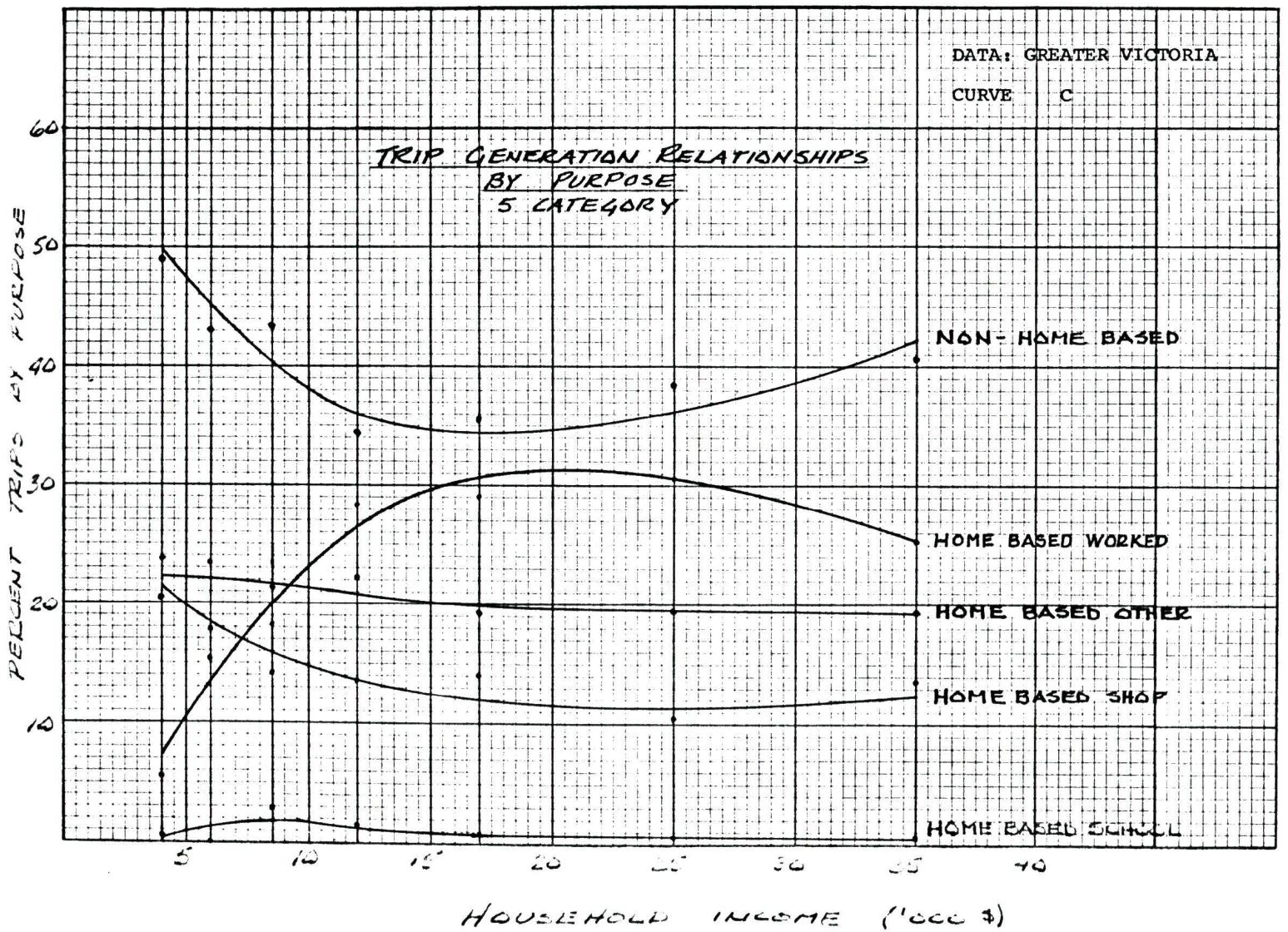
Home to Work trips	= 19%	x $T._2$	=	12398
Home to Shop trips	= 16%	x $T._2$	=	10441
Home to School trips	= 2%	x $T._2$	=	1305
Home to Other trips	= 22%	x $T._2$	=	14356
Non-Home Based trips	= 41%	x $T._2$	=	26754
				65254 p.t.

Upper Middle Income $T._3$ = 251876 person trips

Home to Work trips	= 30%	x $T._3$	=	75563
Home to Shop trips	= 13%	x $T._3$	=	32744
Home to School trips	= 1%	x $T._3$	=	2519
Home to Other trips	= 21%	x $T._3$	=	52894
Non-Home Based trips	= 35%	x $T._3$	=	88157
				251876 p.t.

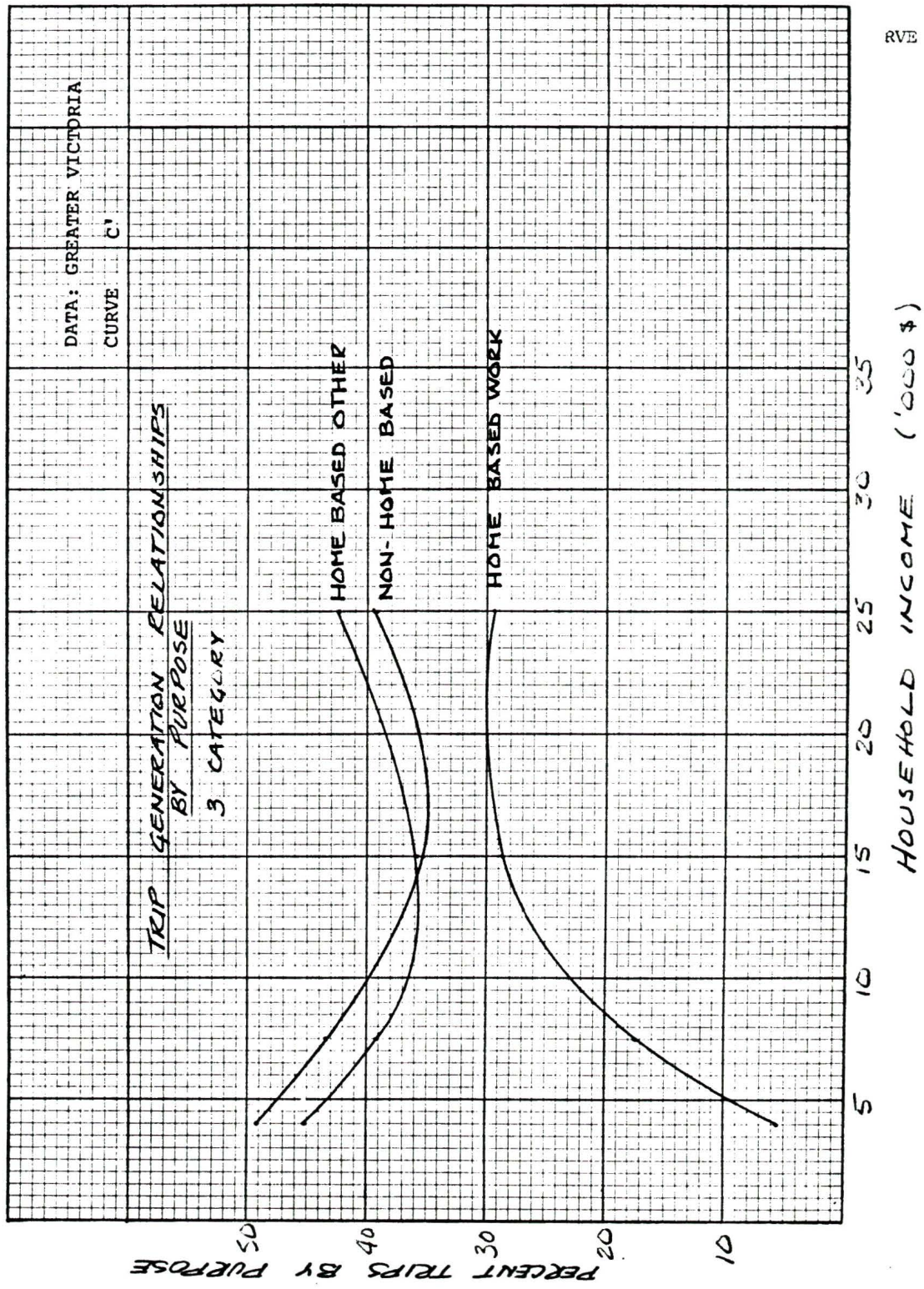
Higher Income $T._4$ = 258615 person trips

Home to Work trips	= 36%	x $T._4$	=	93101
Home to Shop trips	= 12%	x $T._4$	=	31034
Home to School trips	= 1%	x $T._4$	=	2586
Home to Other trips	= 20%	x $T._4$	=	51723
Non-Home Based trips	= 31%	x $T._4$	=	80171
				258615 p.t.


DATA: GREATER VICTORIA
CURVE C
TRIP GENERATION RELATIONSHIPS
BY PURPOSE
5 CATEGORY
NON-HOME BASED
HOME BASED WORKED
HOME BASED OTHER
HOME BASED SHOP
HOME BASED SCHOOL
PERCENT TRIPS BY PURPOSE
60
50
40
30
20
10
5
10
15
20
25
30
35
40
HOUSEHOLD INCOME ('000 $)

CURVE C

CURVE C'


DATA: GREATER VICTORIA
CURVE C'
TRIP GENERATION RELATIONSHIPS
BY PURPOSE
3 CATEGORY
HOME BASED OTHER
NON-HOME BASED
HOME BASED WORK
PERCENT TRIPS BY PURPOSE
HOUSEHOLD INCOME ('000 $)
10
20
30
40
50
5
10
15
20
25
30
35

4 TOTAL TRIPS PRODUCED BY MODE (See Curve D)

Low Income $T._1$ = 21037 person trips (p.t.)

Auto Driver	=	55%	x	$T._1$	= 11570
Auto Passenger	=	24%	x	$T._1$	= 5049
Transit Passenger	=	21%	x	$T._1$	= 4418
Other	=	0%	x	$T._1$	= 0
					21037 p.t.

Lower Middle Income $T._2$ = 65254 person trips

Auto Driver	=	60%	x	$T._2$	= 39152
Auto Passenger	=	25%	x	$T._2$	= 16314
Transit Passenger	=	9%	x	$T._2$	= 5873
Other	=	6%	x	$T._2$	= 3915
					65254 p.t.

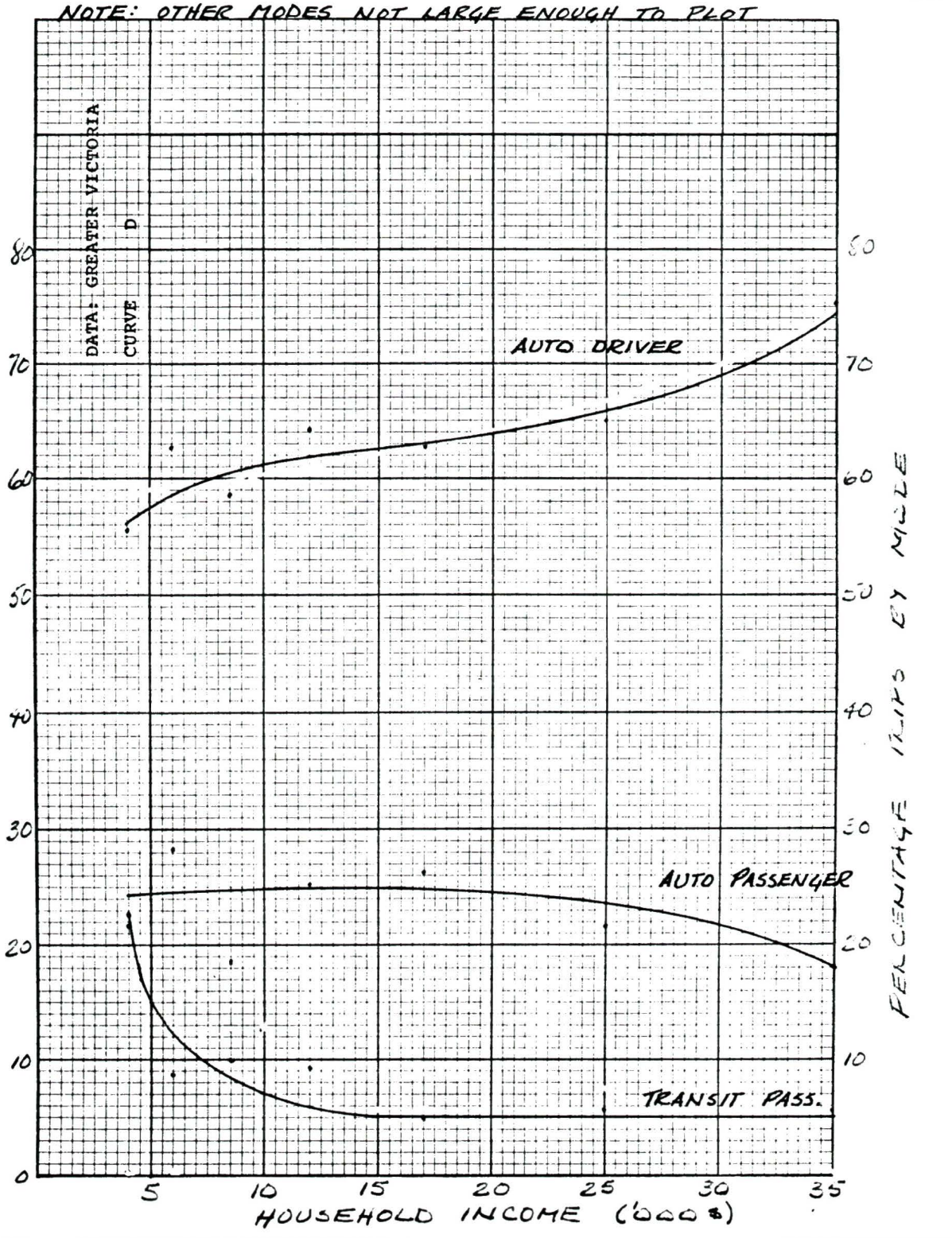
Upper Middle Income $T._3$ = 251876 person trips

Auto Driver	=	63%	x	$T._3$	= 158682
Auto Passenger	=	25%	x	$T._3$	= 62969
Transit Passenger	=	5%	x	$T._3$	= 12594
Other	=	7%	x	$T._3$	= 17631
					251876 p.t.

Higher Income $T._4$ = 258615 person trips

Auto Driver	=	66%	x	$T._4$	= 170686
Auto Passenger	=	24%	x	$T._4$	= 62068
Transit Passenger	=	5%	x	$T._4$	= 12931
Other	=	5%	x	$T._4$	= 12931
				TOTAL	258615 p.t.

CURVE D


NOTE: OTHER MODES NOT LARGE ENOUGH TO PLOT
DATA: GREATER VICTORIA
CURVE D
AUTO DRIVER
AUTO PASSENGER
TRANSIT PASS.
PERCENTAGE TRIPS BY MODE
HOUSEHOLD INCOME ('000 $)
0
10
20
30
40
50
60
70
80
5
10
15
20
25
30
35

The results of these cross-classifications may be plugged into census tract data where income breakdowns and car ownership rates enable acceptable short term (5 years) predictions to be made concerning anticipated travel demands by distribution and modal split in a planning area.

Although not covered in this exercise, a similar technique may be applied to trip attraction rates by the commercial or non-residential sector using employment and student data for given commercial zones in the city. See Table A which illustrates a functional trip generation matrix. Trip attraction rates are cross classified from an O-D survey at the destination side and are tabulated according to zonal distinations. Each zone must be weighted according to its employment characteristics, and student enrollments.

An actual example of a cross-classification of trip rates is formed in Table B.

Reasonableness Check

The method I have used to check the general strength of the relationships deduced is analysis of variance of the three key independents by the dependent variable. The dependent variable is person trips per household, and the independent variables are household income, car ownership per household, and household population.

As is evident from the 3-way anova, the residual is very large and our three classes manage only to explain some 36% of the total variation. This result is probably caused by extreme cells being loaded with very high within-class variance attributed to a small cell size. See printout named ANOVA RUN in Attachment F. Additionally, an interaction estimate should not be used to compute F scores. The reasons for this approach

are:

1. The interaction effects are fairly small and appear not to be absorbing other unidentified variables.
2. The unequal cell size produces larger residual SS values that do not reflect the true variance of the background population within each class.
3. The interaction effect is also accentuated by unequal cell size.
4. Theory clearly supports significant variance to exist between these three variables and certainly the error variance within each class is expected to be significantly less than that between class variation.

Table A*

Functional Trip Generation Matrix

Trip Purpose	Trips/ Hshld	Non-Retail	R E T A I L CBD	Shop Centre	Other	Univ.	High Sch.	Other
Home-Based Work	-	1.70	1.70	1.70	1.70	-	-	-
Home-Based Shop	-	-	2.00	9.00	4.00	-	-	-
Home-Based School	-	-	-	-	-	0.90	1.60	1.20
Home-Based Other	0.70	0.60	1.10	4.00	2.30	-	-	-
Non-Home Based	0.30	0.40	1.00	4.60	2.30	-	-	-

* "Trip Generation Analysis", U.S. Dept. of Transportation, Aug '75 page 41.

Table B*

Example of Trip Attraction
Procedure For Metro Washington
Council of Gov'ts (D.C.)

Non-Residential (Trips/Employee)

L U	Home-Based Work	Home-Based Shop	Home-Based Other	Non-Home Based
Other	1.78	0	5.87	0.90
Industrial	1.62	0	0.45	0.34
Institutional	1.20	0	1.43	0.35
Office-Core(Ring 0&1)	1.60	0	0.15	0.13
Fringe (Ring 2)	1.63	0	0.22	0.23
Sub-Ring (Ring 3-7)	1.74	0	0.45	0.30
Shopping-Retail Core	1.68	2.00	1.17	1.05
Fringe DC	1.68	0.39	2.33	1.26
DC Non Core	1.68	2.54	2.23	1.86
Arlington-Alex	1.68	4.72	3.82	3.46
Silver Spring	1.68	3.85	2.52	2.34
Alexandria	1.68	4.50	2.43	2.64
Suburban	1.68	8.99	4.34	4.59
Residential (trips/HH)				
Core	0.66	0	1.08	0.42
Remainder	0.06	0	0.57	0.23

* "Trip Generation Analysis", U.S. Dept. of Transportation, Aug '75
Page 43.

5. Very little is likely to be gained by using the interaction effect indicates that collinearity exists to some degree between the independent variables.
6. Since an unequal cell design has been used with a significance level of .15 ,thus, preventing the likelyhood of rejecting the null hypothesis thereby greatly increasing the probability of making a TYPE II error.

As result of this, the graphs illustrated in curves A-C' must be interpreted on the basis of empircal logic and the accepted relationships identified in the literature of transport studies. As a final note, if a 2-way cross-classification design is used in its place with the dependent classed by car ownership and household population then quite sighnificant results occur. (See Attachment E.).

car availability	F	= 2.669
	P(F)	= .163
Household Population	F	= 2.089
	P(F)	= .22

Therefore a rejection of the null hypothesis places significance on the classes used for trip production. Here the a priori is that no significant within class variation exists.

Conclusion

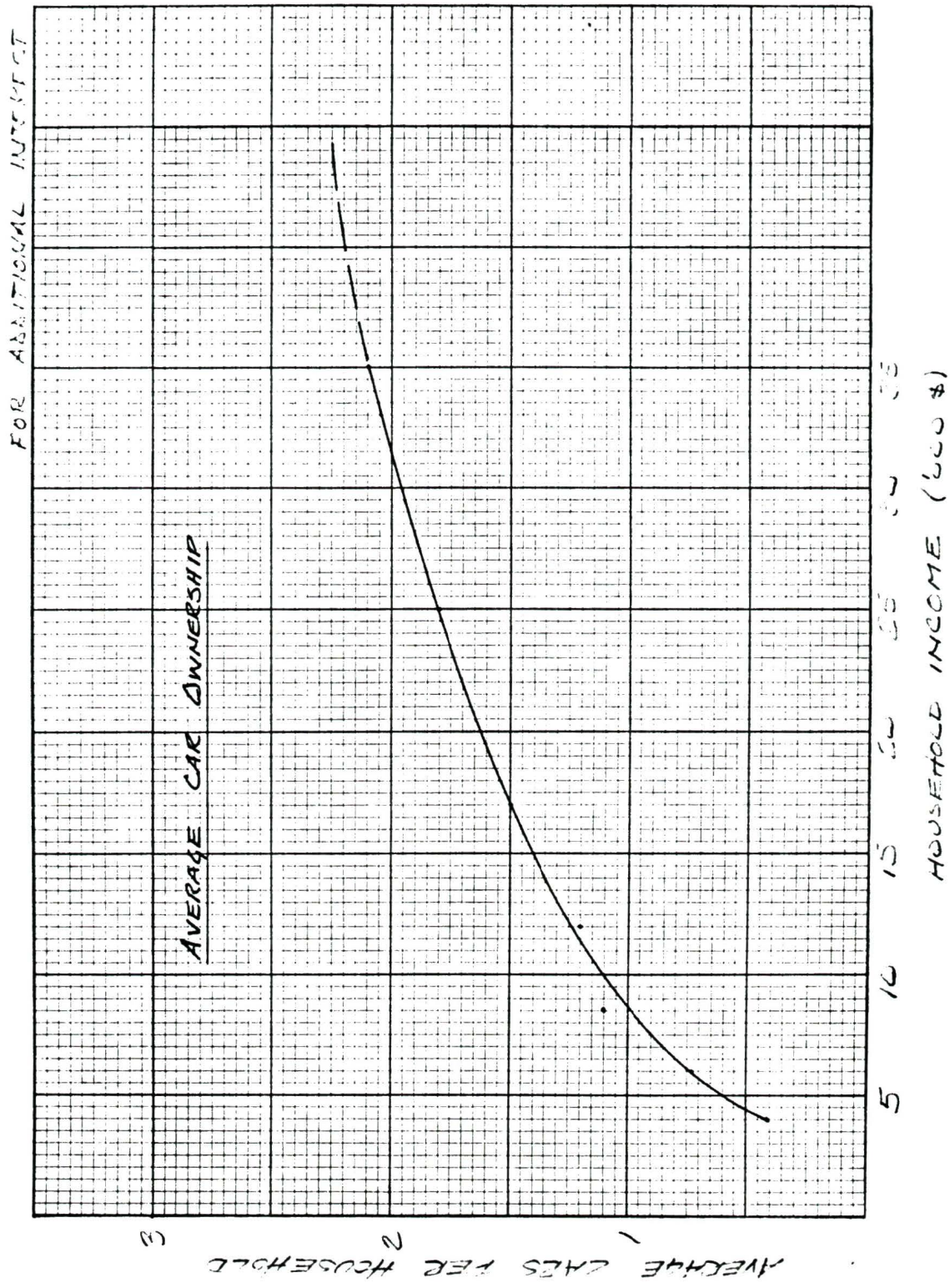
The results found in the cross-classification checks for statistical adequacy compare favourably with other cities of similar size in North America. The assumption that income and car availability are useful explanatory variables in disaggregate trip generation is generally supported in this cross-classification exercise. The error involved

can be assumed to be sampling error particularily where cell sizes are very small. Cross-classification would appear to be a more adaptable to making changes over time than with methods which use grouped data such as least squares regression. As a general indicator of trip generation this rather cost effective approach would find use in smaller urban planning areas where less detail and accuracy is not warranted. Cross-classification would be particularily useful in land use planning and transit planning.

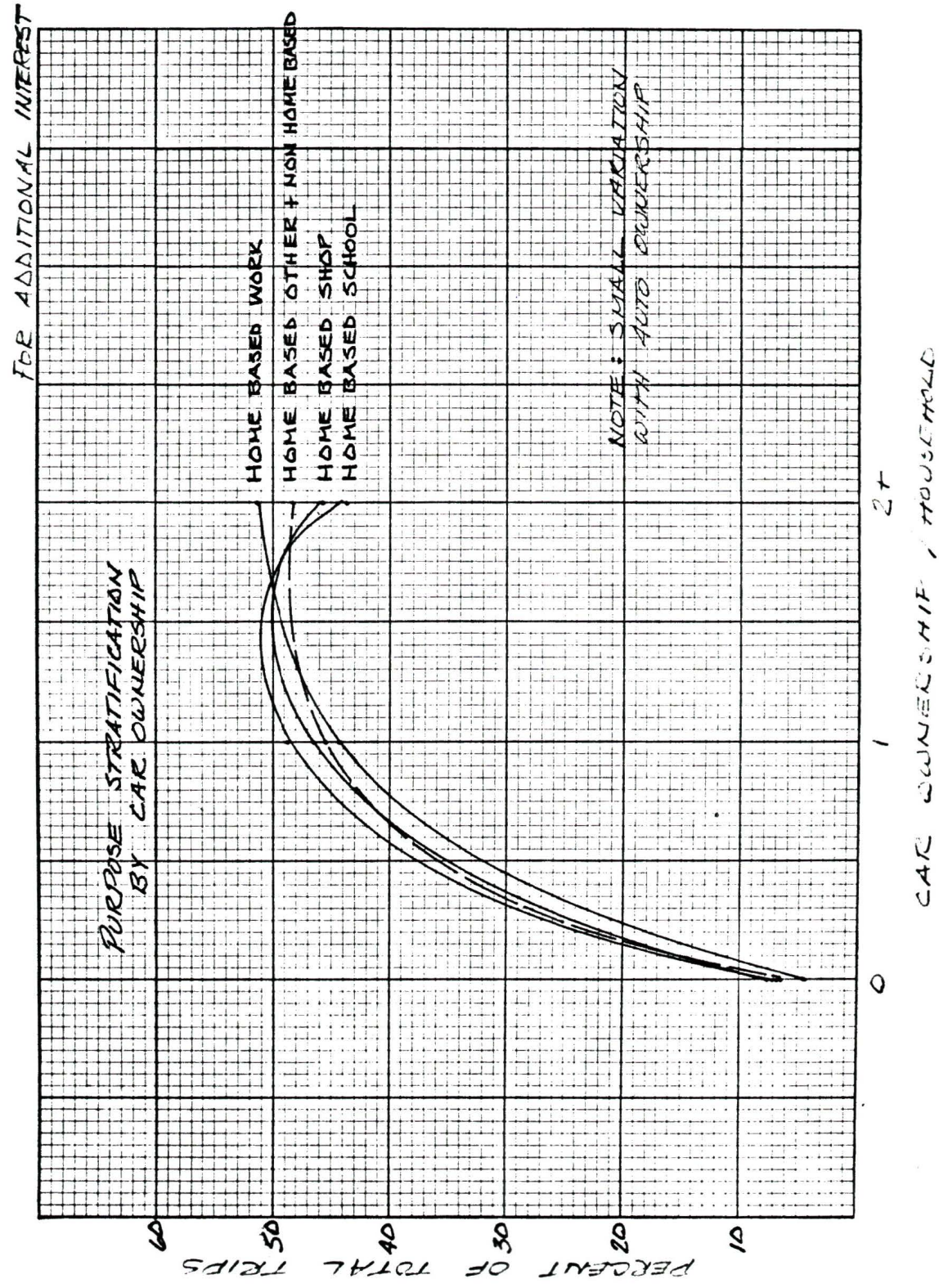
Final Note:

Additional cross-classification experiments are plotted in curves E & F.

CURVE E


AVERAGE CAR OWNERSHIP
AVERAGE CARS PER HOUSEHOLD
HOUSEHOLD INCOME (000 $)
FOR ADDITIONAL INTEREST

CURVE F


FOR ADDITIONAL INTEREST
PURPOSE STRATIFICATION BY CAR OWNERSHIP
HOME BASED WORK
HOME BASED OTHER + NON HOME BASED
HOME BASED SHOP
HOME BASED SCHOOL
NOTE: SMALL VARIATION WITH AUTO OWNERSHIP
PERCENT OF TOTAL TRIPS
60
50
40
30
20
10
0
1
2+
CAR OWNERSHIP / HOUSEHOLD

ATTACHMENT A

(See APPENDIX B)

ATTACHMENT B

(See APPENDIX F)

ATTACHMENT C

Trip Purpose Table

Aggregation of trip purpose model from 5 groups to 3, cross- classified with income aggregated to 4 groups from 7.

INCOME GROUPS (000's $)	<$5	$5-10	$10-20	>$ 20
Home Based Work	7 (5.74%)	80 (17.5%)	462 (28.8%)	440 (29.3%)
Home Based Other	55 (45.1%)	179 (39.1%)	576 (35.9%)	636 (42.4%)
Non-Home Based	60 (49.2%)	199 (43.4%)	567 (35.3%)	587 (39.1%)
TOTALS	122	458	1605	1501

ATTACHMENT D

Home Based Work - Cross-Classification

	Rate	CAR = 0			
INC 1	5.74	2.6	.63	.11	0
2	15.45	1.7	.3	0	0
3	18.21	.73	2.2	.7	8.0
4	28.33	5.1	7.1	1.4	.5
5	29.0	.58	3.48	0	1.74
6	30.65	0	2.8	5.5	0
7	25.20	0	0	0	0

Persons / Household TOTAL = 45.17
= 45

Home Based Shop - Cross-Classification

	Rate	CAR = 0			
INC 1	23.77	10.7	2.6	.47	0
2	17.89	1.97	.36	0	0
3	14.03	.56	1.68	.56	6.17
4	13.71	2.47	3.42	.68	.27
5	14.08	.28	1.68	0	.8
6	10.42	0	.93	1.88	0
7	13.82	0	0	0	0

Persons / Household TOTAL = 37.86
= 38

ATTACHMENT D (continued)

Home Based School

	Rate	CAR = 0			
INC 1	0.82	.37	.1	.01	0
2	0	0	0	0	0
3	2.99	.11	.36	.12	1.3
4	1.42	.25	.36	.07	.03
5	.95	.02	.11	0	.06
6	.71	0	.06	.12	0
7	.81	0	0	0	0

Persons / Household TOTAL = 3.5
= 45

Home Based Other

	Rate	CAR = 0			
INC 1	20.49	9.22	2.25	.4	0
2	23.58	2.6	.47	0	0
3	21.19	.48	2.5	.85	9.3
4	22.12	3.98	5.53	1.1	.4
5	19.33	.38	2.31	0	1.16
6	19.70	0	1.77	3.55	0
7	19.24	0	0	0	0

Persons / Household TOTAL = 48.8
= 49

ATTACHMENT D (continued)

Non-Home Based

	Rate	CAR = 0			
INC 1	49.18	22.13	5.41	.98	0
2	43.09	4.74	.86	0	0
3	43.58	1.74	5.23	1.74	19.18
4	34.41	6.19	8.60	1.72	.69
5	35.92	.72	4.31	0	0
6	38.52	0	3.47	6.93	0
7	40.92	0	0	0	0

Persons / Household TOTAL = 96.81
= 97

Home Based Work

	Rate	CAR = 1			
INC 1	5.74	2.47	.11	.34	0
2	15.45	4.48	6.8	2.32	0
3	18.21	5.28	17.85	4.19	10.74
4	28.33	13.03	36.26	14.17	34.28
5	29.0	11.89	45.82	33.93	43.21
6	30.65	2.45	26.36	20.54	72.03
7	25.20	1.01	3.28	4.28	20.16

Persons / Household TOTAL = 437.27

ATTACHMENT D (continued)

Home Based Shop

	Rate	CAR = 1			
INC 1	23.77	10.22	.48	1.43	0
2	17.89	5.19	7.87	2.68	0
3	14.03	4.07	13.75	3.23	8.28
4	13.71	6.31	17.55	6.86	16.59
5	14.08	5.77	22.25	16.47	20.98
6	10.42	.83	8.96	6.98	24.49
7	13.82	.55	1.80	2.35	11.06

Person / Household TOTAL = 226.98

Home Based School

	Rate	CAR = 1			
INC 1	0.82	.35	.02	.05	0
2	0	0	0	0	0
3	2.99	.87	2.93	.69	1.76
4	1.42	.65	1.82	.71	1.72
5	0.95	.39	1.50	1.11	1.42
6	0.71	.06	.61	.48	1.67
7	0.81	.03	.11	.14	.65

Person / Household TOTAL = 19.72

ATTACHMENT D (continued)

Home Based Other

	Rate	CAR = 1			
INC 1	20.49	8.81	.41	1.23	0
2	23.58	6.84	10.38	3.54	0
3	21.19	6.15	20.77	4.87	12.50
4	22.12	10.18	28.31	11.06	26.77
5	19.33	7.93	30.54	22.62	28.80
6	19.70	1.58	16.94	13.20	46.30
7	19.24	.77	2.50	3.27	15.39

Persons / Household TOTAL = 341.63

Non-Home Based

	Rate	CAR = 1			
INC 1	49.18	21.15	.98	2.95	0
2	43.09	12.50	18.96	6.46	0
3	43.58	12.64	42.71	10.02	25.71
4	34.41	15.83	44.04	17.21	41.64
5	35.92	14.73	56.75	42.03	53.52
6	28.52	3.08	33.13	25.81	90.52
7	40.92	1.64	5.32	6.96	32.74

Persons / Household TOTAL = 639.01

Category - CAR = 2+ Table infered from CAR = 0 and CAR = 1 Totals.

Subtotals taken from Purpos Run.

Note: CAR = 2+ inferred from previous two tabulations.

ATTACHMENT E

Primary Results of Two-Way Anova

Model 1 - 3 x 4:2-Way with 7 Replicates (Cell size = 7)

Results - 1. Interaction effect between household population and car availability was not significant at α .05

p - .0158 for $F_{I6,72} = 2.827$

2. Both the row (car avail.) and column (household pop.) effects were insignificant at α .05

p = .001 and .0012 respectively for $F_{R2,72} = 7.549$ and $F_{c3,72} = 7.549$

By combining I with E revised F ratios were produced.

$E' = E + I = 310382.0238/ (E_{df} + I_{df}) = 3979.257$
$E_{df} = 72$ & $I_{df} = 6$

making all F ratios even smaller and less significant

$F_r = 6.61863$ $d.f._{2,78}$ $p = .0022$

$F_c = 5.18046$ $d.f._{3,78}$ $p = .0026$

Results improved but even a double improvement does not reveal what is likely to be in the data.

Model 2 - 3 x 4:2-Way with 0 replicate (Cell size = 1)

This model assumes that no significant error exists in the groups (within class variation is near 0) and that all the unexplained or residual variation is actually an interaction effect.

The results were quite different.

Results

Source of Variation:

	SS	d.f.	$\bar{x}^2$	F
TOTAL	1215920.9	11		
COLUMNS	432901.6	3	144300	2.09
ROWS	368721.2	2	184360	2.67
INTERACTION	414298.2	6	69050	

F_c prob. = .163 (16.3%) reject H_0

F_r prob. = .220 (22.0%) reject H_0

$$\text{Multiple } R^2 = \frac{SS_y - SS_{within}}{SS_y} = \frac{SS_r + SS_c + SS_i}{SS_y}$$

$$= \frac{1215920.9 - 0}{1215920.9} = 1.0$$

From model one we have:

$$R^2 = \frac{424899.56 - 251196.57}{424899.56}$$

$$= .4088 \quad \text{and} \quad R = .63938$$

and the F - statistic is as follows:

$$F = \frac{(SS_r + SS_c + SS_i)/\text{d.f.}}{SS_E / \text{d.f.}}$$

$$F = 4.53$$

$$F_{prob} = .000035$$

Where; $d.f._1 = K_r K_c - 1 = 11$ and $d.f._2 = N - K_r K_c = 72$

BS47900

ATTACHMENT F

FILE: CARINC RUN WITH HOME DATA INPUT

WITH CHANGES TO INCOME.

```
$WATFIV (57873,120),NOEXT,NOWARN
      REAL CLASS,T,KLASS,A
      INTEGER C,I
      DIMENSION CLASS(7,3),KLASS(7,3),A(7,3)
      DATA CLASS/21*0./
      DATA KLASS/21*0./
C
      DO 10 K=1,494
      READ(5,100,END=999)C,I,T
100   FORMAT(T19,I2,T24,I1,F2.0)
C
       IF (I.EQ.0.OR.I.GT.7) I=4
       C=C+1
       IF (C.GE.3) C=3
C
      CLASS(I,C)=CLASS(I,C) + T
10     KLASS(I,C)=KLASS(I,C) + 1
C
       DO 11 M=1,7
       DO 11 N=1,3
      IF (KLASS(M,N).EQ.0) GO TO 11
      IF (CLASS(M,N).EQ.0) GO TO 11
      A(M,N)=CLASS(M,N)/KLASS(M,N)
11    CONTINUE
999    WRITE(6,300)((CLASS(M,N),M=1,7),N=1,3)
       WRITE(6,300)((KLASS(M,N),M=1,7),N=1,3)
       WRITE(6,300)((A(M,N),M=1,7),N=1,3)
300    FORMAT('0',/////7F15.2///)
      STOP
      END
```

$ENTRY

TOTAL TRIPS IN CATEGORY

INCOME ('000'$)		<5	5-7	7-10	10-14	14-20	20-30	>30
	0	58.00	13.00	64.00	50.00	20.00	27.00	0.00
CAR OWNER SHIP	1	51.00	88.00	209.00	345.00	465.00	396.00	114.00
	2+	18.00	26.00	87.00	176.00	383.00	748.00	348.00

TOTAL HOUSE HOLDS IN CATEGORY

	64.7	31.7	15.1	16.3	3.7	2.7	0
Δ	22.00	13.00	8.00	17.00	4.00	3.00	0.00

AVERAGE # CARS/INC. → .41 .73 1.1 1.2 1.5 1.8 2.1

	29.4	63.4	64.2	58.7	58.7	39.3	29.3
1	10.00	26.00	34.00	61.00	64.00	44.00	12.00
	5.9	4.9	20.8	25.0	37.6	58	70.7
2+	2.00 x2	2.00 x2	11.00 2.2	26.00 2.3	41.00 2.4	65.00 2.5	29.00 2.6
	34	41	53	104	109	112	41

TRIPS / HOUSEHOLD IN EACH CATEGORY

	<$5	$5-7	$7-10	$10-14	$14-20	$20-30	$30 0÷0=0 or 0
0	2.64	1.00	8.00	2.94	5.00	9.00	0
1	5.10	3.38	6.15	5.66	7.27	9.00	9.50
2+	9.00	13.00	7.91	6.77	9.34	11.51	12.00
Ave RATE	5.58	5.79	7.35	5.12	7.20	9.84	7.17

CORE USAGE OBJECT CODE= 1376 BYTES, ARRAY AREA= 252 BYTES, TOTAL AREA AVAILABLE= 132224 BYTES
DIAGNOSTICS NUMBER OF ERRORS= 0, NUMBER OF WARNINGS= 0, NUMBER OF EXTENSIONS= 0
COMPILE TIME= 0.09 SEC, EXECUTION TIME= 0.86 SEC, WATFIV - JUL 1973 V1L4 13.51.39 SUNDAY 20 APR 80

ATTACHMENT F1 cont...

FILE: PURPOSE RUN

```
      SWATFIV (S7872,120),NOEXT,NOWARN
 1          REAL CLASS
 2          INTEGER I,FT,P
 3          DIMENSION CLASS(6,7)
 4          DATA CLASS/42*0./
            C
 5          DO 10 K=1,3734
 6          READ (5,100,END=999)I,FT
 7    100   FORMAT (T24,I1,T49,I2)
            C
 8            IF (I.EQ.0) I=4
 9            IF (I.GT.7) I=4
10               IF(FT.GE.61.OR.FT.LE.69) P=5
11               IF(FT.LT.61.OR.FT.GT.69) P=6
12             IF(FT.EQ.0) P=1
13               IF(FT.EQ.61.OR.FT.EQ.16) P=2
14               IF(FT.EQ.62.OR.FT.EQ.26) P=3
15               IF(FT.EQ.65.OR.FT.EQ.56) P=4
            C
16          CLASS(P,I)=CLASS(P,I) + 1
17    10    CONTINUE
            C
18    999   WRITE(6,200)((CLASS(P,I),P=1,6),I=1,7)
19    200   FORMAT('0',////6F12.0////)
20          STOP
21          END
```

Type Record:

	SENTRY NO TRIPS	HOME BASED WORK	BA	HOME LABEL SHOP	HOME LABEL SCHOOL	HOME LABEL OTHER	NON-HOME LABEL	TOTALS	TOTALS WITHOUT NO TRIPS INCL.
INCOME #1 $\bar{X}_1$ < $4000 = $4000	7.	7. 5.74		29. 23.77	1. .82	25. 20.49	60. 49.18	129	122
INCOME #2 $\bar{X}_2$ = $6000	12.	19. 15.45		22. 17.89	0. 0	29. 23.58	53. 43.09	135	123
INCOME #3 $\bar{X}_3$ = $8500	3.	61. 18.21		47. 14.09	10. 3.11	71. 21.19	146. 43.52	338	335
INCOME #4 $\bar{X}_4$ > $12,500	16.	219. 29.03		106. 13.11	11. 1.42	171. 22.12	266. 34.31	789	773

ATTACHMENT F2

$\bar{X}_4$ = 12000

INCOME #5	6.	243.	118.	8.	162.	301.	838	832
$ 14 - 20		29.0	14.08	.95	19.33	35.92		
$\bar{X}_5$ = $17000								
INCOME #6	3.	347.	118.	8.	223.	436.	1135	1132
$ 20 - 30		30.65	10.42	.71	19.70	38.52		
$\bar{X}_6$ = $25,000								
INCOME #7	1.	93. 25.20	51. 13.82	3. .81	71. 19.24	151. 40.92	370	369
7 $30	48	989	491	41	752	1413	3734	3686
$\bar{X}_7$ = $35,000								

CORE USAGE OBJECT CODE= 1144 BYTES, ARRAY AREA= 168 BYTES, TOTAL AREA AVAILABLE= 132224 BYTES

DIAGNOSTICS NUMBER OF ERRORS= 0, NUMBER OF WARNINGS= 0, NUMBER OF EXTENSIONS= 0

COMPILE TIME= 0.07 SEC, EXECUTION TIME= 4.95 SEC, WATFIV - JUL 1973 V1L4 16.29.33 SATURDAY 19 APR 80

B-47768

ATTACHMENT F2 cont...

FILE 1 MODE RUN

```
      $WATFIV (57872,120),NOEXT,NOWARN
      INTEGER CLASS,I,M
      DIMENSION CLASS(7,10)
      DATA CLASS/70*0/
C
      DO 10 K=1,3734
      READ (5,100,END=999)I,M
100   FORMAT(23X,I1,23X,I1)
C
          IF(I.EQ.0.OR.I.GT.7) I=4
          M=M+1
          IF(M.GT.10) M=1
        IF (M.EQ.0) GO TO 10
      CLASS(I,M)=CLASS(I,M) + 1
10    CONTINUE
C
999   WRITE(6,200)((CLASS(I,M),I=1,7),M=1,10)
200   FORMAT(' ',/////7I10///)
      STOP
      END

      $ENTRY
```

BSATFJA

INCOME in 000's	<5	$5-7	$7-10	$10-14	$14-20	$20-20	$20		
NO TRIP MADE	10	12	8	22	8	6	1	67	% 13% of HCHLDS MADE NO TRIP'S.
WITHOUT LAST TWO MODES	110	113	309	699	774	1039	344		
TOTALS PER INCOME	119	123	330	767	830	1129	369		
AUTO DRIVER	61	71	181	448	486	675	259	2181	59.5 %
	55.5	62.8	58.6	64.1	62.8	65.0	75.3		
AUTO PASSENGER	24	32	57	176	204	226	62	781	21.3 %
	21.8	28.3	18.4	25.2	26.4	21.8	18.0		
TRANSIT PASSENGER	25	10	31	64	39	60	20	249	6.8 %
	22.7	8.8	10.0	9.2	5.0	5.8	5.8		
TRUCK DRIVER	0	0	39	9	37	61	3	149	4.0 %
T.D., T.P., TAX, etc	0	0	12.9	1.6	5.8	5.8	.9		

ATTACHMENT F 3

TRK PASSENGER	0	0	1	0	3	14	0	18	0.5 %
TAXI PASS.	0	0	0	1	5	3	0	9	.25 %
PARK & RIDE	0	0	0	1	0	0	0	1	0 %
BIKE	7	10	15	42	29	56	20	179	4.9 %
WALK TO WORK	2	0	6	26	27	34	5	100	2.7 %

TRIP TOTAL 3601 = 7.4 TPS/HSHLD

CORE USAGE OBJECT CODE= 760 BYTES, ARRAY AREA= 280 BYTES, TOTAL AREA AVAILABLE= 132224 BYTES
DIAGNOSTICS NUMBER OF ERRORS= 0, NUMBER OF WARNINGS= 0, NUMBER OF EXTENSIONS= 0
COMPILE TIME= 0.06 SEC, EXECUTION TIME= 4.54 SEC, WATFIV - JUL 1973 V1L4 14.41.22 SATURDAY 19 APR 80

FILE: ANOV RUN WITH -HOME DATA INPUT

WITH CHANGES TO INCOME

```
      $WATFIV (S7873,120),NOEXT,NOWARN
 1          INTEGER C,I,P
 2          REAL ANOV,ANOVA,T,A
 3          DIMENSION ANOV(3,4),ANOVA(3,4),A(3,4)
 4          DATA ANOV/12*0./
 5          DATA ANOVA/12*0./
 6          DATA A/12*0./
 7    C      DO 10 K=1,494
 8          READ(5,100,END=999)C,I,T
 9    100   FORMAT(18X,I2,3X,I1,F2.0)
10    C        IF(I.EQ.0.OR.I.GT.7) I=3
11             IF(I.EQ.1) I=1
12             IF(I.LE.3.AND.I.GE.2) I=2
13             IF(I.LE.5.AND.I.GE.4) I=3
14             IF(I.LE.7.AND.I.GE.6) I=4
15    C        C=C+1
16             IF(C.GE.3) C=3
17    C      ANOV(C,I)=ANOV(C,I) + T
18           ANOVA(C,I)=ANOVA(C,I) + 1
19    10     CONTINUE
20           DO 11 M=1,3
21           DO 11 N=1,4
22             IF(ANOV(M,N).EQ.0) GO TO 11
23             IF(ANOVA(M,N).EQ.0) GO TO 11
24           A(M,N)=ANOV(M,N)/ANOVA(M,N)
25    11     CONTINUE
26    C
27    999    WRITE(6,200)((ANOV(M,N),M=1,3),N=1,4)
28           WRITE(6,200)((ANOVA(M,N),M=1,3),N=1,4)
29           WRITE(6,300)((A(M,N),M=1,3),N=1,4)
30    200    FORMAT(' ',/////3F15.0///)
31    300    FORMAT(' ',/////3F15.2///)
32           STOP
             END
```

SENTRY

TOTAL PER.-TRIPS BY CLASS

$	0	1	2+
<5	58.	51.	18.
$5-10	77.	297.	113.
$10-20	70.	810.	559.

CAR OWNERSHIP

TOTALS/CAR OWNERSHIP CATEGORY

0	1	2+	
232 -	1668	1786	
45.52 = 45	437.21 = 436	506	HOME BASED WORK
37.9 = 38	226.78 = 228	225	HOME BASED SHOP
3.15 = 43	19.72 = 20	18	HOME BASED SCHOOL

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ATTACHMENT F4

270.

				75.5 = 77	341.6 = 342	361	HOME LABEL OTHER
				96.81 = 97	579.01 = 579 (LAO)	676	NON-HOMED BASED
>$20	27.	510.	1096.	PERCENTAGES BY CAR OWNERSHIP & TRIP PURPOSE			
	TOTAL HOUSEHOLDS BY CLASS			0	1	2+	TOTALS
<$5	0 22.	1 10.	2+ 2.	4.55	44.29	51.16	989 HBW
				7.74	46.44	45.82	491 HBS
$5-10	21.	60.	13.	7.32	48.78	43.90	41 HBSc
				6.52	45.48	48.01	752 HBO
$10-20	21.	125.	67.	6.86	45.29	47.84	1413 NHB
>$20	3.	56.	94.				
	~~TOTAL~~ PERSON-TRIPS / HOUSEHOLD BY CLASS			AVE RATE			
<$5	0 2.64	1 5.10	2+ 9.00	5.58			
$5-10	3.67	4.95	8.69	5.77			

ATTACHMENT F 4 cont...

$10-20	3.33	6.48	8.34	6.05
$>20	9.00	9.11	11.66	9.92

CORE USAGE OBJECT CODE= 1768 BYTES, ARRAY AREA= 144 BYTES, TOTAL AREA AVAILABLE= 132224 BYTES
DIAGNOSTICS NUMBER OF ERRORS= 0, NUMBER OF WARNINGS= 0, NUMBER OF EXTENSIONS= 0
COMPILE TIME= 0.11 SEC, EXECUTION TIME= 0.89 SEC, WATFIV - JUL 1973 V1L4 13.49.14 SUNDAY 20 APR 80

BS47786

ATTACHMENT F4 cont...

FILE: ANOVA RUN WITH HOME DATA INPUT

WITH CHANGES TO INCOME

```
      $WATFIV (S7873,120),NOEXT,NOWARN
 1          INTEGER P,C,I
 2          REAL ANOVA,CLASS,KLASS,T
 3          DIMENSION ANOVA(3,4,7),CLASS(3,4,7),KLASS(3,4,7)
 4          DATA ANOVA/84*0./
 5          DATA CLASS/84*0./
 6          DATA KLASS/84*0./
 7    C      DO 10 K=1,494
 8          READ(5,100,END=999)P,C,I,T
 9    100   FORMAT(15X,I2,1X,I2,3X,I1,F2.0)
10    C       IF(I.EQ.0.OR.I.GT.7) I=4
11          IF(P.EQ.0) P=1
12            IF(P.GT.4) P=4
13            C=C+1
14            IF(C.GE.3) C=3
15    C     CLASS(C,P,I)=CLASS(C,P,I) + T
16          KLASS(C,P,I)=KLASS(C,P,I) + 1
17    10    CONTINUE
18            DO 11 L=1,3
19            DO 11 M=1,4
20            DO 11 N=1,7
21              IF (CLASS(L,M,N).EQ.0) GO TO 11
22              IF (KLASS(L,M,N).EQ.0) GO TO 11
23          ANOVA(L,M,N)=CLASS(L,M,N)/KLASS(L,M,N)
24    11    CONTINUE
25    C
26    999   WRITE(6,200)(((CLASS(C,P,I),C=1,3),P=1,4),I=1,7)
27          WRITE(6,200)(((KLASS(C,P,I),C=1,3),P=1,4),I=1,7)
28          WRITE(6,200)(((ANOVA(C,P,I),C=1,3),P=1,4),I=1,7)
29    200   FORMAT(' ',////3F7.2,6X,3F7.2,6X,3F7.2,6X,3F7.2////)
30          STOP
            END
```

RED VALUES SHOW INCOME AGGREGATED TO 4 GROUPS FROM 7.

BEFORE	AFTER
1	1
2	2
3	3
4	3
5	4
6	4
7	4

TOTAL TRIPS / CATEGORY

SENTRY

(1)			(2)			(3)			(4)			
0	1	2+	0	1	2+	0	1	2+	0	1	2+	
45.00	43.00	0.00	11.00	2.00	18.00	2.00	6.00	0.00	0.00	0.00	0.00	< 5
2.6			.63			.11			0			
11.00	29.00	0.00	2.00	44.00	0.00	0.00	15.00	0.00	0.00	0.00	26.00	5 - 7
1.7			.3									
15	58	0	14	142	35	4	38	4	44	59	74	
4.00	29.00	0.00	12.00	98.00	35.00	4.00	23.00	4.00	44.00	59.00	48.00	7 - 10
.72			2.2			.7			8.0			

	0	1	2+	0	1	2+	0	1	2+	0	1	2+	
	18.00	46.00	0.00	25.00	128.00	27.00	5.00	50.00	24.00	2.00	121.00	125.00	10 - 14
	5.1			7.1			1.4			.5			
	20	87	0	37	286	70	5	167	106	8	270	383	
	2.00	41.00	0.00	12.00	158.00	43.00	0.00	117.00	82.00	6.00	149.00	258.00	14 - 20
	.58			3.48			0			1.74			
	0.00	8.00	0.00	9.00	86.00	96.00	18.00	67.00	186.00	0.00	235.00	466.00	20 - 30
	0			2.8			5.5			0			
	0	12	8	9	99	129	18	84	259	0	315	700	
	0.00	4.00	8.00	0.00	13.00	33.00	0.00	17.00	73.00	0.00	80.00	234.00	> 30

TOTAL HOUSEHOLDS / CATEGORY

	(1) 0	1	2+	(2) 0	1	2+	(3) 0	1	2+	(4) 0	1	2+	
	15.00	8.00	0.00	6.00	1.00	2.00	1.00	1.00	0.00	0.00	0.00	0.00	< 5
	5.00	12.00	0.00	8.00	12.00	0.00	0.00	2.00	0.00	0.00	0.00	2.00	5 - 7
	6	18	0	12	32	6	1	6	1	2	4	6	
	1.00	6.00	0.00	4.00	20.00	6.00	1.00	4.00	1.00	2.00	4.00	4.00	7 - 10
	7.00	17.00	0.00	8.00	26.00	7.00	1.00	8.00	6.00	1.00	10.00	13.00	10 - 14

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	8	24	0	10	50	14	1	27	17	2	24	36		
	1.00	7.00	0.00	2.00	24.00	7.00	0.00	19.00	11.00	1.00	14.00	23.00	14 - 20	
	0.00	2.00	0.00	1.00	11.00	11.00	2.00	9.00	18.00	0.00	22.00	36.00	20 - 30	
	0	3	1	1	13	15	2	11	24	0	29	54		
	0.00	1.00	1.00	0.00	2.00	4.00	0.00	2.00	6.00	0.00	7.00	18.00	730	
	PERSON-TRIPS PER HOUSEHOLD / CATEGORY													
	0	1	2+	0	1	2+	0	1	2+	0	1	2+		
	3.00	5.38	0.00	1.83	2.00	9.00	2.00	6.00	0.00	0.00	0.00	0.00	< 5	
	2.20	2.42	0.00	0.25	3.67	0.00	0.00	7.50	0.00	0.00	0.00	13.00	5 - 7	
	2.5	3.22	0	1.17	4.44	5.83	4	6.33	4	22	14.75	12.33		
	4.00	4.83	0.00	3.00	4.90	5.83	4.00	5.75	4.00	22.00	14.75	12.00	7 - 10	
	2.57	2.71	0.00	3.13	4.92	3.86	5.00	6.25	4.00	2.00	12.10	9.62	10 - 14	
	2.5	3.63	0	3.70	5.72	5.00	5.00	6.19	6.24	4.00	11.25	10.64		
	2.00	5.86	0.00	6.00	6.58	6.14	0.00	6.16	7.45	6.00	10.64	11.22	14 20 / 20 - 00	

0.00 4.00 0.00	9.00 7.82 8.73	9.00 7.44 10.33	0.00 10.68 12.94	20 - 30
0 4.0 8.00	9.00 7.62 8.60	9.00 7.64 10.79	0 10.86 12.96	
0.00 4.00 8.00	0.00 6.50 8.25	0.00 8.50 12.17	0.00 11.43 13.00	730

CORE USAGE OBJECT CODE= 1728 BYTES, ARRAY AREA= 1008 BYTES, TOTAL AREA AVAILABLE= 132224 BYTES
DIAGNOSTICS NUMBER OF ERRORS= 0, NUMBER OF WARNINGS= 0, NUMBER OF EXTENSIONS= 0
COMPILE TIME= 0.10 SEC, EXECUTION TIME= 1.07 SEC, WATFIV - JUL 1973 V1L4 13.52.33 SUNDAY 20 APR 80

BC47810

ATTACHMENT F5 cont...

3-WAY ANOVA ... INCL. ..., CAN'T BE REDESIGNED, MISSING FOR ... WITH ... PER MONTH.

```
//HOGAN JOB (******************),'RSCS,CORNETT',
// CLASS=A,MSGCLASS=A,PRTY=06,TIME=(0005,00)
LOG IEF403I HOGAN     STARTED TIME=20.59.07
LOG IEF404I HOGAN     ENDED   TIME=20.59.21
// EXEC SPSS
//GO.SYSIN DD *
IEF236I ALLOC. FOR HOGAN    GO
IEF237I 252    ALLOCATED TO STEPLIB
IEF237I 253    ALLOCATED TO FT01F001
IEF237I 251    ALLOCATED TO FT02F001
IEF237I 252    ALLOCATED TO FT10F001
IEF142I - STEP WAS EXECUTED - COND CODE 0000
IEF285I   SYS003.SPSSMV80                                KEPT
IEF285I   VOL SER NOS= SYS003.
IEF285I   SYS80109.T205906.RF103.HOGAN.R0000001          DELETED
IEF285I   VOL SER NOS= SYS004.
IEF285I   SYS80109.T205906.RF103.HOGAN.R0000002          DELETED
IEF285I   VOL SER NOS= SYS002.
IEF285I   SYS003.SPSSUD80                                KEPT
IEF285I   VOL SER NOS= SYS003.
IEF373I STEP /GO      / START 80109.2059
IEF374I STEP /GO      / STOP  80109.2059 CPU    0MIN 03.20SEC STOR VIRT 312K
***UVIC ****01*************************************************************************************PF****
***UVIC *          PROGRAM = SPSS                    CPU TIME =     3.20 SEC          PAGES        $0.21 CPU      0.5  *
***UVIC * COMPLETION CODE = 0000                ELAPSED TIME =    14.70 SEC          0  IN        $0.04 EXCPS    0.5  *
***UVIC *          DPRTY = 224                  STORAGE USED =   312K                0 OUT        $0.06 CARDS    0.5  *
***UVIC *      VIRT CARDS = 509                       REGION =   320K                             $0.31 TOTAL FOR STEP *
***UVIC *                                                                                                              *
***UVIC *     109-252       5-253       3-251       2-252                                                             *
***UVIC ********************************************************************************************************
IEF298I  HOGAN    SYSOUT=A,
IEF375I  JOB /HOGAN    / START 80109.2059
IEF376I  JOB /HOGAN    / STOP  80109.2059 CPU    0MIN 03.20SEC
***UVIC ********************************************************************************************************
***UVIC *          PRTY = 6                          CPU TIME =     3.20 SEC                                        *
***UVIC *      VIRT CARDS = 509                 ELAPSED TIME =    14.77 SEC          CENTRAL                       *
***UVIC *          DATE = APR 18/80              READER TIME =     0.75 SEC                                        *
***UVIC ********************************************************************************************************
***UVIC *    JOB COST = $0.31       CHARGES TO DATE = $660.45       ALLOCATION = $710.00       BALANCE = $49.55     *
***UVIC ****80109-7554478-HOGAN*************************************************************************************
```

ATTACHMENT 4

ATTACHMENT G

BS47460

```
SPSS BATCH SYSTEM                                                    04/18/80        PAGE    1
SPSS FOR OS/360, VERSION M, RELEASE 8.0, DECEMBER 17, 1979

DEFAULT SPACE ALLOCATION..      ALLOWS FOR..    102 TRANSFORMATIONS
WORKSPACE      71680 BYTES                     409 RECODE VALUES + LAG VARIABLES
TRANSPACE      10240 BYTES                    1641 IF/COMPUTE OPERATIONS

                    1 RUN NAME        A 3-WAY ANOVA WITH THREE FACTORS
                    2 FILE NAME       ANOVA TRIP GENERATION MODEL 1
                    3 VARIABLE LIST   NPERS NCARS INCOME NOTRIPS
                    4 INPUT MEDIUM    CARD
                    5 INPUT FORMAT    FIXED (15X,F2.0,1X,F2.0,3X,F1.0,F2.0)

                     ACCORDING TO YOUR INPUT FORMAT, VARIABLES ARE TO BE READ AS FOLLOWS

                     VARIABLE  FORMAT  RECORD     COLUMNS

                     NPERS     F 2. 0        1    16-  17
                     NCARS     F 2. 0        1    19-  20
                     INCOME    F 1. 0        1    24-  24
                     NOTRIPS   F 2. 0        1    25-  26

THE INPUT FORMAT PROVIDES FOR    4 VARIABLES.     4 WILL BE READ
IT PROVIDES FOR  1 RECORDS ('CARDS') PER CASE.  A MAXIMUM OF    26 'COLUMNS' ARE USED ON A RECORD.

                    6 N OF CASES      494
                    7 VAR LABELS      NPERS     NUMBER OF PERSONS PER HSHLD
                    8                 NCARS     NUMBER OF CARS AVAILABLE
                    9                 INCOME    ANNUAL INCOME PER HSHLD
                   10                 NOTRIPS   NUMBER OF TRIPS BY HSHLD IN 24 HR. PERIOD
                   11 VALUE LABELS    INCOME    (1) UP TO $6999 (2)$7000 TO $20000 (3)ABOVE $30T
                   12 ANOVA           NOTRIPS BY INCOME(1,3)  NPERS(1,4) NCARS(0,2)
                   13 OPTIONS         7,10
                   14 STATISTICS      1,2

'ANOVA' PROBLEM REQUIRES      9324 BYTES OF SPACE.

                   15 READ INPUT DATA
```

FILE ANOVA (CREATION DATE = 04/18/80) TRIP GENERATION MODEL 1

* * * * * * * * * * A N A L Y S I S O F V A R I A N C E * * * * * * * * * *

NOTRIPS
BY INCOME
NPERS NUMBER OF PERSONS PER HSHLD
NCARS

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	6053.023	7	864.718	33.836	0.000
INCOME	2763.204	2	1381.602	54.062	0.000
NPERS	3137.835	3	1045.945	40.927	0.000
NCARS	151.984	2	75.992	2.974	0.052
2-WAY INTERACTIONS	536.492	16	33.531	1.312	0.185
INCOME NPERS	248.686	6	41.448	1.622	0.139
INCOME NCARS	270.758	4	67.690	2.649	0.033
NPERS NCARS	50.979	6	8.496	0.332	0.920
3-WAY INTERACTIONS	40.035	7	5.719	0.224	0.980
INCOME NPERS NCARS	40.034	7	5.719	0.224	0.980
EXPLAINED	6629.551	30	220.985	8.647	0.0
RESIDUAL	11832.469 ?	463	$\sqrt{25,556}$ = 5.05 =		
TOTAL	18462.020	493	37.448		

INTERACTION DESIGN F OF P.
25.79 7.16
41.20
31.19
2.27
NOT POSSIBLE IN REAL POP

ϵ of regression equation. (See Attach. B)

THIS ANOVA ONLY REHASHES THE REGRESSION APPROACH

494 CASES WERE PROCESSED.
0 CASES (0.0 PCT) WERE MISSING.

ATTACHMENT G cont...

FILE ANOVA (CREATION DATE = 04/18/80) TRIP GENERATION MODEL 1

* * * M U L T I P L E C L A S S I F I C A T I O N A N A L Y S I S * * *

NOTRIPS
BY INCOME
NPERS NUMBER OF PERSONS PER HSHLD
NCARS

GRAND MEAN = 7.46

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	UNADJUSTED ETA	ADJUSTED FOR INDEPENDENTS DEV'N	ADJUSTED FOR INDEPENDENTS BETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	ADJUSTED FOR INDEPENDENTS + COVARIATES BETA
INCOME							
1 UP TO $6999	108	-3.03		-1.57			
2 $7000 TO $20000	249	-0.61		-0.35			
3 ABOVE $30T	137	3.50		1.87			
			0.39		0.21		
NPERS							
1	83	-3.99		-2.58			
2	162	-2.20		-1.82			
3	92	0.07		-0.36			
4	157	4.34		3.46			
			0.52		0.40		
NCARS							
0	67	-4.00		-1.33			
1	251	-0.82		-0.15			
2	176	2.69		0.72			
			0.37		0.11		
MULTIPLE R SQUARED					0.328		
MULTIPLE R					0.573		

ATTACHMENT G cont...

APPENDIX F TRIP GENERATION USING MULTIPLE REGRESSION (Victoria)

```
                                    COLUMN NUMBERS
CARD    1   5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80
NUMBER  |...|....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
    1   C.R.D. HOME SURVEY TRIP GENERATION REGRESSION
    2     492     4     1     0     1     0     0     1     1     1    -1     1     0     0     0
    3   (A4,3X,F2.0,3X,F2.0,3X,F2.0,3X,F5.0)
    4   N PERSN CARSNOTRIPINCOME
    5   5515
    6       1     4     2     2    12000
    7       4     4     2    13    12000
    8       7     6     1     5    12000
    9       9     2     1     8    12000
   10      10     5     1     6    25000
   11      11     4     2     4    12000
   12      15     3     1     8    12000
   13      19     2     1     2     6000
   14      20     3     0     5    12000
   15      21     2     1     4    12000
   16      22     2     2     4    12000
   17      24     2     1     6     8500
   18      25     2     1     2    12000
   19      34     2     1     4     8500
   20      37     2     2     4    25000
   21      40     2     1     0     8500
   22      42     2     0     4    12000
   23      43     3     1     6    12000
   24      45     2     1     9     6000
   25      46     3     1    11    17000
   26      48     3     1     0    25000
   27      49     4     0    24     8500
   28      50     2     1     8    25000
   29      60     2     1     4    17000
   30      65     1     0     2     6000
   31      68     2     0     0    12000
   32      71     1     1     2    25000
   33      75     1     1     5     6000
   34      76     2     1     4    12000
   35      78     1     1     4     8500
   36      82     3     0     2     4000
   37      83     1     1     4     6000
   38      86     2     1     2    12000
   39      88     1     0     4    12000
   40      98     3     2     2    17000
   41      99     2     2     9     8500
   42     100     2     1     2    12000
   43     102     4     2    12     25000
   44     103     1     0     2     4000
   45     105     3     1     6     8500
   46     106     2     2     2    12000
   47     111     2     2     2    12000
   48     114     4     1     2    12000
   49     115     4     1    19     8500
   50     118     2     1     6    12000
          |...|....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
          1   5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80
```


44939

CARD NUMBER	COLUMN NUMBERS 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80
51	125 3 3 6 12000
52	126 4 1 2 12000
53	158 2 0 6 12000
54	159 2 2 6 17000
55	162 1 0 2 12000
56	170 3 2 4 17000
57	171 2 1 4 12000
58	175 2 0 2 12000
59	176 2 2 6 8500
60	180 3 0 4 8500
61	181 6 3 25 17000
62	185 2 1 11 17000
63	189 1 1 4 12000
64	190 2 1 4 12000
65	202 3 1 4 12000
66	206 3 1 15 6000
67	207 4 2 8 12000
68	208 4 2 8 25000
69	209 2 1 6 12000
70	210 3 1 7 25000
71	212 2 2 9 12000
72	213 2 1 6 12000
73	217 5 1 9 25000
74	221 4 2 8 25000
75	224 2 2 4 8500
76	228 5 1 14 25000
77	231 2 2 6 12000
78	232 1 1 4 4000
79	233 2 2 10 25000
80	238 2 1 8 12000
81	241 4 2 4 25000
82	243 4 2 8 17000
83	245 5 2 16 12000
84	246 4 3 6 12000
85	247 3 1 6 17000
86	250 5 2 6 25000
87	252 2 2 10 17000
88	255 4 0 20 8500
89	256 7 3 8 25000
90	257 2 2 7 25000
91	258 3 1 2 12000
92	259 3 1 5 17000
93	265 4 2 8 8500
94	266 6 2 7 17000
95	267 4 1 17 25000
96	268 3 1 12 17000
97	269 5 1 2 25000
98	271 3 1 6 17000
99	272 3 2 10 17000
100	273 2 1 16 17000

149841

CARD NUMBER	COLUMN NUMBERS 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80
101	276 3 1 10 12000
102	277 5 2 7 17000
103	281 3 1 6 4000
104	286 2 1 6 12000
105	288 3 2 4 12000
106	294 6 2 10 17000
107	295 4 2 6 17000
108	297 5 1 24 12000
109	301 1 1 0 12000
110	302 1 1 8 17000
111	310 3 2 10 25000
112	314 1 1 2 6000
113	316 2 1 6 17000
114	319 5 2 35 25000
115	324 2 1 6 8500
116	325 1 1 5 8500
117	328 2 2 4 35000
118	333 4 3 12 25000
119	335 5 1 12 25000
120	342 5 3 22 12000
121	343 3 2 10 35000
122	346 3 2 11 12000
123	360 4 1 11 25000
124	361 4 1 8 25000
125	363 4 2 14 25000
126	368 3 2 10 12000
127	369 5 2 8 25000
128	371 2 1 11 35000
129	372 2 2 2 8500
130	373 5 1 18 25000
131	378 3 3 14 17000
132	381 5 1 8 8500
133	382 2 1 6 17000
134	383 2 1 13 25000
135	389 2 2 11 25000
136	394 3 2 11 25000
137	397 2 1 4 12000
138	398 8 2 17 25000
139	414 4 2 8 4000
140	417 3 1 11 17000
141	420 4 3 17 17000
142	425 2 1 2 17000
143	428 5 1 18 12000
144	437 2 1 4 25000
145	449 3 2 14 25000
146	452 4 1 24 17000
147	455 4 1 8 17000
148	456 4 1 15 8500
149	457 2 2 10 17000
150	459 3 2 2 12000

CARD NUMBER	COLUMN NUMBERS 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80
151	463 4 2 9 12000
152	464 3 1 4 8500
153	468 1 0 0 4000
154	479 2 0 2 8500
155	496 2 2 12 4000
156	499 2 1 5 8500
157	500 4 1 12 17000
158	501 5 2 11 8500
159	507 2 2 13 25000
160	515 4 2 8 12000
161	517 4 1 3 17000
162	518 3 2 12 25000
163	530 1 1 0 6000
164	531 3 1 8 17000
165	536 4 2 6 25000
166	541 4 2 8 12000
167	542 6 2 12 25000
168	543 5 1 15 35000
169	550 3 2 11 25000
170	557 4 2 9 12000
171	558 5 4 14 35000
172	562 1 1 4 12000
173	566 4 3 22 25000
174	567 2 1 8 17000
175	568 4 2 6 25000
176	576 4 3 11 35000
177	581 3 3 7 12000
178	584 2 0 4 12000
179	589 2 1 14 25000
180	590 5 4 10 35000
181	591 4 1 14 25000
182	592 1 1 4 12000
183	610 5 2 16 17000
184	617 1 0 0 6000
185	618 3 1 15 12000
186	620 2 2 15 35000
187	623 2 2 6 4000
188	626 2 2 2 12000
189	628 3 2 4 17000
190	630 4 2 11 12000
191	633 6 1 16 17000
192	634 4 2 2 17000
193	635 2 1 10 17000
194	641 5 2 10 25000
195	642 2 1 8 12000
196	647 4 1 2 12000
197	648 4 2 24 17000
198	655 4 3 32 35000
199	669 4 2 6 17000
200	673 4 2 6 12000

CARD NUMBER	COLUMN NUMBERS 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80
201	675 1 1 2 12000
202	680 7 2 4 25000
203	682 4 2 8 12000
204	683 1 1 6 25000
205	685 3 1 9 12000
206	686 2 2 4 35000
207	691 4 2 2 12000
208	694 2 2 4 25000
209	695 5 2 9 12000
210	699 2 2 0 17000
211	700 4 2 31 17000
212	702 3 1 10 12000
213	703 4 2 12 12000
214	705 8 2 6 17000
215	710 5 2 9 17000
216	711 2 1 4 25000
217	714 5 1 32 25000
218	716 4 2 7 25000
219	725 3 1 8 17000
220	746 1 1 2 17000
221	747 2 1 2 6000
222	749 1 0 2 4000
223	751 1 1 2 12000
224	758 1 1 0 12000
225	759 2 1 10 8500
226	771 7 2 19 25000
227	772 4 1 12 17000
228	773 2 2 16 25000
229	778 4 2 12 25000
230	787 2 1 2 6000
231	801 2 2 7 12000
232	804 2 1 2 12000
233	805 2 1 4 12000
234	807 4 2 13 35000
235	811 2 2 10 8500
236	818 4 2 10 25000
237	820 3 2 5 17000
238	822 4 2 10 25000
239	826 1 0 2 17000
240	830 2 1 4 12000
241	835 2 1 0 6000
242	847 4 1 10 17000
243	848 2 1 2 12000
244	854 2 2 14 25000
245	855 2 0 4 8500
246	856 2 1 12 8500
247	859 2 1 10 8500
248	866 2 0 0 12000
249	876 1 0 5 12000
250	886 2 2 8 25000

CARD NUMBER	COLUMN NUMBERS 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80
251	887 1 0 0 12000
252	891 2 1 0 12000
253	903 1 0 4 4000
254	909 3 1 0 12000
255	919 2 1 6 12000
256	923 1 0 0 12000
257	926 2 1 0 17000
258	927 1 1 3 8500
259	930 2 1 0 8500
260	931 2 0 8 12000
261	937 2 1 11 17000
262	939 2 0 4 8500
263	946 4 1 8 12000
264	949 3 1 0 6000
265	955 2 0 0 12000
266	970 1 1 5 12000
267	983 2 0 0 4000
268	986 1 1 3 4000
269	997 3 1 10 12000
270	1003 1 0 2 4000
271	1005 2 0 2 4000
272	1010 4 1 10 25000
273	1015 2 0 8 12000
274	1034 3 1 6 12000
275	1039 1 0 4 6000
276	1042 2 1 2 6000
277	1043 2 0 0 6000
278	1047 1 1 4 4000
279	1053 3 2 12 25000
280	1057 2 1 4 17000
281	1058 2 1 2 8500
282	1061 1 1 4 4000
283	1066 3 1 4 12000
284	1070 3 3 15 25000
285	1077 4 1 11 35000
286	1078 2 1 8 25000
287	1079 2 1 5 12000
288	1087 1 1 8 8500
289	1089 1 1 2 12000
290	1090 2 1 12 17000
291	1096 6 2 10 35000
292	1106 4 2 21 25000
293	1111 2 1 8 6000
294	1115 4 2 13 17000
295	1118 3 1 9 8500
296	1120 4 2 10 25000
297	1129 5 2 0 17000
298	1137 1 0 0 4000
299	1141 2 0 0 12000
300	1144 1 0 2 12000

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CARD NUMBER	COLUMN NUMBERS 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80
301	.1153 1 2 8 35000
302	.1166 1 1 2 12000
303	.1167 1 0 5 12000
304	.1168 2 1 6 17000
305	.1177 2 2 4 12000
306	.1179 3 2 12 25000
307	.1181 4 2 7 25000
308	.1183 2 1 8 8500
309	.1184 6 3 14 17000
310	.1187 2 2 10 35000
311	.1189 2 2 4 12000
312	.1191 2 1 4 12000
313	.1195 2 1 0 6000
314	.1196 1 0 0 4000
315	.1199 1 1 0 12000
316	.1204 2 0 0 6000
317	.1217 1 1 3 6000
318	.1225 1 0 3 12000
319	.1235 2 1 4 17000
320	.1239 2 2 6 12000
321	.1243 2 1 0 25000
322	.1245 3 2 0 12000
323	.1250 5 2 12 12000
324	.1253 3 2 16 25000
325	.1255 5 1 6 12000
326	.1258 4 2 8 12000
327	.1259 4 2 18 25000
328	.1260 2 1 10 12000
329	.1261 3 1 14 25000
330	.1262 5 3 18 17000
331	.1263 4 1 4 12000
332	.1265 3 2 4 25000
333	.1269 3 2 10 25000
334	.1273 1 1 2 12000
335	.1276 4 1 15 25000
336	.1281 2 1 0 17000
337	.1282 6 2 26 25000
338	.1286 2 1 0 8500
339	.1287 2 1 4 17000
340	.1296 4 2 13 12000
341	.1298 4 1 4 35000
342	.1303 3 2 10 35000
343	.1304 2 1 6 12000
344	.1305 2 1 16 25000
345	.1312 2 1 10 17000
346	.1314 2 0 0 4000
347	.1316 3 3 6 25000
348	.1317 2 1 11 17000
349	.1318 4 1 2 17000
350	.1321 3 1 6 12000

CARD NUMBER	COLUMN NUMBERS 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80
351	.1334 2 0 4 4000
352	.1338 2 1 7 25000
353	.1340 5 2 16 17000
354	.1342 4 1 18 35000
355	.1343 4 3 18 35000
356	.1350 2 0 2 6000
357	.1351 2 1 4 12000
358	.1357 2 1 6 17000
359	.1361 2 4 3 25000
360	.1363 1 1 2 17000
361	.1365 3 3 28 35000
362	.1373 2 0 1 12000
363	.1377 2 1 4 8500
364	.1378 3 1 2 12000
365	.1388 4 1 14 25000
366	.1390 1 1 2 4000
367	.1394 1 0 5 6000
368	.1395 3 2 4 25000
369	.1398 4 1 14 35000
370	.1400 3 2 18 12000
371	.1415 2 1 6 8500
372	.1420 1 1 2 6000
373	.1425 3 2 8 25000
374	.1426 6 1 3 25000
375	.1433 1 1 2 17000
376	.1439 1 0 2 4000
377	.1444 0 0 3 4000
378	.1448 1 0 9 4000
379	.1467 2 0 0 12000
380	.1473 2 1 2 8500
381	.1483 3 2 2 17000
382	.1484 6 2 17 6000
383	.1490 1 1 2 12000
384	.1492 3 2 12 35000
385	.1495 6 2 8 12000
386	.1503 2 1 3 12000
387	.1505 2 2 2 12000
388	.1506 2 1 0 17000
389	.1515 2 0 9 25000
390	.1519 3 1 8 25000
391	.1521 1 1 23 4000
392	.1523 1 1 4 12000
393	.1524 2 0 3 4000
394	.1531 6 1 14 12000
395	.1545 3 1 0 12000
396	.1547 1 0 12 4000
397	.1563 2 0 2 12000
398	.1565 1 1 0 6000
399	.1589 1 1 4 17000
400	.1591 3 1 2 17000

14984?

COLUMN NUMBERS

CARD NUMBER	1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80
401	.1597 3 1 8 25000
402	.1599 1 1 0 12000
403	.1600 4 3 14 35000
404	.1601 4 1 6 17000
405	.1602 6 2 31 25000
406	.1603 3 1 4 17000
407	.1604 4 2 17 25000
408	.1608 5 3 20 35000
409	.1611 1 1 8 17000
410	.1613 3 1 8 25000
411	.1615 5 2 5 35000
412	.1617 1 1 0 12000
413	.1622 5 2 14 25000
414	.1623 2 0 0 12000
415	.1624 3 2 6 25000
416	.1625 2 1 6 8500
417	.1626 3 3 12 17000
418	.1645 2 1 5 8500
419	.1646 2 1 3 12000
420	.1647 1 1 5 6000
421	.1648 2 1 19 12000
422	.1650 1 1 9 12000
423	.1654 1 1 2 12000
424	.1658 3 0 11 25000
425	.1675 1 1 4 12000
426	.1691 1 1 6 8500
427	.1692 4 0 6 17000
428	.1698 2 0 4 17000
429	.1699 2 1 6 17000
430	.1712 1 0 4 8500
431	.1733 2 1 6 6000
432	.1734 4 2 8 17000
433	.1741 3 2 2 17000
434	.1742 2 1 2 12000
435	.1743 5 2 15 17000
436	.1745 2 1 2 17000
437	.1750 6 3 16 25000
438	.1755 1 1 4 12000
439	.1759 3 0 7 12000
440	.1765 1 1 3 4000
441	.1769 1 1 3 8500
442	.1770 4 2 4 12000
443	.1776 1 1 0 4000
444	.1780 1 1 4 35000
445	.1783 4 1 8 12000
446	.1786 3 1 4 17000
447	.1788 4 2 9 6000
448	.1791 6 2 4 12000
449	.1792 3 1 6 25000
450	.1793 7 1 17 8500

CARD NUMBER	COLUMN NUMBERS 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80
451	.1797 2 1 9 17000
452	.1798 3 2 4 12000
453	.1803 4 1 22 17000
454	.1807 2 1 10 12000
455	.1811 3 1 4 17000
456	.1814 3 2 4 8500
457	.1821 3 2 14 25000
458	.1823 1 1 15 17000
459	.1826 3 2 6 12000
460	.1830 4 1 10 35000
461	.1832 4 0 2 12000
462	.1836 2 0 0 6000
463	.1843 1 1 2 12000
464	.1849 2 0 2 4000
465	.1853 1 0 4 4000
466	.1855 5 1 27 12000
467	.1856 5 1 23 17000
468	.1857 5 3 15 12000
469	.1858 4 2 8 17000
470	.1861 5 1 2 25000
471	.1862 4 1 6 25000
472	.1864 2 1 7 6000
473	.1867 2 1 2 4000
474	.1873 4 1 2 25000
475	.1875 2 1 6 8500
476	.1877 4 1 6 12000
477	.1878 3 1 13 17000
478	.1889 5 1 10 12000
479	.1896 4 1 17 12000
480	.2000 3 1 2 17000
481	.2003 2 1 2 35000
482	.2004 2 1 0 12000
483	.2006 1 0 2 12000
484	.2010 3 2 8 12000
485	.2026 3 2 9 12000
486	.2044 4 2 17 12000
487	.2078 4 1 14 25000
488	.2106 3 1 6 35000
489	.2118 5 1 0 17000
490	.2120 2 2 6 17000
491	.2132 5 3 17 25000
492	.2166 4 1 13 12000
493	.2192 1 0 0 6000
494	.2194 2 1 4 12000
495	.2202 1 0 0 4000
496	.2204 5 2 14 8500
497	.2232 3 1 5 17000

C.R.D. HOME SURVEY TRIP GENERATION REGRESSION

MULTIPLE REGRESSION PROGRAM UVIC MULRG2 (VERSION: 31 OCT 78)

SPECIFICATIONS FOR THIS PROBLEM

NO. OF OBSERVATIONS PER VARIABLE = 492
NO. OF VARIABLES = 4
INPUT DATA TO BE READ FROM CARDS
INPUT DATA TO BE SAVED ON DISK UNIT 1 UNFORMATTED
INPUT DATA NOT PRINTED
CASE ID TO BE READ
NO MISSING DATA CODE CARD TO BE READ
RESIDUALS TO BE CALCULATED AND PRINTED BUT NOT SAVED
NUMBER OF FORMAT CARDS FOR DATA INPUT = 1
READ IN FORMAT = (A4,3X,F2.0,3X,F2.0,3X,F2.0,3X,F5.0)

T PROBABILITIES FOR CORRELATION COEFFICIENTS TO BE PRINTED

NO REGRESSION PARAMETER CARD TO BE READ
DEFAULT VALUES ASSIGNED
INVERSION TOLERANCE VALUE = 1.000000D-06
F TO ENTER = 0.010000
F TO REMOVE = 0.005000
(USED ONLY IN STEP-WISE REGRESSION)

CASES TO BE SPLIT AS FOLLOWS FOR RESIDUALS DISTRIBUTION TESTS:
(IF RESIDUALS CALCULATION IS REQUESTED)
FIRST HALF OF CASES IN ONE SET AND REMAINING CASES IN THE OTHER

VARIABLE NAMES READ:

NUMBER	NAME	NUMBER	NAME	NUMBER	NAME	NUMBER	NAME
1	N PERS	2	N CARS	3	NOTRIP	4	INCOME

NUMBER OF REGRESSIONS REQUESTED = 1

C.R.D. HOME SURVEY TRIP GENERATION REGRESSION

VARIABLE NAME	NUMBER	MEAN	STANDARD DEVIATION	# OF CASES = 492
N PERS	1	2.8373984	1.4278235	
N CARS	2	1.2804878	0.78074157	
NOTRIP	3	7.4491870	6.1139435	
INCOME	4	15645.325	7996.9265	

144710

C.R.D. HOME SURVEY TRIP GENERATION REGRESSION

CORRELATION MATRIX PAGE 1 OF 1 PAGE(S)

	N PERS	N CARS	NOTRIP	INCOME
N PERS	1.000000 0.0	0.483128 0.0	0.517687 0.0	0.392257 0.0
N CARS	0.483128 0.0	1.000000 0.0	0.400646 0.0	0.448511 0.0
NOTRIP	0.517687 0.0	0.400646 0.0	1.000000 0.0	0.383081 0.0
INCOME	0.392257 0.0	0.448511 0.0	0.383081 0.0	1.000000 0.0

(CORRELATION COEFFICIENT/T-PROBABILITY)

149851

C.P.D. HOME SURVEY TRIP GENERATION REGRESSION

REGRESSION NUMBER 1 STEP NUMBER 0

DEPENDENT VARIABLE: NOTRIP (NUMBER 3)

INDEPENDENT VARIABLES NAME	NUMBER	TYPE	CORRELATION WITH DEPENDENT VARIABLE	CORRELATION SQUARED	SIGNIFICANCE F VALUE*	F PROB
N PERS	1	5	0.517687	0.268000	179.39861	0.0
N CARS	2	5	0.400646	0.160517	93.69284	0.0
INCOME	4	5	0.383081	0.146751	84.27573	0.0

*DEGREES OF FREEDOM = (1, 490)

NUMBER OF VARIABLES OF EACH TYPE TO BE ENTERED
STEP-WISE INTO THE REGRESSION:
TYPE 3 (STEPPED IN AND KEPT IN) = 0
TYPE 4 (STEPPED IN THEN FREED) = 0
TYPE 5 (COMPLETELY FREE) = 3

MAXIMUM NUMBER OF STEPS = 6

C.R.D. HOME SURVEY TRIP GENERATION REGRESSION

REGRESSION NUMBER 1 STEP NUMBER 1

DEPENDENT VARIABLE: NOTRIP (NUMBER 3)

INDEPENDENT VARIABLES NAME	NUMBER	...IN.THE.REGRESSION... REGRESSION COEFFICIENT	STANDARDISED COEFFICIENT (BETA WT)	STANDARD ERROR OF COEFFICIENT	T VALUE	F VALUE TO REMOVE	F PROB	...NOT.IN.THE.REGRESSION... PIVOT VALUE (TOLERANCE)	PARTIAL CORRELATION	F VALUE TO ENTER
N PERS	1*	2.2167362	0.517687	0.165502	13.39398	179.39861	0.0			
N CARS	2	-	-	-	-	-	-	0.766587	0.200959	20.57909
INCOME	4	-	-	-	-	-	-	0.846134	0.228735	26.99689
INTERCEPT		1.1594232		0.525594	2.20593	4.86613	0.0279			

(* MARKS VARIABLE ENTERED OR REMOVED)

MULTIPLE CORRELATION R = 0.517687
R SQUARED = 0.268000
ADJUSTED R SQUARED = 0.266506
STD. ERROR OF ESTIMATE = 5.236243

ANALYSIS OF VARIANCE FOR REGRESSION

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	F VALUE	F PROB
REGRESSION	1	4918.79355	4918.79355	179.39861	0.0
RESIDUAL	490	13434.93612	27.41824		
TOTAL	491	18353.72967			

C.R.D. HOME SURVEY TRIP GENERATION REGRESSION

REGRESSION NUMBER 1 STEP NUMBER 2

DEPENDENT VARIABLE: NOTRIP (NUMBER 3)

INDEPENDENT VARIABLES NAME	NUMBER	...IN.THE.REGRESSION... REGRESSION COEFFICIENT	STANDARDISED COEFFICIENT (BETA WT)	STANDARD ERROR OF COEFFICIENT	T VALUE	F VALUE TO REMOVE	F PROB	...NOT.IN.THE.REGRESSION... PIVOT VALUE (TOLERANCE)	PARTIAL CORRELATION	F VALUE TO ENTER
N PERS	1	1.8593917	0.434234	0.175331	10.60502	112.46647	0.0			
N CARS	2	-	-	-	-	-	-	0.687307	0.138212	9.50354
INCOME	4*	0.16265508D-03	0.212750	0.31304BD-04	5.19585	26.99689	0.0000			
INTERCEPT		-0.37143950		0.590880	-0.62862	0.39516	0.5299			

(* MARKS VARIABLE ENTERED OR REMOVED)

MULTIPLE CORRELATION R = 0.553442
R SQUARED = 0.306298
ADJUSTED R SQUARED = 0.303461
STD. ERROR OF ESTIMATE = 5.102632

ANALYSIS OF VARIANCE FOR REGRESSION

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	F VALUE	F PROB
REGRESSION	2	5621.70759	2810.85380	107.95673	0.0
RESIDUAL	489	12732.02208	26.03685		
TOTAL	491	18353.72967			

C.R.D. HOME SURVEY TRIP GENERATION REGRESSION

REGRESSION NUMBER 1 STEP NUMBER 3

DEPENDENT VARIABLE: NOTRIP (NUMBER 3)

INDEPENDENT VARIABLES NAME	NUMBER	...IN.THE.REGRESSION... REGRESSION COEFFICIENT	STANDARDISED COEFFICIENT (BETA WT)	STANDARD ERROR OF COEFFICIENT	T VALUE	F VALUE TO REMOVE	F PROB	...NOT.IN.THE.REGRESSION... PIVOT VALUE (TOLERANCE)	PARTIAL CORRELATION	F VALUE TO ENTER
N PERS	1	1.64352R3	0.383822	0.187400	8.77016	76.91579	0.0			
N CARS	2*	1.0873508	0.138853	0.352718	3.08278	9.50354	0.0022			
INCOME	4	0.130160120-03	0.170247	0.327720-04	3.97105	15.76925	0.0001			
INTERCPT		-0.64289445		0.592389	-1.08526	1.17778	0.2783			

(* MARKS VARIABLE ENTERED OR REMOVED)

MULTIPLE CORRELATION R = 0.565287
R SQUARED = 0.319549
ADJUSTED R SQUARED = 0.315366
STD. ERROR OF ESTIMATE = 5.058836

ANALYSIS OF VARIANCE FOR REGRESSION

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	F VALUE	F PROB
REGRESSION	3	5864.92044	1954.97348	76.39055	0.0
RESIDUAL	488	12488.80924	25.59182		
TOTAL	491	18353.72967			

NO FURTHER VARIABLES SATISFIED F-VALUE OR TOLERANCE FOR ADDITION TO OR REMOVAL FROM THE REGRESSION EQUATION. THEREFORE, COMPUTATION FOR THIS REGRESSION WILL BE TERMINATED

C.R.D. HOME SURVEY TRIP GENERATION REGRESSION

REGRESSION NUMBER 1 DEPENDENT VARIABLE: NOTRIP (NUMBER 3)

SUMMARY TABLE

STEP NUMBER	INDEPENDENT VARIABLE NAME	NUMBER		MULTIPLE CORRELATION R	R SQRD	R SQRD INCREASE	ADJUSTED R SQRD	F VALUE TO ENTER/REMOVE	NUMBER OF INDEPENDENT VARIABLES INCLUDED
1	N PERS	1	ENTERED	0.51769	0.26800	0.26800	0.26651	179.39861	1
2	INCOME	4	ENTERED	0.55344	0.30630	0.03830	0.30346	26.99689	2
3	N CARS	2	ENTERED	0.56529	0.31955	0.01325	0.31537	9.50354	3

MAXIMUM ADJUSTED R SQUARED OF 0.315366 ACHIEVED AT STEP 3.

144/16

C.R.D. HOME SURVEY TRIP GENERATION REGRESSION

DURBIN-WATSON STATISTIC = 2.019999
FIRST ORDER AUTOCORRELATION STATISTIC = -0.012681

RUNS TEST:

TOTAL NUMBER OF RUNS =	253	EXPECTED MEAN RUNS =	245.207317
NO. POSITIVE RESIDUALS =	225	STANDARD DEVIATION =	10.998334
NO. NEGATIVE RESIDUALS =	267	NORMAL PROBABILITY =	0.507

SKEWNESS STATISTIC =	1.123070	KURTOSIS STATISTIC =	2.788690
STANDARD DEVIATION =	0.110097	STANDARD DEVIATION =	0.219754
NORMAL PROBABILITY =	0.000	NORMAL PROBABILITY =	0.000

KOLMOGOROV-SMIRNOV TEST OF NORMALITY OF RESIDUALS DISTRIBUTION:

INTERVALS	OBSERVED RESIDUALS FREQUENCY	RELATIVE FREQUENCIES RESIDUALS	RELATIVE FREQUENCIES NORMAL	RELATIVE CUMULATIVE FREQUENCIES RESIDUALS	RELATIVE CUMULATIVE FREQUENCIES NORMAL	ABSOLUTE DIFFERENCES
/LT-3	0	0.0	0.0013	0.0	0.0013	0.00135
GE-3/LT-2	5	0.0102	0.0214	0.0102	0.0227	0.01259
GE-2/LT-1	51	0.1037	0.1359	0.1138	0.1587	0.04484
GE-1/LT 0	211	0.4289	0.3413	0.5427	0.5000	0.04268
GE 0/LT 1	171	0.3476	0.3413	0.8902	0.8413	0.04890
GE 1/LT 2	33	0.0671	0.1359	0.9573	0.9772	0.01993
GE 2/LT 3	12	0.0244	0.0214	0.9817	0.9986	0.01694
GE 3/	9	0.0183	0.0013	1.0000	1.0000	0.00000

MAXIMUM ABSOLUTE DIFFERENCE = 0.04890
FOR SAMPLE SIZE = 492
PROBABILITY = 0.190

KOLMOGOROV-SMIRNOV TEST OF EQUALITY OF DISTRIBUTIONS OF RESIDUALS IN TWO SETS:

INTERVALS	OBSERVED FREQUENCIES SET 1	OBSERVED FREQUENCIES SET 2	RELATIVE FREQUENCIES SET 1	RELATIVE FREQUENCIES SET 2	RELATIVE CUMULATIVE FREQUENCIES SET 1	RELATIVE CUMULATIVE FREQUENCIES SET 2	ABSOLUTE DIFFERENCES
/LT-3	0	0	0.0	0.0	0.0	0.0	0.0
GE-3/LT-2	2	3	0.0081	0.0122	0.0081	0.0122	0.00407
GE-2/LT-1	24	27	0.0976	0.1098	0.1057	0.1220	0.01626
GE-1/LT 0	105	106	0.4268	0.4309	0.5325	0.5528	0.02033
GE 0/LT 1	85	86	0.3455	0.3496	0.8780	0.9024	0.02439
GE 1/LT 2	19	14	0.0772	0.0569	0.9553	0.9593	0.00406
GE 2/LT 3	6	6	0.0244	0.0244	0.9797	0.9837	0.00406
GE 3/	5	4	0.0203	0.0163	1.0000	1.0000	0.00000

MAXIMUM ABSOLUTE DIFFERENCE = 0.02439
FOR SAMPLE SIZES = 246
AND = 246
PROBABILITY = 1.000

TEST OF HOMOSKEDASTICITY OF RESIDUALS:

SET	DEGREES OF FREEDOM	SUM OF SQUARED RESIDUALS	MEAN SQUARE RESIDUALS	F VALUE	F PROB
1	242	6663.66976	27.53581	1.14395	0.1481
2	242	5825.13948	24.07082		

END OF JOB

Local Government Reports
Used In This Study

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4. Capital Regional District and B. C. Transit,"Annual Operating Agreement, 1982-83", Victoria, 1982.

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7. Capital Regional District, "Victoria Metropolitan Area-- Existing and Future Employment Estimates For Transportation Demand Modelling", Victoria, May 1979.

8. Capital Regional District, "Assessment Of Transit Service Coverage In Downtown Victoria", Technical Report 3, Victoria, September 1979.

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IMPACT ASSESSMENT OF ALRT - Study Design TP 5115 Transport Canada

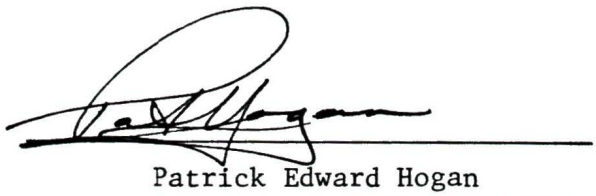
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Author



Patrick Edward Hogan

April, 1985