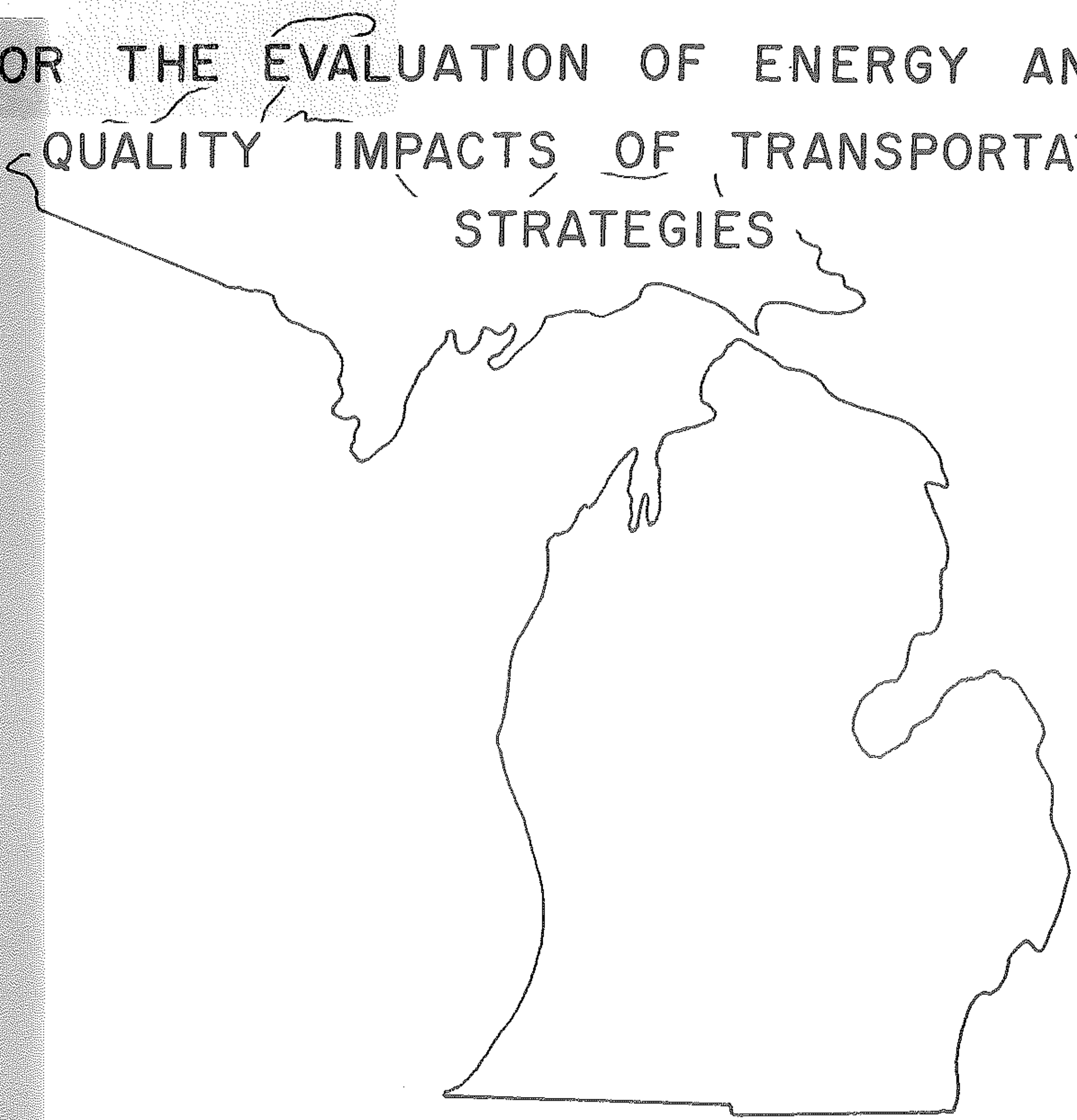
THE DEVELOPMENT OF A MULTINOMIAL LOGIT TRAVEL DEMAND MODEL FOR THE EVALUATION OF ENERGY AND AIR QUALITY IMPACTS OF TRANSPORTATION STRATEGIES



MICHIGAN DEPARTMENT OF TRANSPORTATION

FINAL REPORT

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THE DEVELOPMENT OF A MULTI-NOMIAL LOGIT TRAVEL DEMAND MODEL FOR THE EVALUATION OF ENERGY AND AIR QUALITY IMPACTS OF TRANSPORTATION STRATEGIES

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1980

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EXECUTIVE SUMMARY

The purpose of this study was to test the feasibility of developing a multinomial logit mode-split model for urban areas with 200,000 population or more. The logit model was designed for the purpose of providing mode-split information for more than two modes. The modelling process was accomplished by adapting an aggregate data base to the Urban Transportation Planning System (UTPS) computer program ULOGIT to calibrate a set of logit models. One of the major objectives in this study was to utilize available information to develop the models and avoid the collection of new household (disaggregate) data.

A number of logit models were calibrated and evaluated in this study using the Flint metropolitan area (Genesee County, Michigan) as a case study. The modelling approach was initially tested for a two-mode example (auto/transit), in which four models were calibrated. Upon the completion of this task, more complex models were developed to provide mode split information between five modes representing various levels of automobile occupancy and transit. These modes were:

- Automobile - drive alone
- Automobile - one passenger
- Automobile - two passengers
- Automobile - three or more passengers
- Transit - bus service

A total of five multi-modal logit models were calibrated and evaluated, three for work-trip purposes and two for nonwork purposes.

The calibration of the logit models was accomplished using a fraction of the total trips. The acceptance and rejection of these models were based on two sets of criteria: (1) statistical reports produced by the ULOGIT program, and (2) application of the model on the 100% sample of the

trips. The statistical tests produced by ULOGIT were used primarily to reject "unacceptable" models. The comparison of the model results (using a 100% sample of trips) to the observed mode-split was made to determine the acceptability of the models. Comparisons between the "estimated" and the observed trip tables on a trip interchange basis were accomplished by comparing the Trip Length Frequency curves for the model results and observed data.

Two models were analyzed to investigate their sensitivity to changes in transportation system characteristics. A majority of the sensitivity tests provided results which were consistent with expected behavioral reactions to transportation system impacts. However, in some instances, the sensitivity results indicated a need to improve the model formulations.

The results of the study indicate that the development of multi-nomial logit mode-split models (for more than two modes) is feasible using aggregate data. The study indicates that the potential of applying this approach in other urban areas is quite high, although further calibration and validation efforts are needed before a more wide-spread application is warranted. Specifically, more effort should be directed towards "fine-tuning" the (dis)utility equations to improve the models' predictive capabilities. Furthermore, additional data should be collected with the objective of further validation of high-occupancy mode models. Studies should also be directed towards investigating "penalties" associated with using high-occupancy modes, as well as determining optimal sampling rates for calibration purposes which would take into account the trade-offs between the predictive quality of the model and the associated computer costs for larger sample sizes.

1. INTRODUCTION

Urban transportation planning can be defined as the process of developing, testing, monitoring and evaluating short-range and long-range transportation alternatives which are soundly conceived in order to meet the goals and objectives of the urban community. Travel demand forecasting constitutes the most critical element of the planning process and represents the greatest challenge to transportation planners. The importance of deriving a realistic set of travel demand estimates for the planning horizon lies in the fact that these demand data define the framework within which all alternatives are to be developed. The plan to be finally implemented over the planning horizon, must be "adequate" for the projected travel needs and demands.

The development of a reliable multi-modal travel demand model as a part of the transportation planning process for urban areas with a population of 200,000 or more is a goal of the Michigan Department of Transportation (MDOT). A major element of such demand models is the process of allocating travel amongst various modes, commonly referred to as the "mode-split" process. In the past, efforts have been made by the MDOT to develop general travel demand models based upon the use of diversion curves to determine modal split[1]. These models, however, can "handle" only two travel modes at a time (e.g., auto and transit) and are, thus, relatively insensitive to changes in travel demand as a result of diverse auto occu-

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[1] Example: "Flint Area Transit Study: Testing of Short Range and Long Range Transit Alternatives using the UTPS Transit System Model", Department of Civil Engineering, Wayne State University, 1980.

pancy levels. In addition, to "fit" these diversion curve models to a specific study area, a significant amount of manpower is required each time a study area is to be evaluated. Finally, these models require further diversity in their application in order to provide travel demand tests and evaluations for a greater number and type of transportation strategies, as required for many transportation planning programs.

1.1 Study Needs

The MDOT has recognized the need to develop travel demand model capabilities in order to provide an effective means of testing and evaluating various transportation strategies (e.g; transit and ridesharing programs) for urban areas containing a population of 200,000 or more. These models, when fully developed, will be useful not only for testing the demand consequences of alternate transportation strategies, but also for evaluating the energy and air quality effects of these actions. It has become necessary to develop new demand choice models, using available software such as the UTPS package, that can be utilized to test the demand consequences of various alternate transportation strategies. The most desirable attributes of such a modelling approach are:

1. The model must be multi-nomial in nature and should have the capability to perform mode split between more than two modes,
2. The model should require a smaller data base, or less of a data collection effort than the diversion curve technique for calibration purposes,
3. The model should be more responsive to the needs and characteristics of smaller urbanized areas and it should lend itself to use

for predictive purposes without a lengthy and involved process of calibration,

4. The model should be sensitive to changes in transportation system attributes as well as trip maker characteristics, and
5. The model should lend itself for use in determining the energy, air quality, and other impacts of various transportation strategies.

1.2 Organization of the Report

The MDOT retained the services of Goodell-Grivas, Inc. to investigate the feasibility of an alternative demand modelling approach that would address the needs of urban areas over 200,000 population. This report describes the procedures used to develop and test a multi-nomial logit model utilizing the UTPS computer package. The report is organized in the following sections:

1. Introduction and organization of the report.
2. Purpose and scope of the study, including a discussion on the ULOGIT model and the use of aggregate vs. disaggregate data base.
3. Procedure for utilizing the ULOGIT model in the logit modelling process. This section includes a general discussion on preparation of the data inputs, development of the calibration file, selection of the independent and dependent variables, development of the (dis)utility equations and the use of the (dis)utility equations to perform mode split.
4. Description of the area characteristics of Genesee County which was used as a case study site, and a discussion on the data base used in the case study.

5. Development of the (dis)utility equations for the bimodal model (auto and transit) and for the multi-modal (transit and four auto occupancy levels) applications, and a discussion of the various tests used to evaluate the (dis)utility expressions.
6. A discussion of the modelling and calibration results for the bimodal example (auto/transit split).
7. A discussion of the modelling and calibration results for the multi-modal models developed for work and nonwork trip purposes.
8. Results of the sensitivity analysis on the developed logit models.
9. Conclusions and recommendations for further study.

2. PURPOSE AND SCOPE OF STUDY

The purpose of this project is to test the feasibility of developing a multi-nomial, multi-modal logit travel demand model for urban areas with populations of 200,000 or more. Once such a model is developed in complete form, it can be used to provide an effective means of testing and evaluating various transportation strategies (i.e., line-haul transit, carpooling, express bus systems, etc.), as well as evaluating the energy and air quality impacts of those actions.

The multi-nomial logit models resulting from this study were developed using the ULOGIT computer program from the Urban Transportation Planning System (UTPS) modelling package. The UTPS modelling package is a collection of IBM System/360-370 computer programs for use in planning multimodal transportation systems. UTPS was developed by and is maintained under sponsorship of the Urban Mass Transportation Administration (UMTA) and the Federal Highway Administration (FHWA) of the U.S. Department of Transportation. The UTPS computer package consist of 21 independent computer programs in which one program creates or reads the input or output of another. The ULOGIT model, as documented in the UTPS package, calibrates the mode choice and demand estimation formula in a linear logit form. ULOGIT in itself does not compute the allocation of trips into different modes, but develops the necessary calibration factors in the form of (dis)utility equations that can be used to generate multi-modal travel estimates comparable with the observed data. The model internally uses the concept of maximum likelihood to calibrate the (dis)utility equations and provides the best fit to a set of observed travel data through the use of a number of independent variables.

An important element of this study relates to the controversy of utilizing aggregate vs. disaggregate data for calibrating the logit model. Traditionally, logit models are oriented to the use of a household data base (disaggregate), as the argument has been made that mode choice decisions are typically made at the household level and as such these decisions do not reflect zonal (aggregate) characteristics. However, most mode choice analyses have traditionally used zonal data, primarily based upon time and cost considerations. Therefore, a major thrust of this study was to investigate the use of zonal data, in the most meaningful way for logit purposes, without any significant loss of accuracy.

Another important objective of the study was to determine the sensitivity of the model to changes in the transportation system characteristics. The travel demand model developed in this study was tested using various changes in transit level of service, fare, fuel price changes, etc. to determine how sensitive the model is to these changes.

2.1 The Logit Approach

A logit mode-split model is essentially a process for allocating travel among a number of available modes (systems), based upon factors such as: the relative attractiveness of the system, the socio-economic characteristics of the users and land use characteristics at the trip destination, etc. For example, as travel time by transit between two locations increases, transit travel becomes less attractive. Similarly, as parking becomes more expensive and less available (particularly in CBD areas), the attractiveness of transit is likely to increase.

A logit-model attempts to incorporate mode-choice decisions through the use of a set of mathematical formulations using various explanatory variables (cost,time, etc.) that may conceivably affect such traveler decisions. Equations are developed to reflect actual travel characteristics, based upon the relative composite attractiveness (dis)utility of each mode compared to other avaialble modes. Mathematical formulations describing this process are described in detail in Section 3 of this report.

ULOGIT is essentially a calibration program that can be used to develop different (dis)utility equations for mode-split purposes for a set of independent explanatory variables. ULOGIT also provides a series of statistical tests to provide a "goodness of fit" between the model output and the observed data. When the model is successfully calibrated, the (dis)utility parameters can be used along with necessary travel and network data to calculate the allocation of trips between the different modes. The final demand estimation can be accomplished through the use of the UMODEL or UMATRIX models from the UTPS package.

The designation of the logit approach for travel demand purposes was based on the following considerations:

- The model should accurately predict mode choice for various transportation strategies.
- The model should not require extensive data collection efforts.
- The model will be developed using existing data on a zonal (aggregated) level.
- The model framework could be adaptable to any urban area over 200,000 population.

- The model should be sensitive to changes in transportation system attributes as well as to trip-maker characteristics (i.e., changes in transit operating strategies, fare structures, fuel prices, socio-economic characteristics, population distribution, etc.).
- The model should lend itself to use for determining the energy, air quality and other impacts of various transportation strategies.

2.2 Aggregate Versus Disaggregate Data Base

One of the important attributes of this study is the use of data aggregated on a zonal level, as described earlier. Recent modelling efforts utilizing the logit approach have concentrated on using disaggregate data (household level) as contrasted to aggregate (zonal) data to describe trip-maker characteristics. While the use of household level data definitely has significant merits, the non-availability of such data generally poses a serious constraint to the use of this model.

Disaggregate travel demand models have been cited as being a more desirable means of describing the relative importance of explanatory variables (those variables used in mode selection). Therefore, disaggregate models are more suitable for analyzing and forecasting mode choice behavior. In particular[1]:

- Disaggregate choice models are data efficient and require significantly less observations to calibrate than do models aggregated at a zonal level. This is particularly important for areas where transit trips represent a small proportion of the total trips.
- Disaggregate choice models are less sensitive to variations caused by unidentified locational parameters. This is because in the samp-

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[1] ULOGIT User's Guide, U.S. DOT, UMTA, FHWA, July 7, 1977.

ling process, individual observations are selected from the entire study area (in disaggregate models) which tends to cancel out some of the unidentified locational parameters which are incorporated on a zonal level analysis. On the other hand, zonal trip data may exhibit locational biases based on the makeup of the zones and the connection of the zone centroids to the network.

- Disaggregate choice models are highly sensitive to the variation in all variables. Some studies indicate that a significant variation in travel and socio-economic variables is lost when individual characteristics are aggregated on a zonal level. If zones were strictly homogeneous in land use and trip-maker characteristics, variability would not be a major concern. Although homegeneity is a prime concern in defining each zone in a study area, there is always some variation within a zone.
- Disaggregate models are more consistent with theories of travel demand behavior.

However, one of the major objectives of this study was to develop a demand choice forecasting model which would require data bases readily available for most agencies. Since many planning agencies choose to work with aggregate data, data is usually available on a zonal level. Thus, the emphasis of the study was to adapt aggregate or zonal data for use in the logit model. The model developed in the study also used socio-economic and land use data converted from census reports into traffic analysis zones. This data, along with zonal interchange data (travel time, cost, etc.) was appended to zonal trip tables to significantly reduce the cost and time expenditures in the modelling effort.

2.3 The Logit Application

The models developed in this study were evaluated utilizing the Flint metropolitan area (located in Genesee County, Michigan) as a case study. The Flint area was selected for the study area because it is a typical urban area within the State of Michigan. The area has an existing viable data base, and a transit system has been in operation in the area for a number of years, with existing ridership and operational data. Two modelling efforts were made:

1. Develop a demand choice model between two modes;
   - Automobile
   - Transit (bus services)
2. Develop demand choice models, between five modes;
   - Automobile - drive alone
   - Automobile - one passenger
   - Automobile - two passengers
   - Automobile - Three or more passengers
   - Transit

Separate models for the five mode case were made for work and non-work trip purposes. The modelling effort only related to the use of home based trips.

3. PROCEDURE FOR UTILIZING THE ULOGIT MODELLING PROCESS

This section describes the logit model and the framework used by the Consultant to develop (dis)utility equations using the UTPS computer program ULOGIT.

The multi-nomial logit model used in this study can be expressed as:

$$P(i-j/m) = \frac{EXP(-U(i-j/m))}{\sum_{m=1}^{N} EXP(-U(i-j/m))} \qquad (A)$$

Where:

$P(i-j/m)$ = Proportion of total person trips from zone i to zone j using mode m.

N = Total number of travel modes (m). The modes are numbered consecutively 1 through N.

Further,

$U(i-j/m)$ = (dis)utility value of a trip from i to j using mode m.

$$= F_c(i-j/m) + F_t(i-j/m) + F_s(i-j/m) \qquad (B)$$

Where:

$F_c(i-j/m)$ = A function of the cost of making the trip from i to j by mode m. (C)

$F_t(i-j/m)$ = A function of the time (or distance) involved in making the trip from i to j by mode m. (D)

$F_s(i-j/m)$ = A function of the socio-economic characteristics of the trip maker or land use characteristics associated with trips from i to j by mode m. (E)

The functions C and D can be regarded as a travel impedance or resistance function. Function E can be regarded as an impedance or resistance function associated with travel by a particular mode. It should also be noted that the P(i-j/m) value calculated by equation A would be a number between zero and unity, depending upon the relative (dis)utility of the trip for the given mode. The more attractive a given mode is (as reflected by the corresponding impedance Functions C, D, and E), the smaller the cumulative disutility value as derived from equation B. A smaller value of disutility would have the effect of apportioning more trips into the mode. Further, it can be shown that:

$$\sum_{m=1}^{N} P(i-j/m) = 1.00 \qquad \text{(F)}$$

Equation (F) simply signifies that the sum of all the percentages of trips allocated among N modes for a given zonal interchange will be 100.

Each of the three (dis)utility functions can be developed as a linear combination of relevant variables, each variable being adjusted by a coefficient as follows:

$$F(i-j/m) = [\alpha_1 X_1 + \alpha_2 X_2 + \ldots\ldots\ \alpha_n X_n] \qquad \text{(G)}$$

Where:

$F(i-j/m)$ = Impedance Function (time, cost, distance, etc.) for trips from i to j using mode m.

X_i = Individual elements within the impedance function (e.g., in-vehicle time, waiting time, out-of-pocket cost, parking cost, etc.).

α_i = Coefficients to be derived as a part of the model calibration.

The multi-nomial logit model, described above, was utilized in this study. The four principle steps involved in the logit modelling process is shown in Figure 1. These steps include: Data preparation, Developing of a calibration file (using UMODEL), Developing and evaluating the (dis)utility equations (using ULOGIT) and performing mode split (using UMODEL or UMATRIX). The selection of this particular approach for the development of the logit model by the Consultant was based upon the Consultant's past experience with the UTPS computer package, the knowledge about the data base and its limitations, and the features of the computer system which was utilized in this study. A more detailed overview of the process used in the ULOGIT Modelling Process is shown in Figure 2. The principal UTPS computer programs used in this study were UMODEL and ULOGIT. However, a majority of the work done with UMODEL (building file calibration and mode split) could have also been completed using UMATRIX. Other UTPS packages used in this study include UMCON, UMATRIX, and UFMTR.

A general description of each major step of the logit modelling process (as used in the study) is provided in the following sections.

3.1 Step 1: Data Preparation

The first step is to prepare the data to be used in the calibration file development (Figure 2). Three types of data are used:

1. Observed trip data
2. Trip interchange impedance data
3. Zonal socio-economic and land use data

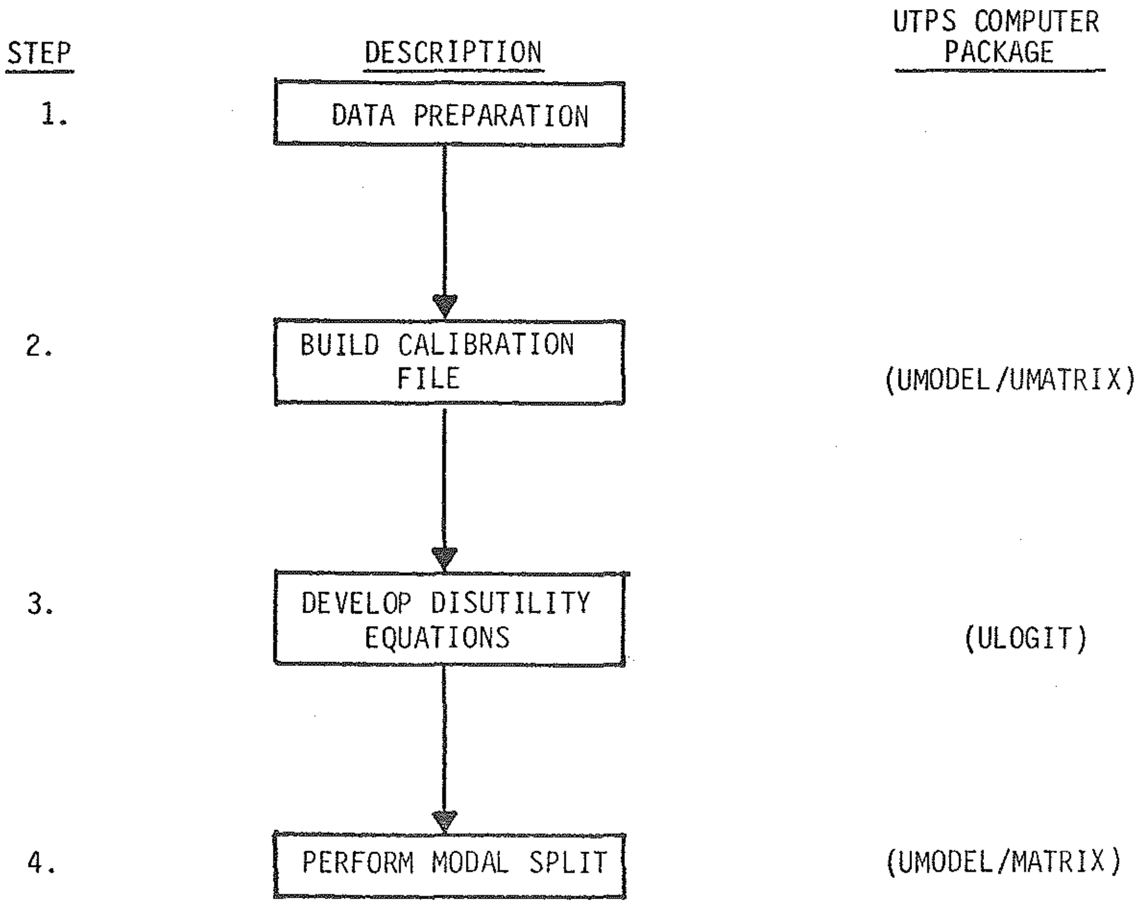


Figure 1. The primary steps in logit modelling process.

Figure 2 - Overview of the ULOGIT Modelling Process

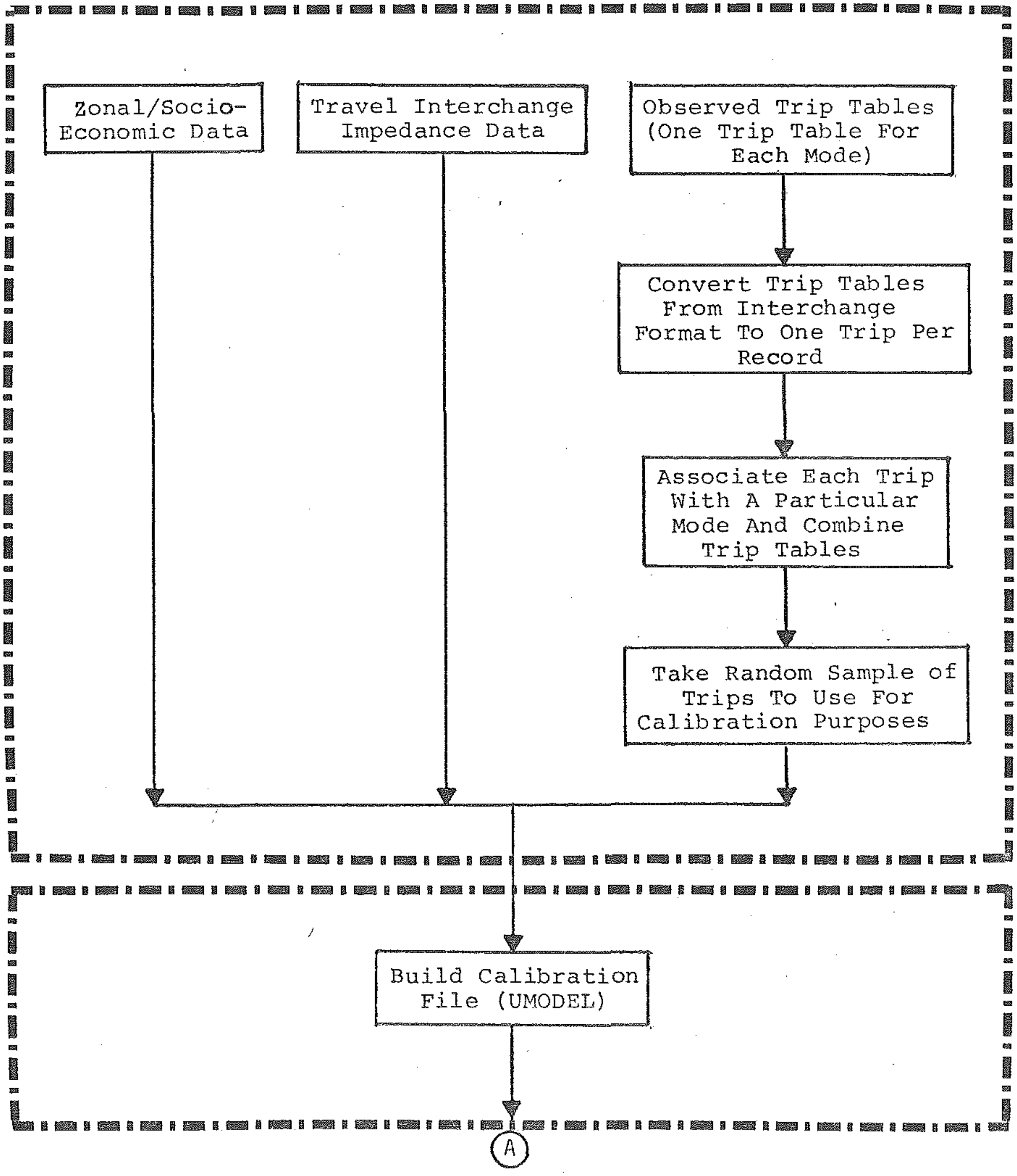
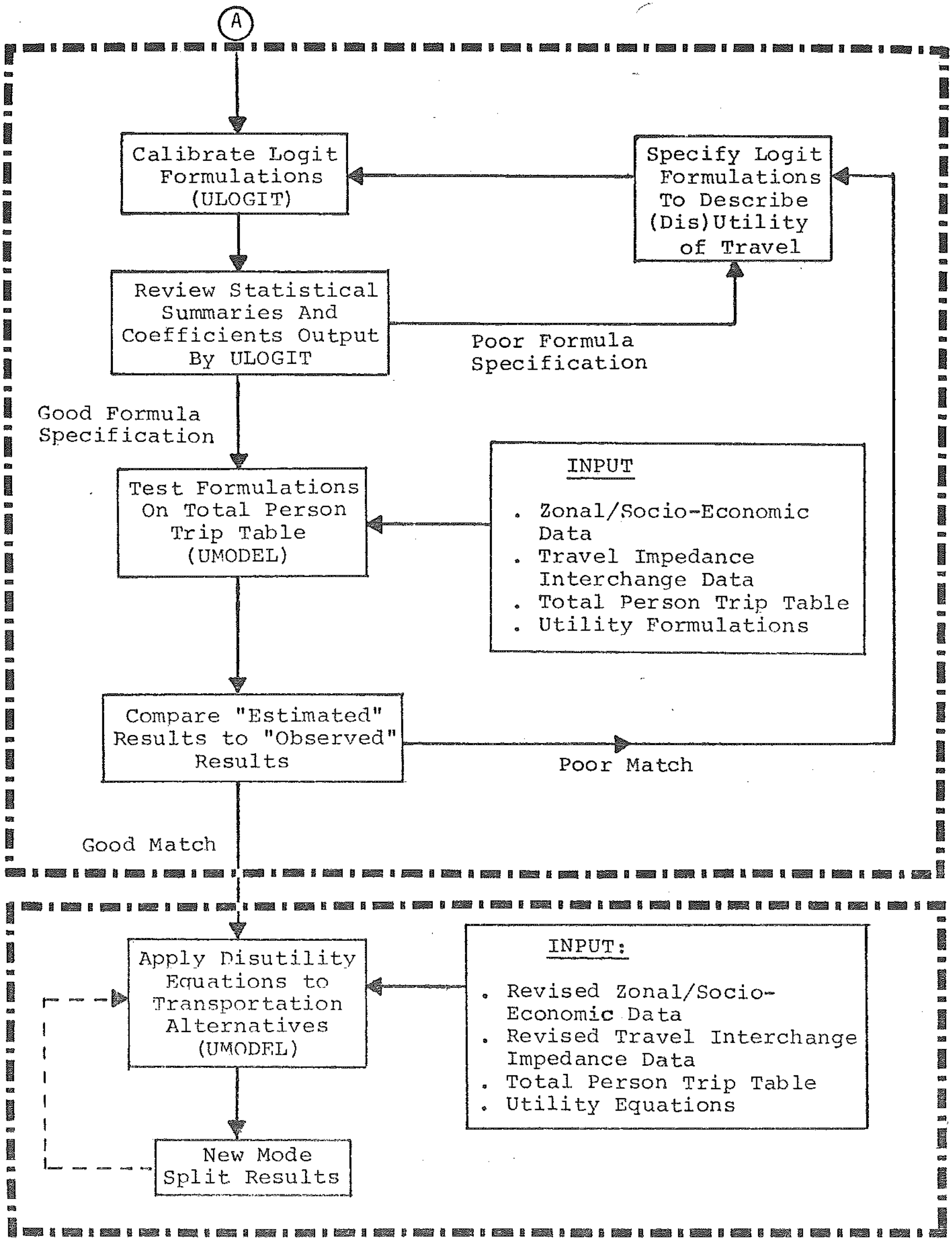


Figure 2 (Continued)



As described earlier, this study involved the development of a travel demand model using data aggregated on a zonal level. The ULOGIT computer program and the logit approach is ideally designed to use disaggregate data, therefore, some modifications were made to the aggregate data bases, particularly the observed trip data to lend itself for use for ULOGIT purposes. The following discussion summarizes what each type of data should consist of, how it is obtained, and how it will be used.

3.1.1 Observed Trip Data: The observed trip data used in this study consisted of individual, mode specific trip tables. For example, if a travel demand model is to be developed for five modes, five trip tables would be needed, one for each mode. The sum of the five mode specific trip tables would be the total person trip table.

In preparing the trip data to be used for calibration purposes, the observed trips should be coded on a household level (i.e., disaggregate trips). The trip tables provided by MDOT, however, were aggregated on a zonal basis which consisted of a numerical value representing the total number of trips for each zone pair in the study area. To obtain a disaggregate format (i.e. one trip per record), the zonal trip tables were converted into the format of a household trip file so that each record in the file contained a single trip. For example, instead of having a total of 32 trips (on a single data file record) between origin zone A and destination zone B for a zonal interchange, the file should be converted to show 32 separate trip records for travel between zones A and B, one trip per record. This task can be accomplished through the use of a number of FORTRAN statements.

The observed trip tables (converted to a single trip per record) are used in the ULOGIT program to develop mode-specific (dis)utility equations describing travel in an area. They are used to "calibrate" the (dis)utility equations so that the final set of equations will provide an estimated trip interchange value and mode split which will provide a desirable match with the observed data. This is done within the ULOGIT program using the maximum likelihood concept. It typically involves a large number of computations that requires the use of substantial computer time. Computer costs for the ULOGIT program is a direct function of the number of data points (observed trips), the number of equations (modes) and the length of the equations (number of independent variables). To minimize computer costs, a fraction or a sample of the total number of observed trips (1 - 20% depending on the number of trip records and number of zones) is normally used in the calibration process. This sample should be randomly selected and should use a similar distribution of trips between modes as the total observed data. For example, in a two mode case where the observed mode split is 90% auto and 10% transit ridership, the sample of trips used for calibration should contain the same 90-10 split between auto and transit modes.

Ideally when the trip data is a "true" household data base, a small number of trip records may be used to provide a representative reliable sample. However, in instances where aggregate data base serves as the basis of information, a larger number of trip records must be used to attain the same level of reliability in the results. If too many trip records are used, computer costs will increase significantly. Caution should be exercised in selecting a minimum sample size, particularly where one mode may represent a very small percentage of the total trips. This is the case in the Flint metropolitan area where transit trips represent approximately 0.8% of the work trips and 0.4% of the nonwork trips. Selection of a small sample (percentage-wise) can result in a small number of trips being used to calibrate the (dis)utility equation for the respective mode. This can produce some inaccuracy in the model. As such, to obtain a reliable (dis)-utility equation for transit trips in an area like Flint, a larger sample of observed trips is required for calibration.

Once the trip tables are converted into the proper format (with each trip record associated to a particular mode) and a sample of the total trips has been obtained, the sample trip data can be used to develop the calibration file (Step 2).

3.1.2 Trip Interchange Impedance Data: Trip interchange impedance data refers to a time, distance, or cost variable associated with travel between zones. This data is usually in the form of transit or highway skim trees. The highway skim tree data in this study was obtained from the MDOT. Highway skim trees may also be obtained from the UTPS program UROAD. Transit skim trees used in this study were output from the UTPS program UPSUM.

The skim trees may be modified to show a travel time ratio comparing travel time of two modes between zone pairs such as (travel time for transit)/(travel time by auto). Distance skim trees may be used to develop the out-of-pocket travel cost for the automobile modes. For example, a variable defined as [(Trip Length) x (Cost per Mile) + Parking Costs]/[Number of Vehicle Occupants] utilizes the distance skim trees for this purpose. Skim trees may also be factored or modified to show other types of variables such as trip interchange density variables. An example of this variable is $\mathrm{LOG}_{10}[T_{ij} \times D_{ij} \times A_i \times A_j]$ where T_{ij} is the number of trips between zone i and j, D_{ij} is the travel distance (miles) between zone i and j, A_i is the size of zone i (acres) and A_j is the size of zone j (acres). This particular variable can be useful in describing the (dis)utility of carpooling.

The trip interchange data, along with the observed trip data and the zonal data were used to develop the calibration file.

3.1.3 Zonal Socio-Economic and Land Use Data: Socio-economic data included the zonal characteristics of income, household size (number of persons), automobile availability, zone size (acreage), population, land uses, parking costs, etc. Socio-economic and land use data were obtained in part from census reports and other data bases and grouped into traffic analysis zones.

Zonal averages of these characteristics constitutes an aggregate data base. Zonal averaging of socio-economic characteristics of the trip-maker is a shortcoming in the modelling process. It would be preferable to know the income and other characteristics of each traveler along with the matching of the trip-makers characteristics to the selection of a particular mode. This information would provide greater detail about the decision making criteria of the traveler. Zonal averaging of data not only removes the matching of socio-economic variables of a particular individual to his/her mode of travel, but it also removes a considerable amount of variance in a variable.

In the calibration file, the zonal data is associated to a particular trip end. For example, parking costs should be associated with the destination zone of a trip, since these costs are incurred at the end of the trip. Similarly, household income data should be associated with the origin zone of a trip since household income conceivably can affect mode choice decisions. The assignment of a variable to a trip end is done when the calibration file is developed (Step 2).

In certain cases, a number of zonal variables (socio-economic and land use) may be combined to "create" a new composite variable. For example, zonal population, may be divided by zonal land area to create a density measure, (i.e., population per unit area). The identification of such new variables is a common and useful practice in most modelling exercises. The practice of selective weighting of variables to increase or decrease the trip producing characteristics of a zone through the use of adjustment factors can be accomplished to describe certain characteristics of the study area.

It is generally advisable to assemble a large number of variables at this stage for possible use in the development of the (dis)utility equations. However, the selection of variables should be made based upon perceived (or intuitive) causal relationships with the decision making process for mode choice. For example, variables such as income and automobile availability have been shown to have a significant impact on mode choice. Other variables such as zone size (acreage), may not always have an impact on mode choice and would be less desirable to use.

Variables which are difficult to predict should be avoided. For example, resident labor force in a zone may be very difficult to predict because of the uncertainty of future economic conditions and the increasing numbers of women entering the work force. Therefore, this variable may be undesirable to use even though it may provide a decent "fit" to the observed trip data. The final selection of variables should relate to the transportation strategies to be tested. That is, if new transit system alternatives are to be evaluated, variables such as travel time by transit should be used.

3.2 Step 2: Building Calibration File

The calibration file is constructed using the UTPS program UMODEL (Figure 2). The calibration file consists of a matrix in which the rows correspond to observed trip records (one trip per record) and the columns correspond to variables. These variables include mode choice (dependent variable), travel times, costs, socio-economic and zonal description variables (independent variables) to provide (dis)utility information regarding the trip.

The calibration file provides a specification of variable names, units, and all possible variables which may be used in the ULOGIT runs. An example of a calibration file setup is shown in Appendix 2.

The dependent variable relates to the mode of travel and assumes a binary form. Each trip record in the calibration file is associated with one and only one mode, and that mode has to be identified with "0" or "1". For example, in a three mode situation where columns i, j, and k in the calibration file are associated with the auto mode, carpool mode, and transit mode respectively, only three possibilities can exist.

	Columns in the Calibration File		
	i	j	k
Auto mode	1	0	0
Carpool mode	0	1	0
Transit mode	0	0	1

In this manner, each trip is assigned to a mode and a trip can never be assigned to more than one mode.

3.3 Step 3: Developing (Dis)utility Equations

This step involves using the UTPS computer program ULOGIT to develop coefficients for user developed (dis)utility equations. The input to the

ULOGIT program is the calibration file developed in the previous step (Figure 2). When using the ULOGIT program, a disutility equation is developed for each mode (dependent variable) from the observed characteristics of the trip makers (independent variables) as specified in the calibration file. For each dependent variable, an equation is formulated consisting of independent variables, coefficients and bias coefficients. The independent variables are travel impedance or socio-economic variables associated with each trip as input into the calibration file. The coefficients are weights given to the independent variables and the bias coefficients are constants (which may or may not be used) and act as intercepts or "global" adjustments to the (dis)utility equations. Bias coefficients are usually included in an equation to explain "unknown" or unmeasurable characteristics of a mode such as privacy or convenience. This type of coefficient may also be used in lieu of several minor variables (which only have a small impact on the characteristics of a mode in composite form) or to simply form a better fit of the equation.

An example formulation for a three mode case is as follows:[1]

Mode	Coefficients	Variables
Auto Users	= Time Coef + Cost Coef + Auto Bias	* Auto Time * Auto Cost
Pool Users	= Time Coef + Cost Coef + Pool Bias	* Pool Time * Pool Cost
Transit User	= Time Coef + Cost Coef	* Transit Time * Transit Cost

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[1] NOTE: This example formulation is used for illustrative purposes to show the use of ULOGIT and is not used as a model in the study.

In this example, three (dis)utility equations are being calibrated for three modes (dependent variables) using a combination of independent variables, coefficients and bias coefficients.

The dependent variables are:

- Auto Users
- Pool Users[1]
- Transit Users

The independent variables are:

- Auto Time
- Auto Cost
- Pool Time
- Pool Cost
- Transit Time
- Transit Cost

The coefficients are:

- Time Coef
- Cost Coef

The bias coefficient are:

- Auto Bias
- Pool Bias

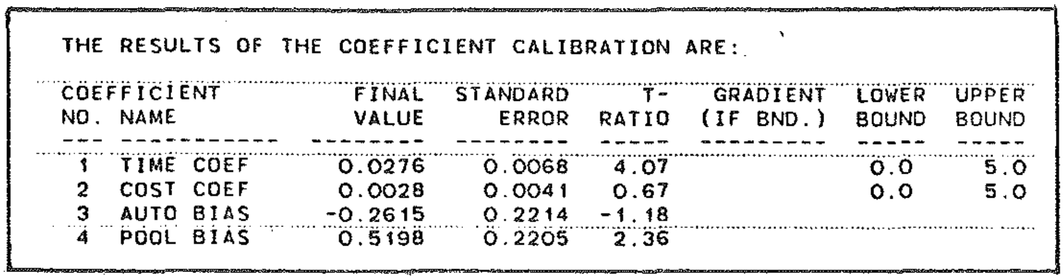
The user is required to input the form of the equation, select the independent variables from the calibration file and arrange the variables, coefficients and bias coefficients in a manner which will logically explain mode choice. The ULOGIT program calibrates the disutility equation to the observed trips using the principle of maximum likelihood. The output of

---

[1] NOTE: The "Pool Users" mode can be further broken down into additional modes indicating various auto occupancy levels.

the ULOGIT program are values of coefficients and bias coefficients for the estimation formulas (Figure 3). ULOGIT also outputs various measures describing the quality of the calibration effort (see Section 5.3).

Figure 3. Final Coefficient Values



```
THE RESULTS OF THE COEFFICIENT CALIBRATION ARE:

COEFFICIENT              FINAL   STANDARD     T-   GRADIENT  LOWER  UPPER
NO. NAME                 VALUE      ERROR  RATIO  (IF BND.)  BOUND  BOUND
--- ------------      --------   --------  -----  ---------  -----  -----
  1 TIME COEF           0.0276     0.0068   4.07               0.0    5.0
  2 COST COEF           0.0028     0.0041   0.67               0.0    5.0
  3 AUTO BIAS          -0.2615     0.2214  -1.18
  4 POOL BIAS           0.5198     0.2205   2.36
```

Initial estimates of the coefficients and bias coefficients may be input by the programmer, otherwise those coefficients are assumed to be zero by the program. The coefficients may also be bounded by an upper and/or lower value.

For the three-mode example shown above, the disutility of each mode is as follows:

Auto Users = EXP(0.276 * Auto Time+.0028 * Auto Cost-.2615) = EXP(U(1))

Pool Users = EXP(.0276 * Pool Time+.0028 * Pool Cost+.5198) = EXP(U(2))

Transit Users = EXP(.0276 * Transit Time+.0028 * Transit Cost) = EXP(U(3))

To find the utilities of each mode, the signs of the coefficients and bias coefficients should be reversed.

In specifying (dis)utility equations, appropriate care must be exercised to avoid nonunique coefficients that might seriously disrupt the calibration effort. The nonuniqueness may occur due to the following conditions (among others):

- Each (dis)utility equation contains a bias coefficient and the bias coefficients are all different.
- The same variable is included in all (dis)utility expressions. This is unacceptable even if the variable is factored by a different coefficient in each equation.
- Two bias coefficients occur in the same (dis)utility equation but neither occurs in any other.

To avoid these problems, the user should carefully read the ULOGIT Calibration Program documentation and the ULOGIT User's Guide.

Once a calibration has been completed, the (dis)utility expressions must be thoroughly checked for logic and statistical reliability. ULOGIT produces a series of reports to help accomplish this task. These reports are described in Section 5.3 and in the ULOGIT User's Guide.

If the reports indicate that the (dis)utility equations are not valid, a new set of expressions must be defined and the calibration process must be repeated. If the reports produced by ULOGIT indicate an acceptable set of equations, one further test must be conducted to accept the equations. Since the (dis)utility equations were developed on a 1% - 20% sample of the total person trips, there is a need to test the equations on the entire trip table. This step is completed using UMODEL (or UMATRIX) through the development of an "estimated" trip table. If the estimated trip table can be shown to match the observed trip table, the calibration process is complete and testing of various transportation strategies can begin.

If however, the estimated trip table does not acceptably match the observed trip table, further calibration is necessary. Such a situation may arise, even after the calibration results might apparently indicate an acceptable (dis)utility equation. In other words, the calibration process is not complete until after the model has been applied to the total trip table and the mode split has been favorably matched with the observed mode split. A poor match between the estimated and observed trip table may be due to an insufficient sample size, a nonrandom or improperly selected sample, inadequate equation specification, problems with certain data elements or other related problems. If sampling or data variables are considered to be a problem, the deficiencies should be corrected and a new calibration file should be developed. If a poor match is caused due to improper (dis)utility expressions, new equations should be formulated and calibrated. Some disparity between observed and estimated trip tables can be corrected by applying adjustment factors to the (dis)utility expressions. For example, in the three mode case if it is determined that transit is always under-predicted at all zones by a factor of 10%, than the utility of transit travel can be increased appropriately to "fine tune" the model. If there is a problem of under-prediction or over-prediction at a few selected zones, then zonal adjustment factors may be applied to rectify this.

3.4 Step 4: - Utilizing the (Dis)utility Equations to Perform Modal Split

This step uses UMODEL to apply the calibrated (dis)utility equations to various transportation alternatives and trip tables (Figure 2). Transportation strategies which can be evaluated using UTPS include new transit operating strategies, adding new bus lines, revising transit fares, cost changes, ridesharing, park and ride lots, etc. The transportation strategies to be tested must impact the variables which are in the (dis)utility expressions. If, for example, a cost variable is not in the (dis)utility expression, then a transportation strategy which only impacts cost (such as a transit fare increase) can not be tested.

The probability of selecting a mode is based on the relative utility of using a mode. The ULOGIT model provides linear equations in the form of <u>dis</u>utility as described earlier in this chapter. Therefore, the signs of the coefficients must be reversed to perform mode-split in UMODEL. To illustrate this, suppose for the three mode situation discussed in Section 3.3 that the <u>dis</u>utilities of using modes 1, 2, and 3 are EXP(U(1)), EXP(U(2)), and EXP(U(3)), respectively. Then the probability that a rider will choose mode 1 based on the utility of using that mode is:

$$P(1) = \frac{EXP(-U(1))}{EXP(-U(1)) + EXP(-U(2)) + EXP(-U(3))}$$

The total number of people using mode 1 to travel from zone i to j is:

$$T_{1ij} = P(1)_{ij} * TPT_{ij}$$

Where:

T_{1ij} = the number of trips using mode 1 between zones i and j

$P(1)_{ij}$ = probability of using mode 1 to travel between zones i and j (based on the utility of the mode)

TPT_{ij} = total number of persons traveling from zone i to j

The allocation of trips to each mode (automobile, carpool, and transit) for travel between all zone pairs can be accomplished similarly.

4. CASE STUDY: Genesee County Area

The Flint metropolitan area (Genesee County, Michigan) was used as a test site to illustrate the use of the ULOGIT modelling process. The Flint area was selected because it is representative of most urbanized areas within the State of Michigan, it has a viable data base, and because of the existence of a transit system which has been in operation for a number of years. The emphasis on this phase of the study was to use the Flint area as a demonstration site and not to select a particular model which will be used in a planning study for the area. As such, a number of different models were calibrated and tested for the purpose of evaluating the logit modelling process.

4.1 Description of the Study Area

The Flint metropolitan area used in this study encompasses Genesee County, Michigan. The urbanized area not only includes the City of Flint but also includes the Cities of Burton, Mount Morris, Davison, Grand Blanc, Swartz Creek, Flushing and several unincoporated areas as shown in Figure 4.

The 1970 and 1980 population for the urbanized areas in Genesee County are given in Table 1. The urbanized area had a population of 330,178 persons in 1970. An in-house study conducted by the Genesee County Metropolitan Planning Commission indicates a 1.6% decrease in the 1980 urbanized population to 324,703. The majority of the urban population decrease is expected to occur within the City of Flint while population increases are expected in outlying urban areas such as, Davison Township, Grand Blanc Township, Grand Blanc City, Flint Township, the City of Swartz Creek, etc.

Figure 4 - Genesee County Urbanized Area (Shaded Portion of Map)

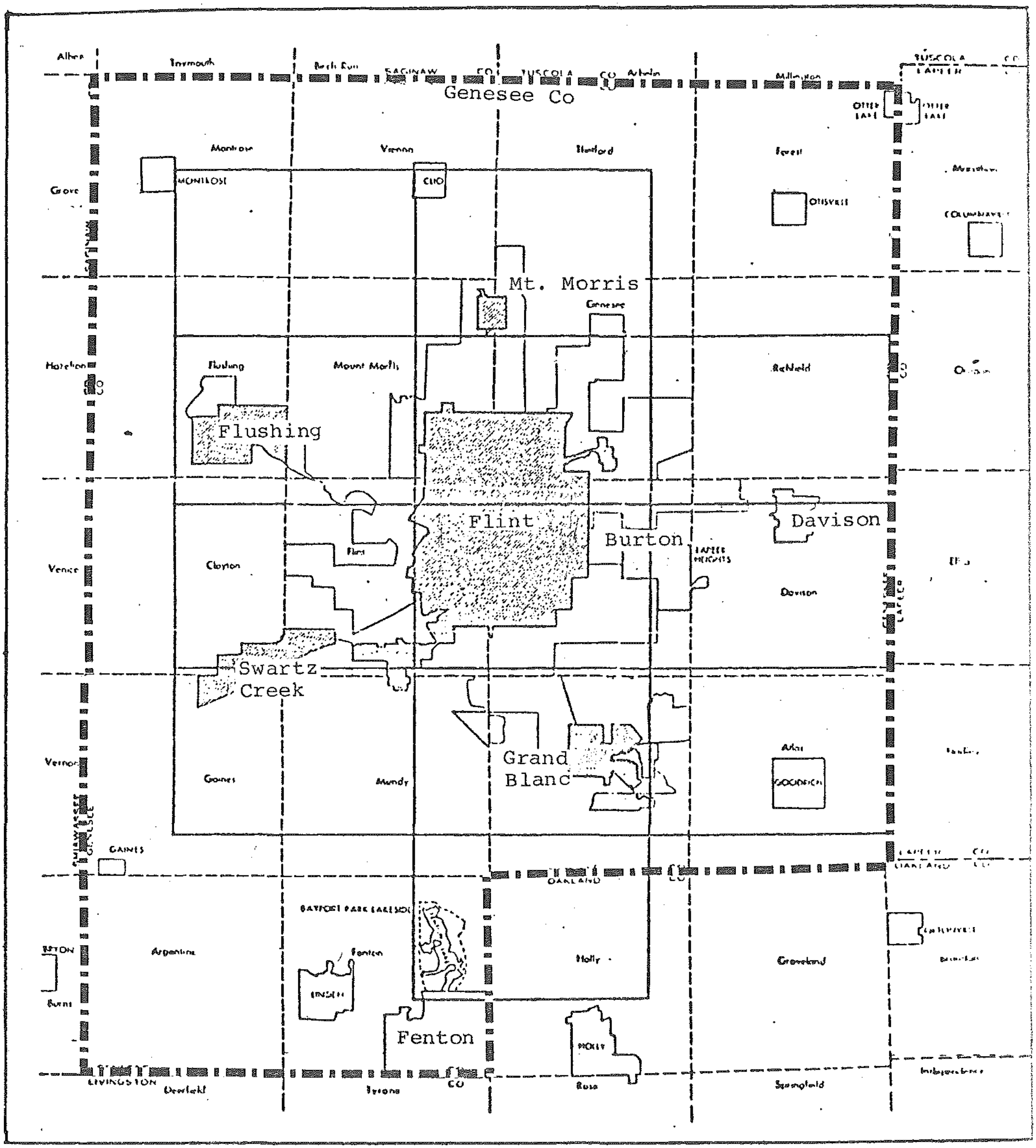


Table 1 - Genesee County Urbanized Population Data

Governmental Unit	Percent Population Within Urbanized Area[1]	1970 Urbanized Area Population[1]	1980 Projected Urbanized Area Population[2]	Percent Change 1970-80
Flint City	100	193,317	166,739	-13.7
Flushing City	100	7,190	7,764	+8.0
Grand Blanc City	100	5,132	6,815	+32.8
Mt. Morris City	100	3,772	3,489	-7.5
Swartz Creek City	100	4,928	6,353	+28.9
Burton	97	31,660	33,921	+7.1
Davison Township	30	2,480	3,695	+50.0
Flint Township	86	25,758	34,058	+32.2
Flushing Township	21	1,480	1,907	+28.9
Genesee Township	85	21,675	21,281	-1.8
Grand Blanc Town.	60	11,593	16,652	+43.8
Mt. Morris Town.	66	19,393	19,769	+1.9
Mundy Township	11	903	1,166	+29.1
Thetford Township	14	847	1,094	+29.2
Totals		330,128	324,703	-1.6

[1] Estimates prepared by ICF, Inc., based on "1970 Block Statistics, Flint Urbanized Area", U.S. Bureau of Census

[2] Projections: Genesee County Metropolitan Planning Commission; May, 1977

Note: The urbanized area does not correspond to the entire Genesee County study area

As a result, the population for the entire county has remained relatively unchanged since 1970. The distribution of population has changed slightly with a shift of people away from the central city to the suburban and rural areas.

The general distribution of land uses in the Flint area is shown in Table 2. The city itself has several large automobile manufacturing complexes, making it one of the largest employment centers in the State. Industrial land use constitutes a major land activity within the urban area.

Travel within the Flint urbanized area presently represents an extensive utilization of the private automobile. Public transit has been in existence in the Flint area since 1961, except for a short period of time during 1971 when the Flint Mass Transit Authority was being formed. The current average daily ridership on the transit system is approximately 9,200 person trips, which represents a very small fraction of the total daily travel in the Flint area. A 1974 transit study by ICF[1], Inc. found Flint to be similar to other urban areas of its size in its need for transit services.

The transit system which existed in 1978 was used in this study as the base transit network. The transit service, as provided by the system is designed primarily to serve the Central Business District (CBD). The base transit system consists of 12 radial routes which converge on a central transfer point in downtown Flint. The 1978 system configuration is displayed in Figure 5.

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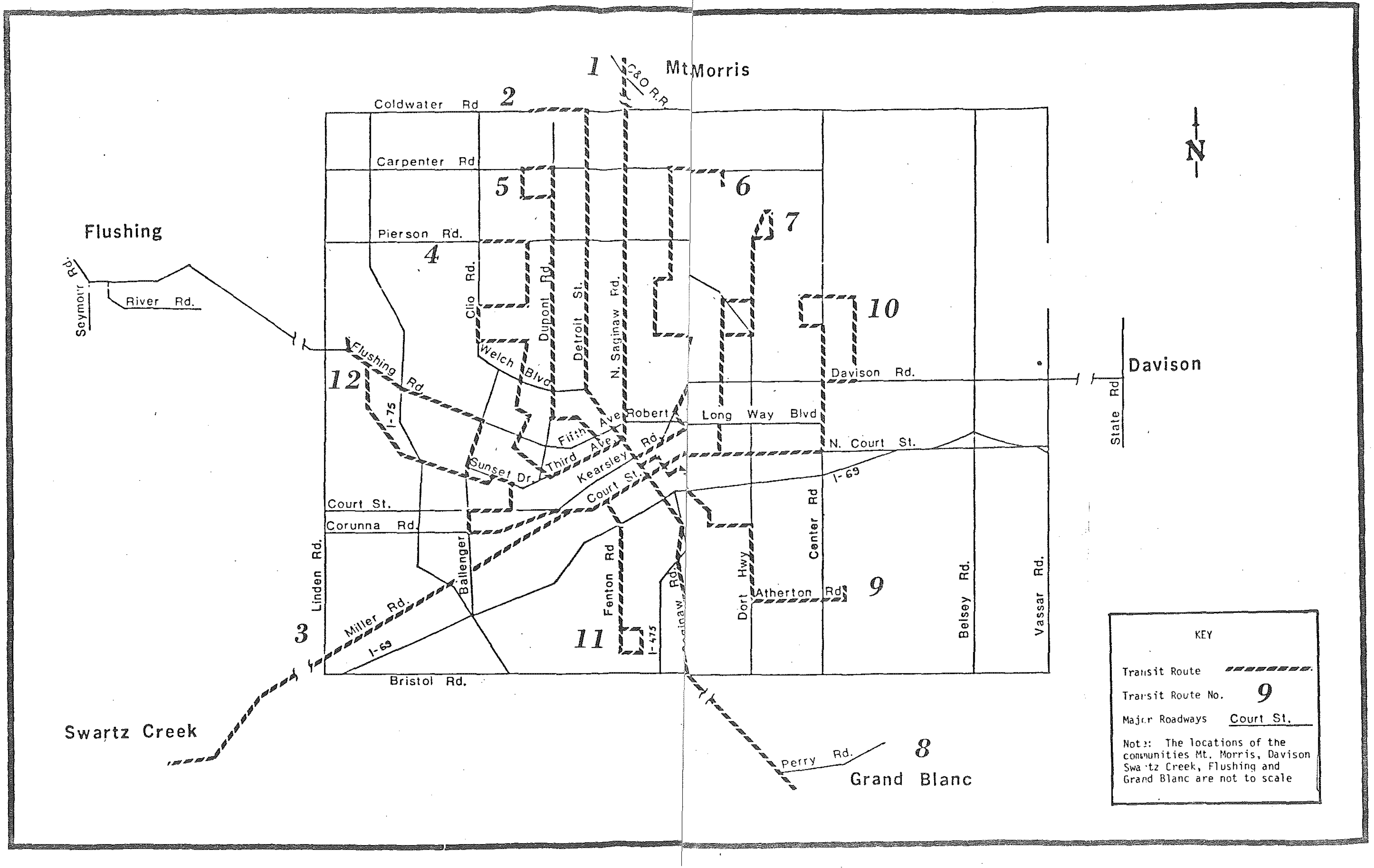
[1] "A Five Year Mass Transit Development Plan for Flint, Michigan" (Draft), November 11, 1974, ICF, Inc., 1828 L Street NW, Suite 709, Washington, D.C. 20023.

Table 2 - 1975 Land Use Characteristics for the Genesee County Urbanized Area

		Residential			Non-Residential				
City	Total	1 & 2 Family	Multi-Family	Other	Industrial	Retail/ Commercial	Cultural/ Recreation	Other	Vacant And Misc.
Flint	21,171	6,960	368	169	1,506	2,165	1,065	1,327	7,611
Burton	14,805	3,616	44	28	196	714	614	425	9,168
Flushing	2,303	940	18	16	6	68	101	79	1,075
Grand Blanc	2,175	660	34	9	57	66	6	503	840
Mt. Morris	629	340	8	0	0	23	11	58	189
Swartz Creek	2,620	538	41	0	94	93	41	94	1,719
Balance of Urban Area*	207,164	28,681	806	1084	654	4,927	2,408	2,725	165,878
Total	250,867	41,735	1,319	1306	2,513	8,056	4,246	5,211	186,481

* Includes total area of townships even though only portions of some townships are in the Flint urbanized area.



Note: The locations of the communities Mt. Morris, Davison Swartz Creek, Flushing and Grand Blanc are not to scale

Figure 5 - Flint Transit System (1978)

Transit service operates for a period of approximately 11 hours, of which 6 hours are peak period operation (a.m. and p.m. peak periods) and 5 hours are off-peak operation. Headways for peak and off-peak service are listed in Table 3.

4.2 Data Base

All data used in this study was provided by the Michigan Department of Transportation (MDOT) for the Flint metropolitan area with the exception of the Transit Trip Table and network which was obtained from the Civil Engineering Department at Wayne State University (as developed in past modelling studies for the Flint area). The following is a summary of the data types and sources used in this study include:

- Auto occupancy trip tables based on trip purpose (work, nonwork) and number of occupants in the vehicle (drive alone, one passenger, two passengers, and three or more passengers) were provided by MDOT and represented 1966 travel data. This trip data was the most recent data available for the City of Flint and was based on an origin-destination study performed by MDOT in 1966.
- Highway skim trees based on travel time and travel distance were provided by MDOT for the 1978 highway network.
- Transit trip tables and the transit network and skim trees, were provided by the Civil Engineering Department at Wayne State University. The trip tables do not represent actual or observed trip data but were calibrated from matching line loadings as output from the UTPS module ULOAD to observed line loadings of the 1978 Flint transit system.[1]

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[1] "Flint Area Transit Study: The Testing of Short-range and Long-range Alternatives Using the UTPS Modelling System", Department of Civil Engineering, Wayne State University, 1980.

Table 3 — Operating Headways For Flint Transit Routes

(1978)

Route No.	Route	Peak Headway (Minutes)	Off-Peak Headway (Minutes)
4	Civic Park	20	30
5	Dupont Street	20	30
2	Detroit Street	20	30
1	N. Saginaw	20	30
6	Lewis-Selby	20	30
7	Franklin	20	30
10	Richfield	20	30
9	Lapeer	20	30
8	S. Saginaw	20	30
11	Fenton Road	60	60
3	Genesee Valley	20	30
12	Beecher-Corunna	20	30

- Socio-Economic and land use data was obtained from MDOT, some of which was taken from 1970 census data and other items represented estimated* 1975 data for the study area. Various data elements included:
  - Average zonal income
  - Parking and unparking times
  - Zonal employment
  - Zonal population
  - Zone size and land use
  - Number of dwelling units in a zone
  - Auto ownership
  - Land use data
  - Parking costs
  - Others

Some of the data elements such as income and automobile availability were taken from 1970 data. Other data items such as population, zonal employment, number of dwelling units and land use are from the year 1975. In addition, 1966 auto occupancy trip tables and 1978 transit trip tables and skim trees were used. Ideally, all of the data should have been taken from the same time period. Since all of the data items were not available for the same time period, the best available data was used. In many cases it was assumed that the data items would be sufficiently representative of existing conditions in the study year. By using existing data, significant delays and costs for collecting new data were avoided.

The practice of using data from different years was considered acceptable in this study for the following reasons:

---

*1975 estimates made by the Genesee County Metropolitan Planning Commission.

1. Population and land uses were considered relatively stable over the past 10-15 years. It was further assumed that travel patterns and vehicle occupancy levels have also remained relatively unchanged from 1966 levels.
2. This study was designed to be a demonstration of the modelling process and not a planning study which will result in the recommendation of a new transportation strategy or system implementation.

It was recognized that problems with the data base may affect the predictive capability of the model itself. The possible occurrence of this problem was anticipated and carefully analyzed to avoid rejecting a valid model.

5. DEVELOPING LOGIT EQUATIONS

Two modelling efforts were conducted in this study. The first effort was to develop mode split model for two modes, auto and transit. The second modelling effort was to develop mode split between five modes, transit and auto at four occupancy levels. The description of each (dis)-utility formulation is described below.

5.1 Auto-Transit Mode Split Model

This model was used as an example and to compare with past modelling efforts which utilized the diversion curve technique for mode split. The observed trip table and skim trees for both modes were based upon 1978 data. The existing mode split for 1978 was:

Auto Trips	=	1,054,605	(99.4%)
Transit Trips	=	6,468	(.6%)
Total Trips		1,061,073	(100%)

Because of the small percentage of transit trips, a large number of trip records (21,220) were used for calibration purposes. These 21,220 trip records represented 2% sample of the total trips of which 21,092 (99.4% of the sample) were auto trips and 128 (.6% of the sample) were transit trips. The use of over 20,000 trip records should generally be avoided because of high computing costs, but was necessitated in this case because of the extremely small percentage of transit trips.

Four different (dis)utility formulations were calibrated to the sample of observed trips. Variables used to describe (dis)utility included land use, income, population per acre, travel time ratio, travel cost, etc.

Attempts were made to utilize variables and formulations which are used as mode selection criteria, or which describe transportation system attributes. The two-mode models are summarized in Appendix 5.

Of the four models calibrated on the sample of trips, one was selected to be tested on a total person trip table. The results for the auto transit mode split models are given in Section 6.1.

5.2 Five Mode Example

The main thrust of the study was to develop a multi-nomial logit model for various automobile occupancy levels along with transit. As such, a five mode example was developed and calibrated. The modes included:

- Automobile - Drive alone
- Automobile - One passenger
- Automobile - Two passengers
- Automobile - Three or more passengers
- Transit

Separate models were formulated for work and nonwork trip purposes. The automobile occupancy trip tables (for work and nonwork trip purposes) were based on 1966 travel surveys in the Flint metropolitan area. The transit trip tables were based on the 1978 Flint transit system developed from past modelling studies conducted at Wayne State University in 1979. The use of a data base from two different time periods within the same modelling exercise is generally inadvisible. However, there were two factors that should be duly considered in justifying the use of such data based. They are:

1) It has been assumed that during the past 10-15 years relatively minor changes in auto occupancy levels have occurred in the study

area. Furthermore, the 1966 transit ridership was not expected to be greatly different from the 1978 data.

2) The purpose of the study was to test the feasibility of using the logit approach for demand estimation, and not necessarily to develop actual demand estimates for planning purposes.

The transit trip tables obtained for this study were based on peak and off-peak transit service and were not associated with work or nonwork trip purposes. For the purposes of this study, the following conversion was made based on observed characteristics made for the Flint transit system:

<u>Peak Transit Trips (3,741 trips)</u>

30% Work Trips
70% Nonwork Trips

<u>Off-Peak Transit Trips (2,727 trips)</u>

22% Work Trips
78% Nonwork Trips

The trip tables were revised to show the following:

Transit Work Trips = 1,721 trips
Transit Nonwork Trips = 4,747 trips

The observed trips for the work trip tables were distributed between the five modes as shown in Table 4. There were a total of 203,347 work trips, a majority of which were by the "drive alone" mode (86.4%). Transit represented only .8% of the total work trips. A 5% sample was randomly

Table 4. Observed Trip Distribution and Sample Size For Work Trips

Mode	Observed Trips	% of Total	Sampled Trips
Auto - Drive alone	175,690	86.4	8,784
Auto - One passenger	18,934	9.3	946
Auto - Two passengers	4,395	2.2	219
Auto - Three or more passengers	2,607	1.3	130
Transit	1,721	.8	86
Total	203,347	--	10,165

Table 5. Observed Trip Distribution and Sample Size For Nonwork Trips

Mode	Observed Trips	% of Total	Sampled Trips
Auto - Drive alone	438,087	38.2	5,841
Auto - One passenger	367,304	32.1	4,897
Auto - Two passengers	152,085	13.3	2,027
Auto - Three or more passengers	183,002	16.0	2,440
Transit	4,747	.4	63
Total	1,145,225	--	15,268

selected for calibration purposes, using a total of 10,165 trip records. Trip length frequency curves for each mode are given in Appendix 1.

Three models were formulated to show the (dis)utility of travel for work trips using the five modes. Each of these models represent different combinations of the impedance and zonal variables that were selectively identified from the calibration file. The models are discussed and evaluated in Section 7.1 of the report. The work models are summarized in Appendix 5.

The observed trips for nonwork trip purposes were distributed between the five modes as shown in Table 5. There were 1,145,225 nonwork trips which is approximately 5.6 times the number of work trips. The most common modes used were "drive alone" (38.2% of the nonwork trips) and "automobile - one passenger" (32.1% of the nonwork trips). Unlike work trips, the number of "three or more passenger" auto trips 16.0%) was larger than the "two passenger" auto trips (13.3%) for nonwork purposes. The transit mode represented .4% of the total nonwork trips. A 1.3% sample of trips was randomly selected for calibration purposes, using a total of 15,268 trip records. Trip length frequency curves for each mode are provided in Appendix 1. Two models were formulated to show the (dis)utilities for the five modes. The models are discussed and evaluated in Section 7.3 of the report. The nonwork models are shown in Appendix 5.

5.3 Tests to Evaluate Logit Formulations[1]

As described earlier, the technique of maximum likelihood is used to develop linear (dis)utility equations for each mode being analyzed when a

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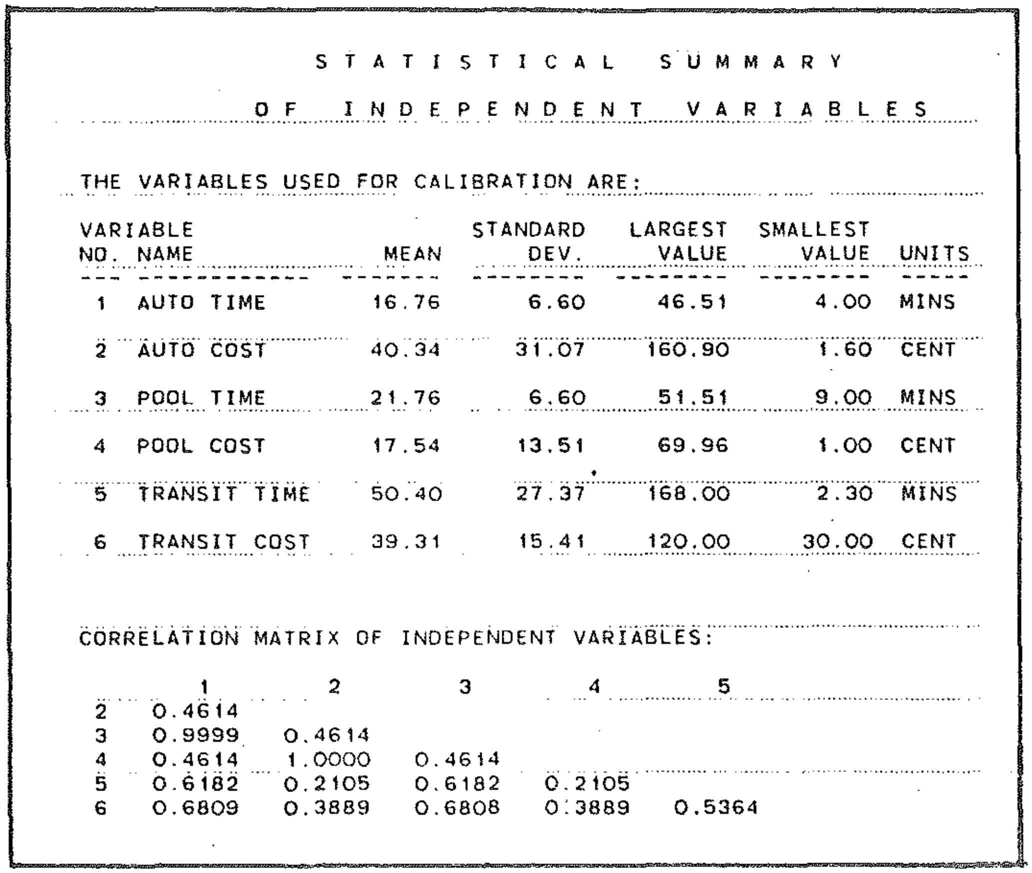
[1] Materials presented in this section are a adopted from the draft publication "ULOGIT User's Guide" published by UMTA.

set of independent variables is specified. Unlike the regression technique, however, there is no unique and direct means of determining the best model from amongst a set of candidate logit models developed. The ULOGIT program produces a variety of statistical measures concerning the significance of the coefficients and the "goodness of fit" of the model. But it is important to point out that the user should not rely too heavily on the statistical tests to identify the "best" model. These tests are designed more for eliminating unacceptable models, rather than making objective comparisons among the models or choosing the best one. *The best ULOGIT model should not be identified based on the highest statistics alone. Significant emphasis should be placed on factors such as reasonableness, and an intuitive understanding of causal factors that might determine mode choice.*

A total of seven tests as output by ULOGIT that should be used in interpreting the results, rejecting the unacceptable models and choosing the acceptable ones are described below.

5.3.1 Correlation Between Variables: Report 2 of the ULOGIT Output presents a statistical summary of all the independent variables used in the model along with a correlation matrix. The correlation matrix should be used in deciding which variables should not be used in the same composite (dis)utility equation, as explanatory variables with a high degree of correlation should not be used together. Implicit in the formulation of linear equations common to disaggregate models is the assumption that the variables are independent. While it is virtually impossible to have uncorrelated variables, the use of the highly correlated variables in the same (dis)utility equation should be avoided. Within the same calibration exercise, the use of correlated variables in different (dis)utility expressions (for different modes) is permissible. A sample copy of Report 2 is enclosed.

Table 6 - Sample Copy of ULOGIT Report 2



```
                  S T A T I S T I C A L   S U M M A R Y

                 O F   I N D E P E N D E N T   V A R I A B L E S


THE VARIABLES USED FOR CALIBRATION ARE:

VARIABLE                           STANDARD   LARGEST   SMALLEST
NO. NAME                     MEAN     DEV.      VALUE      VALUE  UNITS
--- ------------         -------  --------  --------   --------  -----
 1  AUTO TIME              16.76      6.60     46.51       4.00  MINS

 2  AUTO COST              40.34     31.07    160.90       1.60  CENT

 3  POOL TIME              21.76      6.60     51.51       9.00  MINS

 4  POOL COST              17.54     13.51     69.96       1.00  CENT

 5  TRANSIT TIME           50.40     27.37    168.00       2.30  MINS

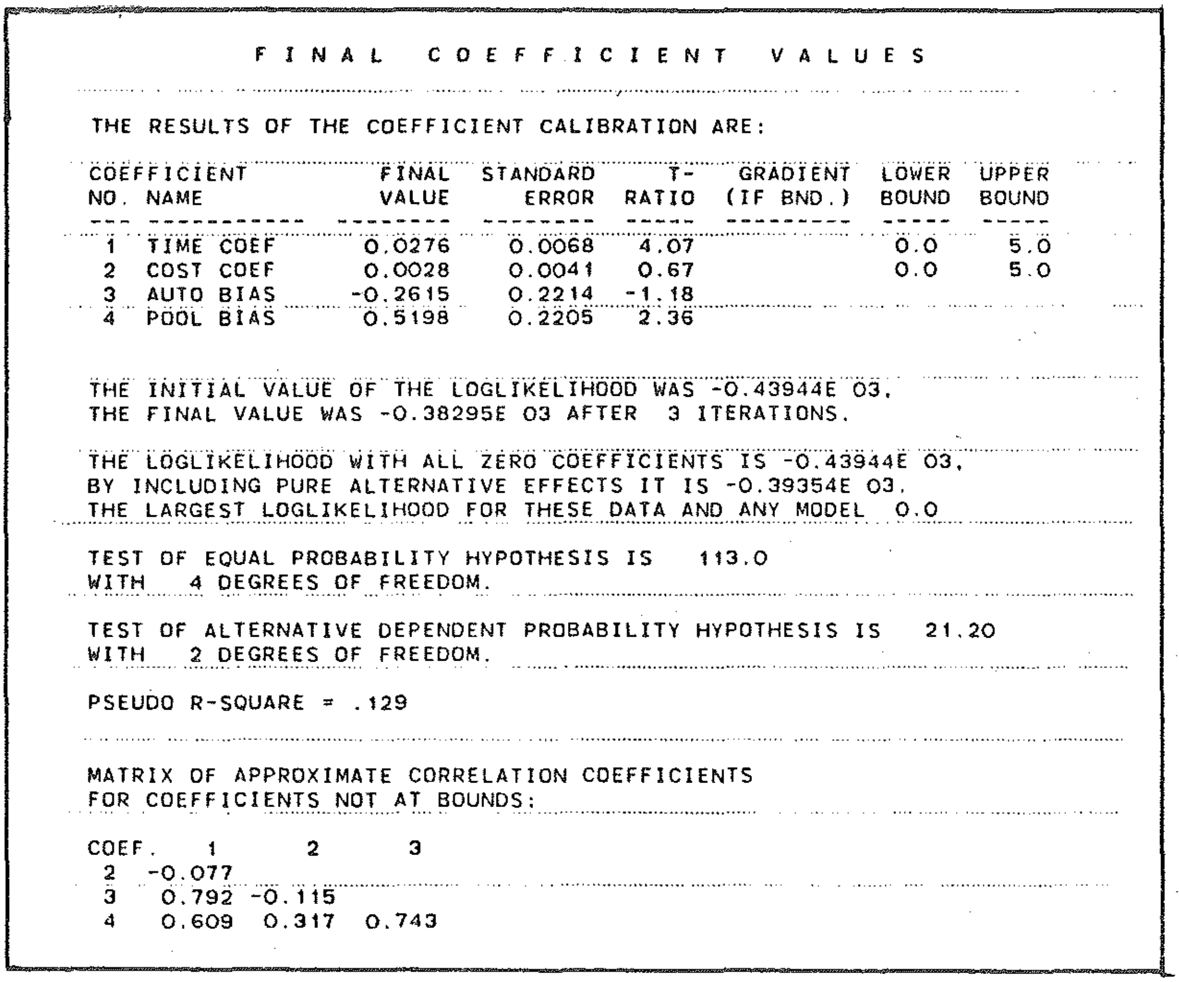
 6  TRANSIT COST           39.31     15.41    120.00      30.00  CENT


CORRELATION MATRIX OF INDEPENDENT VARIABLES:

          1          2          3          4          5
 2    0.4614
 3    0.9999     0.4614
 4    0.4614     1.0000     0.4614
 5    0.6182     0.2105     0.6182     0.2105
 6    0.6809     0.3889     0.6808     0.3889     0.5364
```

5.3.2 Test of (Dis)utility Coefficients: Report 3 of ULOGIT Output provides a series of statistical tests that are considered extremely valuable in interpreting the test results. The signs of the coefficients under the "final value" column in Report 3 are reversed from how they should be used in the application of the logit formulation in UMODEL (mode-split). Typically, the impedance variables (e.g., travel, time, cost, distance) are expected to have a positive sign in ULOGIT Report 3. A sample copy of the Report 3 is enclosed herewith.

Table 7 - Sample Copy of ULOGIT Report 3



```
                 F I N A L   C O E F F I C I E N T   V A L U E S

  THE RESULTS OF THE COEFFICIENT CALIBRATION ARE:

 COEFFICIENT              FINAL  STANDARD     T-    GRADIENT  LOWER  UPPER
 NO. NAME                 VALUE     ERROR  RATIO  (IF BND.)  BOUND  BOUND
 --- ------------      --------  --------  -----  ---------  -----  -----
   1 TIME COEF           0.0276    0.0068   4.07               0.0    5.0
   2 COST COEF           0.0028    0.0041   0.67               0.0    5.0
   3 AUTO BIAS          -0.2615    0.2214  -1.18
   4 POOL BIAS           0.5198    0.2205   2.36


 THE INITIAL VALUE OF THE LOGLIKELIHOOD WAS -0.43944E 03.
 THE FINAL VALUE WAS -0.38295E 03 AFTER  3 ITERATIONS.

 THE LOGLIKELIHOOD WITH ALL ZERO COEFFICIENTS IS -0.43944E 03,
 BY INCLUDING PURE ALTERNATIVE EFFECTS IT IS -0.39354E 03.
 THE LARGEST LOGLIKELIHOOD FOR THESE DATA AND ANY MODEL  0.0

 TEST OF EQUAL PROBABILITY HYPOTHESIS IS    113.0
 WITH   4 DEGREES OF FREEDOM.

 TEST OF ALTERNATIVE DEPENDENT PROBABILITY HYPOTHESIS IS   21.20
 WITH   2 DEGREES OF FREEDOM.

 PSEUDO R-SQUARE = .129


 MATRIX OF APPROXIMATE CORRELATION COEFFICIENTS
 FOR COEFFICIENTS NOT AT BOUNDS:

 COEF.    1       2       3
   2  -0.077
   3   0.792  -0.115
   4   0.609   0.317   0.743
```

5.3.3 T-Test of Coefficients: The values in the "T-Ratio" column in Report 3 are designed to indicate if the variable in question has a meaningful role in the (dis)utility equation. The test seeks to determine if the coefficient is not significantly different from zero, where the null hypothesis is:

$HO: \emptyset = 0$ ($\emptyset$ = coefficient)

The null hypothesis is tested against the alternative hypothes $H1: \emptyset = 0$, making this a two-tail test. If the hypothesis is accepted, the conclusion is that the variable is not making a significant contribution in explaining part of the variation in the observed data. The rejection of the hypothesis would indicate otherwise namely: the contribution of this variable is significant. In testing the hypothesis, the "t" value is calculated as:

$$t_{cal} = \frac{\text{Final Value of Coefficient}}{\text{Standard Error}}$$

If t_{cal} exceeds "t" critical, the null hypothesis is to be rejected. The critical "t" value is obtained from standard "t" tables at an acceptable level of confidence appropriate for the number of degrees of freedom (df). The (df) in this case equals the difference between the number of observations and the number of parameters used in the model. At 95% confidance level, for degrees of freedom exceeding 120, the critical "t" value is ±1.96.

5.3.4 Test of Equal Probability Hypothesis: The null hypothesis tested here can be stated as:

HO: All modes have the same probability of being chosen, and that probability is equal to 1/(# of modes).

Report 3 also prints out the value of Log-Likelihood (LL) for the data with the initial and final model coefficients. From the LL values, the quantity "CHI" is calculated as:

CHI = 2*(L1-L0)

L1 = Final value of the log-likelihood function (pertaining to the fitted model)

L0 = Initial value of the log-likelihood function (pertaining to the assumption that all modes have the same probability of being chosen).

In order to test the hypothesis outlined, the user should compare the value of CHI with a Chi-Square statistic of the appropriate degrees of freedom at a specified confidence level. The associated degrees of freedom is equal to the number of coefficients in the fitted model. If the value of CHI is greater than that obtained from the Chi-Square distribution, the null hypothesis H0 is to be rejected. The fitted model is considered better than the equal shares model: i.e., the effects due to the coefficients are to be regarded as significant.

It should be noted that this is a relatively "weak" test for model significance and can only reject extremely poor models. Unless the model specification is totally erroneous or the model contains only irrelevant explanatory variables, it will typically be found acceptable by this statistical tests.

5.3.5 Test of Prior Probability Hypothesis: The null hypothesis tested here can be stated as:

H0: The probability that a mode is chosen is proportional to the total number of users, in all observations, selecting the mode.

In Report 3, the value of the log-likelihood is printed by including pure alternative effects and by allowing the choice probabilities to equal the actual proportion of users observed selecting each mode. The quantity "CHI" is calculated as:

CHI = 2*(L1-L0)

Where:

L1 = Final value of the log-likelihood function (pertaining to the fitted model)

L0 = Value of the log-likelihood function including the effects of the pure alternatives (pertaining to the prior-probability or "market share" model)

In order to test the hypothesis, the value of CHI calculated is compared with a Chi-Square statistic for the appropriate degree of freedom at a specified confidence level. The associated degrees of freedom is equal to the number of coefficients in the fitted model excluding the bias coefficients. If the value of CHI is greater than that obtained from the CHI-Square distribution, the null hypothesis is to be rejected. It can then be concluded that the fitted model is better than the prior probability model: i.e., the probability that a mode is chosen is not proportional to the number of users observed selecting the mode.

This test, like the previous one, is also a relatively weak test for model significance. However, it is more stringent than the equal share likelihood ratio test since the prior probabilities contain more information than the equal shares. Past experience shows that models developed from large samples (over 150) will rarely fail both tests.

5.3.6 Pseudo R-Squared Test: The value Pseudo R-Square is also presented in Report 3. Pseudo R-Square is often referred to as the Likelihood Ratio Index, is computed as follows:

Pseudo R-Squared = 1 - (L1/L0)

Where:

L1 = Final value of the log-likelihood function,

L0 = Initial value of the log-likelihood function.

The value of Pseudo R-Square should lie between 0 and 1. The pseudo R-square statistic provides a gross measure of how well the model fits the data compared to other disaggregate mode choice models. In the past, typical mode choice models with three to five alternatives have been calibrated with pseudo R-Squared in the range of 0.2 - 0.4. Although a high value of Pseudo R-Square is desirable, models should not be selected on the basis of the highest pseudo R-Square value alone.

5.3.7 Observed vs. Estimated Totals: Report 4, as output from ULOGIT, is a contingency table that can be used to test the null hypothesis, HO,

HO: The data is fitted well, i.e., the observed demand indeed comes from a population having the estimated choice probabilities.

The testing of this hypothesis is accomplished by computing Chi-Squared statistics as:

$$SUM\ ((EST\ (A,O) - OBS\ (A,O))^2 * /EST(A,O):\ A=1,\text{-----},NA;\ O=1,\text{----},NO),$$

Where:

NA = Number of alternatives (modes)

NO = Number of observation

OBS(A,O) = W(O) * X(A,O)

EST(A,O)=W(O) * P(A,O) * SUM(X(A1,O): A1=1,-----.# of alternatives.

X(A,O) = Value of the dependent variable corresponding to alternative A, at observation O,

P(A,O) = Probability that alternative A is chosen at observation O, based on the calibrated model, and

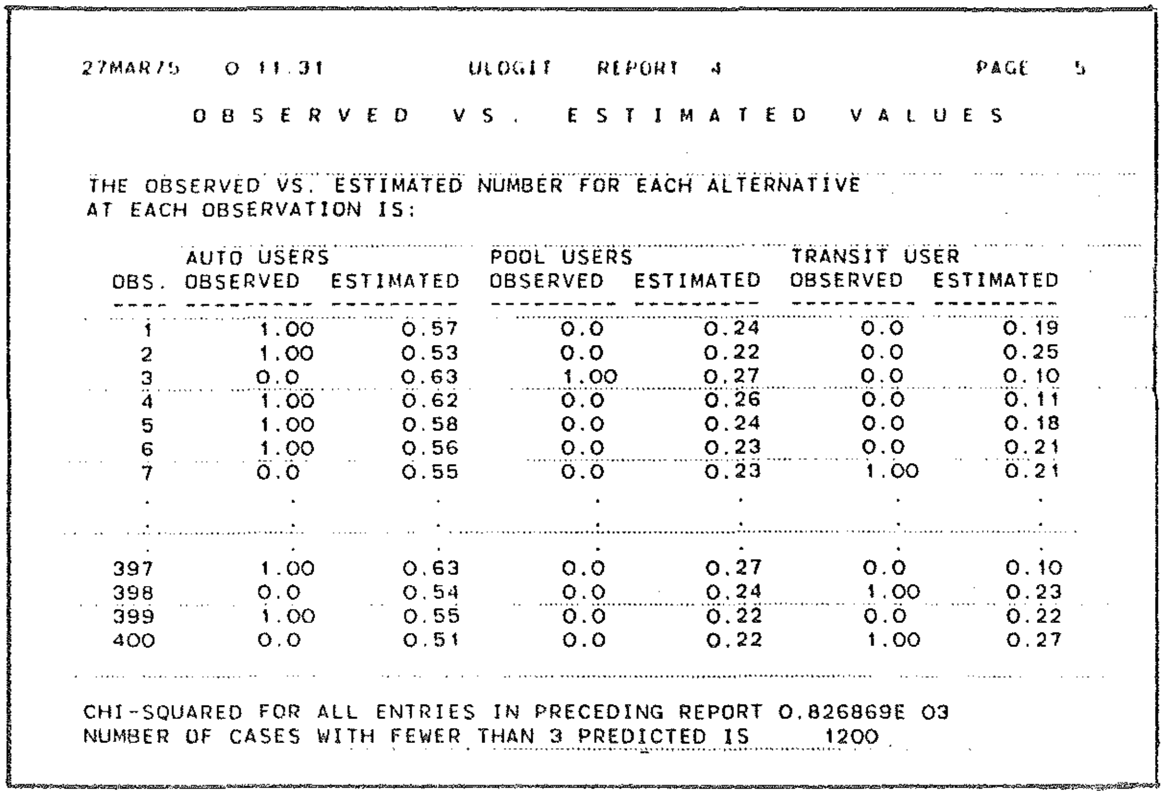
(O) = Weight associated with observation O, or unity if no weight is specified.

The associated degrees of freedom V, is computed as:

V = (NO-1)*(NA-1)

The value of Chi-Squared calculated as printed in Report 4 can be compared to a Chi-Square statistic from a distribution with V degrees of freedom at a specified confidence level. The acceptance or the rejection of the hypothesis is accomplished following the same set of rules described above. A copy of Report 4 is attached.

Table 8 - Sample Copy of ULOGIT Report 4



```
27MAR75    0 11.31           ULOGIT    REPORT  4                     PAGE    5

       O B S E R V E D   V S .   E S T I M A T E D   V A L U E S

THE OBSERVED VS. ESTIMATED NUMBER FOR EACH ALTERNATIVE
AT EACH OBSERVATION IS:

       AUTO USERS                POOL USERS               TRANSIT USER
  OBS. OBSERVED  ESTIMATED  OBSERVED  ESTIMATED  OBSERVED  ESTIMATED
  ---- --------- ---------  --------- ---------  --------- ---------
    1      1.00      0.57       0.0       0.24       0.0       0.19
    2      1.00      0.53       0.0       0.22       0.0       0.25
    3      0.0       0.63       1.00      0.27       0.0       0.10
    4      1.00      0.62       0.0       0.26       0.0       0.11
    5      1.00      0.58       0.0       0.24       0.0       0.18
    6      1.00      0.56       0.0       0.23       0.0       0.21
    7      0.0       0.55       0.0       0.23       1.00      0.21
    .       .         .          .         .          .         .
    .       .         .          .         .          .         .
    .       .         .          .         .          .         .
  397      1.00      0.63       0.0       0.27       0.0       0.10
  398      0.0       0.54       0.0       0.24       1.00      0.23
  399      1.00      0.55       0.0       0.22       0.0       0.22
  400      0.0       0.51       0.0       0.22       1.00      0.27

CHI-SQUARED FOR ALL ENTRIES IN PRECEDING REPORT 0.826869E 03
NUMBER OF CASES WITH FEWER THAN 3 PREDICTED IS      1200
```

In addition to the above seven tests a number of other reports and diagrams are printed or a part of the ULOGIT output. These include scatter diagrams for all alternatives, comparison between observed vs. estimated totals, compound (dis)utility difference plots and a table of elasticities. These are not discussed in this report. A complete discussion of these results is available in the publication entitled "ULOGIT User's Guide" published by the UMTA.

6. ULOGIT RESULTS FOR THE TWO-MODE MODELS

Using the procedure described in Section 3, a number of logit models were formulated and calibrated for the bimodal and multi-modal situations. This section of the report describes the formulation of each of the models, and presents a discussion on the statistical tests output by ULOGIT for each model. To assess the effectiveness of the models in representing the observed trip characteristics for the study area, the following factors were reviewed:

- The application of the variables in explaining trip characteristics,
- The significance of variables in explaining the trip characteristics,
- The comparison of "observed" versus "estimated" trips by mode, and
- Other statistics used in correlating the variables and trip characteristics.

The application of the variables in explaining the trip characteristics can be shown by the sign of the coefficients. The sign of the coefficient associated with each variable identifies the "disutility" or "utility" of the variable in explaining the trip characteristics. For example, the variable "highway travel time" can be used to explain the trip characteristics of the automobile mode. If the coefficient for "highway travel time" is output as a positive value, the variable represents a "disutility" (since a "positive" variable is setup as a disutility in ULOGIT) in explaining the characteristics of automobile trips.

Therefore, as travel time increases, the disutility of travel increases, which is logical. If the coefficient corresponding to travel time is output as a negative value, it would be interpreted as having a utility. In other words, as travel time increases the utility of the auto trips increases. Situations where utility might increase with increases in travel time should be considered illogical.

In addition, comparisons are made between the observed trip tables and the estimated trip tables as output by the models to further evaluate the "goodness of fit" of the developed equations.

6.1 Description of the Two-Mode Logit Models

A set of four models were formulated and calibrated to explain the trip characteristics for the bimodal situation. These models did not distinguish between a trip purpose (i.e., work and nonwork) and the models were related to home based trips. The results of two models are presented in this Section, and the ULOGIT reports describing the specification, calibration and statistical summaries of all four models can be found in Appendix 3. A summary of the two mode models is provided in Appendix 5.

The variables used to define trip characteristics of each mode were obtained from the calibration file. These variables were selected for use based on the anticipated effect on the trip-making characteristics for each mode. A list of variables and variable names from the calibration file is shown in Table 9. A description of these variables is provided in Appendix 4.

MODEL 1

The formulation for this model is shown in Table 10. The first column of Table 10 indicates the mode as follows:

Table 9 - List of Variables in the Calibration File for the Two-Mode Models

VAR ID #	VARIABLE NAME	UNITS
1	ZONE NUMBER	
2	INCOME	$/YEAR
3	LANDUSE	CLASS
4	TERMINAL TIME P	MINUTES
5	TERMINAL TIME A	MINUTES
6	EMPLOYMENT	PERSONS
7	TOTAL ACRES	ACRES
8	RESIDENTIAL ACRES	ACRES
9	INDUSTRIAL ACRES	ACRES
10	UNDEVELOPED ACRES	ACRES
11	RETAIL WHOLESALE ACRES	ACRES
12	RECREATIONAL ACRES	ACRES
13	POPULATION	PERSONS
14	DWELLING UNITS	UNITS
15	HIGHWAY SKIM TREE	MINUTES
16	TRNS SKIM TREE	MINUTES
17	TRNS RUN TIME	MINUTES
18	TRNS WAIT TIME	MINUTES
19	HWY DIST	MILES
20	HWY COST	$
21	EXCESS TIME	MINUTES
22	ORIGIN ZONE	
23	DESTINATION ZONE	
24	PT MODE	PT
25	OT MODE	OT
26	A MODE	A TRIPS
27	TRNS MODE	TR TRIPS
28	POP PER DU	POP/DU
29	POP PER ACRE	POP/ACRE
30	POP	POP/100
31	EMPLY	EMP/100
32	INPENT	PENTILE
33	WTR TIME	MINUTES
34	WAUTO TIME	MINUTES
35	TTRW	MIN/MIN
36	TTR	MIN/MIN

A MODE = Automobile Mode
TRNS MODE = Transit mode (bus service)

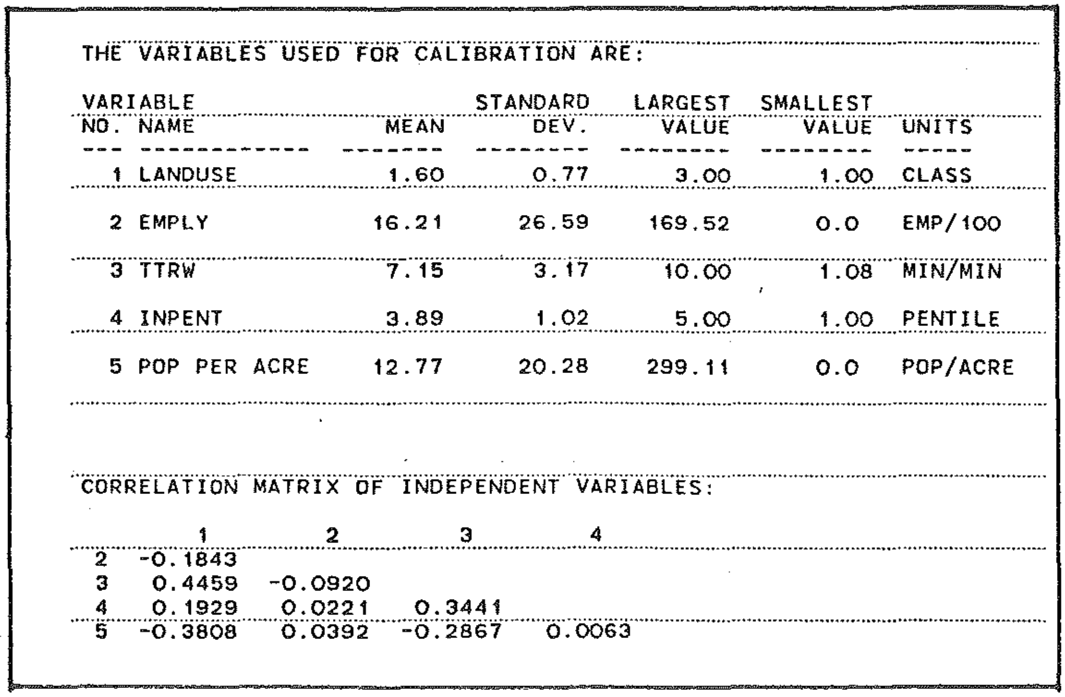
Table 10 - Formula Specification for Model 1

Mode	Coefficient	Variable
A MODE	= A2	* LANDUSE
	+ B2	* EMPLY
	+ A BIAS	
TRNS MODE	= A1	* TTRW
	+ B1	* INPENT
	+ C1	* POP PER ACRE

Travel time for both modes is used to describe the characteristics of transit trips by using the variable TTRW (weighted travel time for transit/weighted travel time by automobile). Other variables used in this model were basically socio-economic and land use variables which include: income (INPENT), employment (EMPLY), population density (POP PER ACRE) and land use (LANDUSE).

Values for the variables used in the model, along with the correlation matrix of independent variables are shown in Table 11.

Table 11 - Statistical Summary of Independent Variables



```
THE VARIABLES USED FOR CALIBRATION ARE:

VARIABLE                        STANDARD   LARGEST   SMALLEST
NO. NAME              MEAN        DEV.       VALUE     VALUE   UNITS
--- ------------   -------   ---------   --------- --------- -----
  1 LANDUSE           1.60        0.77        3.00      1.00  CLASS

  2 EMPLY            16.21       26.59      169.52      0.0   EMP/100

  3 TTRW              7.15        3.17       10.00      1.08  MIN/MIN

  4 INPENT            3.89        1.02        5.00      1.00  PENTILE

  5 POP PER ACRE     12.77       20.28      299.11      0.0   POP/ACRE


CORRELATION MATRIX OF INDEPENDENT VARIABLES:

          1          2          3          4
 2  -0.1843
 3   0.4459    -0.0920
 4   0.1929     0.0221    0.3441
 5  -0.3808     0.0392   -0.2867     0.0063
```

The variables were obtained from the calibration file (Table 9) which was developed in an earlier step. It should be noted that a travel time ratio of 10 (TTRW=10) denotes an unconnected zone pair for the transit mode.

From the ULOGIT calibration process, the final values of the coefficients were calculated as shown in Table 12.

Table 12 - Final Coefficient Values and Other Statistics for Model 1

```
THE RESULTS OF THE COEFFICIENT CALIBRATION ARE:

COEFFICIENT                FINAL  STANDARD      T-   GRADIENT  LOWER   UPPER
NO. NAME                   VALUE     ERROR   RATIO  (IF BND.)  BOUND   BOUND
--- ------------ --------  --------  -----  ---------  -----   -----
 1  A1                    1.1217    0.1034   10.85
 2  B1                    0.1881    0.0799    2.35
 3  C1                    0.0212    0.0051    4.13
 4  A2                   -0.3775    0.2141   -1.76
 5  B2                    0.0100    0.0024    4.16
 6  A BIAS                0.4714    0.3868    1.22

THE INITIAL VALUE OF THE LOGLIKELIHOOD WAS -0.14709E 05,
WHILE THE FINAL VALUE WAS -0.63663E 03 AFTER  9 ITERATIONS.

THE LOGLIKELIHOOD WITH ALL ZERO COEFFICIENTS IS -0.14709E 05,
WHILE BY INCLUDING PURE ALTERNATIVE EFFECTS IT IS -0.78178E 03.
THE LARGEST LOGLIKELIHOOD FOR THESE DATA AND ANY MODEL  0.0

TEST OF EQUAL PROBABILITY HYPOTHESIS IS  0.2814E 05
WITH   6 DEGREES OF FREEDOM.

TEST OF ALTERNATIVE DEPENDENT PROBABILITY HYPOTHESIS IS    290.3
WITH   5 DEGREES OF FREEDOM.

PSEUDO R-SQUARE = .957
```

The final values for the coefficients in Table 12 are in terms of a disutility. To find the utility of a mode reverse the signs of the coefficients. A review of the application of the variables in explaining travel characteristics reveals the following:

- The LANDUSE variable represents a "utility". This variable is coded as follows:

  1 = Urban Land Uses
  2 = Suburban Land Uses
  3 = Rural Land Uses

Therefore, there is a higher utility associated with using the auto mode in urbanized areas.

- The variable EMPLY represents a "disutility". As the employment in an area increases, the number of trips by the auto mode decreases.
- Similarly, the TTRW factor represents a "disutility". As the weighted travel time ratio (transit/auto) increases, the trips by the transit mode decreases.
- The INPENT factor also represents a "disutility". An increase in the income of a group will result in less trip-making by the transit mode.
- Finally, the POP PER ACRE factor is a "disutility" factor. As it increases, the trips by transit will decrease.

These factors generally agree with general transportation planning-related considerations.

A review of the significance of factors is performed by utilizing the "T-ratio". The T-ratios are given in Table 12. Values of 1.96 are used to represent the 95.0% confidence level in the variables. These ratios show the significance of all variables except LANDUSE and the A BIAS factor.

These two variables represents an insignificant factor in explaining auto trip-making characteristics. They could be excluded from the equation and an alternate variable may be selected to improve the modelling capabilities. The exclusion of the LANDUSE variable or the A BIAS factor would result in slight change in trip-making characteristics for each mode as predicted by the model.

A comparison of the observed vs. estimated trips is provided in Table 13.

Table 13 - Comparison of Observed vs. Estimated Trips for Model 1

ALTERNATIVE	OBSERVED	ESTIMATED	STD. RESIDUAL	CORR. COEF.	CORR. RATIO	NO. CELLS
A MODE	21092.0	21018.2	6.294	0.001	0.012	19
TRNS MODE	128.0	145.9	-1.520	0.010	0.010	18

By a general comparison, Table 13 indicates a reliable match of the auto and transit mode data. However, this test is not considered a conclusive statistical test since the comparison is conducted on only a 2% sample of the total person trip table. An appropriate comparison would be to use 100% of the observed trips to identify the degree of likeness to the model results.

Other statistics relating to the model indicate:

- The "pseudo R-square" value (Table 12) for this model is 0.957 which represents a highly acceptable fit to the data.
- The "standardized residual" (Table 13), indicates the number of standard deviations that the observed and estimated trips by mode differ. A higher value will denote a more significant difference. The standard residual for the transit mode indicates an acceptable comparison exists. For the auto mode, a lower confidence level in the match of the results exists.
- The "correlation coefficient" and the "correlation ratio", as defined for this model (Table 13) indicate an acceptable comparison of results.

Overall, this model presents a reasonable representation of the observed trip data. some inaccuracies may result from the use of certain variables and the sample size used for the transit mode.

MODEL 2

The formulation for Model 2 is shown in Table 14.

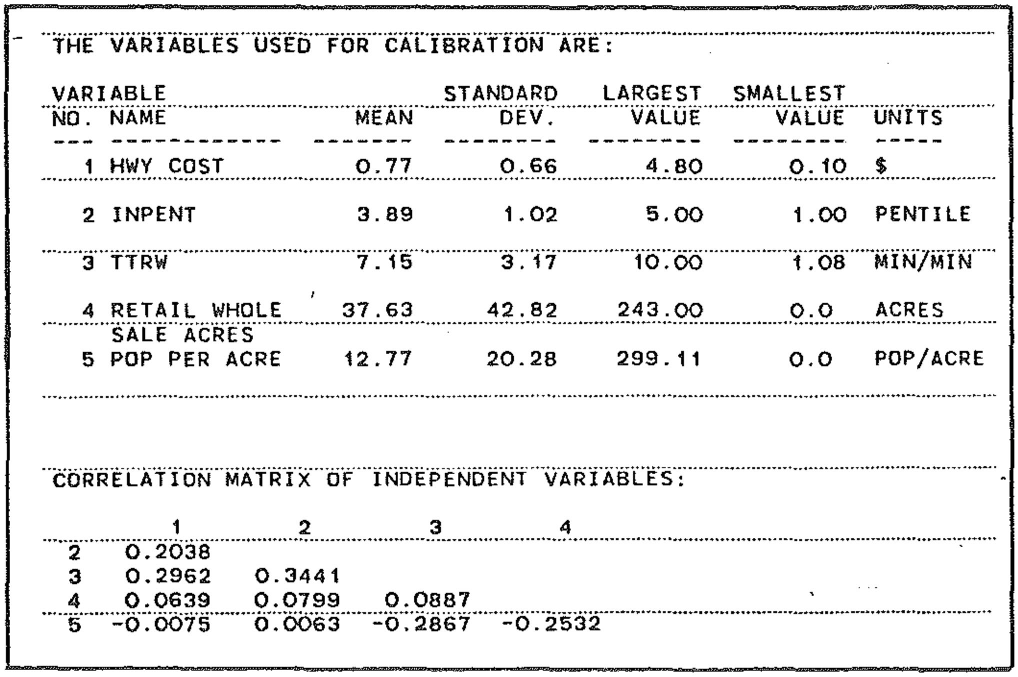
Table 14 - Formula Specification for Model 2

Mode	Coefficient	Variable
A MODE	= A2	* HWY COST
	+ B2	* INPENT
	+ A BIAS	
TRNS MODE	= A1	* TTRW
	+ B1	* RETAIL WHOLESALE ACRES
	+ C1	* POP PER ACRE

Model 2 utilizes the travel time for both modes (TTRW) as well as travel cost for the automobile mode (HWY COST) to explain travel characteristics. Other variables used include Income (INPENT), land use (RETAIL WHOLESALE ACRES) and population density (POP PER ACRE). The variables used in this model were taken from the calibration file listing shown in Table 9.

Values for the variables used in the model, along with the correlation matrix of independent variables is shown in Table 15.

Table 15 - Statistical Summary of Independent Variables



```
THE VARIABLES USED FOR CALIBRATION ARE:

VARIABLE                          STANDARD   LARGEST   SMALLEST
NO. NAME                  MEAN      DEV.       VALUE      VALUE   UNITS
--- ------------       -------  --------   --------   --------    -----
  1 HWY COST              0.77      0.66       4.80       0.10    $

  2 INPENT                3.89      1.02       5.00       1.00    PENTILE

  3 TTRW                  7.15      3.17      10.00       1.08    MIN/MIN

  4 RETAIL WHOLE         37.63     42.82     243.00       0.0     ACRES
    SALE ACRES
  5 POP PER ACRE         12.77     20.28     299.11       0.0     POP/ACRE



CORRELATION MATRIX OF INDEPENDENT VARIABLES:

           1         2         3         4
  2   0.2038
  3   0.2962    0.3441
  4   0.0639    0.0799    0.0887
  5  -0.0075    0.0063   -0.2867   -0.2532
```

The final values of the coefficients as calculated from the ULOGIT calibration process are shown in Table 16.

Table 16 - Final Coefficient Values and other Statistics for Model 2

```
THE RESULTS OF THE COEFFICIENT CALIBRATION ARE:

COEFFICIENT              FINAL  STANDARD     T-   GRADIENT  LOWER  UPPER
NO. NAME                 VALUE     ERROR  RATIO  (IF BND.)  BOUND  BOUND
--- ------------- --------  --------  -----  ---------  -----  -----
 1  A1              0.9934    0.0724  13.72
 2  B1              0.0059    0.0021   2.81
 3  C1              0.0259    0.0049   5.23
 4  A2              1.5765    0.1273  12.39
 5  B2              0.1629    0.0749   2.18
 6  A BIAS         -1.9359    0.3166  -6.11


THE INITIAL VALUE OF THE LOGLIKELIHOOD WAS -0.14709E 05,
WHILE THE FINAL VALUE WAS -0.65161E 03 AFTER  8 ITERATIONS.

THE LOGLIKELIHOOD WITH ALL ZERO COEFFICIENTS IS -0.14709E 05,
WHILE BY INCLUDING PURE ALTERNATIVE EFFECTS IT IS -0.78178E 03.
THE LARGEST LOGLIKELIHOOD FOR THESE DATA AND ANY MODEL  0.0

TEST OF EQUAL PROBABILITY HYPOTHESIS IS  0.2811E 05
WITH   6 DEGREES OF FREEDOM.

TEST OF ALTERNATIVE DEPENDENT PROBABILITY HYPOTHESIS IS    260.3
WITH   5 DEGREES OF FREEDOM.

PSEUDO R-SQUARE = .956
```

A review of the application of the variables in explaining travel characteristics reveals the following:

- The weighted travel time ratio variable (Transit/Auto) represents a "disutility". The number of transit trips will decrease as transit travel times increases.
- The land use variable represents a "disutility" for transit trips. The more acres of Retail/Wholesale land use in a zone, the fewer trips by transit.
- The POP PER ACRE factor represents a "disutility". The greater the population density, the fewer number of transit trips.
- The HWY COST variable associated with automobile travel represents a "disutility". Higher travel costs will decrease the number of automobile trips.

- The Income factor, INPENT, associated with the auto mode represents a "disutility". Higher income groups will tend to use automobile to a greater extent.

Two factors produce unexpected results, RETAIL WHOLESALE ACRES and POP PER ACRE. However, using a variable such as the number of retail acres in a zone may be a poor variable to use and may provide misleading results. Population density variables may also be poor variables to use to describe trip characteristics in some instances. Although transit lines are planned to serve the heaviest populated trip interchanges, there may be instances where transit will not serve heavily populated areas. This is especially true in areas where transit service is "underdeveloped". Therefore, during calibration, a density variable may not always provide adequate results.

A review of the <u>significance</u> of factors is performed by utilizing the T-ratio. The T-ratios for Model 2 are give in Table 16. Values of 1.96 are used to represent the 95% confidence level in the variables. These T-ratios show that of all variables are significant in explaining travel characteristics.

A comparison of Observed vs. Estimated Trips is provided in Table 17.

Table 17 - Comparison of Observed vs. Estimated Trips for Model 2.

ALTERNATIVE	OBSERVED	ESTIMATED	STD. RESIDUAL	CORR. COEF.	CORR. RATIO	NO. CELLS
A MODE	21092.0	20999.8	7.495	0.001	0.018	24
TRNS MODE	128.0	165.9	-3.063	0.007	0.016	23

A general comparison of observed and estimated trips in Table 17 indicates a very good match for automobile trips and a moderate over-estimation for the transit trips.

Other statistics relating to the model includes:

- The "pseudo R-square" value (Table 16) for this model is 0.956 which represents a highly acceptable fit to the data.
- The "standard residual" (Table 17) for the transit mode represents an adequate comparison between observed and estimated trips. A lower confidence level in the match of the results exists for the auto mode.
- The "correlation coefficient" and the "correlation ratio" as defined for this model (Table 17) indicate an acceptable comparison of results.

Overall, this model presents an acceptable representation of the observed trip data. It would be advisable to use different land use variables and density variables for use in the transit (dis)utility equation.

6.2 Comparison of the Model Results to the Observed Trip Table:

As described in Section 3, one of the most important tests for the model is a comparison of the model is a comparison of the estimated results to the observed results for the entire trip table (100% sample). If the comparison to the observed mode split for the total trip table is favorable, then the model can be accepted. If not, new logit formulations must be specified and calibrated.

Because the development of a two-mode model was not a major element in this study, only one of these models was applied to the total person trip table and used to compare with the observed mode-split. Model 1 was used in UMODEL to develop estimated mode-split results as shown in Table 18.

Table 18 - Comparison of Observed vs. Estimated
Mode Split for Model 1

MODE	OBSERVED TRIPS	ESTIMATED TRIPS (MODEL 1)
Automobile	1,054,605	1,057,014
Transit	6,468	4,059
TOTAL	1,061,073	1,061,073

This table shows that the model under-predicts transit trips on an overall basis, but not by an extreme measure. This error in modelling transit trips may be due to a number of factors such as the method in which the transit trip table was developed, the extremely small sample of transit trips used in calibration, inadequate formula specification, errors in the data base, etc. Further, analysis should be completed to compare the model results to the observed results on a trip interchange basis. It may be advisable to recalibrate the model on a different or larger sample of transit trips to increase the accuracy of results. Adjustment factors may be used (on a zonal basis or on a "global" basis) if needed to attain a reliable match to the observed data.

7. ULOGIT RESULTS FOR THE FIVE-MODE MODELS

Five models were developed to explain the trip characteristics for the five mode situation (transit and four auto-occupancy levels). Of these, three models were developed to fit the observed work trip data (Models 3,4 and 5) and two models identified the nonwork trip characteristics (Models 6 and 7). These models were used to identify an "estimated" number of trips for each mode using the program UMODEL in the mode split process. The models are listed in Appendix 5.

In evaluating the models, the same factors described in Section 6 were carefully reviewed. These factors included:

- The application of the variables in explaining trip characteristics (sign of the coefficient),
- The significance of variables in explaining the trip characteristics,
- The comparison of "observed" versus "estimated" trips by mode, and
- Other statistics used in correlating the variables and trip characteristics.

A final test for the adequacy of the model was the application of the (dis)utility equations to the entire trip tables (100% sample) for the respective trip purposes. If a favorable comparison occurs between the "estimated" trip tables (as output by the model) and the observed trip table, the model can be accepted.

7.1 Description of Logit Models for Work Trips:

The results of the three logit models which were formulated and calibrated to describe mode-split for work trips are presented in this section of the report. In formulating the equations the variables were selected from the calibration file to define the work trip characteristics of the specific modes. The candidate list of variables in the calibration file is shown in Table 19. For each of the three models, variables were selectively identified from the calibration file (Table 19) for incorporation into the logit equations. A description of these variables is provided in Appendix 4.

MODEL #3

The formulation for this model is shown in Table 20. The first column of Table 20 indicates the mode as follows:

- WDA = Automobile - drive alone work trips
- WONE = Automobile - one passenger work trips
- WTWO = Automobile - two passenger work trips
- WTHREE = Automobile - three or more passenger work trips
- TRANSIT = Bus service - work trips

The variable travel time is used in each equation to describe the (dis)utility of using a mode along with other variables such as income (PENTILE), zonal employment (EMPLY), automobile availability (AUTOS PER POP), etc.

Table 19 - List of Variables in the Calibration File for the Five-Mode Models for Work Trips

VAR ID #	VARIABLE NAME	UNITS
1	ZONE NUMBER	
2	INCOME	$/YEAR
3	TERMINAL TIME P	MINUTES
4	TERMINAL TIME A	MINUTES
5	EMPLOYMENT	PERSONS
6	TOTAL ACRES	ACRES
7	RESIDENTIAL ACRES	ACRES
8	INDUSTRIAL ACRES	ACRES
9	UNDEVELOPED ACRES	ACRES
10	RETAIL WHOSL ACRES	ACRES
11	RECREATIONAL ACRES	ACRES
12	POPULATION	PERSONS
13	DWELLING UNITS	UNITS
14	RES LABOR FORCE	PERSONS
15	PARKING COSTS	CENTS
16	AUTO OWNERSHIP	AUTOS/ZN
17	ZERO AUTOS	FAMILIES
18	TIMEDA	MINUTES
19	TRNS TIME	MINUTES
20	TRNS RUN TIME	MINUTES
21	TRNS WAIT TIME	MINUTES
22	HGWY SKIM DIST	MILES
23	ORIGIN ZONE	
24	DESTINATION ZONE	
25	WDA	TRIPS
26	WONE	TRIPS
27	WTWO	TRIPS
28	WTHREE	TRIPS
29	TRANSIT	TRIPS
30	POP PER DU	POP/DU
31	POP PER ACRE	POP/ACRE
32	TRNS FARE	CENTS
33	EMPLY	EMP/100
34	POP	POP/100
35	AUTOS PER POP	AUTO/POP
36	PENTILE	PENT
37	TIME1	MINUTES
38	TIME2	MINUTES
39	TIME3	MINUTES
40	COSTDA	CENTS
41	COST1	CENTS
42	COST2	CENTS
43	COST3	CENTS
44	WTRNS TIME	MINUTES
45	EXCESS	MINUTES
46	TTR	MIN/MIN

Table 20 - Formula Specification for Model 3

Mode	Coefficient	Variable
WDA	= A1	* HGWY SKIM TIME
	+ B1	* PENTILE
	+ A BIAS	
WONE	= A1	* HONE
	+ B2	* EMPLY
WTWO	= A1	* HTWO
	+ B3	* RLF PER ACRE
WTHREE	= A1	* HTHREE
	+ B4	* AUTOS PER POP
TRANSIT	= A5	* WTRNS TIME
	+ B5	* ZERO AUTOS

The names of certain variables in Model 3, such as HONE, are not listed in Table 19. This is because after Model 3 was developed the calibration file was revised to include additional variables. During this time some of the variable names were also modified. These modifications were intended to make the variable names more descriptive of the nature of the variable. As such, the variable name HONE was changed to TIME1 (highway skim time for the one-passenger automobile mode). Although several variables names were changed, the values of the variables remained unchanged. To find a complete description of all variables and variable names see Appendix 4.

Values for the variables used in the model along with the correlation matrix of the independent variables are shown in Table 21.

Table 21 - Statistical Summary of Independent Variables

```
THE VARIABLES USED FOR CALIBRATION ARE:

VARIABLE                        STANDARD   LARGEST  SMALLEST
NO.,NAME                 MEAN     DEV.      VALUE     VALUE   UNITS
--- ------------      -------  --------  --------  --------   -----
  1 HGWY SKIM TI        18.24      8.96     70.00      2.00   MINUTES
    ME
  2 PENTILE              3.91      0.97      5.00      1.00   PENT

  3 HONE                19.32      8.99     71.10      3.10   MINUTES

  4 EMPLY               35.66     48.28    163.99      0.0    EMP/100

  5 HTWO                20.32      9.00     72.10      4.10   MINUTES

  6 RLF PER ACRE         5.69      7.49    100.59      0.0    RLF/ACRE

  7 HTHREE              21.93      8.96     73.70      5.70   MINUTES

  8 AUTOS PER PO         0.98     11.47    253.00      0.0    AUTO/POP
    P
  9 WTRNS TIME         266.00    211.53    500.00     22.00   MINUTES

 10 ZERO AUTOS          61.12     70.44    328.00      0.0    FAMILIES



CORRELATION MATRIX OF INDEPENDENT VARIABLES:

          1         2         3         4         5         6         7
          8         9
  2   0.1640
  3   0.9970    0.1693
  4   0.1510   -0.0680    0.1524
  5   0.9967    0.1696    0.9992    0.1524
  6   0.0366    0.0664    0.0380   -0.1416    0.0379
  7   0.9971    0.1626    1.0003    0.1518    0.9992    0.0362
  8  -0.0126   -0.0883   -0.0123   -0.0104   -0.0123   -0.0365   -0.0125
  9   0.3335    0.3287    0.3349   -0.0588    0.3348   -0.1332    0.3340
     -0.0185
 10  -0.1946   -0.6326   -0.1923    0.0413   -0.1922    0.0853   -0.1945
      0.1468   -0.3047
```

From the ULOGIT calibration process, the final values of the coefficients were calculated as shown in Table 20.

These variables were obtained from the calibration file built during an earlier step. It should be noted that the "auto per population" variable shows an error in the data. It indicates that a value of 253 autos per population occur, which is a gross exaggeration. Upon close examination of the data file, it was noted that this unrealistic value of autos per population occurred at only one zone in the 315 zone study area. Since all of the auto per population values were within realistic limits for the remaining 314 zones and the average zonal value for this variable was .98 autos per population, this error in the data base was considered to have a minor impact on the model. Since an error was discovered in the data file, an effort was made to search for similar errors in other variables in the data file.

Table 22. Final Coefficient Values and Other Statistics for Model 3.

```
THE RESULTS OF THE COEFFICIENT CALIBRATION ARE:

COEFFICIENT              FINAL  STANDARD     T-   GRADIENT  LOWER  UPPER
NO. NAME                 VALUE     ERROR  RATIO  (IF BND.)  BOUND  BOUND
--- ------------ --------  --------  -----  ---------  -----  -----
  1  A1                0.3460    0.0234  14.81
  2  B1               -0.0830    0.0300  -2.76
  3  A BIAS           -1.7602    0.1278 -13.77
  4  B2               -0.0024    0.0007  -3.61
  5  B3                0.1225    0.0145   8.47
  6  B4                1.5972    0.2370   6.74
  7  A5                0.1207    0.0083  14.47
  8  B5               -0.0007    0.0013  -0.55

THE INITIAL VALUE OF THE LOGLIKELIHOOD WAS -0.16360E 05,
WHILE THE FINAL VALUE WAS -0.53323E 04 AFTER  9 ITERATIONS.

THE LOGLIKELIHOOD WITH ALL ZERO COEFFICIENTS IS -0.16360E 05,
WHILE BY INCLUDING PURE ALTERNATIVE EFFECTS IT IS -0.53464E 04.
THE LARGEST LOGLIKELIHOOD FOR THESE DATA AND ANY MODEL  0.0

TEST OF EQUAL PROBABILITY HYPOTHESIS IS  0.2206E 05
WITH   8 DEGREES OF FREEDOM.

TEST OF ALTERNATIVE DEPENDENT PROBABILITY HYPOTHESIS IS   28.26
WITH   4 DEGREES OF FREEDOM.

PSEUDO R-SQUARE = .674
```

The final values for the coefficients shown in Table 22 are in terms of a disutility. To find the utility of a mode, the signs of the coefficients are to be reversed. A review of the coefficients associated with the variables reveals the following findings:

- In this model, travel time data (highway and transit) was considered a "disutility" factor, i.e., as the highway travel time for a specific mode increased, the desirability of a trip being made by that mode decreased.
- The PENTILE factor represented the income group of trip-makers. Its negative coefficient identifies it as a "utility" factor, i.e., as the income level increases, the more desirable the "Automobile - drive alone" (WDA) mode becomes.
- The employment factor also represents a "utility." As the number of employed individuals in an area increases, the trips made in the "automobile - one passenger" (WONE) mode increases.
- The RLF (resident labor force) per acre factor represents a "disutility" factor. As the RLF per acre increases, the trip-making characteristics of the "Automobile - two passengers" (WTWO) mode decreases.
- The "autos per population" factor also represents a "disutility". As the number of autos per population increases, the "Automobile - three or more passengers" mode decreases.
- The "zero auto families" factor represents a "utility" factor. As the value increases, the desirability of transit trips also increases.

In all cases, except the RLF PER ACRE factor, the variables and coefficients adequately explain the trip characteristics.

The significance of the factors is performed by reviewing the figures under the "T-ratio" column. The T-ratios for Model 3 are given in Table 22. Values of 1.96 are used to represent the 95.0% confidence level in the variables. These ratios show the statistical significance of all the included variables except ZERO AUTOS. This variable thus represents an insignificant factor in explaining transit trip-making characteristics as it exists in the model. It could be excluded from the analysis and an alternate variable selected. These steps would result in a slight change in the corresponding disutility equations.

A comparison of the observed vs. estimated trips is provided in Table 23.

Table 23 - Comparison of Observed vs. Estimated Trips for Model 3

ALTERNATIVE	OBSERVED	ESTIMATED	STD. RESIDUAL	CORR. COEF.	CORR. RATIO	NO. CELLS
WDA	8784.0	8749.9	0.986	0.002	0.009	19
WONE	946.0	815.7	4.763	0.000	0.002	10
WTWO	219.0	324.5	-5.971	0.001	0.004	8
WTHREE	130.0	152.3	-1.819	0.001	0.000	3
TRANSIT	86.0	110.3	-2.519	0.006	0.029	24

This table indicates an excellent match of the "Automobile-drive alone" (WDA) trips. Other alternatives have some differences. These differences may be attributed in part to the small number of trips sampled or inadequate variable selection. However, Table 23 is a comparison of the sampled trips (5% of the total observed work trip table) to the results of the model. The model was calibrated based on the sample of observed trips and only gives an indication of how the model relates to the sampled trips. It does not necessarily give a good indication of how the model compares with the total person trips.

A review of other statistics related to the model reveals the following:

- The "pseudo R-Square" value for this model is 0.674 (Table 22). It represents an acceptable fit of the data.
- The "standardized residual" indicates the number of standard deviations that the observed and estimated trips by mode differ. A higher value will denote a more significant difference. Values of this statistic are shown in Table 23.
- The "correlation coefficient" and the "correlation ratio" as defined for this model, indicates an acceptable comparison of results (Table 23).

Overall, this model is a reasonable representation of the observed trip data. Some inaccuracy may result from the use of certain variables and the sample size used for several alternatives. The model provides an excellent fit to "Automobile-drive alone" trip patterns, although in other cases, some differences are observed.

MODEL 4

The variable travel time was used (in one form or another) to describe the (dis)utility of using a particular mode for work trips along with other variables in this model. Model 4 is somewhat similar to Model 3. The major differences between the two models are that the variables indicating zonal employment (EMPLY) and Resident Labor force (RLF PER ACRE) are eliminated in Model 4. A cost variable is included for the "Automobile - three or more passenger" mode (WTHREE), some bias coefficients are eliminated along the variable ZERO AUTOS (The number of zero auto families per zone). The disutility equations for Model 4 are shown in Table 24.

Table 24 - Formula Specification for Model 4

Mode	Coefficient	Variable
WDA	= A1	* TIMEDA
	+ B1	* PENTILE
	+ A BIAS	
WONE	= A1	* TIME1
WTWO	= A1	* TIME2
	+ B3	* POP PER ACRE
	+ P2 BIAS	
WTHREE	= A1	* TIME3
	+ C4	* COST3
	+ P3 BIAS	
TRANSIT	= A5	* WTRNS TIME
	+ B5	* AUTOS PER POP
	+ T BIAS	

The values of the variables and the correlation matrix of the independent variables are shown in Table 25. The independent variables were obtained from the calibration file (Table 19).

Table 25 - Statistical Summary of Independent Variables

```
THE VARIABLES USED FOR CALIBRATION ARE:

VARIABLE                         STANDARD    LARGEST   SMALLEST
NO. NAME                 MEAN        DEV.      VALUE      VALUE  UNITS
--- ------------      -------    --------   --------   --------  -----
  1 TIMEDA              18.24        8.96      70.00       2.00  MINUTES

  2 PENTILE              3.91        0.97       5.00       1.00  PENT

  3 TIME1               19.32        8.99      71.10       3.10  MINUTES

  4 TIME2               20.32        9.00      72.10       4.10  MINUTES

  5 POP PER ACRE        15.06       19.79     268.69       0.00  POP/ACRE

  6 TIME3               21.93        8.96      73.70       5.70  MINUTES

  7 COST3                1.02        3.63      19.36       0.08  CENTS

  8 WTRNS TIME         266.00      211.53     500.00      22.00  MINUTES

  9 AUTOS PER PO         0.98       11.47     253.00        0.0  AUTO/POP
    P


CORRELATION MATRIX OF INDEPENDENT VARIABLES:

          1         2         3         4         5         6         7
          8
 2   0.1640
 3   0.9970    0.1693
 4   0.9967    0.1696    0.9992
 5   0.0412    0.0709    0.0430    0.0432
 6   0.9971    0.1626    1.0003    0.9992    0.0421
 7   0.0579    0.0565    0.0585    0.0585    0.5053    0.0583
 8   0.3335    0.3287    0.3349    0.3348   -0.1324    0.3340   -0.0716
 9  -0.0126   -0.0883   -0.0123   -0.0123   -0.0366   -0.0125   -0.0112
    -0.0185
```

From the ULOGIT calibration process, the final values of the coefficients were calculated as shown in Table 26.

Table 26 - Final Coefficient Values and Other Statistics for Model 4

```
THE RESULTS OF THE COEFFICIENT CALIBRATION ARE:

COEFFICIENT                 FINAL  STANDARD     T-   GRADIENT  LOWER  UPPER
NO. NAME                    VALUE     ERROR  RATIO  (IF BND.)  BOUND  BOUND
--- ------------ --------  --------  -----  ---------  -----  -----
  1  A1                    0.2620    0.0219  11.95
  2  B1                   -0.1010    0.0295  -3.43
  3  A BIAS               -1.5290    0.1218 -12.55
  4  B3                    0.0110    0.0048   2.27
  5  P2 BIAS               1.0760    0.0971  11.08
  6  C4                   -0.0740    0.0148  -5.02
  7  P3 BIAS               1.4480    0.1161  12.47
  8  A5                    0.0810    0.0070  11.58
  9  B5                   -0.0070    0.0039  -1.80
 10  T BIAS                0.8310    0.3283   2.53


THE INITIAL VALUE OF THE LOGLIKELIHOOD WAS -0.52428E 04,
WHILE THE FINAL VALUE WAS -0.52428E 04 AFTER  1 ITERATIONS.

THE LOGLIKELIHOOD WITH ALL ZERO COEFFICIENTS IS -0.16360E 05,
WHILE BY INCLUDING PURE ALTERNATIVE EFFECTS IT IS -0.53464E 04.
THE LARGEST LOGLIKELIHOOD FOR THESE DATA AND ANY MODEL  0.0

TEST OF EQUAL PROBABILITY HYPOTHESIS IS  0.2223E 05
WITH  10 DEGREES OF FREEDOM.

TEST OF ALTERNATIVE DEPENDENT PROBABILITY HYPOTHESIS IS   207.2
WITH   6 DEGREES OF FREEDOM.

PSEUDO R-SQUARE = .680
```

In assessing the effectiveness of the model in explaining the results, a review of the <u>application</u> of the variables was conducted as follows:

- The travel time data (TIMEDA, TIME1, TIME2, TIME3, WTRNS TIME) represents a "disutility" factor. Longer travel times will result in less trip-making by the specific mode.

- The PENTILE factor represents a "utility". As the income level increases, the more desirable the "Automobile-drive alone" (WDA) mode becomes.
- The "population per acre" represents a "disutility" factor. The higher the population per acre, the lower the trip-making characteristics by the "Automobile-two passengers" (WTWO) mode occurs.
- The travel cost factor (COST3) represents a "utility" factor. As the costs of a trip increases, the more likely that the "Automobile - three or more passengers" (WTHREE) mode would occur.
- The "autos per population" factor represented a "utility". It is assumed that the number of transit trip would increase with an increase in the number of autos per population.

For all cases, except the "autos per population" factor, the variables and coefficients adequately explain the trip characteristics. The "auto per population" factor results in some inaccuracy for the transit trip estimates. This factor, however, is not considered significant in the model descripton of the observed data.

In reviewing the significance of the factors, the T-ratio's are given in Table 26. Considering a 95% confidence level (T-ratio=1.96), all variables are considered significant in defining the trip characteristics except for the "autos per population" data used in explaining transit trip characteristics. Excluding this factor would result in a slight change in trip-making characteristics.

A comparison of the observed vs. estimated trips is provided in Table 27.

Table 27 - Comparison of Observed vs. Estimated Trips for Model 4

ALTERNATIVE	OBSERVED	ESTIMATED	STD. RESIDUAL	CORR. COEF.	CORR. RATIO	NO. CELLS
WDA	8784.0	8727.7	1.617	0.002	0.008	15
WONE	946.0	958.9	-0.439	0.000	0.001	7
WTWO	219.0	217.7	0.086	0.001	0.000	3
WTHREE	130.0	128.9	0.099	0.002	0.010	6
TRANSIT	86.0	118.4	-3.119	0.010	0.033	22

This comparison displays an excellent match for trips by all modes except "transit" trips. The discrepancy occurring in transit trips can be partially attributed to the small sample size used to define the model and the variable selection mentioned earlier within this model description.

Other statistics relating to the model include:

- The "pseudo R-square" value is 0.680 which relates an acceptable fit of the data (Table 26).
- The "standardized residual" (Table 27) indicates acceptable comparisons of the observed vs. estimated data for all modes except the transit mode. The transit comparisons, however, represent a moderate level of confidence in the compared data. It should be noted that transit is a small percentage of overall trips (<1.0%) and the small sample size may cause some of the discrepancy.
- The "correlation coefficient" and the "correlation ratio" (Table 27) indicate an acceptable comparison of results.

This model produces a highly favorable representation of trip-making characteristics for the observed data. Some discrepancy exists within the transit mode, however, which may be related to the lack of an adequate sample size. An adjustment factor included in the disutility equation for the transit mode may alleviate some of this discrepancy.

MODEL 5

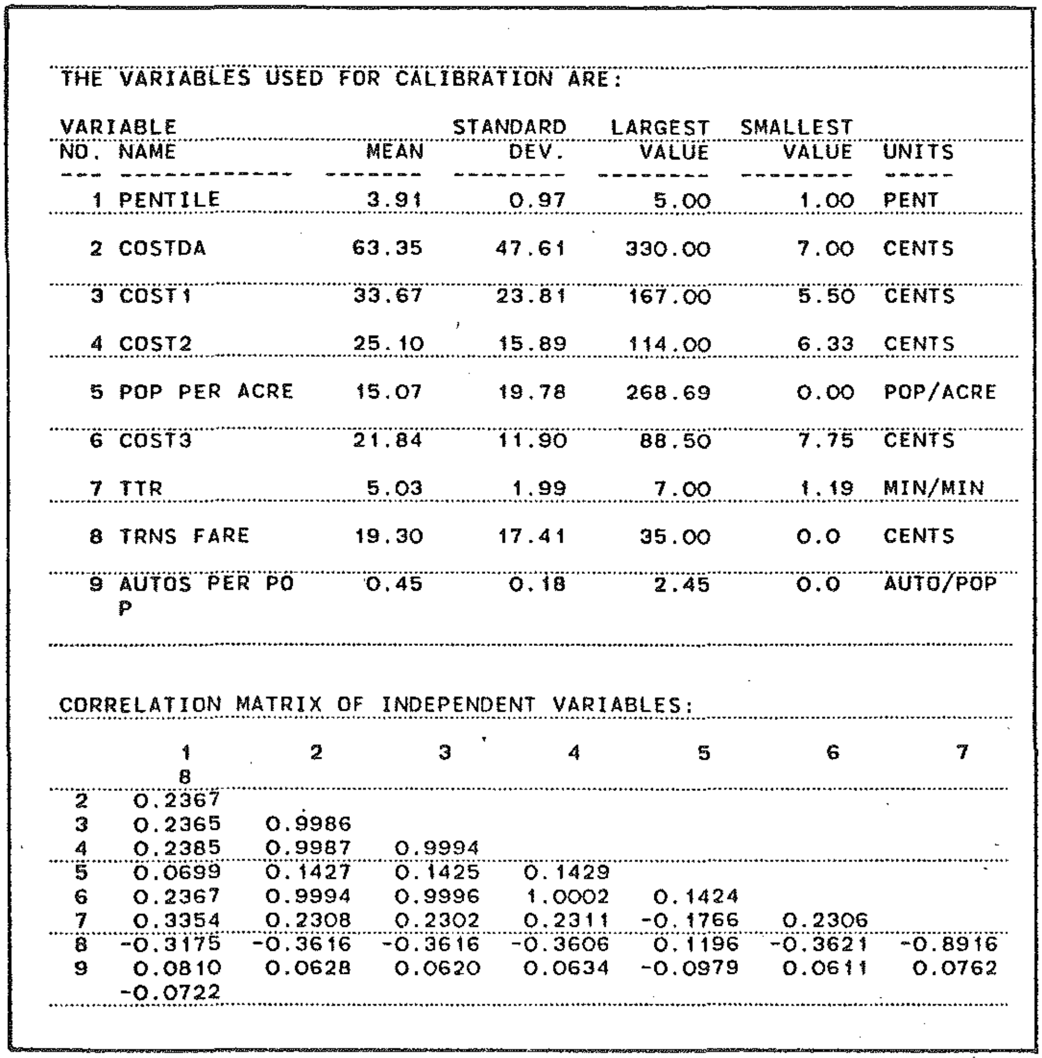
In specifying the formula in this model a variable for "out-of-pocket costs per person" was defined and used to describe the (dis)utility of using a particular mode for work trips. The out-of-pocket costs for auto modes include a travel cost (per mile) plus parking costs. The costs are assumed equally divided amongst the riders. For transit trips, a 35¢ fare is used for all trips (which is representative of the fare system and rate used in 1978). In addition, to variables representing travel time (TTR) was used to describe the (dis)utility of travel by transit. The formula specification for Model 5 is shown in Table 28.

Table 28 - Formula Specification for Model 5

Mode	Coefficient	Variable
WDA	= A1	* PENTILE
	+ B1	* COSTDA
WONE	= B2	* COST1
	+ BIAS1	
WTWO	= B3	* COST2
	+ BIAS2	
WTHREE	= A4	* POP PER ACRE
	+ B4	* COST3
TRANSIT	= A5	* TTR
	+ B5	* TRNS FARE
	+ C5	* AUTOS PER POP

The values of the variables and the correlation matrix of the independent variables are shown in Table 29.

Table 29 - Statistical Summary of Independent Variables



```
THE VARIABLES USED FOR CALIBRATION ARE:

VARIABLE                           STANDARD   LARGEST   SMALLEST
NO. NAME                    MEAN       DEV.      VALUE      VALUE  UNITS
--- ------------         -------   --------   --------   --------  -----
  1 PENTILE                 3.91       0.97       5.00       1.00  PENT

  2 COSTDA                 63.35      47.61     330.00       7.00  CENTS

  3 COST1                  33.67      23.81     167.00       5.50  CENTS

  4 COST2                  25.10      15.89     114.00       6.33  CENTS

  5 POP PER ACRE           15.07      19.78     268.69       0.00  POP/ACRE

  6 COST3                  21.84      11.90      88.50       7.75  CENTS

  7 TTR                     5.03       1.99       7.00       1.19  MIN/MIN

  8 TRNS FARE              19.30      17.41      35.00       0.0   CENTS

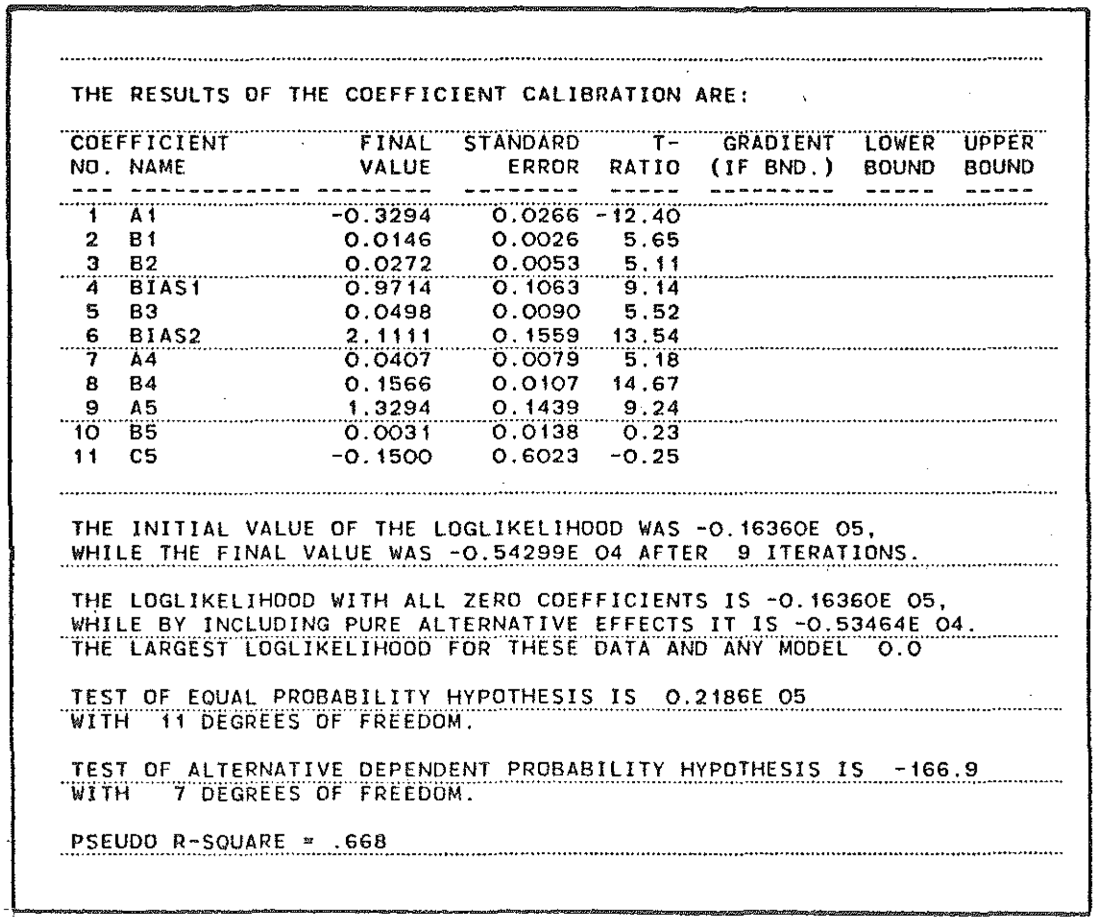
  9 AUTOS PER PO            0.45       0.18       2.45       0.0   AUTO/POP
    P


CORRELATION MATRIX OF INDEPENDENT VARIABLES:

             1         2         3         4         5         6         7
             8
 2     0.2367
 3     0.2365    0.9986
 4     0.2385    0.9987    0.9994
 5     0.0699    0.1427    0.1425    0.1429
 6     0.2367    0.9994    0.9996    1.0002    0.1424
 7     0.3354    0.2308    0.2302    0.2311   -0.1766    0.2306
 8    -0.3175   -0.3616   -0.3616   -0.3606    0.1196   -0.3621   -0.8916
 9     0.0810    0.0628    0.0620    0.0634   -0.0979    0.0611    0.0762
      -0.0722
```

The final values of the coefficients were calculated from the ULOGIT calibration process as shown in Table 30.

Table 30 - Final Coefficient Values and Other Statistics for Model 5



```
THE RESULTS OF THE COEFFICIENT CALIBRATION ARE:

COEFFICIENT              FINAL   STANDARD     T-   GRADIENT  LOWER  UPPER
NO. NAME                 VALUE      ERROR  RATIO  (IF BND.)  BOUND  BOUND
--- ------------ --------  --------  -----  ---------  -----  -----
  1  A1                -0.3294     0.0266 -12.40
  2  B1                 0.0146     0.0026   5.65
  3  B2                 0.0272     0.0053   5.11
  4  BIAS1              0.9714     0.1063   9.14
  5  B3                 0.0498     0.0090   5.52
  6  BIAS2              2.1111     0.1559  13.54
  7  A4                 0.0407     0.0079   5.18
  8  B4                 0.1566     0.0107  14.67
  9  A5                 1.3294     0.1439   9.24
 10  B5                 0.0031     0.0138   0.23
 11  C5                -0.1500     0.6023  -0.25

THE INITIAL VALUE OF THE LOGLIKELIHOOD WAS -0.16360E 05,
WHILE THE FINAL VALUE WAS -0.54299E 04 AFTER  9 ITERATIONS.

THE LOGLIKELIHOOD WITH ALL ZERO COEFFICIENTS IS -0.16360E 05,
WHILE BY INCLUDING PURE ALTERNATIVE EFFECTS IT IS -0.53464E 04.
THE LARGEST LOGLIKELIHOOD FOR THESE DATA AND ANY MODEL  0.0

TEST OF EQUAL PROBABILITY HYPOTHESIS IS  0.2186E 05
WITH  11 DEGREES OF FREEDOM.

TEST OF ALTERNATIVE DEPENDENT PROBABILITY HYPOTHESIS IS  -166.9
WITH   7 DEGREES OF FREEDOM.

PSEUDO R-SQUARE = .668
```

In assessing the effectiveness of the model in explaining the results, a review of the application of the variables was conducted as shown below.

- The PENTILE factor represents a "utility". As the income level increases, the more desirable the "Automobile-drive alone" (WDA) mode becomes.
- The COSTDA factor represents a "disutility". As highway user costs increase, the "Automobile-drive alone" trips decrease.

- COST1 represents a "disutility" factor. As the highway user costs increases, it is expected that the "Automobile - one passenger" (WONE) mode trips will decrease.
- The COST2 factor represents a "disutility". As the highway user cost increases, the likelihood of trips in the "automobile - two passengers" (WTWO) mode decreases.
- "Population per acre" represents a disutility factor. As population density increases, the "Automobile - three or more passengers" (WTHREE) mode is expected to decrease.
- The COST3 factor represents a "disutility". As the cost increases, the "Automobile - three or more passengers" (WTHREE) trips decreased.
- The TTR factor represents a "disutility". As the travel time ratio (TRANSIT/AUTOMOBILE) increases, the likelihood of transit use would decrease.
- The TRNS FARE factor represents a "disutility". As the fare increases, the trips using transit are expected to increase.
- The "AUTOS PER POP" factor represents a "utility". It is assumed that as the automobile availability increases, the number of transit trips would increase.

In one instance, the variable did not represent the "disutility" which would be expected. The variable is the AUTOS PER POP factor for TRANSIT TRIPS. Zones in which automobile availability is low should encourage more travel by transit. For the other cases, the variables and coefficients adequately explain the trip-making tendencies.

In reviewing the significance of factors, the T-ratios are given in Table 30. Using a 95% confidence level (T-ratio = 1.96), all factors for the "Automobile-drive alone", "Automobile - one passenger", and "Automobile - two passengers" and Automobile - three or more passengers" modes are considered statistically insignificant. The T-ratio corresponding to the TTR variable for the transit mode is also considered significant. The other variables for the transit mode, TRNS FARE and AUTOS PER POP have an insignificant impact on the disutility equations as shown by the T-ratios.

A comparison of the observed vs. estimated trips is provided in Table 31.

Table 31 - Comparisons of Observed vs. Estimated Trips for Model 5

ALTERNATIVE	OBSERVED	ESTIMATED	STD. RESIDUAL	CORR. COEF.	CORR. RATIO	NO. CELLS
WDA	8784.0	8685.5	2.808	0.003	0.008	15
WONE	946.0	944.3	0.058	0.000	0.003	12
WTWO	219.0	218.9	0.009	0.002	0.001	6
WTHREE	130.0	217.5	-6.060	0.000	0.002	13
TRANSIT	86.0	86.4	-0.048	0.009	0.009	16

This comparison indicates an excellent match of all modes except the "Automobile - three or more passengers" (WTHREE) mode. This discrepancy can be primarily attributed to some degree of insensitivity to cost factors in the 1966 travel data. To reflect the impact of existing cost factors, more recent trip data should be acquired.

Other statistics relating to the model include:

- The "pseudo R-square" value is 0.668 (Table 30), which represents an acceptable fit of the data.
- The "standardized residual" (Table 31) indicates very good comparisons of the data for the "Automobile - one passenger", "Automobile - two passengers", and "transit" modes. The "Automobile-drive alone" represents an adequate comparison, and the "Automobile -

three or more passengers" modes represents a poor comparison of the estimated results to the observed data.

- The "correlation coefficient" and the "correlation ratio" (Table 31) indicate a good comparison of the data.

7.2 Comparison of Work Model Results to the Observed Trip Tables:

As described in Section 3, one of the most important tests of the model is a comparison of the estimated results to the observed results for the entire trip table (100% of the sample).

Each of the models for work trips described in 7.1 were tested using the total person trip table (for work trips) to provide mode split information using the UMODEL computer program. The results of mode split are shown in Table 32. This table shows the following results on a total trip end summary basis.

- Model 3 appears to be an excellent predictor of "Drive - Alone" automobile trips. This model under-estimated the number of "Automobile - one passenger" trips by a small amount and over-estimated the higher occupancy automobile trips and transit trips.
- Model 4 did a very good job of predicting mode split for all of the auto modes but over-predicted for transit trips. This over-prediction of transit trips may be due to poor formula specification or inaccuracies in developing the transit trip tables (see Section 4.2).
- Model 5 did an excellent job in predicting the number of trips for the "drive alone", "one passenger" and "two passenger" auto occupancy modes and transit. This model, however, over-predicted the number of "three or more passenger" auto trips.

Table 32 - Comparison of Observed vs. Estimated Mode Split for Work Trips

Mode	Observed Trips	Estimated Trips			
		Model 3 Trips	Model 4 Trips	Model 5 Trips	Model 4 Adjusted
Drive Alone	175,690	175,262	174,870	173,943	175,759
1 Passenger	18,934	16,357	19,205	18,947	19,306
2 Passenger	4,395	6,485	4,355	4,386	4,386
3+ Passenger	2,607	3,055	2,578	4,349	2,569
Transit	1,721	3,027	3,337	2,386	1,879

203,347

Table 33 - Comparison of Observed vs. Estimated (Model 4) Trip Length Frequency Means and Variances for Work Trips

	Drive Alone	1 Pass.	2 Pass.	3 or More Pass.	Transit
Mean	*	--	*	*	*
Observed	18.320	17.930	17.924	18.498	40.152
Estimated	18.279	18.125	18.147	18.320	40.369
Variance	*	*	*	*	--
Observed	79.195	93.990	95.486	91.193	199.055
Estimated	81.271	80.090	82.500	80.400	263.571

* = No significant difference at 95% level of confidence.

In an attempt to test the "goodness of fit" of the models to the observed trip data on a trip interchange basis, a comparison of trip length frequency (TLF) curves for the observed vs. estimated trips by each mode was performed. This check would assure that the trip data from the two sources were from the same population or distribution. This test, although not entirely conclusive, would be a good indication of the acceptability of the model.

The comparison of observed vs. estimated trip length frequency curves was conducted for Model 4. This model was selected for this test because it had best match of mode split to the observed trip table. The TLF curves for Model 4 were obtained using the UTPS program UFMTR. These curves are shown in Appendix 1. The observed TLF curves for work trips are also shown in Appendix 1.

A visual comparison of the TLF curves shows similarity in the curve form, particularly for the "Drive Alone" automobile mode. The observed TLF curves for the other auto modes and transit modes, however, are not as continuous (or smooth) as the estimated TLF curves. In most situations, a smoother, more continuous TLF curve is expected for observed trip data. The small number of trips, some "locational biases", or other reasons may be the cause of the discontinuities in the observed TLF curves.

A more accurate comparison between the observed and estimated TLF curves can be made using statistical testing procedures. The outputs of the trip length frequency data computes the mean, variance, standard deviation, and the sample total used for the TLF curves (see Appendix 1). Using these data, statistical tests for the mean and variance of the two populations were performed. The test of the means of two populations was performed as follows:

$$Z = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

Where: Z = difference in means

$\overline{X}_1$ = mean of population group 1

$\overline{X}_2$ = mean of population group 2

S_1^2 = variance of population group 1

S_2^2 = variance of population group 2

n_1 = sample size of population group 1

n_2 = sample size of population group 2

To use this test, the hypothesis: that there is no difference in the mean is made, or:

$HO: \mu_1 = \mu_2$

At the 95% level of confidence, if $Z > 1.96$ the reject HO and the conclusion is that the means are from different populations. If $Z < 1.96$, then HO is accepted and the conclusion is that the means are from the same population.

Similarly, the test of variance (the shape of the curve) is used to determine that the population groups are from the same population. This F-test is of the form:

$$F = \frac{S_1^2}{S_2^2} \quad \text{or } F = \frac{S_2^2}{S_1^2} \qquad \text{[whichever is larger]}$$

Where: F = distribution of variance test
S_1 = variance of population group 1
S_2 = variance of population group 2

In the F-test, it is customary to utilize the larger value of variance in the denominator regardless of the population group. For large population groups, the critical F value is 1.20. As such, if the calculated "F" value is less than 1.20, the variances are considered similar and represent population groups from a similar population. Using the F-distribution tables and a 95% confidence level, the similarity of variances can be determined for all situations. Table 33 shows the results of these tests on comparisons of the estimated and observed trip data.

The results of the T-test of means and the F-test of variance indicates an acceptable fit between the TLF curves from Model 4 and the observed TLF curves in 8 out of 10 cases.

In an attempt to investigate the possibility of more closely matching the estimated trips (Model 4) and the observed trips, an adjustment factor was applied to the (dis)utility function for transit trips. The results of the trip end summary is shown in Table 30 under the column "Model 4 adjusted". The adjustment factor used was 0.54 times the utility of travel by transit. The adjustment used in this model does not result in significant changes in the travel patterns. It is generally not advisable to use models which required large adjustment factors.

7.3 Logit Models for Non-Work Trips

The results of the logit models which were formulated and calibrated to describe mode split for nonwork trips are presented in this section of the report. At the outset of the modelling exercise, the variables were selected from the calibration file to define the nonwork trip character-

Table 34 - List of Variables in the Calibration File for the Five-Mode Models for Non-Work Trips

VAR ID #	VARIABLE NAME	UNITS
1	ZONE NUMBER	
2	INCOME	$/YEAR
3	TERMINAL TIME P	MINUTES
4	TERMINAL TIME A	MINUTES
5	EMPLOYMENT	PERSONS
6	TOTAL ACRES	ACRES
7	RESIDENTIAL ACRES	ACRES
8	INDUSTRIAL ACRES	ACRES
9	UNDEVELOPED ACRES	ACRES
10	RETAIL WHOSL ACRES	ACRES
11	RECREATIONAL ACRES	ACRES
12	POPULATION	PERSONS
13	DWELLING UNITS	UNITS
14	RES LABOR FORCE	PERSONS
15	PARKING COSTS	$/DAY
16	AUTO OWNERSHIP	AUTOS/ZN
17	ZERO AUTOS	FAMILIES
18	TIMEDA	MINUTES
19	TRNS TIME	MINUTES
20	TRNS RUN TIME	MINUTES
21	TRNS WAIT TIME	MINUTES
22	HGWY SKIM DIST	MILES
23	ORIGIN ZONE	
24	DESTINATION ZONE	
25	NWDA	TRIPS
26	NWONE	TRIPS
27	NWTWO	TRIPS
28	NWTHREE	TRIPS
29	TRANSIT	TRIPS
30	POP PER DU	POP/DU
31	POP PER ACRE	POP/ACRE
32	POP	POP/100
33	AUTOS PER POP	AUTO/POP
34	PENTILE	PENT
35	TIME1	MINUTES
36	TIME2	MINUTES
37	TIME3	MINUTES
38	COSTDA	CENTS
39	COST1	CENTS
40	COST2	CENTS
41	COST3	CENTS
42	WTRNS TIME	MINUTES
43	EXCESS	MINUTES
44	TTR	MIN/MIN
45	TRNS FARE	CENTS

istics of the specific modes. Variables were selectively identified from the calibration file (Table 34) for incorporation into the logit models for nonwork trips. A description of the variables is provided in Appendix 4.

MODEL 6

The variable "travel time" was used (in one form or another) to describe the (dis)utility of using a particular for nonwork trips. Other variables used in the formulation include Income (PENTILE), Family size (POP PER DU) and automobile availability (AUTOS PER POP). The formula coefficient specification for Model 5 is shown in Table 35. The first column of Table 35 indicates the mode of travel as follows:

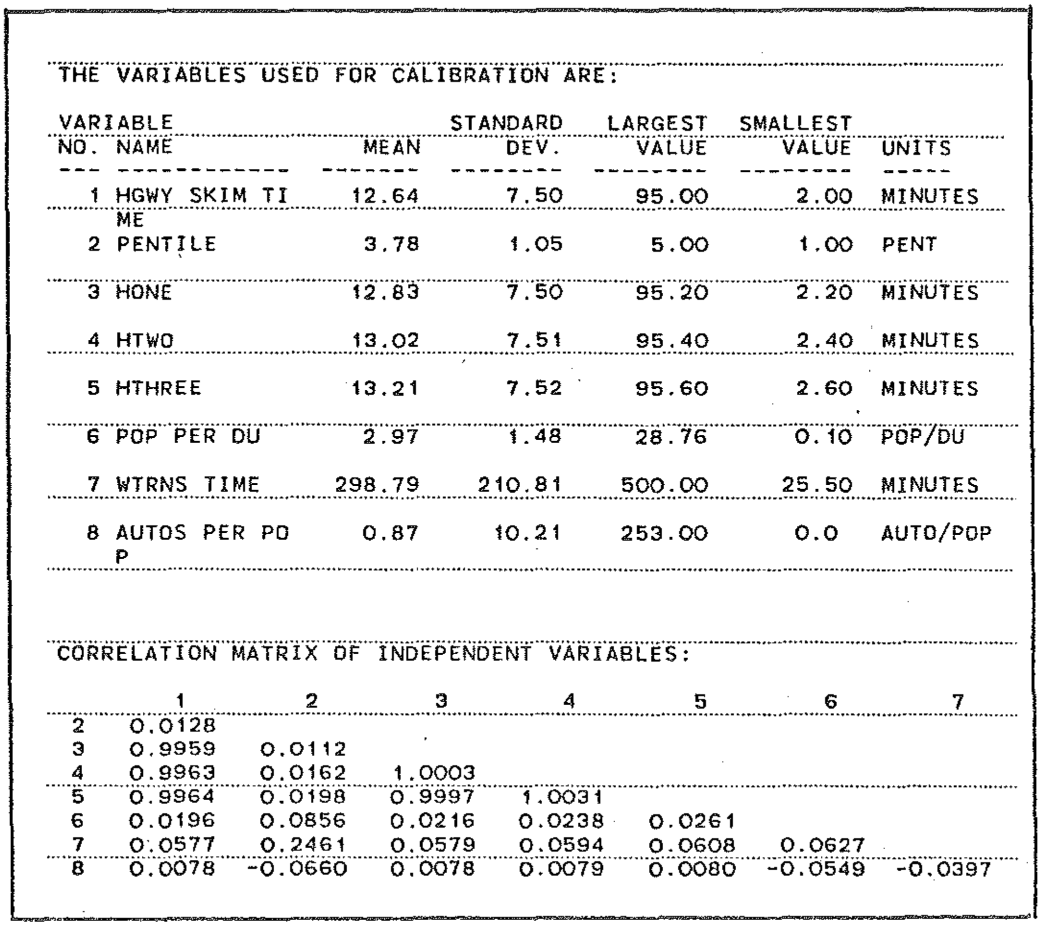
- NWDA = Automobile - Drive alone nonwork trips
- NWONE = Automobile - One passenger nonwork trips
- NWTWO = Automobile - Two passenger nonwork trips
- NWTHREE = Automobile - Three or more passenger nonwork trips
- TRANSIT = Bus Service - Nonwork trips

Table 35 - Formula Specification for Model 6

Mode	Coefficient	Variable
NWDA	= A1	* HGWY SKIM TIME
	+ B1	* PENTILE
NWONE	= A1	* HONE
	+ BIAS2	
NWTWO	= A1	* HTWO
	+ BIAS3	
NWTHREE	= A1	* HTHREE
	+ B4	* POP PER DU
TRANSIT	= A5	* WTRNS TIME
	+ B5	* AUTOS PER POP
	+ BIAS	

The values of the variables and the correlation matrix of independent variables are shown in Table 36, as taken from the calibration file for nonwork trips (Table 34).

Table 36 - Statistical Summary of Independent Variables



```
THE VARIABLES USED FOR CALIBRATION ARE:

VARIABLE                        STANDARD    LARGEST   SMALLEST
NO. NAME              MEAN        DEV.       VALUE      VALUE   UNITS
--- ------------   -------    --------   --------   --------   -----
  1 HGWY SKIM TI     12.64        7.50      95.00       2.00   MINUTES
    ME
  2 PENTILE           3.78        1.05       5.00       1.00   PENT

  3 HONE             12.83        7.50      95.20       2.20   MINUTES

  4 HTWO             13.02        7.51      95.40       2.40   MINUTES

  5 HTHREE           13.21        7.52      95.60       2.60   MINUTES

  6 POP PER DU        2.97        1.48      28.76       0.10   POP/DU

  7 WTRNS TIME      298.79      210.81     500.00      25.50   MINUTES

  8 AUTOS PER PO      0.87       10.21     253.00       0.0    AUTO/POP
    P



CORRELATION MATRIX OF INDEPENDENT VARIABLES:

          1          2          3          4          5          6          7
 2    0.0128
 3    0.9959     0.0112
 4    0.9963     0.0162     1.0003
 5    0.9964     0.0198     0.9997     1.0031
 6    0.0196     0.0856     0.0216     0.0238     0.0261
 7    0.0577     0.2461     0.0579     0.0594     0.0608     0.0627
 8    0.0078    -0.0660     0.0078     0.0079     0.0080    -0.0549    -0.0397
```

The final values of the coefficients were calculated from the ULOGIT calibration process as shown in Table 37.

Table 37 - Final Coefficient Variables and Other Statistics for Model 6

```
THE RESULTS OF THE COEFFICIENT CALIBRATION ARE:

COEFFICIENT           FINAL   STANDARD     T-   GRADIENT   LOWER   UPPER
NO. NAME              VALUE      ERROR  RATIO  (IF BND.)   BOUND   BOUND
--- ------------ --------   --------  -----  ---------   -----   -----
 1  A1             0.2103     0.0189  11.14
 2  B1            -0.0349     0.0141  -2.48
 3  BIAS2         -0.0204     0.0559  -0.37
 4  BIAS3          0.8192     0.0586  13.99
 5  B4             0.1853     0.0196   9.45
 6  A5             0.0155     0.0021   7.33
 7  B5            -0.0061     0.0041  -1.48
 8  BIAS           5.4663     0.2773  19.72

THE INITIAL VALUE OF THE LOGLIKELIHOOD WAS -0.24573E 05,
WHILE THE FINAL VALUE WAS -0.20118E 05 AFTER  7 ITERATIONS.

THE LOGLIKELIHOOD WITH ALL ZERO COEFFICIENTS IS -0.24573E 05,
WHILE BY INCLUDING PURE ALTERNATIVE EFFECTS IT IS -0.20094E 05.
THE LARGEST LOGLIKELIHOOD FOR THESE DATA AND ANY MODEL   0.0

TEST OF EQUAL PROBABILITY HYPOTHESIS IS    8909.
WITH   8 DEGREES OF FREEDOM.

TEST OF ALTERNATIVE DEPENDENT PROBABILITY HYPOTHESIS IS   -48.70
WITH   4 DEGREES OF FREEDOM.

PSEUDO R-SQUARE = .181
```

In assessing the effectiveness of the model in explaining the result, a review of the application of the variables was conducted as shown below.

- The travel time by automobile represents a "disutility" function. As the skim time increases, the trips for automobile modes decrease.
- The PENTILE factor represents a "utility". As the income level increases, the more desirable the "Automobile-drive alone" mode becomes.
- The POP PER DU factor represents a "disutility". As the population per dwelling unit increases, the "Automobile - three or more passengers" trips decreases.

- The WTRNS TIME is a "disutility" factor. As the weighted transit travel time increases, the desirability for the transit mode decreases.
- The AUTOS PER POP factor is a "utility" factor. As the automobile availability increases, the transit usage increases.

For most of these variables, the sign of the coefficient adequately represents the trip characteristics. The "auto per population" factor results in a slight inaccuracy in the transit trip estimates. This factor, however, is not considered significant in the model description of the observed data.

For reviewing the significance of the factors, T-ratios are given in Table 37. Representing a 95% confidence level (T-ratio = 1.96), all variables are considered significant in defining the trip characteristics except for the "autos per population" data used in explaining transit trip characteristics. Excluding this factor would result in only a minor change in trip-making characteristics for the other modes.

A comparison of observed vs. estimated trips is provided in Table 38.

Table 38 - Comparison of Observed vs. Estimated Trips for Model 6

ALTERNATIVE	OBSERVED	ESTIMATED	STD. RESIDUAL	CORR. COEF.	CORR. RATIO	NO. CELLS
NWDA	5841.0	5690.5	2.523	0.000	0.001	6
NWONE	4897.0	4879.9	0.297	0.000	0.000	6
NWTWO	2027.0	2021.9	0.122	0.000	0.000	5
NWTHREE	2440.0	2578.5	-2.997	0.001	0.003	12
TRANSIT	63.0	77.1	-1.692	0.002	0.007	16

This comparison indicates an acceptable match for all modes. This test is, however, a weak statistical test and does not necessarily provide conclusive evidence regarding the model's accuracy. A further test has to be made with this model on the total nonwork trip table (100% population).

Other statistics relating to the model include:

- The "pseudo R-square" value (Table 37) is 0.181, representing a moderate fit of the data.
- The "standardized residual" (Table 38) indicates acceptable comparisons of the data for all nonwork trips. In particular, the "Automobile - one passenger" and "Automobile - two passengers" modes are highly accurate.
- The "correlation coefficient" and "correlation ratio" (Table 38) indicate acceptable comparisons of the data.

Overall, this model is a reasonable representation of the observed nonwork trip data. Its use is favorable for all of the specified modes.

MODEL 7

In the formula specification for this model, a variable representing out-of-pocket costs was used to describe the (dis)utility of each mode for nonwork trips. The out of pocket costs for auto modes included travel cost (per mile) plus parking costs. The costs are assumed equally shared amongst the riders. For transit trips, a 35¢ fare was used for all trips. In addition, a variable relating to travel time (TTR) is included in the (dis)utility equation for the transit mode. The formula specification for Model 7 is shown in Table 39.

Table 39 - Formula Specification for Model 7

Mode	Coefficients	Variable
NWDA	= A1	* PENTILE
	+ B1	* COSTDA
NWONE	= B2	* COST1
	+ BIAS1	
NWTWO	= B3	* COST2
	+ BIAS2	
NWTHREE	= A4	* POP PER ACRE
	+ B4	* COST3
TRANSIT	= A5	* TTR
	+ B5	* TRNS FARE
	+ C5	* AUTOS PER POP

The values of the variables and the correlation matrix of independent variables is shown in Table 40.

Table 40 - Statistical Summary and Correlation Matrix of Independent Variables

```
THE VARIABLES USED FOR CALIBRATION ARE:

VARIABLE                          STANDARD   LARGEST   SMALLEST
NO. NAME               MEAN        DEV.       VALUE     VALUE    UNITS
--- ------------     -------   --------   --------  --------   -----
  1 PENTILE            3.78        1.05       5.00      1.00   PENT

  2 COSTDA            40.42       39.20     430.00      7.00   CENTS

  3 COST1             22.21       19.61     217.00      5.50   CENTS

  4 COST2             17.46       13.08     147.33      6.33   CENTS

  5 POP PER ACRE      11.14       16.83     278.29      0.00   POP/ACRE

  6 COST3             16.10        9.80     113.50      7.75   CENTS

  7 TTR                5.69        1.75       7.00      1.31   MIN/MIN

  8 TRNS FARE         18.26       17.48      35.00      0.0    CENTS

  9 AUTOS PER PO       0.45        0.21       2.45      0.0    AUTO/POP
    P


CORRELATION MATRIX OF INDEPENDENT VARIABLES:

          1         2         3         4         5         6         7
          8
 2    0.1026
 3    0.1023    0.9987
 4    0.1050    0.9999    0.9989
 5    0.0552    0.2153    0.2149    0.2153
 6    0.1027    1.0006    0.9991    1.0004    0.2147
 7    0.2631   -0.0224   -0.0235   -0.0217   -0.3017   -0.0251
 8    0.2404    0.1316    0.1315    0.1321   -0.2474    0.1311    0.7816
 9    0.1326    0.0241    0.0237    0.0260   -0.0726    0.0234   -0.0287
     -0.0020
```

The final values of the coefficients were calculated from the ULOGIT calibration process as shown in Table 41.

Table 41 - Final Coefficient Values and Other Statistics for Model 7

```
THE RESULTS OF THE COEFFICIENT CALIBRATION ARE:

COEFFICIENT                 FINAL   STANDARD      T-   GRADIENT   LOWER   UPPER
NO. NAME                    VALUE      ERROR   RATIO  (IF BND.)   BOUND   BOUND
--- ------------------ --------   --------   -----  ---------   -----   -----
  1  A1                  -0.0209     0.0123   -1.70
  2  B1                   0.0268     0.0020   13.75
  3  B2                   0.0478     0.0039   12.36
  4  BIAS1                0.1045     0.0463    2.26
  5  B3                   0.0773     0.0060   12.99
  6  BIAS2                0.6938     0.0508   13.66
  7  A4                   0.0035     0.0015    2.35
  8  B4                   0.1108     0.0073   15.26
  9  A5                   1.0508     0.1111    9.46
 10  B5                   0.1838     0.2056    0.89
 11  C5                   4.3457     0.7905    5.50

THE INITIAL VALUE OF THE LOGLIKELIHOOD WAS -0.20049E 05,
WHILE THE FINAL VALUE WAS -0.20049E 05 AFTER  2 ITERATIONS.

THE LOGLIKELIHOOD WITH ALL ZERO COEFFICIENTS IS -0.24573E 05,
WHILE BY INCLUDING PURE ALTERNATIVE EFFECTS IT IS -0.20094E 05.
THE LARGEST LOGLIKELIHOOD FOR THESE DATA AND ANY MODEL  0.0

TEST OF EQUAL PROBABILITY HYPOTHESIS IS    9048.
WITH  11 DEGREES OF FREEDOM.

TEST OF ALTERNATIVE DEPENDENT PROBABILITY HYPOTHESIS IS    90.91
WITH   7 DEGREES OF FREEDOM.

PSEUDO R-SQUARE =  .184
```

In assessing the effectiveness of the model in explaining the result, a review of the <u>application</u> of the variables was conducted as shown below.

- The PENTILE factor represents a "utility". As the income level increases, the more desirable the "Automobile-drive alone" (NWDA) mode becomes.
- The COSTDA factor represents a "disutility" in this model. As the highway user costs increases, the "Automobile-drive alone" (NWDA) trips are expected to become less attractive.
- COST1 represents a "disutility" factor. As the highway user costs of this mode increases, the "Automobile - one passenger" trips decrease.

- The COST2 factor also represents a "disutility" similar to the other cost variables. As costs increas, the "Automobile - two passengers" trips decrease.
- The POP PER ACRE factor represent a "disutility". As the population per acre increases, the trips using the "Automobile - three or more passengers" mode decreases.
- The COST3 factor represents a "disutility". As the highway user costs for this mode increase, the trips by "Automobile - three or more passengers" mode decreases.
- The TTR factor is a "disutility". As the travel time ratio (Transit/Automobile) increases, the trips using the transit mode will decrease.
- The TRNS FARE represents a "disutility" factor. As the transit fare increases, the transit mode will become less attractive.
- The AUTOS PER POP factor represents a "disutility". As the automobile availability increases, trips using the transit mode are expected to decrease.

In this model, the variables relate to the expected travel characteristics, with the possible exception of the POP PER ACRE variable.

In reviewing the <u>significance</u> of factors, the T-ratios are given in Table 41. Using a 95% level (T-ratio = 1.96), the significance of the cost factors in explaining the nonwork trip data for the automobile modes is evident. The T-ratio associated with the transit fare variable indicates that it is not a significant factor. The travel time ratio and the automobile availability represent significant factors while income (PENTILE), appears to be an insignificant factor in explaining travel characteristics.

A comparison of the observed vs. estimated trips is provided in Table 42.

Table 42 - Comparison of Observed vs. Estimated Trips for Model 7

ALTERNATIVE	OBSERVED	ESTIMATED	STD. RESIDUAL	CORR. COEF.	CORR. RATIO	NO. CELLS
NWDA	5841.0	5728.2	1.888	0.001	0.001	7
NWONE	4897.0	4885.0	0.209	0.003	0.003	9
NWTWO	2027.0	2023.9	0.073	0.000	0.000	5
NWTHREE	2440.0	2540.2	-2.179	0.000	0.000	10
TRANSIT	63.0	71.3	-1.037	0.003	0.014	19

This comparison indicates a very good match for all modes.

Other statistics relating to the model include:

- The "pseudo R-square" value (Table 41) is 0.184, a moderate fit of the data.
- The "standardized residual" (Table 42) indicates a very good comparisons for the "Automobile - one passenger" and "Automobile - two passengers" modes. For the other modes, the standard residual indicates an acceptable comparison.
- The "correlation coefficient" and "correlation ratio" (Table 42) indicate a good comparison with the observed data.

Overall, this model represents a very good representation of the observed non-work trip data. The model was primarily designed to include cost factors to describe the (dis)utility of nonwork trips. Due to the differences in behavioral characteristics (since 1968) relating to cost factors, an improved model may be calibrated with more recent travel data.

7.4 Comparison of the Nonwork Model Results to the Observed Trip Tables:

To evaluate the predictive capability of the model, a comparison was made to the total observed nonwork trip tables. Previous comparisons of the model results made by the ULOGIT program only utilized 1.3% sample of the observed Nonwork Trip Table (which was used to calibrate the model).

Models 6 and 7 were both applied to the total person trip table (for nonwork trips) to provide model split information using the UMODEL computer program. The results of the mode split are shown in Table 43. This table shows the following on a total trip end summary basis.

- Model 6 predicts mode split at an acceptable level for the first three auto-occupancy levels (Drive alone, one passenger and two passengers). There is a slight over-prediction for the "three or more passenger" automobile mode and a over-prediction for transit trips.
- Model 7 does an excellent job of matching mode split for the "one passenger" and "two passenger" auto modes. Under-predictions occur for the "drive alone" auto modes and transit modes, and an over-prediction occurs for the "three of more passenger" auto mode.

In an attempt to test the "goodness of fit" of the model to the observed data on a trip interchanges basis, a comparison of observed vs. estimated trip length frequency curves was performed.

A comparison of observed vs. estimated trip length frequency curves was conducted for Model 6. This model was selected because it had the best match to the observed nonwork trip table. The TLF curves for model 6 were obtained using the UTPS program UFMTR. These curves are shown in Appendix 1 as are the observed TLF curves for nonwork trips.

Table 43 - Comparison of Observed vs. Estimated Mode Split For Non-Work Trips

Mode	Observed Trips	Estimated Trips	
		Model 6 Trips	Model 7 Trips
Drive Alone	438,087	427,874	432,423
1 Passenger	367,304	366,755	368,792
2 Passenger	152,085	151,878	152,726
3+ Passenger	183,002	193,534	190,506
Transit	4,767	9,597	760

1,145,245

Table 44 - Comparison of Observed vs. Estimated Trip Length Frequency Means and Variances (Model 6) For Non-Work Trips

	Drive Alone	1 Pass.	2 Pass.	3 or More Pass.	Transit
Mean	-	-	-	-	-
Observed	12.317	13.236	12.580	12.364	47.261
Estimated	12.650	12.646	12.645	12.635	53.481
Variance	*	*	*	*	-
Observed	52.784	62.703	57.418	54.239	250.003
Estimated	57.222	56.889	56.870	55.831	423.401

* = No significant difference at 95% level of confidence.

A visual comparison of the TLF curves shows a similarity in the curve form to all auto-occupancy levels. A statistical comparison was made for the TLF mean and variances between the observed data points and the results of Model 6. The means and frequencies are shown in Table 44. This table indicates that there is a difference in the TLF means for all modes (at a 95% level of confidence). The test for variance indicated no significant difference between the observed and estimated results for automobile modes.

8. SENSITIVITY ANALYSIS

One of the most important attributes in a travel demand model is its sensitivity to changes in transportation system characteristics. A model should be developed so that it accurately reflects the possible impacts resulting from changes in the transportation system due to new alternatives. The model must be able to test new transportation strategies (or variations in existing transportation strategies) which are of concern to transportation planners. These transportation system strategies may include ridership incentive programs, park-and-ride facilities, new transit systems, etc. As such, the travel demand model must incorporate those variables which will be effected by the transportation strategy. For example, if a new parking management program for CBD area calls for increased parking costs, a variable representing parking costs should be incorporated into the (dis)utility function. If new operating headways for bus service are to be tested, the model must be sensitive to travel time (or accessibility), particularly for transit modes.

The ULOGIT program produces a table of elasticities (Report 8) for each variable which can be used to evaluate the <u>sensitivity</u> of the model. The elasticities as reported by ULOGIT are defined as "the percentage change in alternative choice probability (i.e., demand) expected from a one percent change in the associated independent variable.[1] The elasticities provided by ULOGIT are only defined at a particular point which is the mean value of independent variables used in the model formula specification (as shown in Report 2). The elasticities will generally not be the same for other values of the independent variables. A listing of the elasticities for each model is provided in Appendix 3.

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[1] "ULOGIT" Calibration Program", UMTA, FHWA, USDOT, April 1979.

As a part of this project a total of six transportation system alternatives were tested on three logit models developed in the project. Three of the transportation system changes involved operational changes to the transit (bus) system and were tested on Model 4 (five-mode model for work trips).

The second set of alternatives involved changing various costs associated with travel by automobile and transit. These transportation system changes were tested on Model 5 (five-mode model for work trips). These tests and their results are described below.

8.1 Changes in Transit Operating Strategies

The changes in operating strategies which were tested included increased transit accessability by adding new transit lines and variations in the transit headway. Travel time by the atomobile modes and the other independent variables remained unchanged. The transit system changes were conceived based on alternatives tested in previous UTPS studies for the Flint Area.[1] These alternatives reflected rear-world changes which can occur in the study area.

The sensitivity tests on transit operating strategies were conducted using Model 4 (five-mode model for work trips) which was adjusted to match the observed mode split for work trips. As described in section 6.2.1, this model incorporated the variable "travel time" into the (dis)utility formulation.

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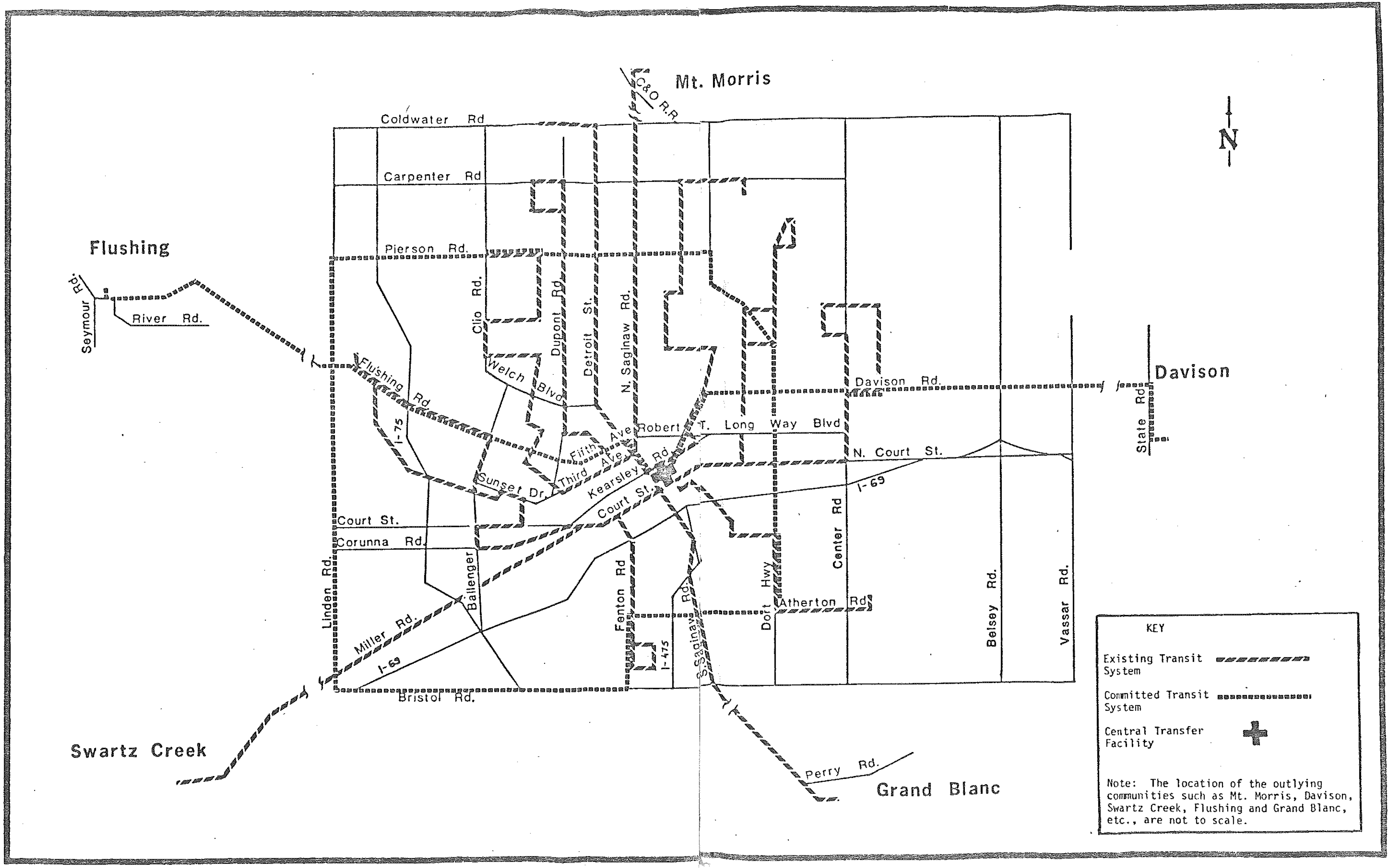
[1] "Flint Area Transit Study: The Testing of Short-range and Long-range Alternatives Using the UTPS Modelling System", Department of Civil Engineering, Wayne State University, 1980.

Based on changes in the (dis)utility for the transit mode (due to variations in the travel time variable), the proportion of trips assigned to the transit mode are expected to increase or decrease accordingly. Since the total number of trips remains constant, the number of trips assigned to the auto modes are also expected to vary.

The three alternatives tested are described below:

- Alternative A: This alternative is to decrease transit travel time by increasing the frequency of bus service. Travel time by transit is comprised of walk time, plus time waiting for the bus, plus in-vehicle run time. Wait time for transit, as computed by the UTPS computer program, is a function of 1/2 the operating headway. When operating headways are increased, walk times and in-vehicle run times remain relatively unchanged, however, the wait time will decrease. As such, in modelling this alternative, wait time was decreased by 50%. The decrease in wait time represents an increase in frequency of service. The mode split results for this alternative are shown in Table 45.
- Alternative B: This alternative is to add three transit routes and increase operating headways to 30 minutes. The transit system used in this alternative represents the Existing and Committed transit system for the Flint metropolitan area which is shown in Figure 7. This transit skim tree for this particular system was developed in a study conducted at Wayne State University using UTPS.

The three transit routes added to the existing system consists of the Bristol loop which encircles the City of Flint, a route from the Flint CBD to the City of Davison (east of Flint) and a route



Note: The location of the outlying communities such as Mt. Morris, Davison, Swartz Creek, Flushing and Grand Blanc, etc., are not to scale.

Figure 7 - Flint Transit System Used in Alternative B and C For Sensitivity Analysis

from the Flint CBD to the City of Flushing (west of Flint.) The operating headway used for the Existing and Committed transit system is 30 minutes. It is important to note that Model 4 was calibrated using a 20 minute headway for the base transit system. As such, the accessibility of transit service will increase, but travel times by transit will also increase. The results for this alternative are shown in Table 45.

- Alternative C: This alternative is similar to Alternative B, with respect to system configuration (Figure 7). However, the headway for the entire system is reduced to 10 minutes. The results for this alternative are shown in Table 45.

Table 45 - Mode Split Results For Changes In
Transit Operating Strategies Using Model 4 (Adjusted)

MODE	BASE CONDITIONS (MODEL 4 ADJUSTED)	ALTERNATIVE A	ALTERNATIVE B	ALTERNATIVE C
Drive Alone	175,759	173,306	176,302	172,165
1 Passenger	19,306	19,026	19,376	18,908
2 Passenger	4,386	4,316	4,397	4,295
3+ Passenger	2,569	2,553	2,607	2,535
Transit	1,879	5,786	1,179	9,387

The reduction of waiting time by 50% (alternative A) resulted in increasing the transit ridership by a factor of 3 over the base conditions. Transit usage increased from .9% of the total work trips to 2.8% of the total work trips. The auto-occupancy modes each decreased by an amount of 1.5% to .6%.

Alternative B (adding 3 routes and increasing bus headways to 30 minutes) resulted in a sizable reduction in transit ridership, as shown in Table 45. As a result of the reduction in transit ridership, a slight increase in each auto-occupancy mode was recorded.

Alternative C (adding 3 routes and decreasing bus headways to 10 minutes) resulted in a significant increase in the use of transit over the base conditions. This increase is approximately five times the base condition ridership of 1879 daily transit work trips. As a result, ridership of each automobile-occupancy mode decreased by approximately 2%.

These results indicate that the model is highly sensitive to changes in travel time. Changes in transit ridership also have some form of an impact on ridership levels for all four remaining modes.

8.2 Changes in Transportation System Costs

Tests on the sensitivity of the model due to variations in transportation system costs were conducted on Model 5 (for work trips). Model 5 incorporated out-of-pocket costs to describe the (dis)utility of travel for each particular mode. The costs were defined as a cost per person (per trip), thus making travel by a high occupancy vehicle financially desirable. Three alternative cost (or pricing) strategies were evaluated as described below.

- Alternative D: This alternative involved an increase in the out-of-pocket travel cost (per mile) associated with each automobile mode. Travel costs were increased from 10¢ per mile (per person) to 20¢ per mile (per person). The results are shown in Table 46.
- Alternative E: This alternative involved the development of a downtown parking system management program in the form of a fare increase. In this alternative, each zone within the City of Flint which had a high number of employees per acre was assessed an

additional 50¢ per vehicle parking cost. This plan is intended to increase the utility of travel by higher occupancy vehicles along with transit travel for work trips in the Flint area. The results of this alternative are shown in Table 46.

- Alternative F: Alternative F is a plan to increase transit fares from 35¢ to 70¢. A reduction in transit ridership is expected unless the current transit users are "captive" riders. The results are shown in Table 46.

Table 46 - Mode Split Results For Changes In Transportation System Costs Using Model 5

MODE	BASE CONDITION MODEL 5	ALTERNATIVE D	ALTERNATIVE E	ALTERNATIVE F
Drive Alone	173,943	175,738	174,176	174,086
1 Passenger	18,947	19,273	19,579	18,962
2 Passenger	4,386	3,284	4,144	4,389
3+ Passenger	4,395	910	2,701	4,353
Transit	2,386	5,960	3,434	2,134

The results for Alternative D and E indicate that the model is not properly sensitive to increased ridership costs for the automobile modes. In the calibrated model, the signs of the coefficient are all correct for the cost variables, however, the T-ratios indicate that cost is a much more important factor for the higher occupancy modes for automobile travel. As such, the impact due to an increase in cost per person in the high occupancy auto modes outweighs the increased disutility cost (per person) in the drive-alone automobile mode. This results in an apparent shift in ridership to the lower occupancy automobile mode (Drive Alone) which is not representative of what is expected to occur. In both alternatives, however, transit is seen as an increasingly attractive mode of travel.

These sensitivity results indicate a need to re-structure the cost model (Model #5). To correct the apparent discrepancy, the new formulation should have the same coefficient for cost for all auto modes so that everyone will have a similar sensitivity to cost. Income and other like variables can be used to differentiate between individuals who are more apt to travel in lower occupancy vehicles. A similar reformulation should be made for Model 7, the cost-based model for nonwork trips.

In Alternative F, transit becomes slightly less attractive due to increased transit fares. The model indicates, however, that transit fare at its present level, is not a major decision criterion for using transit by the current riders.

9. CONCLUSIONS

The broad purpose of this study was to investigate the feasibility of using the logit approach for (multi)modal-split purposes in urban areas with populations above 200,000 through the use of commonly available data. A number of conclusions can be drawn from this study regarding the logit approach, the feasibility of using aggregate data for demand estimation purposes, and the transferability of the model to other urbanized areas within the State. The conclusions are outlined below:

1. The logit approach is a valid approach to travel demand modelling both for bimodal as well as for multi-modal analysis. The use of a (dis)utility function to describe mode selection based on a resistance (impedance) to travel is consistent with the behavioral aspects of the trip-maker that might influence his travel decision. Trip-makers normally consider several factors prior to selecting their mode of travel based on the (dis)utility characteristics of each mode. A multi-nomial logit model attempts to calibrate a set of travel, socio-economic and land use variables to replicate such a decision-making process. This approach is more logical than the diversion curve method and is more consistent with the theories of travel demand behavior. The diversion curve technique can treat only two modes at a time unless a significant amount of additional effort is expended using complex formulations. Furthermore, diversion curves allow fewer variables to be used in defining trip-maker characteristics for the same amount of effort expended in the logit modelling process.

2. Once a calibration file has been created, several different logit formulations can be tested by selectively including explanatory

variables in (dis)utility equations through the use of ULOGIT. The calibration and evaluation of the (dis)utility equation can be accomplished within a short period of time. The traditional diversion curve technique, on the other hand, requires a significant amount of manpower and effort to calibrate a single set of variables to travel in an area. If a new variable is revised or added to the calibration effort in the diversion curve technique, a large amount of effort has to be invested to calibrate the new model.

3. The computer cost to calibrate a logit model (using the UTPS program ULOGIT) to a set of observed mode-split data is a function of the number of data points (observed trips), the number of equations (modes) and the number of terms (independent explanatory variables) used in the model. The number of observed trips (sample size) is one of the most significant factors. A typical ULOGIT computer run in this study which used a 5% sample of the observed trips (10,165 of 203,347 total trips) in the five mode model for work trips cost approximately 3 to 5 times the amount of a calibration run for the diversion curve method (UMODEL) using a 100% sample of trips. Although the ULOGIT computer costs are appreciably higher for a single calibration run than the UMODEL computer costs, there is a significant savings in the amount of time, manpower and number of computer runs required when the ULOGIT computer program is utilized properly. This can result in a sizable reduction of in the total calibration costs while obtaining an enhanced travel demand model.

4. For large sample sizes, the calibration of a multi-modal logit model (comprised of several independent variables and coefficients) may utilize a significant amount of computer costs. However, insufficient sample sizes will result in inadequate formula calibration. The trade off between computing costs in model calibration and the predictive capability of the model must be duly considered at the outset of the calibration process.

5. Many of the statistical tests and model evaluation measures produced by the ULOGIT computer program are inconclusive. The statistical tests should be used primarily for the purpose of eliminating unacceptable model formulations. The selection of the best model requires a clear understanding of all the statistical tests, and should not be based on the highest statistics alone.

   In addition, the model should be tested using the total person-trip table (100% population) to properly evaluate the models' demand estimating capability. This step requires the use of the calibrated (dis)utility equations to allocate the total person trips among the candidate modes through the use of the UMODEL program, and conducting another set of statistical tests to assess the goodness of fit of the model. The calibration effort is <u>not</u> considered finalized without completing this step. A model that might appear acceptable based on the initial ULOGIT reports may be found unacceptable when applied to the 100% population.

6. The logit approach lends itself quite well to the simultaneous modelling of several modes representing various levels of automobile occupancy in addition to transit. The ULOGIT program can calibrate up to 10 modes at a time. It is extremely difficult, if not virtually impossible, to accomplish this task with the diversion curve method.

7. The process of logit modelling can be transferred to other urban areas across the State. The specific logit models, however, require recalibration to each new study area. In recalibrating an existing model to a new area, it is advisable to use past values as initial estimates of the coefficients. This may reduce the calibration effort as well as the computer costs. Because of features unique to a particular area, it may be necessary to include additional (or revised) explanatory variables within the logit formulations.

8. Because the type of data used in the Flint Case Study is commonly available for similar urban areas, the transferability of the model to other urban areas for further validation purposes, does not appear to pose any major problem.

9. The study shows that the nonavailability of disaggregate, household data is not a major problem for logit models. While it is desirable that such disaggregate data be used when available, in the absence of such data, the use of travel data (being assumed to be representative of the household in question) can produce valid and acceptable results.

10. The use of zonal averaging of data reduces the variability of the socio-economic information for the individual trip maker. This reduction in variability causes additional calibration effort and less "accuracy" in the model. This loss in accuracy, however, is not to the extent such that the aggregate approach is invalid. Travel data available to most planning agencies is typically aggregated on a zonal basis, making the availability of household level (disaggregate) data virtually impossible for demand estimation purposes. Because of the time, manpower and monetary savings associated with using existing aggregated data, this method is extremely attractive.

11. When developing the (dis)utility formulations to be applied to a study area. The explanitory variables should be carefully selected to reflect actual mode choice decision criterion used by the trip-maker such as travel time or cost. In addition, the explainatory variables must be quantifiable, predictable and available for use in the design year. The use of variables that do not have the above properties should be discouraged.

    Furthermore, the model should be designed such that it is sensitive to the transportation alternatives which are to be tested. For example, if alternatives in the design year vary with respect to cost, then travel cost must be included in the model formulation. If travel costs are not expected to vary between future alternatives, then cost need not be an integral part of the model formulation.

    These same criteria should hold true when selecting between different logit models. The selected model must be sensitive to the appropriate travel characteristics, and the variables should be quantifiable, predictable, available and should represent factors used in actual mode choice decisions.

9.1 Recommendations

This study represents an important effort in utilizing the logit concept to develop mode-split models for urban areas of 200,000 population. A review of the relevant literature conducted during the course of this study indicated that only limited efforts have been made in this direction, although the theoretical use of the logit approach has been long established. The reasons for such a limited use of this concept in the past is the lack of requisite data on the household level, and the lack of effort in the past to orient the use of zonal data to these types of models. As such, the prime emphasis of this study was to test the feasibility of using logit models utilizing the type of data most commonly available for urban areas of 200,000 population or above.

In particular, there are two elements associated with logit models that make them extremely powerful tools for mode-split analysis. These are its ability (1) to treat more than two modes at a time, and (2) to allocate trips in a manner that appears to be consistent with the behavioral aspects of the trip maker in making actual mode choice decisions.

As outlined earlier in the chapter, this study has successfully addressed this issue and a number of logit models have been developed within the framework of the available data base. The study indicates that the potential for applying this approach in other urban areas, is quite high, although further calibration and validation effort is warranted before a more widespread application of this concept is practiced. Specifically, the following recommendations are made:

1. More effort should be made to improve the predictive capability of the models through further "fine-tuning" of the (dis)utility equations.

2. Additional data (socio-economic, land use and transit) should be collected with the objective of further validation of high occupancy mode models with rising energy costs and increased ridesharing programs. Further planning studies are warranted to address travel demand issues related to high occupancy modes.

3. Since cost is a major incentive in high occupancy modes, considerable attention should be diverted to developing models which include cost variables. Studies should also be directed towards identifying various time or cost "penalties" related to high occupancy vehicles (i.e., time or cost penalties associated with picking up/dropping off passengers).

4. Further studies should be directed towards selecting proper sample sizes for calibrating formulations. In particular, studies should be directed towards the use of a higher percentage of transit trips within the sample to improve the calibration of transit characteristics. A constant sampling rate for all candidate modes (as used in this study) might result in a very small sample size for transit trips. On the other hand, in order to increase the sample size for transit trips, it would be necessary to increase the sample size for all other modes by the same proportion. Further studies should be made to investigate the use of different sampling rates for different modes to provide improved formulations for modes with low ridership.

5. Further analysis is needed to develop measures for optimum sampling rates that would take into account the trade off's between the predictive quality of the model and the associated computer costs for larger sample sizes.

6. Additional studies are necessary to determine the type of socio-economic and land use data that may be collected with a commitment of minimum resources, but which can considerably improve the predictive quality of the logit model.

7. There is a need to collect transit trip data to develop an "observed" transit person-trip table (which can be stratified by trip purpose) to use in model calibration. Observed transit trip tables were not available for this study and therefore had to be synthesized based on known travel patterns and characteristics of transit users in the Flint area. It is preferable to use actual observed data for planning purposes, especially in situations when transit represents a small portion of the total trips. A small change in transit ridership may make a significant difference in the calibrated model.

8. The logit concept should be used in a similar urban area in Michigan. The prime emphasis should be on the sensitivity analysis of the models developed in this study. In testing the sensitivity, the air quality impact and the impact of various transportation strategies should be of primary concern. When such a study is undertaken, the models developed in this study can be further "fine tuned" with new data.

APPENDIX 1

TRIP LENGTH FREQUENCY CURVES

```
     **** FLINT **** OBSERVED TLF CURVE - WORK D.A. TRIPS

                             UFMTR                               PAGE    3

     WORKDA
                         TRIP LENGTH DISTRIBUTION
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    0    8   16   24   32   40   48   56   64   72   80
    +----+----+----+----+----+----+----+----+----+----+    %  CUM% COUNT
   0.                                                    0.0   0.0     0
   1.                                                    0.0   0.0     0
   2.                                                    0.0   0.0    66
   3..                                                   0.1   0.2   251
   4......                                               0.9   1.0  1519
   5.........                                            1.2   2.3  2188
   6..........                                           1.4   3.7  2477
   7....................                                 3.0   6.7  5251
   8.................                                    2.5   9.2  4439
   9......................                               3.4  12.6  5990
  10...........................                          4.2  16.8  7301
  11................................                     5.0  21.8  8828
  12..................................                   5.3  27.1  9281
  13....................................                 5.6  32.7  9820
  14....................................                 5.5  38.2  9743
  15...................................                  5.4  43.6  9451
  16.................................                    5.1  48.7  8944
  17.............................                        4.4  53.1  7785
  18.......................................              6.1  59.2 10739
  19...........................                          4.2  63.5  7421
  20..........................                           4.0  67.5  7043
  21...........................                          4.2  71.7  7348
  22.....................                                3.3  74.9  5715
  23.................                                    2.6  77.5  4486
  24...............                                      2.3  79.8  4029
  25..................                                   2.7  82.5  4767
  26..............                                       2.1  84.6  3703
  27...........                                          1.6  86.1  2772
  28............                                         1.7  87.9  3047
  29...........                                          1.6  89.5  2830
  30...........                                          1.6  91.1  2770
  31.........                                            1.3  92.3  2239
  32.......                                              1.0  93.3  1723
  33...                                                  0.4  93.7   622
  34.......                                              1.0  94.7  1725
  35.....                                                0.7  95.3  1198
  36....                                                 0.5  95.8   862
  37....                                                 0.4  96.3   745
  38...                                                  0.4  96.6   617
  39....                                                 0.5  97.1   860
  40...                                                  0.3  97.4   546
  41..                                                   0.2  97.6   358
  42...                                                  0.3  97.9   527
  43..                                                   0.2  98.1   307
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     **** FLINT **** OBSERVED TLF CURVE - WORK D.A. TRIPS

                                   UFMTR                               PAGE    4

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    +----+----+----+----+----+----+----+----+----+----+            %   CUM% COUNT
  44..                                                           0.2  98.3   375
  45..                                                           0.2  98.5   357
  46..                                                           0.2  98.7   290
  47..                                                           0.1  98.8   198
  48...                                                          0.2  99.0   434
  49..                                                           0.1  99.2   231
  50.                                                            0.1  99.2   130
  51..                                                           0.2  99.5   390
  52..                                                           0.1  99.6   186
  53.                                                            0.1  99.6   129
  54.                                                            0.1  99.7    98
  55.                                                            0.0  99.7    17
  56..                                                           0.1  99.8   149
  57.                                                            0.0  99.8    69
  58.                                                            0.0  99.8    34
  59.                                                            0.0  99.9    32
  60.                                                            0.0  99.9    34
  61.                                                            0.0  99.9    34
  62.                                                            0.0  99.9    34
  63.                                                            0.0  99.9    34
  64.                                                            0.0  99.9     0
  65.                                                            0.0  99.9     0
  66.                                                            0.0  99.9     0
  67.                                                            0.0  99.9     0
  68.                                                            0.0 100.0    69
  69.                                                            0.0 100.0    16
  70.                                                            0.0 100.0    17
  71. (ALL REMAINING COUNTS ARE ZERO)                            0.0 100.0     0

          MEAN         VARIANCE       STD DEV   SUM(COUNT(I))    SUM(I*COUNT(I))
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                              UFMTR                          PAGE     3

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 0.                                                   0.0   0.0     0
 1.                                                   0.0   0.0     0
 2.                                                   0.0   0.0     0
 3.                                                   0.0   0.0     0
 4.......                                             1.2   1.2   230
 5.................                                   3.2   4.4   602
 6.....                                               0.8   5.2   160
 7......................                              4.3   9.5   806
 8...............                                     2.9  12.4   542
 9........................                            4.6  16.9   862
10..................                                  3.4  20.3   648
11...........................................         8.3  28.7  1580
12..........................                          5.0  33.6   940
13.........................                           4.8  38.4   906
14......................                              4.2  42.6   788
15.........................                           4.8  47.4   916
16...................................                 6.8  54.2  1280
17...................                                 3.6  57.8   688
18..........................                          5.0  62.8   948
19.............                                       2.3  65.1   436
20..................                                  3.5  68.6   654
21......................                              4.3  72.9   810
22..............                                      2.6  75.4   484
23..............                                      2.6  78.0   498
24.......                                             1.2  79.3   236
25...........                                         2.0  81.3   388
26......                                              1.1  82.4   204
27...........                                         2.1  84.5   392
28.........                                           1.6  86.1   296
29..........                                          1.8  87.9   340
30.........                                           1.6  89.4   302
31...........                                         2.1  91.5   396
32.......                                             1.2  92.8   234
33...                                                 0.4  93.1    70
34.....                                               0.7  93.9   134
35..........                                          1.7  95.6   326
36.                                                   0.0  95.6     0
37.                                                   0.0  95.6     0
38..                                                  0.2  95.7    32
39..                                                  0.2  95.9    38
40.                                                   0.0  95.9     0
41....                                                0.5  96.5    96
42.                                                   0.0  96.5     0
43.......                                             1.1  97.6   212
44...                                                 0.3  97.9    64
45.                                                   0.0  97.9     0
46...                                                 0.3  98.2    64
47.                                                   0.0  98.2     0
48.                                                   0.0  98.2     0
49....                                                0.5  98.8   102
50....                                                0.7  99.5   130
51.                                                   0.0  99.5     0
52..                                                  0.2  99.6    32
53. (ALL COUNTS FROM INTERVAL  53 THRU  62 ARE ZERO)  0.0  99.6     0
63...                                                 0.4 100.0    68
64. (ALL REMAINING COUNTS ARE ZERO)                   0.0 100.0     0

        MEAN      VARIANCE     STD DEV  SUM(COUNT(I))   SUM(I*COUNT(I))
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      17.930         93.990      9.695         18934.           339488.
```

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                                UFMTR                             PAGE    3

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                        TRIP LENGTH DISTRIBUTION
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   +----+----+----+----+----+----+----+----+----+----+     %   CUM%  COUNT
  0.                                                      0.0   0.0      0
  1.                                                      0.0   0.0      0
  2.                                                      0.0   0.0      0
  3.                                                      0.0   0.0      0
  4....                                                   1.2   1.2     51
  5....                                                   1.1   2.3     48
  6....                                                   1.2   3.4     51
  7................................                      12.6  16.0    552
  8....                                                   1.2  17.1     51
  9.......                                                2.3  19.4     99
 10................                                       6.0  25.4    264
 11.................                                      6.2  31.6    273
 12.......                                                2.4  34.0    105
 13..........                                             3.4  37.4    150
 14....                                                   1.2  38.6     51
 15.......                                                2.3  40.9    102
 16...............                                        5.7  46.6    252
 17....                                                   1.1  47.7     48
 18................                                       5.9  53.6    258
 19.................                                      6.3  59.9    276
 20............                                           4.4  64.3    195
 21..................                                     7.0  71.3    306
 22.......                                                2.6  73.9    114
 23.......                                                2.3  76.1     99
 24....                                                   1.2  77.3     51
 25.............                                          4.6  81.9    204
 26..................                                     6.8  88.7    300
 27.                                                      0.0  88.7      0
 28.......                                                2.3  91.1    102
 29.......                                                2.3  93.3     99
 30.......                                                2.3  95.6     99
 31.                                                      0.0  95.6      0
 32......                                                 2.1  97.7     93
 33. (ALL COUNTS FROM INTERVAL  33 THRU  59 ARE ZERO)     0.0  97.7      0
 60.......                                                2.3 100.0    102
 61. (ALL REMAINING COUNTS ARE ZERO)                      0.0 100.0      0

          MEAN        VARIANCE       STD DEV  SUM(COUNT(I))   SUM(I*COUNT(I))
          ----        --------       -------  -------------   ---------------
        17.924          95.486         9.772          4395.            78774.
```

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   **** FLINT **** OBSERVED TLF CURVE - WORK 3+ PASS TRIPS

                              UFMTR                          PAGE     3

   WORK 3+P
                       TRIP LENGTH DISTRIBUTION
   IMPEDANCE = UMODEL  (TABLE 2001)        TRIPS = UMODEL  (TABLE 1001)

  0    2    4    6    8    10   12   14   16   18   20
  +----+----+----+----+----+----+----+----+----+----+     % CUM% COUNT
 0.                                                     0.0   0.0     0
 1.                                                     0.0   0.0     0
 2.                                                     0.0   0.0     0
 3.                                                     0.0   0.0     0
 4.......                                               2.5   2.5    64
 5.                                                     0.0   2.5     0
 6.                                                     0.0   2.5     0
 7.                                                     0.0   2.5     0
 8.........                                             3.3   5.7    85
 9.                                                     0.0   5.7     0
10....................                                  7.7  13.4   200
11...................                                   7.2  20.6   187
12..............                                        5.2  25.8   136
13.                                                     0.0  25.8     0
14.........................                             9.5  35.3   247
15.................                                     6.3  41.6   165
16..................................                   13.0  54.6   340
17.                                                     0.0  54.6     0
18..............                                        5.4  60.0   140
19.................                                     6.5  66.5   170
20.......................................              15.0  81.5   392
21. (ALL COUNTS FROM INTERVAL  21 THRU  26 ARE ZERO)    0.0  81.5     0
27..............                                        5.1  86.6   132
28.........                                             3.3  89.9    85
29.                                                     0.0  89.9     0
30..............                                        5.1  94.9   132
31. (ALL COUNTS FROM INTERVAL  31 THRU  50 ARE ZERO)    0.0  94.9     0
51..............                                        5.1 100.0   132
52. (ALL REMAINING COUNTS ARE ZERO)                     0.0 100.0     0

        MEAN      VARIANCE     STD DEV  SUM(COUNT(I))    SUM(I*COUNT(I))
        ----      --------     -------  -------------    ---------------
      18.498        91.193       9.549          2607.             48224.
```

```
     **** FLINT **** OBSERVED TLF CURVE - TRANSIT WORK TRIPS

  7OCT80  14.35.05             UFMTR                         PAGE    3

     TRAN WORK
                           TRIP LENGTH DISTRIBUTION
     IMPEDANCE = UPSUM    (TABLE 2001)       TRIPS = UMODEL  (TABLE 1001)

    0    6   12   18   24   30   36   42   48   54   60
    +----+----+----+----+----+----+----+----+----+----+    %   CUM% COUNT
  0.                                                     0.0   0.0     0
  1. (ALL COUNTS FROM INTERVAL   1 THRU  14 ARE ZERO)    0.0   0.0     0
 15..                                                    0.2   0.2     3
 16.                                                     0.1   0.2     1
 17...                                                   0.3   0.5     5
 18......                                                0.6   1.1    10
 19.......                                               0.7   1.8    12
 20.............                                         1.4   3.2    24
 21...............                                       1.6   4.8    28
 22.............                                         1.4   6.2    24
 23.................                                     2.0   8.2    34
 24..............................                        3.5  11.7    60
 25......................                                2.6  14.2    44
 26..........................                            2.9  17.1    50
 27........................                              2.8  19.9    48
 28............................                          3.2  23.1    55
 29..................................                    4.0  27.1    68
 30...............................                       3.6  30.7    62
 31..................                                    2.0  32.7    35
 32...................................                   4.1  36.8    71
 33....................                                  2.3  39.1    39
 34.....................                                 2.4  41.5    42
 35..........................                            3.0  44.5    51
 36.............................                         3.4  47.9    58
 37................                                      1.9  49.7    32
 38.................                                     1.9  51.7    33
 39......................                                2.6  54.2    44
 40.......................                               2.7  56.9    46
 41..............                                        1.6  58.5    27
 42.......................                               2.7  61.1    46
 43...........................                           3.1  64.2    53
 44..............                                        1.5  65.7    26
 45..............                                        1.6  67.3    27
 46.............                                         1.5  68.7    25
 47..........................                            2.8  71.6    49
 48............                                          1.3  72.9    22
 49...........                                           1.2  74.1    21
 50..............                                        1.5  75.6    26
 51..........................                            3.0  78.6    52
 52......................                                2.5  81.1    43
 53...........                                           1.2  82.3    21
 54...................                                   2.1  84.5    37
 55.......                                               0.7  85.2    12
 56.......                                               0.7  85.9    12
```

```
**** FLINT **** OBSERVED TLF CURVE - TRANSIT WORK TRIPS

                          UFMTR                                PAGE    4

TRAN WORK
                        TRIP LENGTH DISTRIBUTION
IMPEDANCE = UPSUM    (TABLE 2001)        TRIPS = UMODEL  (TABLE 1001)

 0     6    12    18    24    30    36    42    48    54    60
 +-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+      %   CUM%  COUNT
57............                                                   1.3  87.2    22
58...............                                                1.6  88.7    27
59..........                                                     1.0  89.8    18
60......                                                         0.6  90.4    10
61...........                                                    1.2  91.5    20
62.......                                                        0.8  92.3    13
63.........                                                      1.0  93.3    17
64........                                                       0.9  94.1    15
65........                                                       0.9  95.0    15
66...                                                            0.3  95.3     5
67.....                                                          0.5  95.8     9
68......                                                         0.6  96.5    11
69...                                                            0.2  96.7     4
70.....                                                          0.5  97.2     8
71..                                                             0.2  97.3     3
72....                                                           0.4  97.7     7
73..                                                             0.2  97.9     3
74...                                                            0.3  98.2     5
75..                                                             0.2  98.4     3
76.                                                              0.1  98.4     1
77.                                                              0.1  98.5     1
78..                                                             0.1  98.6     2
79...                                                            0.2  98.8     4
80....                                                           0.3  99.2     6
81.                                                              0.0  99.2     0
82.                                                              0.1  99.2     1
83.                                                              0.0  99.2     0
84....                                                           0.3  99.6     6
85..                                                             0.1  99.7     2
86.                                                              0.0  99.7     0
87.                                                              0.1  99.8     1
88.                                                              0.1  99.8     1
89.                                                              0.0  99.8     0
90.                                                              0.0  99.8     0
91.                                                              0.0  99.8     0
92..                                                             0.1  99.9     2
93.                                                              0.0  99.9     0
94.                                                              0.0  99.9     0
95.                                                              0.1 100.0     1
96. (ALL REMAINING COUNTS ARE ZERO)                              0.0 100.0     0

         MEAN        VARIANCE      STD DEV   SUM(COUNT(I))   SUM(I*COUNT(I))
         ----        --------      -------   -------------   ---------------
       40.152        199.055       14.109           1721.            69102.
```

```
     **** FLINT **** OBSERVED TLF CURVE - NONWORK D.A. TRIPS

                              UFMTR                          PAGE    3

     NONWORK DA
                         TRIP LENGTH DISTRIBUTION
     IMPEDANCE = UMODEL  (TABLE 2001)       TRIPS = UMODEL  (TABLE 1001)

   0    10   20   30   40   50   60   70   80   90   100
   +----+----+----+----+----+----+----+----+----+----+      %   CUM% COUNT
  0.                                                      0.0    0.0      0
  1.                                                      0.0    0.0      0
  2....                                                   0.6    0.6   2497
  3....                                                   0.6    1.2   2845
  4.......................                                4.4    5.6  19262
  5...................................                    6.9   12.5  30084
  6....................................                   7.1   19.6  30993
  7.............................................          8.7   28.3  38141
  8...................................                    6.8   35.1  29831
  9......................................                 7.4   42.5  32563
 10................................                       6.1   48.6  26784
 11..................................                     6.6   55.2  29041
 12............................                           5.3   60.6  23421
 13..............................                         5.8   66.4  25417
 14.........................                              4.7   71.1  20800
 15.....................                                  4.0   75.1  17348
 16..................                                     3.3   78.5  14662
 17..................                                     3.4   81.8  14750
 18................                                       3.1   84.9  13488
 19...........                                            2.0   86.9   8597
 20..........                                             1.7   88.6   7522
 21.........                                              1.7   90.3   7359
 22.......                                                1.2   91.5   5305
 23.......                                                1.3   92.7   5536
 24.......                                                1.2   93.9   5114
 25.....                                                  0.8   94.7   3499
 26....                                                   0.5   95.2   2343
 27....                                                   0.6   95.8   2527
 28....                                                   0.5   96.3   2201
 29....                                                   0.5   96.8   2250
 30...                                                    0.5   97.3   2110
 31...                                                    0.3   97.6   1449
 32..                                                     0.3   97.9   1166
 33...                                                    0.3   98.2   1339
 34..                                                     0.2   98.4    917
 35..                                                     0.2   98.6    982
 36..                                                     0.1   98.8    602
 37..                                                     0.1   98.9    481
 38.                                                      0.1   99.0    365
 39..                                                     0.1   99.1    487
 40.                                                      0.1   99.2    313
 41..                                                     0.1   99.3    629
 42..                                                     0.1   99.4    549
 43..                                                     0.1   99.5    502
 44.                                                      0.0   99.6    189
 45.                                                      0.0   99.6    178
 46.                                                      0.0   99.7    193
 47.                                                      0.0   99.7     84
 48.                                                      0.0   99.7    106
 49.                                                      0.1   99.8    279
 50.                                                      0.0   99.8     54
 51.                                                      0.0   99.8    106
 52.                                                      0.0   99.9    176
 53.                                                      0.0   99.9    148
 54.                                                      0.0   99.9    175
 55.                                                      0.0   99.9     55
 56.                                                      0.0   99.9     16
 57.                                                      0.0  100.0     43
 58.                                                      0.0  100.0     92
 59.                                                      0.0  100.0      0
 60.                                                      0.0  100.0      0
 61.                                                      0.0  100.0     36
 62.                                                      0.0  100.0     36
 63. (ALL COUNTS FROM INTERVAL  63 THRU  82 ARE ZERO)     0.0  100.0      0
 83.                                                      0.0  100.0     33
 84.                                                      0.0  100.0     17
 85. (ALL REMAINING COUNTS ARE ZERO)                      0.0  100.0      0

         MEAN         VARIANCE        STD DEV   SUM(COUNT(I))    SUM(I*COUNT(I))
         ----         --------        -------   -------------    ---------------
       12.317          52.784          7.265        438087.           5395880.
```

```
    **** FLINT **** OBSERVED TLF CURVE - NONWORK 1 PASS TRIPS

                                UFMTR                           PAGE    3

    NONWORK 1P
                         TRIP LENGTH DISTRIBUTION
    IMPEDANCE = UMODEL  (TABLE 2001)        TRIPS = UMODEL  (TABLE 1001)

   0    8    16   24   32   40   48   56   64   72   80
   +----+----+----+----+----+----+----+----+----+----+      %   CUM% COUNT
  0.                                                   0.0   0.0     0
  1.                                                   0.0   0.0     0
  2.....                                               0.6   0.6  2136
  3....                                                0.4   1.0  1620
  4..........................                          4.0   5.0 14532
  5...................................                 5.5  10.5 20256
  6........................................            6.2  16.7 22786
  7...................................................  7.9  24.6 29174
  8......................................              6.0  30.6 21914
  9..............................................      7.3  37.9 26696
 10......................................              5.9  43.8 21588
 11.......................................             6.1  49.9 22546
 12.....................................               5.7  55.6 20886
 13....................................                5.5  61.1 20334
 14..................................                  5.2  66.4 19246
 15...........................                         4.1  70.5 15176
 16.........................                           3.8  74.3 14044
 17........................                            3.7  78.0 13568
 18........................                            3.6  81.6 13342
 19................                                    2.5  84.1  9048
 20..............                                      2.0  86.1  7410
 21...........                                         1.6  87.7  5766
 22...........                                         1.6  89.3  5954
 23.........                                           1.2  90.5  4506
 24.......                                             1.0  91.5  3714
 25........                                            1.1  92.7  4154
 26......                                              0.7  93.4  2752
 27......                                              0.7  94.2  2686
 28......                                              0.7  94.9  2646
 29.......                                             0.9  95.8  3318
 30.....                                               0.6  96.4  2148
 31...                                                 0.4  96.8  1456
 32....                                                0.4  97.2  1516
 33...                                                 0.4  97.6  1436
 34...                                                 0.4  97.9  1316
 35..                                                  0.2  98.1   672
 36..                                                  0.1  98.2   376
 37..                                                  0.1  98.3   456
 38..                                                  0.2  98.5   758
 39..                                                  0.1  98.6   326
 40..                                                  0.2  98.8   562
 41..                                                  0.2  99.0   880
 42..                                                  0.1  99.1   338
 43..                                                  0.1  99.2   432
 44..                                                  0.1  99.3   374
 45..                                                  0.1  99.4   380
 46..                                                  0.2  99.6   592
 47.                                                   0.0  99.6   104
 48.                                                   0.0  99.6     0
 49.                                                   0.0  99.7   138
 50.                                                   0.1  99.7   250
 51.                                                   0.0  99.8   110
 52.                                                   0.0  99.8   174
 53.                                                   0.1  99.9   282
 54.                                                   0.0  99.9    40
 55.                                                   0.0  99.9     0
 56.                                                   0.0  99.9     0
 57.                                                   0.0  99.9   138
 58.                                                   0.0  99.9     0
 59.                                                   0.0  99.9     0
 60.                                                   0.0  99.9     0
 61.                                                   0.0  99.9     0
 62.                                                   0.0  99.9    66
 63. (ALL COUNTS FROM INTERVAL  63 THRU  68 ARE ZERO)  0.0  99.9     0
 69.                                                   0.0 100.0    34
 70. (ALL COUNTS FROM INTERVAL  70 THRU  86 ARE ZERO)  0.0 100.0     0
 87.                                                   0.0 100.0    80
 88. (ALL COUNTS FROM INTERVAL  88 THRU  94 ARE ZERO)  0.0 100.0     0
 95.                                                   0.0 100.0    72
 96. (ALL REMAINING COUNTS ARE ZERO)                   0.0 100.0     0

          MEAN       VARIANCE      STD DEV   SUM(COUNT(I))   SUM(I*COUNT(I))
          ----       --------      -------   -------------   ---------------
        13.236         62.703        7.919         367304.          4861508.
```

```
  **** FLINT **** OBSERVED TLF CURVE - NONWORK 2 PASS TRIPS

                              UFMTR                          PAGE    3

  NONWORK 2P
                         TRIP LENGTH DISTRIBUTION
  IMPEDANCE = UMODEL  (TABLE 2001)       TRIPS = UMODEL  (TABLE 1001)

 0    2    4    6    8    10   12   14   16   18   20
 +----+----+----+----+----+----+----+----+----+----+     %  CUM% COUNT
 0.                                                     0.0   0.0     0
 1.                                                     0.0   0.0     0
 2...                                                   0.7   0.7  1095
 3..                                                    0.4   1.1   603
 4..........                                            3.6   4.7  5451
 5.................                                     6.4  11.1  9786
 6..................                                    6.7  17.9 10260
 7..........................                           10.2  28.1 15477
 8...................                                   7.0  35.1 10674
 9...................                                   7.3  42.4 11064
10................                                      5.9  48.3  9036
11.................                                     6.5  54.8  9915
12.............                                         4.6  59.4  6942
13................                                      6.0  65.4  9159
14............                                          4.5  69.9  6771
15..........                                            3.7  73.5  5601
16..........                                            3.5  77.0  5295
17...........                                           4.1  81.1  6177
18........                                              2.9  84.0  4449
19......                                                1.8  85.8  2790
20......                                                1.8  87.7  2772
21.....                                                 1.7  89.3  2571
22.....                                                 1.8  91.1  2682
23....                                                  1.0  92.1  1542
24...                                                   0.8  92.9  1242
25...                                                   1.0  93.9  1515
26..                                                    0.4  94.3   600
27...                                                   0.7  95.0  1041
28...                                                   1.0  96.0  1506
29.                                                     0.1  96.1   204
30..                                                    0.4  96.5   564
31.                                                     0.1  96.6   123
32...                                                   0.6  97.2   921
33..                                                    0.4  97.6   675
34..                                                    0.3  98.0   528
35..                                                    0.3  98.3   414
36..                                                    0.3  98.6   468
37.                                                     0.2  98.8   288
38.                                                     0.1  98.9   195
39.                                                     0.2  99.0   237
40.                                                     0.1  99.1   108
41..                                                    0.2  99.3   354
42.                                                     0.1  99.5   201
43.                                                     0.1  99.5    99
44.                                                     0.1  99.6    93
45.                                                     0.1  99.7    96
46.                                                     0.1  99.8   198
47.                                                     0.0  99.8     0
48.                                                     0.0  99.8     0
49.                                                     0.0  99.8     0
50.                                                     0.0  99.8     0
51.                                                     0.1  99.9   156
52.                                                     0.0  99.9     0
53.                                                     0.0  99.9     0
54.                                                     0.0  99.9    48
55. (ALL COUNTS FROM INTERVAL  55 THRU  82 ARE ZERO)    0.0  99.9     0
83.                                                     0.1 100.0    99
84. (ALL REMAINING COUNTS ARE ZERO)                     0.0 100.0     0

        MEAN       VARIANCE      STD DEV  SUM(COUNT(I))   SUM(I*COUNT(I))
        ----       --------      -------  -------------   ---------------
      12.580         57.418        7.577        152085.          1913298.
```

```
**** FLINT **** OBSERVED TLF CURVE - NONWORK 3+ PASS TRIPS

                          UFMTR                             PAGE    3

NONWORK 3+P
                       TRIP LENGTH DISTRIBUTION
IMPEDANCE = UMODEL   (TABLE 2001)        TRIPS = UMODEL   (TABLE 1001)

 0    10   20   30   40   50   60   70   80   90   100
 +----+----+----+----+----+----+----+----+----+----+         %   CUM% COUNT
 0.                                                         0.0   0.0     0
 1.                                                         0.0   0.0     0
 2........                                                  1.4   1.4  2524
 3.....                                                     0.8   2.2  1476
 4.......................                                   4.3   6.5  7871
 5.........................................                7.9  14.4 14511
 6...............................                           6.1  20.5 11156
 7...............................................           9.2  29.7 16866
 8...............................                           5.9  35.7 10847
 9.......................................                   7.6  43.2 13837
10....................................                      6.9  50.2 12688
11.............................                             5.7  55.8 10366
12............................                              5.4  61.2  9791
13...................                                       3.7  64.8  6716
14.......................                                   4.5  69.3  8181
15.......................                                   4.3  73.6  7928
16................                                          3.0  76.6  5492
17...............                                           2.8  79.4  5119
18....................                                      3.9  83.3  7101
19..........                                                1.8  85.1  3315
20............                                              2.2  87.3  4048
21.........                                                 1.6  89.0  3017
22.......                                                   1.2  90.2  2248
23........                                                  1.4  91.6  2611
24......                                                    1.0  92.6  1814
25.......                                                   1.2  93.9  2228
26......                                                    0.9  94.8  1738
27....                                                      0.7  95.5  1260
28.....                                                     0.8  96.3  1415
29...                                                       0.3  96.6   591
30..                                                        0.1  96.7   208
31.....                                                     0.8  97.5  1512
32.....                                                     0.7  98.3  1371
33...                                                       0.4  98.7   691
34.                                                         0.1  98.7   124
35...                                                       0.4  99.1   705
36..                                                        0.1  99.3   268
37..                                                        0.2  99.5   406
38.                                                         0.0  99.5    76
39..                                                        0.1  99.6   192
40.                                                         0.0  99.7    64
41.                                                         0.1  99.7   114
42.                                                         0.0  99.7     0
43.                                                         0.0  99.7     0
44.                                                         0.0  99.7     0
45.                                                         0.0  99.8    80
46.                                                         0.1  99.8   148
47. (ALL COUNTS FROM INTERVAL  47 THRU  57 ARE ZERO)         0.0  99.8     0
58.                                                         0.1  99.9   140
59.                                                         0.0  99.9     0
60.                                                         0.0  99.9     0
61.                                                         0.0 100.0    80
62.                                                         0.0 100.0     0
63.                                                         0.0 100.0     0
64.                                                         0.0 100.0     0
65.                                                         0.0 100.0     0
66.                                                         0.0 100.0     0
67.                                                         0.0 100.0    68
68. (ALL REMAINING COUNTS ARE ZERO)                          0.0 100.0     0

        MEAN          VARIANCE       STD DEV  SUM(COUNT(I))   SUM(I*COUNT(I))
        ----          --------       -------  -------------   ---------------
       12.364          54.239         7.365       183002.          2262631.
```

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     **** FLINT **** OBSERVED TLF CURVE - TRANSIT NONWORK TRIPS

                                UFMTR                          PAGE    3

     TRAN NWORK
                         TRIP LENGTH DISTRIBUTION
     IMPEDANCE = UPSUM   (TABLE 2001)        TRIPS = UMODEL  (TABLE 1001)

    0    6   12   18   24   30   36   42   48   54   60
    +----+----+----+----+----+----+----+----+----+----+    %  CUM% COUNT
   0.                                                    0.0   0.0     0
   1. (ALL COUNTS FROM INTERVAL   1 THRU  15 ARE ZERO)   0.0   0.0     0
  16.                                                    0.0   0.0     2
  17.                                                    0.0   0.1     1
  18.                                                    0.0   0.1     2
  19.                                                    0.0   0.1     2
  20..                                                   0.1   0.3     7
  21...                                                  0.2   0.5    11
  22....                                                 0.4   0.9    18
  23....                                                 0.4   1.3    18
  24......                                               0.6   1.9    30
  25........                                             0.8   2.8    40
  26............                                         1.3   4.1    62
  27..............                                       1.5   5.6    73
  28.................                                    1.9   7.5    91
  29............................                         3.2  10.7   153
  30...................                                  2.1  12.9   102
  31...........................                          3.1  16.0   146
  32.............................                        3.3  19.3   157
  33.............................                        3.4  22.6   160
  34......................................               4.5  27.1   212
  35...........................                          3.2  30.3   150
  36....................                                 2.3  32.5   108
  37............................                         3.2  35.7   152
  38...............                                      1.6  37.4    77
  39...............                                      1.6  39.0    77
  40........................                             2.7  41.7   130
  41..........................                           2.9  44.7   140
  42............                                         1.3  46.0    63
  43..........                                           1.1  47.1    54
  44.........................                            2.9  50.1   138
  45......................                               2.5  52.6   120
  46.............                                        1.4  54.0    67
  47...........                                          1.2  55.2    59
  48...............................                      3.6  58.9   172
  49................                                     1.7  60.6    83
  50...................                                  2.2  62.8   105
  51...........                                          1.2  64.0    58
  52............                                         1.3  65.4    64
  53.................                                    1.9  67.3    89
  54.........                                            1.0  68.3    48
  55...............                                      1.7  69.9    79
  56..........                                           1.1  71.0    50
  57...............                                      1.6  72.6    78
```

```
    **** FLINT **** OBSERVED TLF CURVE - TRANSIT NONWORK TRIPS

                               UFMTR                         PAGE    4

    TRAN NWORK
                        TRIP LENGTH DISTRIBUTION
    IMPEDANCE = UPSUM   (TABLE 2001)        TRIPS = UMODEL  (TABLE 1001)

   0    6   12   18   24   30   36   42   48   54   60
   +----+----+----+----+----+----+----+----+----+----+    %  CUM% COUNT
 58.............                                        1.4  74.0    66
 59............................                         3.3  77.3   156
 60.......                                              0.8  78.1    36
 61...........                                          1.2  79.3    57
 62......................                               2.6  81.8   122
 63..........                                           1.0  82.9    49
 64.............                                        1.4  84.3    66
 65.........                                            0.9  85.2    44
 66..........                                           1.0  86.2    49
 67.........                                            1.0  87.2    46
 68.............                                        1.4  88.6    66
 69.......                                              0.7  89.3    32
 70.......                                              0.8  90.0    37
 71........                                             0.8  90.9    40
 72........                                             0.8  91.7    38
 73............                                         1.3  93.0    61
 74......                                               0.6  93.6    30
 75........                                             0.8  94.4    38
 76......                                               0.6  95.0    29
 77..........                                           1.1  96.1    53
 78....                                                 0.4  96.5    17
 79.....                                                0.4  96.9    21
 80....                                                 0.4  97.3    17
 81....                                                 0.3  97.6    15
 82...                                                  0.2  97.8     9
 83...                                                  0.2  98.0     9
 84....                                                 0.4  98.4    19
 85...                                                  0.3  98.7    13
 86..                                                   0.1  98.8     6
 87..                                                   0.1  98.9     6
 88...                                                  0.2  99.1    10
 89..                                                   0.1  99.2     4
 90...                                                  0.2  99.4     9
 91.                                                    0.0  99.4     1
 92..                                                   0.1  99.5     5
 93.                                                    0.0  99.5     1
 94...                                                  0.3  99.8    12
 95.                                                    0.0  99.8     1
 96..                                                   0.1  99.9     4
 97.                                                    0.0  99.9     2
 98.                                                    0.0 100.0     1
 99.                                                    0.0 100.0     0
100.                                                    0.0 100.0     1
101. (ALL COUNTS FROM INTERVAL 101 THRU 107 ARE ZERO)   0.0 100.0     0
108.                                                    0.0 100.0     1
109. (ALL REMAINING COUNTS ARE ZERO)                    0.0 100.0     0

         MEAN      VARIANCE     STD DEV  SUM(COUNT(I))   SUM(I*COUNT(I))
         ----      --------     -------  -------------   ---------------
       47.261       250.003      15.811          4747.           224346.
```

```
**** FLINT **** ESTIMATED TLF CURVE - WORK TRIPS

                              Model 4                             PAGE    3

WORKDA
                        TRIP LENGTH DISTRIBUTION
IMPEDANCE = UMODEL  (TABLE 2001)        TRIPS = DRIVE AL(TABLE 1001)

  0     6    12    18    24    30    36    42    48    54    60
  +-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+     %  CUM%  COUNT
 0.                                                                0.0   0.0      0
 1.                                                                0.0   0.0      0
 2.                                                                0.0   0.0     56
 3..                                                               0.1   0.2    220
 4..........                                                       0.9   1.1   1620
 5...............                                                  1.4   2.5   2464
 6..............                                                   1.3   3.8   2327
 7.................................                                3.3   7.1   5751
 8..........................                                       2.5   9.7   4442
 9...................................                              3.5  13.1   6052
10...........................................                      4.2  17.3   7340
11......................................................           5.4  22.7   9424
12....................................................             5.2  27.9   9010
13......................................................           5.4  33.2   9421
14......................................................           5.4  38.6   9363
15.....................................................            5.3  43.9   9226
16......................................................           5.4  49.2   9378
17...........................................                      4.2  53.5   7385
18.............................................................    6.0  59.5  10482
19..........................................                       4.1  63.6   7209
20..........................................                       4.1  67.7   7180
21..........................................                       4.2  71.9   7323
22................................                                 3.1  75.0   5507
23..........................                                       2.5  77.5   4411
24......................                                           2.1  79.7   3738
25...........................                                      2.7  82.3   4659
26.....................                                            2.1  84.4   3647
27.................                                                1.6  86.1   2849
28..................                                               1.8  87.8   3069
29.................                                                1.6  89.4   2797
30.................                                                1.6  91.0   2842
31..............                                                   1.3  92.4   2307
32...........                                                      1.0  93.4   1778
33....                                                             0.3  93.7    601
34..........                                                       0.9  94.6   1611
35........                                                         0.8  95.4   1333
36.....                                                            0.4  95.8    747
37....                                                             0.4  96.2    650
38....                                                             0.3  96.5    561
39.....                                                            0.4  97.0    782
40...                                                              0.3  97.2    466
41...                                                              0.2  97.5    394
42...                                                              0.3  97.7    462
43...                                                              0.3  98.0    453
```

```
     **** FLINT **** ESTIMATED TLF CURVE - WORK TRIPS
                                     Model 4                         PAGE    4

     WORKDA
                                TRIP LENGTH DISTRIBUTION
     IMPEDANCE = UMODEL   (TABLE 2001)          TRIPS = DRIVE AL(TABLE 1001)

    0     6    12    18    24    30    36    42    48    54    60
    +-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+       %   CUM%  COUNT
  44...                                                              0.2  98.2    384
  45..                                                               0.2  98.4    310
  46..                                                               0.2  98.6    307
  47..                                                               0.1  98.7    174
  48...                                                              0.2  98.9    379
  49..                                                               0.2  99.0    290
  50..                                                               0.1  99.2    229
  51...                                                              0.3  99.4    457
  52..                                                               0.1  99.5    190
  53..                                                               0.1  99.6    112
  54.                                                                0.0  99.6     86
  55.                                                                0.0  99.7     15
  56..                                                               0.1  99.7    128
  57.                                                                0.0  99.8     61
  58.                                                                0.0  99.8     29
  59.                                                                0.0  99.8     28
  60..                                                               0.1  99.9    119
  61.                                                                0.0  99.9     29
  62.                                                                0.0  99.9     29
  63.                                                                0.1  99.9     89
  64.                                                                0.0  99.9      0
  65.                                                                0.0  99.9      0
  66.                                                                0.0  99.9      0
  67.                                                                0.0  99.9      0
  68.                                                                0.0 100.0     60
  69.                                                                0.0 100.0     14
  70.                                                                0.0 100.0     15
  71. (ALL REMAINING COUNTS ARE ZERO)                                0.0 100.0      0

           MEAN         VARIANCE        STD DEV   SUM(COUNT(I))     SUM(I*COUNT(I))
           ----         --------        -------   -------------     ---------------
         18.279           81.271          9.015         174871.            3196480.
```

```
**** FLINT **** ESTIMATED TLF CURVE - WORK TRIPS
```

Model 4

```
                                                                PAGE    5
WORK 1P
                     TRIP LENGTH DISTRIBUTION
IMPEDANCE = UMODEL  (TABLE 2001)        TRIPS = 1 PASS  (TABLE 1002)

  0    8    16   24   32   40   48   56   64   72   80
  +----+----+----+----+----+----+----+----+----+----+      %   CUM%  COUNT
  0.                                                        0.0   0.0      0
  1.                                                        0.0   0.0      0
  2.                                                        0.0   0.0      5
  3..                                                       0.1   0.2     24
  4.......                                                  0.9   1.1    182
  5..........                                               1.4   2.5    272
  6.........                                                1.3   3.9    258
  7.....................                                    3.3   7.1    625
  8.................                                        2.6   9.7    501
  9.......................                                  3.5  13.2    669
 10...........................                              4.3  17.5    821
 11...................................                      5.6  23.0   1069
 12..................................                       5.3  28.4   1021
 13...................................                      5.5  33.9   1065
 14...................................                      5.4  39.3   1044
 15..................................                       5.3  44.7   1021
 16..................................                       5.4  50.1   1036
 17............................                             4.3  54.3    822
 18......................................                   6.0  60.3   1155
 19..........................                               4.1  64.4    781
 20..........................                               4.1  68.5    784
 21...........................                              4.2  72.7    807
 22....................                                     3.0  75.7    585
 23.................                                        2.5  78.3    485
 24..............                                           2.1  80.4    400
 25.................                                        2.6  82.9    496
 26..............                                           2.1  85.0    398
 27...........                                              1.6  86.6    300
 28...........                                              1.7  88.2    319
 29...........                                              1.6  89.8    304
 30...........                                              1.6  91.4    298
 31.........                                                1.3  92.6    243
 32.......                                                  1.0  93.6    185
 33...                                                      0.3  93.9     62
 34......                                                   0.9  94.8    167
 35.....                                                    0.7  95.5    138
 36....                                                     0.4  95.9     82
 37...                                                      0.4  96.3     68
 38...                                                      0.3  96.6     64
 39....                                                     0.4  97.1     86
 40...                                                      0.2  97.3     48
 41..                                                       0.2  97.5     41
 42...                                                      0.2  97.8     47
 43...                                                      0.2  98.0     48
```

```
**** FLINT **** ESTIMATED TLF CURVE - WORK TRIPS
                              Model 4                          PAGE    6

 WORK 1P
                          TRIP LENGTH DISTRIBUTION
 IMPEDANCE = UMODEL   (TABLE 2001)        TRIPS = 1 PASS   (TABLE 1002)

 0     8    16    24    32    40    48    56    64    72    80
 +-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+       %   CUM%  COUNT
44..                                                                0.2  98.2     42
45..                                                                0.2  98.4     34
46..                                                                0.2  98.6     35
47..                                                                0.1  98.7     19
48..                                                                0.2  98.9     40
49..                                                                0.1  99.1     28
50..                                                                0.1  99.2     24
51..                                                                0.2  99.4     46
52..                                                                0.1  99.5     21
53.                                                                 0.1  99.6     12
54.                                                                 0.1  99.6     10
55.                                                                 0.0  99.7      2
56.                                                                 0.1  99.7     14
57.                                                                 0.0  99.8      6
58.                                                                 0.0  99.8      3
59.                                                                 0.0  99.8      3
60.                                                                 0.1  99.9     13
61.                                                                 0.0  99.9      3
62.                                                                 0.0  99.9      4
63.                                                                 0.0  99.9      9
64.                                                                 0.0  99.9      0
65.                                                                 0.0  99.9      0
66.                                                                 0.0  99.9      0
67.                                                                 0.0  99.9      0
68.                                                                 0.0 100.0      7
69.                                                                 0.0 100.0      2
70.                                                                 0.0 100.0      2
71. (ALL REMAINING COUNTS ARE ZERO)                                 0.0 100.0      0

        MEAN        VARIANCE       STD DEV   SUM(COUNT(I))    SUM(I*COUNT(I))
        ----        --------       -------   -------------    ---------------
      18.125          80.090         8.949          19205.           348092.
```

```
    **** FLINT **** ESTIMATED TLF CURVE - WORK TRIPS

                          Model 4                          PAGE     7

    WORK 2P
                          TRIP LENGTH DISTRIBUTION
    IMPEDANCE = UMODEL   (TABLE 2001)        TRIPS = 2PASS    (TABLE 1003)

  0    6   12   18   24   30   36   42   48   54   60
  +----+----+----+----+----+----+----+----+----+----+    %   CUM%  COUNT
 0.                                                    0.0    0.0      0
 1.                                                    0.0    0.0      0
 2.                                                    0.0    0.0      2
 3..                                                   0.1    0.2      6
 4..........                                           1.0    1.2     45
 5..............                                       1.5    2.7     66
 6............                                         1.3    4.1     58
 7...............................                      3.4    7.5    149
 8.........................                            2.8   10.3    121
 9...............................                      3.4   13.7    149
10......................................               4.4   18.1    193
11................................................     5.6   23.7    242
12..............................................       5.3   29.0    231
13...............................................      5.4   34.4    237
14...............................................      5.4   39.8    234
15.............................................        5.1   44.9    223
16............................................         5.1   50.0    221
17.....................................                4.2   54.2    182
18..................................................   5.8   60.0    253
19.....................................                4.2   64.2    185
20...................................                  4.0   68.2    175
21....................................                 4.1   72.4    179
22............................                         3.1   75.5    135
23......................                               2.5   77.9    108
24....................                                 2.1   80.1     93
25......................                               2.4   82.5    106
26...................                                  2.0   84.5     89
27...............                                      1.6   86.2     71
28...............                                      1.7   87.9     73
29...............                                      1.7   89.6     74
30..............                                       1.5   91.1     66
31...........                                          1.2   92.2     51
32.........                                            1.0   93.2     43
33....                                                 0.3   93.5     14
34.........                                            0.9   94.5     41
35........                                             0.8   95.3     35
36.....                                                0.5   95.8     20
37....                                                 0.4   96.1     17
38....                                                 0.4   96.5     16
39.....                                                0.5   97.0     20
40...                                                  0.3   97.2     12
41...                                                  0.2   97.5      9
42...                                                  0.3   97.7     13
43...                                                  0.2   98.0     10
```

```
**** FLINT **** ESTIMATED TLF CURVE - WORK TRIPS
                                Model 4                              PAGE    8
WORK 2P
                         TRIP LENGTH DISTRIBUTION
IMPEDANCE = UMODEL  (TABLE 2001)          TRIPS = 2PASS    (TABLE 1003)

   0    6    12   18   24   30   36   42   48   54   60
   +----+----+----+----+----+----+----+----+----+----+     %   CUM% COUNT
44...                                                     0.3  98.2   11
45...                                                     0.2  98.4    9
46..                                                      0.2  98.6    7
47..                                                      0.1  98.7    3
48...                                                     0.2  98.9    8
49..                                                      0.2  99.0    7
50..                                                      0.1  99.2    6
51...                                                     0.3  99.4   11
52..                                                      0.1  99.5    6
53..                                                      0.1  99.6    4
54.                                                       0.0  99.7    2
55.                                                       0.0  99.7    0
56..                                                      0.1  99.7    3
57.                                                       0.0  99.8    1
58.                                                       0.0  99.8    1
59.                                                       0.0  99.8    0
60.                                                       0.0  99.8    2
61.                                                       0.0  99.9    1
62.                                                       0.0  99.9    0
63.                                                       0.0  99.9    2
64.                                                       0.0  99.9    0
65.                                                       0.0  99.9    0
66.                                                       0.0  99.9    0
67.                                                       0.0  99.9    0
68.                                                       0.0 100.0    2
69.                                                       0.0 100.0    1
70.                                                       0.0 100.0    1
71. (ALL REMAINING COUNTS ARE ZERO)                       0.0 100.0    0

       MEAN        VARIANCE      STD DEV  SUM(COUNT(I))   SUM(I*COUNT(I))
       ----        --------      -------  -------------   ---------------
      18.147         82.500        9.083          4355.            79030.
```

```
    **** FLINT **** ESTIMATED TLF CURVE - WORK TRIPS

                              Model 4                          PAGE    9

    WORK 3+P
                        TRIP LENGTH DISTRIBUTION
    IMPEDANCE = UMODEL  (TABLE 2001)        TRIPS = 3+ PASS (TABLE 1004)

    0    8   16   24   32   40   48   56   64   72   80
    +----+----+----+----+----+----+----+----+----+----+    %  CUM% COUNT
   0.                                                    0.0   0.0     0
   1.                                                    0.0   0.0     0
   2.                                                    0.0   0.0     0
   3..                                                   0.1   0.1     3
   4......                                               0.9   1.0    22
   5..........                                           1.4   2.4    36
   6.........                                            1.2   3.6    31
   7....................                                 3.1   6.7    80
   8................                                     2.4   9.1    63
   9...................                                  2.9  12.1    76
  10.........................                            3.9  16.0   101
  11.................................                    5.1  21.1   132
  12....................................                 5.6  26.7   145
  13....................................                 5.6  32.3   144
  14.......................................              6.1  38.4   157
  15...................................                  5.4  43.8   140
  16....................................                 5.5  49.4   143
  17..............................                       4.7  54.1   121
  18.....................................                5.8  59.9   149
  19..........................                           4.0  63.9   104
  20............................                         4.4  68.3   113
  21............................                         4.4  72.7   113
  22.....................                                3.2  75.8    82
  23................                                     2.4  78.2    61
  24..............                                       2.1  80.3    55
  25.................                                    2.5  82.8    64
  26.............                                        1.9  84.7    48
  27.........                                            1.4  86.0    35
  28...........                                          1.6  87.6    40
  29...........                                          1.6  89.1    40
  30.............                                        1.9  91.1    50
  31.........                                            1.4  92.4    35
  32......                                               0.8  93.2    20
  33...                                                  0.4  93.6    10
  34.......                                              0.9  94.5    23
  35......                                               0.7  95.2    19
  36....                                                 0.4  95.7    11
  37...                                                  0.3  96.0     9
  38...                                                  0.3  96.4     9
  39....                                                 0.5  96.9    13
  40..                                                   0.2  97.1     6
  41...                                                  0.3  97.4     8
  42..                                                   0.2  97.6     4
  43...                                                  0.4  97.9    10
```

```
  **** FLINT **** ESTIMATED TLF CURVE - WORK TRIPS

                    Model 4                           PAGE    10
  WORK 3+P
                          TRIP LENGTH DISTRIBUTION
  IMPEDANCE = UMODEL  (TABLE 2001)        TRIPS = 3+ PASS (TABLE 1004)

   0    8    16    24    32    40    48    56    64    72    80   ,
   +----+----+----+----+----+----+----+----+----+----+            %   CUM%  COUNT
44..                                                             0.2  98.2     6
45..                                                             0.2  98.3     4
46..                                                             0.2  98.5     4
47..                                                             0.1  98.6     3
48...                                                            0.3  98.9     8
49..                                                             0.2  99.1     4
50..                                                             0.1  99.2     3
51..                                                             0.2  99.4     6
52..                                                             0.2  99.6     4
53.                                                              0.1  99.7     2
54.                                                              0.0  99.7     1
55.                                                              0.0  99.7     0
56.                                                              0.0  99.7     1
57.                                                              0.0  99.7     0
58.                                                              0.0  99.7     0
59.                                                              0.0  99.8     1
60.                                                              0.0  99.8     1
61.                                                              0.0  99.8     1
62.                                                              0.0  99.9     1
63.                                                              0.1 100.0     2
64.                                                              0.0 100.0     0
65.                                                              0.0 100.0     0
66.                                                              0.0 100.0     0
67.                                                              0.0 100.0     0
68.                                                              0.0 100.0     1
69. (ALL REMAINING COUNTS ARE ZERO)                              0.0 100.0     0

         MEAN        VARIANCE       STD DEV   SUM(COUNT(I))     SUM(I*COUNT(I))
         ----        --------       -------   -------------     ---------------
       18.320          80.400         8.967           2578.              47230.
```

```
**** FLINT **** ESTIMATED TLF CURVE - TRANSIT WORK TRIPS
                        Model 4                             PAGE    3

 TRAN WORK
                         TRIP LENGTH DISTRIBUTION
 IMPEDANCE = UPSUM    (TABLE 2001)        TRIPS = TRANSIT (TABLE 1005)

  0    6    12   18   24   30   36   42   48   54   60
  +----+----+----+----+----+----+----+----+----+----+        %   CUM%  COUNT
 0...............                                          1.6   1.6    40
 1. (ALL COUNTS FROM INTERVAL   1 THRU   7 ARE ZERO)       0.0   1.6     0
 8..                                                       0.2   1.8     4
 9.                                                        0.0   1.8     0
10.....                                                    0.5   2.3    13
11.                                                        0.0   2.3     0
12....                                                     0.4   2.7     9
13.                                                        0.0   2.7     0
14.........                                                1.0   3.7    24
15.                                                        0.0   3.7     0
16.....                                                    0.5   4.2    12
17..                                                       0.1   4.3     3
18..............                                           1.5   5.8    37
19.........                                                1.0   6.8    24
20.......                                                  0.8   7.6    19
21..........                                               1.1   8.6    26
22.............                                            1.5  10.1    36
23...........                                              1.1  11.3    28
24...........                                              1.2  12.5    29
25.................................                        3.9  16.3    95
26.........................                                2.9  19.2    70
27..........................                               3.0  22.2    74
28........................                                 2.8  25.0    68
29........................                                 2.7  27.7    66
30..........................                               3.0  30.8    74
31..................                                       2.1  32.9    51
32............................. .........                  4.5  37.4   110
33..................                                       2.0  39.4    49
34..........................                               3.4  42.7    82
35.......................... ....                          3.6  46.4    89
36........................... .                            3.3  49.7    81
37.......                                                  0.7  50.4    17
38...........                                              1.2  51.6    29
39.............                                            1.4  53.0    35
40.....................                                    2.5  55.5    61
41................                                         1.8  57.3    44
42.................                                        2.0  59.3    48
43.............                                            1.5  60.8    37
44............                                             1.3  62.1    32
45...............                                          1.7  63.8    41
46.........                                                1.0  64.8    25
47.....................                                    2.4  67.2    59
48..................                                       2.0  69.3    50
49...........                                              1.2  70.5    30
```

```
**** FLINT **** ESTIMATED TLF CURVE - TRANSIT WORK TRIPS

                      Model 4                      PAGE    4

TRAN WORK
                       TRIP LENGTH DISTRIBUTION
IMPEDANCE = UPSUM    (TABLE 2001)       TRIPS = TRANSIT (TABLE 1005)

  0    6   12   18   24   30   36   42   48   54   60
  +----+----+----+----+----+----+----+----+----+----+      %  CUM% COUNT
50............                                           1.4  71.9    33
51..............                                         1.5  73.4    37
52.................                                      2.0  75.3    48
53........                                               0.9  76.2    21
54......................                                 2.5  78.7    62
55.............                                          1.5  80.2    36
56..........                                             1.1  81.3    27
57.............                                          1.4  82.7    34
58...........                                            1.2  83.9    29
59............                                           1.3  85.2    32
60....................                                   2.3  87.5    55
61.........                                              1.0  88.4    24
62......                                                 0.6  89.0    14
63........                                               0.8  89.8    20
64.....                                                  0.5  90.4    13
65.........                                              1.0  91.4    24
66............                                           1.4  92.7    33
67...                                                    0.3  93.0     7
68.............                                          1.4  94.4    34
69........                                               0.9  95.2    21
70...........                                            1.1  96.4    28
71.....                                                  0.5  96.9    13
72...                                                    0.2  97.1     5
73.....                                                  0.5  97.6    11
74............                                           1.3  98.9    32
75.                                                      0.0  98.9     1
76..                                                     0.1  99.1     3
77..                                                     0.2  99.2     4
78..                                                     0.1  99.3     3
79..                                                     0.1  99.4     2
80...                                                    0.2  99.6     5
81.                                                      0.0  99.6     0
82...                                                    0.2  99.8     5
83.                                                      0.0  99.8     0
84..                                                     0.1  99.9     2
85..                                                     0.1 100.0     2
86. (ALL REMAINING COUNTS ARE ZERO)                      0.0 100.0     0

        MEAN       VARIANCE      STD DEV  SUM(COUNT(I))   SUM(I*COUNT(I))
        ----       --------      -------  -------------   ---------------
      40.369       263.571       16.235          2441.             98541.
```

```
   **** FLINT **** ESTIMATED TLF CURVE - NONWORK TRIPS
                                 Model 6                        PAGE   3
   NWORKDA
                        TRIP LENGTH DISTRIBUTION
   IMPEDANCE = UMODEL   (TABLE 2001)          TRIPS = DRIVE AL(TABLE 1001)

  0   10   20   30   40   50   60   70   80   90  100
  +----+----+----+----+----+----+----+----+----+----+        %   CUM%  COUNT
 0.                                                        0.0    0.0      0
 1.                                                        0.0    0.0      0
 2.....                                                    0.7    0.7   3161
 3....                                                     0.6    1.3   2479
 4......................                                   4.1    5.5  17747
 5..................................                       6.6   12.0  28145
 6..................................                       6.6   18.7  28330
 7.............................................            8.8   27.5  37619
 8.................................                        6.4   33.9  27455
 9......................................                   7.4   41.3  31629
10................................                         6.1   47.4  26236
11................................                         6.3   53.7  26918
12...........................                              5.3   59.0  22641
13............................                             5.3   64.3  22850
14.........................                                4.8   69.1  20569
15.....................                                    4.0   73.1  17144
16..................                                       3.4   76.6  14748
17..................                                       3.5   80.1  14849
18..................                                       3.4   83.4  14406
19...........                                              2.1   85.5   8935
20...........                                              1.9   87.4   8202
21.........                                                1.6   89.1   7032
22........                                                 1.4   90.5   6144
23.......                                                  1.3   91.8   5375
24......                                                   1.0   92.8   4483
25......                                                   1.0   93.8   4290
26....                                                     0.7   94.5   2814
27....                                                     0.7   95.1   2823
28....                                                     0.7   95.8   2896
29....                                                     0.6   96.4   2365
30...                                                      0.4   96.8   1869
31...                                                      0.4   97.2   1705
32...                                                      0.4   97.6   1840
33...                                                      0.4   98.0   1566
34..                                                       0.3   98.2   1074
35..                                                       0.2   98.5   1039
36..                                                       0.2   98.6    642
37..                                                       0.1   98.8    620
38..                                                       0.1   98.9    537
39..                                                       0.1   99.0    465
40.                                                        0.1   99.1    395
41..                                                       0.2   99.3    745
42.                                                        0.1   99.4    407
43.                                                        0.1   99.5    388
```

```
**** FLINT **** ESTIMATED TLF CURVE - NONWORK TRIPS
                           Model 6                          PAGE    4
NWORKDA
                         TRIP LENGTH DISTRIBUTION
IMPEDANCE = UMODEL  (TABLE 2001)        TRIPS = DRIVE AL(TABLE 1001)

    0    10    20    30    40    50    60    70    80    90   100
    +----+----+----+----+----+----+----+----+----+----+          %   CUM%  COUNT
 44.                                                         0.1  99.5   250
 45.                                                         0.1  99.6   280
 46.                                                         0.1  99.7   423
 47.                                                         0.0  99.7    72
 48.                                                         0.0  99.7    40
 49.                                                         0.0  99.7   160
 50.                                                         0.0  99.8   115
 51.                                                         0.0  99.8   142
 52.                                                         0.0  99.8   130
 53.                                                         0.0  99.9   162
 54.                                                         0.0  99.9   101
 55.                                                         0.0  99.9    21
 56.                                                         0.0  99.9     6
 57.                                                         0.0  99.9    69
 58.                                                         0.0  99.9    92
 59.                                                         0.0  99.9     0
 60.                                                         0.0  99.9     0
 61.                                                         0.0 100.0    43
 62.                                                         0.0 100.0    39
 63.                                                         0.0 100.0     0
 64.                                                         0.0 100.0     0
 65.                                                         0.0 100.0     0
 66.                                                         0.0 100.0     0
 67.                                                         0.0 100.0    26
 68.                                                         0.0 100.0     0
 69.                                                         0.0 100.0    13
 70. (ALL COUNTS FROM INTERVAL  70 THRU  82 ARE ZERO)        0.0 100.0     0
 83.                                                         0.0 100.0    50
 84.                                                         0.0 100.0     6
 85.                                                         0.0 100.0     0
 86.                                                         0.0 100.0     0
 87.                                                         0.0 100.0    30
 88. (ALL COUNTS FROM INTERVAL  88 THRU  94 ARE ZERO)        0.0 100.0     0
 95.                                                         0.0 100.0    28
 96. (ALL REMAINING COUNTS ARE ZERO)                         0.0 100.0     0

         MEAN       VARIANCE       STD DEV  SUM(COUNT(I))    SUM(I*COUNT(I))
         ----       --------       -------  -------------    ---------------
       12.650         57.222         7.565        427875.           5412729.
```

```
  **** FLINT **** ESTIMATED TLF CURVE - NONWORK TRIPS

                            Model 6                             PAGE    5
  NWORK 1P
                      TRIP LENGTH DISTRIBUTION
  IMPEDANCE = UMODEL  (TABLE 2001)        TRIPS = 1 PASS  (TABLE 1002)

   0    10   20   30   40   50   60   70   80   90  100
   +----+----+----+----+----+----+----+----+----+----+        %  CUM% COUNT
  0.                                                        0.0   0.0     0
  1.                                                        0.0   0.0     0
  2.....                                                    0.7   0.7  2674
  3....                                                     0.6   1.3  2109
  4......................                                   4.1   5.4 15176
  5..................................                       6.5  12.0 23966
  6..................................                       6.6  18.6 24183
  7.............................................            8.7  27.3 31989
  8.................................                        6.4  33.7 23570
  9......................................                   7.4  41.1 27156
 10................................                         6.2  47.3 22584
 11.................................                        6.3  53.6 23167
 12............................                             5.4  59.0 19661
 13............................                             5.4  64.4 19827
 14.........................                                4.8  69.2 17662
 15.....................                                    4.0  73.2 14777
 16..................                                       3.5  76.7 12695
 17..................                                       3.5  80.2 12766
 18..................                                       3.4  83.5 12351
 19...........                                              2.1  85.6  7644
 20...........                                              1.9  87.5  7005
 21.........                                                1.6  89.2  6015
 22........                                                 1.4  90.6  5225
 23.......                                                  1.3  91.8  4587
 24......                                                   1.0  92.9  3818
 25......                                                   1.0  93.9  3625
 26....                                                     0.7  94.5  2393
 27....                                                     0.7  95.2  2404
 28....                                                     0.7  95.8  2455
 29....                                                     0.5  96.4  2003
 30...                                                      0.4  96.8  1593
 31...                                                      0.4  97.2  1447
 32...                                                      0.4  97.6  1564
 33...                                                      0.4  98.0  1324
 34..                                                       0.2  98.2   915
 35..                                                       0.2  98.5   890
 36..                                                       0.2  98.6   552
 37..                                                       0.1  98.8   527
 38..                                                       0.1  98.9   454
 39..                                                       0.1  99.0   402
 40.                                                        0.1  99.1   330
 41..                                                       0.2  99.3   629
 42.                                                        0.1  99.4   353
 43.                                                        0.1  99.5   329
```

```
  **** FLINT **** ESTIMATED TLF CURVE - NONWORK TRIPS
                              Model 6                                PAGE    6
  NWORK 1P
                           TRIP LENGTH DISTRIBUTION
  IMPEDANCE = UMODEL  (TABLE 2001)         TRIPS = 1 PASS  (TABLE 1002)

    0    10    20    30    40    50    60    70    80    90   100
    +----+----+----+----+----+----+----+----+----+----+      %   CUM%  COUNT
 44..                                                        0.1  99.5   210
 45.                                                         0.1  99.6   236
 46..                                                        0.1  99.7   368
 47.                                                         0.0  99.7    63
 48.                                                         0.0  99.7    34
 49.                                                         0.0  99.8   135
 50.                                                         0.0  99.8   100
 51.                                                         0.0  99.8   120
 52.                                                         0.0  99.8   112
 53.                                                         0.0  99.9   139
 54.                                                         0.0  99.9    87
 55.                                                         0.0  99.9    17
 56.                                                         0.0  99.9     5
 57.                                                         0.0  99.9    58
 58.                                                         0.0  99.9    74
 59.                                                         0.0  99.9     0
 60.                                                         0.0  99.9     0
 61.                                                         0.0 100.0    38
 62.                                                         0.0 100.0    33
 63.                                                         0.0 100.0     0
 64.                                                         0.0 100.0     0
 65.                                                         0.0 100.0     0
 66.                                                         0.0 100.0     0
 67.                                                         0.0 100.0    22
 68.                                                         0.0 100.0     0
 69.                                                         0.0 100.0    11
 70. (ALL COUNTS FROM INTERVAL  70 THRU  82 ARE ZERO)        0.0 100.0     0
 83.                                                         0.0 100.0    43
 84.                                                         0.0 100.0     6
 85.                                                         0.0 100.0     0
 86.                                                         0.0 100.0     0
 87.                                                         0.0 100.0    26
 88. (ALL COUNTS FROM INTERVAL  88 THRU  94 ARE ZERO)        0.0 100.0     0
 95.                                                         0.0 100.0    23
 96. (ALL REMAINING COUNTS ARE ZERO)                         0.0 100.0     0

         MEAN        VARIANCE       STD DEV   SUM(COUNT(I))    SUM(I*COUNT(I))
         ----        --------       -------   -------------    ---------------
       12.646         56.889         7.542         366756.            4638094.
```

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 **** FLINT **** ESTIMATED TLF CURVE - NONWORK TRIPS

                        Model 6                            PAGE    7
 NWORK 2P
                         TRIP LENGTH DISTRIBUTION
 IMPEDANCE = UMODEL  (TABLE 2001)        TRIPS = 2PASS   (TABLE 1003)

    0   10   20   30   40   50   60   70   80   90  100
    +----+----+----+----+----+----+----+----+----+----+     %   CUM%  COUNT
   0.                                                     0.0    0.0      0
   1.                                                     0.0    0.0      0
   2.....                                                 0.7    0.7   1108
   3....                                                  0.6    1.3    874
   4......................                                4.1    5.4   6284
   5..................................                    6.5   12.0   9919
   6..................................                    6.6   18.6  10007
   7.............................................         8.7   27.3  13246
   8.................................                     6.4   33.7   9780
   9......................................                7.4   41.1  11247
  10................................                      6.2   47.3   9354
  11.................................                     6.3   53.6   9620
  12............................                          5.4   59.0   8136
  13............................                          5.4   64.4   8185
  14.........................                             4.8   69.2   7314
  15.....................                                 4.0   73.2   6125
  16..................                                    3.5   76.7   5257
  17..................                                    3.5   80.1   5271
  18..................                                    3.4   83.5   5134
  19...........                                           2.1   85.6   3163
  20...........                                           1.9   87.5   2901
  21.........                                             1.6   89.2   2481
  22........                                              1.4   90.6   2164
  23.......                                               1.2   91.8   1896
  24......                                                1.0   92.9   1581
  25......                                                1.0   93.9   1507
  26....                                                  0.7   94.5    994
  27....                                                  0.7   95.2   1003
  28....                                                  0.7   95.8   1015
  29....                                                  0.5   96.4    826
  30...                                                   0.4   96.8    658
  31...                                                   0.4   97.2    603
  32...                                                   0.4   97.6    641
  33...                                                   0.4   98.0    549
  34..                                                    0.2   98.2    376
  35..                                                    0.2   98.5    370
  36..                                                    0.1   98.6    227
  37..                                                    0.1   98.8    215
  38..                                                    0.1   98.9    188
  39..                                                    0.1   99.0    166
  40.                                                     0.1   99.1    138
  41..                                                    0.2   99.3    258
  42.                                                     0.1   99.4    146
  43.                                                     0.1   99.5    139
```

```
 **** FLINT **** ESTIMATED TLF CURVE - NONWORK TRIPS

                         Model 6                          PAGE    8

 NWORK 2P
                           TRIP LENGTH DISTRIBUTION
 IMPEDANCE = UMODEL   (TABLE 2001)        TRIPS = 2PASS    (TABLE 1003)

  0    10    20    30    40    50    60    70    80    90   100
  +----+----+----+----+----+----+----+----+----+----+          %   CUM% COUNT
 44.                                                         0.1  99.5    87
 45.                                                         0.1  99.6   100
 46.                                                         0.1  99.7   150
 47.                                                         0.0  99.7    27
 48.                                                         0.0  99.7    14
 49.                                                         0.0  99.8    55
 50.                                                         0.0  99.8    41
 51.                                                         0.0  99.8    49
 52.                                                         0.0  99.8    48
 53.                                                         0.0  99.9    58
 54.                                                         0.0  99.9    35
 55.                                                         0.0  99.9     7
 56.                                                         0.0  99.9     2
 57.                                                         0.0  99.9    24
 58.                                                         0.0  99.9    30
 59.                                                         0.0  99.9     0
 60.                                                         0.0  99.9     0
 61.                                                         0.0 100.0    16
 62.                                                         0.0 100.0    14
 63.                                                         0.0 100.0     0
 64.                                                         0.0 100.0     0
 65.                                                         0.0 100.0     0
 66.                                                         0.0 100.0     0
 67.                                                         0.0 100.0     9
 68.                                                         0.0 100.0     0
 69.                                                         0.0 100.0     4
 70. (ALL COUNTS FROM INTERVAL  70 THRU  82 ARE ZERO)        0.0 100.0     0
 83.                                                         0.0 100.0    18
 84.                                                         0.0 100.0     2
 85.                                                         0.0 100.0     0
 86.                                                         0.0 100.0     0
 87.                                                         0.0 100.0    11
 88. (ALL COUNTS FROM INTERVAL  88 THRU  94 ARE ZERO)        0.0 100.0     0
 95.                                                         0.0 100.0    10
 96. (ALL REMAINING COUNTS ARE ZERO)                         0.0 100.0     0

        MEAN       VARIANCE     STD DEV   SUM(COUNT(I))    SUM(I*COUNT(I))
        ----       --------     -------   -------------    ---------------
      12.645        56.870       7.541         151877.            1920465.
```

```
   **** FLINT **** ESTIMATED TLF CURVE - NONWORK TRIPS
                            Model 6                          PAGE    9
   NWORK 3+P
                       TRIP LENGTH DISTRIBUTION
   IMPEDANCE = UMODEL  (TABLE 2001)        TRIPS = 3+ PASS (TABLE 1004)

   0   10   20   30   40   50   60   70   80   90  100
   +----+----+----+----+----+----+----+----+----+----+      %   CUM%  COUNT
  0.                                                    0.0    0.0      0
  1.                                                    0.0    0.0      0
  2....                                                 0.7    0.7   1311
  3....                                                 0.6    1.2   1082
  4.....................                                4.1    5.3   7899
  5.................................                    6.5   11.8  12572
  6..................................                   6.5   18.3  12627
  7............................................         8.7   27.0  16798
  8.................................                    6.4   33.5  12465
  9......................................               7.3   40.8  14163
 10................................                     6.2   47.0  12005
 11................................                     6.3   53.3  12189
 12.............................                        5.5   58.8  10677
 13.............................                        5.6   64.4  10758
 14..........................                           4.9   69.3   9505
 15......................                               4.2   73.4   8032
 16...................                                  3.5   76.9   6838
 17..................                                   3.5   80.4   6702
 18..................                                   3.4   83.8   6513
 19...........                                          2.1   85.8   3987
 20...........                                          1.9   87.7   3682
 21.........                                            1.6   89.4   3166
 22........                                             1.4   90.8   2689
 23.......                                              1.2   92.0   2388
 24......                                               1.0   93.0   1938
 25......                                               1.0   94.0   1911
 26....                                                 0.6   94.6   1199
 27...                                                  0.6   95.2   1223
 28..                                                   0.7   95.9   1289
 29....                                                 0.6   96.5   1074
 30...                                                  0.4   96.9    864
 31...                                                  0.4   97.3    727
 32...                                                  0.4   97.7    812
 33...                                                  0.4   98.1    682
 34..                                                   0.2   98.3    469
 35..                                                   0.2   98.5    458
 36..                                                   0.2   98.7    298
 37..                                                   0.1   98.8    260
 38..                                                   0.1   98.9    218
 39..                                                   0.1   99.0    209
 40.                                                    0.1   99.1    175
 41..                                                   0.2   99.3    327
 42.                                                    0.1   99.4    176
 43.                                                    0.1   99.5    176
```

```
**** FLINT **** ESTIMATED TLF CURVE - NONWORK TRIPS

                          Model 6                           PAGE   10
NWORK 3+P
                     TRIP LENGTH DISTRIBUTION
IMPEDANCE = UMODEL  (TABLE 2001)        TRIPS = 3+ PASS (TABLE 1004)

 0    10    20    30    40    50    60    70    80    90   100
 +----+----+----+----+----+----+----+----+----+----+       %   CUM%  COUNT
44.                                                      0.1  99.5   113
45.                                                      0.1  99.6   123
46.                                                      0.1  99.7   186
47.                                                      0.0  99.7    32
48.                                                      0.0  99.7    18
49.                                                      0.0  99.8    68
50.                                                      0.0  99.8    52
51.                                                      0.0  99.8    59
52.                                                      0.0  99.8    60
53.                                                      0.0  99.9    70
54.                                                      0.0  99.9    44
55.                                                      0.0  99.9     9
56.                                                      0.0  99.9     3
57.                                                      0.0  99.9    30
58.                                                      0.0  99.9    37
59.                                                      0.0  99.9     0
60.                                                      0.0  99.9     0
61.                                                      0.0 100.0    19
62.                                                      0.0 100.0    16
63.                                                      0.0 100.0     0
64.                                                      0.0 100.0     0
65.                                                      0.0 100.0     0
66.                                                      0.0 100.0     0
67.                                                      0.0 100.0    10
68.                                                      0.0 100.0     0
69.                                                      0.0 100.0     5
70. (ALL COUNTS FROM INTERVAL  70 THRU  82 ARE ZERO)      0.0 100.0     0
83.                                                      0.0 100.0    21
84.                                                      0.0 100.0     3
85.                                                      0.0 100.0     0
86.                                                      0.0 100.0     0
87.                                                      0.0 100.0    13
88. (ALL COUNTS FROM INTERVAL  88 THRU  94 ARE ZERO)      0.0 100.0     0
95.                                                      0.0 100.0    11
96. (ALL REMAINING COUNTS ARE ZERO)                      0.0 100.0     0

        MEAN        VARIANCE       STD DEV  SUM(COUNT(I))   SUM(I*COUNT(I))
        ----        --------       -------  -------------   ---------------
      12.635          55.831         7.472        193535.          2445280.
```

```
   **** FLINT **** ESTIMATED TLF CURVE - TRANSIT NONWORK TRIPS

                          Model 6                           PAGE     3
   TRAN NWORK
                       TRIP LENGTH DISTRIBUTION
   IMPEDANCE = UPSUM    (TABLE 2001)       TRIPS = TRANSIT (TABLE 1005)

  0    4    8   12   16   20   24   28   32   36   40
  +----+----+----+----+----+----+----+----+----+----+       %  CUM% COUNT
 0..............                                      1.0   1.0    55
 1.                                                   0.0   1.0     0
 2.                                                   0.0   1.0     0
 3.                                                   0.0   1.0     0
 4.                                                   0.0   1.0     0
 5.                                                   0.0   1.0     0
 6..                                                  0.1   1.1     4
 7.                                                   0.0   1.1     0
 8...                                                 0.2   1.3     9
 9.                                                   0.0   1.3     0
10......                                              0.4   1.7    21
11.                                                   0.0   1.7     0
12.......                                             0.5   2.1    25
13.                                                   0.0   2.1     0
14.....                                               0.3   2.5    18
15.                                                   0.0   2.5     0
16...                                                 0.2   2.6     9
17.                                                   0.0   2.6     0
18..                                                  0.1   2.7     4
19...                                                 0.2   2.9     9
20.....                                               0.3   3.2    17
21......                                              0.4   3.6    22
22.......                                             0.5   4.1    25
23....                                                0.2   4.3    12
24.........                                           0.6   4.9    33
25..........                                          0.8   5.7    40
26...............                                     1.1   6.8    61
27................                                    1.2   8.0    63
28...............                                     1.1   9.2    61
29.......................                             1.8  10.9    95
30.........................                           1.9  12.8   101
31...........................                         2.1  14.9   110
32.......................                             1.8  16.7    94
33........................                            1.8  18.5    98
34.......................                             1.8  20.3    95
35.............................                       2.3  22.5   120
36..........................                          2.0  24.5   106
37............................                        2.1  26.6   114
38..............                                      1.1  27.7    56
39......................                              1.7  29.4    91
40......................                              1.7  31.1    91
41..........................                          2.0  33.1   108
42...................                                 1.5  34.6    78
43....................                                1.5  36.1    81
```

```
     **** FLINT **** ESTIMATED TLF CURVE - TRANSIT NONWORK TRIPS

                         Model 6                                   PAGE   4
     TRAN NWORK
                                 TRIP LENGTH DISTRIBUTION
     IMPEDANCE = UPSUM    (TABLE 2001)        TRIPS = TRANSIT (TABLE 1005)

      0    4    8   12   16   20   24   28   32   36   40
      +----+----+----+----+----+----+----+----+----+----+        %   CUM% COUNT
  44.....................                                      1.6  37.7    86
  45.................................                          2.6  40.3   138
  46...............                                            1.1  41.4    59
  47.......................................                    3.0  44.4   161
  48..................                                         1.4  45.8    73
  49....................                                       1.6  47.4    83
  50.........                                                  0.7  48.0    36
  51.........                                                  0.6  48.7    33
  52...............                                            1.1  49.8    60
  53...............                                            1.1  50.9    61
  54.................                                          1.3  52.2    67
  55.................                                          1.3  53.5    69
  56...............                                            1.1  54.6    60
  57.......................                                    1.8  56.4    95
  58.....................                                      1.6  58.0    85
  59..........................                                 2.0  60.0   106
  60..................                                         1.3  61.3    71
  61.....................                                      1.6  62.9    87
  62................                                           1.2  64.2    66
  63..................                                         1.4  65.5    73
  64.........................                                  1.9  67.4   101
  65...............                                            1.1  68.5    59
  66........................                                   1.8  70.4    98
  67.....................                                      1.6  72.0    85
  68................                                           1.2  73.1    63
  69...............                                            1.1  74.3    60
  70..................                                         1.4  75.6    72
  71......................                                     1.7  77.3    88
  72........................                                   1.8  79.1    96
  73...................                                        1.4  80.5    75
  74.............                                              1.0  81.5    53
  75................                                           1.2  82.7    64
  76.............                                              1.0  83.7    53
  77.............                                              0.9  84.6    50
  78...................                                        1.4  86.0    75
  79.......................                                    1.8  87.8    94
  80.........................                                  2.0  89.7   104
  81..............                                             1.1  90.8    57
  82........                                                   0.6  91.4    31
  83.........                                                  0.7  92.0    35
  84.............                                              1.0  93.0    51
  85...........                                                0.8  93.8    41
  86.........                                                  0.7  94.4    36
  87.....                                                      0.4  94.8    19
  88.......                                                    0.5  95.3    26
  89....................                                       1.5  96.8    82
  90........                                                   0.6  97.4    31
  91........                                                   0.5  97.9    28
  92.....                                                      0.3  98.2    17
  93.....                                                      0.3  98.5    15
  94.....                                                      0.3  98.8    16
  95........                                                   0.5  99.3    28
  96...                                                        0.2  99.5    10
  97...                                                        0.2  99.7    10
  98..                                                         0.1  99.8     6
  99.                                                          0.0  99.8     0
 100.                                                          0.0  99.8     1
 101..                                                         0.1  99.9     3
 102.                                                          0.0  99.9     1
 103.                                                          0.0  99.9     1
 104.                                                          0.0  99.9     0
 105.                                                          0.0 100.0     2
 106. (ALL COUNTS FROM INTERVAL 106 THRU 113 ARE ZERO)          0.0 100.0     0
 114.                                                          0.0 100.0     1
 115. (ALL REMAINING COUNTS ARE ZERO)                          0.0 100.0     0

          MEAN        VARIANCE       STD DEV   SUM(COUNT(I))   SUM(I*COUNT(I))
          ----        --------       -------   -------------   ---------------
         53.481       423.401        20.577            5333.           285213.
```

APPENDIX 2

SAMPLE INPUT FOR CALIBRATION FILE, ULOGIT AND MODE-SPLIT EXERCISES

This Appendix contains examples of program listings (JCL and some data items) which were set up to construct a calibration file, calibrate a logit formulation and utilize the logit equation to perform mode-split on the 100% population of trips using the UTPS computer package. Each listing is set up exactly as it was used in the study. A majority of the data items (interchange data and trip tables) were input directly from tape and are not shown in this appendix.

The first listing was used to build the calibration file for work trip using the UTPS program UMODEL.

The second listing is the JCL and disutility equations used to calibrate a logit model using the ULOGIT program. This particular example is the job set up for Model 4 (time based logit model for work trips).

The third is the listing for the Mode-Split exercise in which the disutility equations for Model 4 (which was calibrated using ULOGIT) are applied to the total person trip tables.

2.1 Program listing used to build calibration file

```
X MSGLEVEL=1,CLASS=L.REGION=290K
// EXEC PGM=IEBGENER
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD UNIT=TAPE,VOL=(PRIVATE,RETAIN,SER=003721),
//    DSN=WORK,LABEL=(9,SL),DISP=(OLD,KEEP)
//SYSUT2 DD UNIT=SYSUTS,DSN=&HHTRIPS,DISP=(NEW,PASS),
//    SPACE=(TRK,(20,20))
//SYSIN DD DUMMY
/*
// EXEC PGM=IEBGENER
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD UNIT=TAPE,VOL=(PRIVATE,RETAIN,SER=005299),
//    DSN=F78HSKT,LABEL=(5,SL),DISP=(OLD,PASS)
//SYSUT2 DD UNIT=SYSUTS,DSN=&&HWYSKIM,DISP=(NEW,PASS),
//    SPACE=(TRK,(20,20))
//SYSIN DD DUMMY
/*
// EXEC PGM=IEBGENER
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD UNIT=TAPE,VOL=(PRIVATE,RETAIN,SER=005299),
//    DSN=FHSKMD,LABEL=(10,SL),DISP=(OLD,PASS)
//SYSUT2 DD UNIT=SYSUTS,DSN=&&HSKMD,DISP=(NEW,PASS),
//    SPACE=(TRK,(20,20))
//SYSIN DD DUMMY
/*
// EXEC PGM=IEBGENER
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD UNIT=TAPE,VOL=(PRIVATE,RETAIN,SER=005299),
//    DSN=FLSUMEX,LABEL=(11,SL),DISP=(OLD,KEEP)
//SYSUT2 DD UNIT=SYSUTS,DSN=&&PTSKIM,DISP=(NEW,PASS),
//    SPACE=(TRK,(20,20))
//SYSIN DD DUMMY
/*
// EXEC USERCODE,PROGRAM=UMODEL
//USERCODE.SYSIN DD *
./ CHANGE LIST=ALL,NAME=UMODEL
./ NUMBER INSERT=YES,SEQ1=442000,NEW1=442001,INCR=1
C       POPULATION PER DWELLING UNIT
C
      X(30)=X(12)/X(13)
C
C       POPULATION PER ACRE
C
      X(31)=X(12)/X(6)
C
C       TRANSIT FARE ($.35)
C
      X(32)=0
      IF(X(20).NE.0.0) X(32)=35
C
C       EMPLOYMENT/100
C
      X(33)=X(5)/100
C
C       POPULATION/100
C
      X(34)=X(12)/100
C
```

```
C       AUTOS PER PERSONS
C
      X(35)=X(16)/X(12)
C
C       INCOME PENTILES
C
      IF(X(2).LT.4960) X(36)=1
      IF(X(2).GE.4960.AND.X(2).LT.7520) X(36)=2
      IF(X(2).GE.7520.AND.X(2).LT.9920) X(36)=3
      IF(X(2).GE.9920.AND.X(2).LT.12000) X(36)=4
      IF(X(2).GE.12000) X(36)=5
C
C       HIGHWAY TIME (1,2,3+ PASSANGERS)
C
      X(37)=X(18)+1.1
      X(38)=X(18)+2.1
      X(39)=X(18)+3.7
C
C       HIGHWAY COST (0,1,2,3+ PASSANGERS)
C
      X(40)=10.0*X(22)+X(15)
      IF(X(40).LT.7.0) X(40)=7.0
      X(41)=X(40)/2+2.0
      X(42)=X(40)/3+4.0
      X(43)=X(40)/4+6.0
C
C       WEIGHTED TRANSIT TIME
C       TIME = 1.5 * WALK + RUN + 2 * WAIT
C
      X(44)=1.5*(X(19)-X(20)-X(21))+X(20)+2*X(21)
      IF(X(20).EQ.0) X(44)=500
C
C       TRANSIT EXCESS TIME
C
      X(45)=X(19)-X(20)
      IF(X(20).EQ.0.0) X(45) = 90
C
C       TRAVEL TIME RATIO (TTT/TTA)
C
      X(46)=X(19)/X(18)
      IF(X(46).GE.7) X(46)=7
      IF(X(20).EQ.0) X(46)=7
/*
// EXEC UMODEL,TIME=30,REGION=290K,
//     A8='DSN=&&HHTRIPS,SPACE=(CYL,(1,1))',
//     J1='DSN=&&HWYSKIM,SPACE=(CYL,(1,1))',
//     J2='DSN=&&PTSKIM,SPACE=(CYL,(1,1))',
//     J3='DSN=&&HSKMD,SPACE=(CYL,(1,1))',
//     J8='DSN=CWORK,VOL=SER=008693',UNITJ8=TAPE
//UMODEL.FT18F001 DD &J8,UNIT=TAPE,LABEL=(13,SL),DISP=(NEW,KEEP)
//UMODEL.A1 DD *
   1 6682 5 5 1260   88    27   1    30   30   0  634  351  244 0 272234
   2 5266 5 5 1051   55     2   2    32   19   0   11    5  425    27  7
   3 7465 5 5 2855   41     1   1    25   11   3  181  135 7075    77 83
   4 4449 5 5 2960   38     1   0    28    9   0   34   47 1375    16 43
   5 6340 3 3 1376   28     3   1    17    7   0   76   48 2940    29 28
   6 5172 3 3 1274   29     3   0    19    7   0  126   96 4850   155134
   710823 3 3 1569   37     3   1    13   20   0  124   75   48 0  45 37
   8 6943 3 3 1261   49    12   1    17   15   4  617  219  237 0 229 94
   9 6773 2 2  373   69    22   3    41    1   2  653  288  251 0 319114
```

```
10 6783 2 2   249    49    16     0    27     6   0  720   300   277 0 319100
11 7508 2 2   318   127     8    26    72    21   0  434   155   167 0 183 32
12 7280 3 3   334   110    19     5    76    10   0  635   253   244 0 287 95
13 6583 2 2   123   141    23     2   105    11   0 1216   462   468 0 447135
14 9619 2 2   133   111    40     0    60    11   0 1125   381   433 0 431 11
15 8770 2 2   284    97    24     0    64     9   0  857   547   330 0 451102
16 6526 4 4  1319    58     3     2    30    23   0   15     1     6 0   6 14
17 7612 4 4   888    71     4     1    45    14   7   65    42    25 0  83  7
1814627 5 5  3041   206    41     0    32   124   9  311   149   120 0 266 69
1913588 2 2   194   165    91     0    60    14   0 2219   833   854 01137 40
20     0 4 4  1476   172     0    21   111    39   1    1     1     0 0   0  0
21 6908 4 4   255   140     9    18    96    17   0  123    27    47 0  51  0
2214602 2 2   138   102    29     0    71     1   1  790   291   304 0 446  0
23 9703 2 2   225   155     0    25    97    33   0    7    20     3 0  14  0
2423264 2 2    63   112     8     0    34     7  63  103    37    40 0  46  0
2517545 2 2   155   166   105     0    40     6  15 1615   607   621 0 937 33
2610327 2 2   658   249    92    17    90    50   0 2284   769   879 01068 74
2711976 4 4   545   184    27    13   110    34   0 1186   431   456 0 476  0
2814452 2 2    45   183    68    26    87     2   0 1601   518   616 0 673 22
29 7852 3 3   765   310    74     3   186    41   6 3951  1504  1520 01307161
3010838 2 2   994   272    65     0   168    39   0 1982   713   763 01168 20
3110838 3 3   103   441    62     2   222    18 137 1405   476   541 0 512 47
3212307 2 2   469   250   122     0    81    39   8 2826   912  1087 01292 24
33 9948 2 2   158    94    48     1    37     8   0  965   404   371 0 397 53
34 7552 2 2  2698   171     9   112    49     1   0  109    39    42 0  72  0
35 7340 2 2   735   182    54     5    93    30   0 1825   765   702 0 408120
36 9121 2 2   305   219   108     9    80    22   0 2981  1085  1147 01321104
37 9908 2 2   286   170    78     0    61    31   0 2276   796   876 0 991 57
3814298 1 1   351   311   121     0   154    36   0 3452  1276  1328 01853 66
39 9027 1 1   178   227   111     0    44    11  61 1337   488   514 0 550 77
40 3677 1 1   183   133    36     0    42    48   7  148    75    57 0  50 23
4112766 2 2    64   108    34     0    62     8   4 1081   377   416 0 480 15
42     0 2 216399   414     0   386    28     0   0    1     1     0 0   0  0
4343264 1 1   254   602   247     0   165     0 190  823   328   317 0 552  0
44 8466 2 2    88   203     6     2   112    75   8  349    46   134 0  38  6
4511773 2 2   220   164    96     0    50    16   2 2006   724   772 01034 71
46 9709 2 2   446   195   128     0    54     9   4 2795  1004  1075 01192 97
4711015 2 2    91    76    64     0     8     4   0 1175   373   452 0 425 54
48 9573 2 2    65   101    60     0    30    10   1 1246   404   479 0 508 15
49 8339 1 1   253    92    49     0    33     9   1 1243   424   478 0 515 33
50 8198 1 1   111    78    41     1    29     7   0  823   390   317 0 439 50
5111614 1 1  2410    71    10     0     8    53   0  310   142   119 0 199  7
5213366 2 2   182   260   127     0    70    63   0 1758   750   676 0 989 73
53  913 2 2   450    31     9     7    13     2   0  204   121    78 0 118 26
54 7145 2 2   235    79    37    13    22     7   0  570   280   219 0 256 73
55     0 3 3  4714    71     0    41    29     1   0    1    10     0 0   0  0
56     0 3 3   600    73     0    22    35     4  12  343   151   132 0  98  0
57 7362 3 3  2771    63     8    21    31     3   0  447   151   171 0 178 25
58 6748 4 4   347    84    35     3    24    10  12  978    34   376 0 387150
59 8359 3 3   300    72    36     0    16    20   0  983   397   378 0 360 61
6012178 1 1   374   336   222    11    90     2  11 3422  1253  1316 01742 96
6113381 1 1   223   132    67     0    46    14   5 1535   438   591 0 567 33
6214635 1 1   142   121    72     0    47     2   0 1544   555   594 0 706  7
6311695 1 1   236   107    63     0    35     9   0 1492   540   574 0 735 22
6410193 1 1    81   106    70     0    35     1   0 1334   558   513 0 666 92
65 8812 1 1   370   113    56     0    32    15  10 1020   488   392 0 550 66
6610007 1 1   220    78    34     0    38     6   0  961   412   370 0 507 23
67 7849 2 2    60    78    47     0    29     2   0 1055   373   406 0 358 38
68 8509 2 2   168   122    83     0    32     4   3 1913   768   736 0 975150
69 9381 3 3  2643    74    33     0    26    15   0  849   268   327 0 282 51
```

```
 70 6568 3 3  156   49   15    0   30    4   0  829  470  319 0 462157
 71 6871 4 4  461  109   46    1   45   17   0 1641  605  631 0 602237
 72 7876 3 3  486  120   65    0   37   15   3 2516  819  968 0 766212
 73 7886 3 3  296   98   57    0   33    7   1 2029  630  781 0 660176
 74 8487 3 3  503  165   82    0   47   32   4 2584  816  994 0 847176
 75 9203 1 1  199  151   97    0   46    8   0 2790  934 1073 01060180
 76 8530 1 1  197  140   87    0   39    5   9 2397  767  922 0 900139
 7710963 1 1  353  219  124    0   57    5  33 2351  803  904 01113 26
 7810555 1 1  305  168   97    0   50   21   0 1821  595  701 0 836 37
 7912447 1 1  303  178  123    0   51    4   0 2218  789  853 01012 46
 8012872 2 2  316  153   83    0   48   12  10 2074  654  751 0 950  0
 8111567 1 1  203  169  149    0    9   11   0 2861  919 1036 01256 43
 8213036 2 2   73  147   35    0    7    9  96  517  201  187 0 246 39
 83 7651 1 1  308  180  105    1   61   13   0 2980 1015 1079 01067265
 84 8688 1 1  164  162  107    0   48    7   0 3057  936 1107 01024156
 85 8786 1 1  143  133   87    0   41    5   0 1905  715  690 0 744129
 86 9038 1 1  109  142   52    0   81    9   0 1514  498  548 0 680 35
 8712926 1 1  347  140   83    0   45   12   0 2376  621  860 0 985  6
 8810416 1 1  245  142   70    0   46   23   3 1742  701  631 0 913 26
 8912928 1 1  181  161   54    0   72   35   0 1833  511  664 0 469  0
 9012064 1 1   56  136   83    0   51    2   0 2386  701  864 0 997 26
 9112529 1 1  131  170  126    0   42    2   0 2517  665  911 0 990 12
 9211123 1 1  278  142   71    0   39   32   0 1582  589  573 0 770 20
 9310258 1 1   54  116   71    0   41    4   0 2254  635  816 0 717 66
 94 8119 2 2  346  201   99    1   63   35   3 2615  954  947 0 954156
 95 7858 2 2  174  190   97    1   80   12   0 2669  919  966 0 855192
 96 7629 2 2  184  183   34    0  108   41   0 1964  611  713 0 754135
 97 7184 1 1  396  180   56   20  102    2   0  872  267  316 0 291 37
 9810202 2 2  209  283   74    3  105   81  20 1298  332  471 0 386 72
 99 8507 2 2  275  101   33    0   55   13   0 1377  467  500 0 576108
100 6992 1 1 3376  215   41  101   66    7   0 1119  450  406 0 437131
101 6642 2 2  247  260   68    2  161   29   0  412  329  149 0 686328
102    0 4 4 5675  157    2  126   28    1   0    2    7    1 0   0  0
103    0 4 4 5864  108    0   99    9    0   0    1    4    0 0   0  0
104 7761 2 2  290  150   61    2   59   22   6 2129  825  772 0 868296
105 7413 2 2  818  109   45    6   30   22   6 1212  519  466 0 402243
106 6329 4 4 1425  158   43   46   27   42   0  966  395  372 0 292228
107 5393 4 4  573  102   50    2   24   26   0  760  344  320 0 253286
108 7914 2 2  364   58    9    6   15   20   8  170   49   65 0  63  0
109 7319 2 2  108   90   22    0   41    7  20  604  264  232 0 322 59
110 8790 2 2  125  142   57    1   45   11  28 1719  687  661 0 811147
11110138 2 2  381  157  119    3   22   13   0 1760  753  677 0 844 57
112    0 4 4 3359  155    0  125   26    4   0    1    1    0 0   0  0
113 9669 3 3 3015  153   32   75   40    6   0 1123  397  432 0 389 61
11411193 1 1  196  210   92    1   59   36  22 2515  757  968 0 952 91
115 8362 3 3  683  216   83   17   76   40   0 1772  628  682 0 756 53
116 9105 2 2  541  204  102    2   73   27   0 2539 1034  977 01156181
117 7024 2 2  309  216  114    2   78   22   0 3644 1436 1402 01546326
118 7774 2 2  168   96   28    3   57    8   0  848  346  326 0 294 98
119 7345 2 2  114  873   21    0  838   14   0 1157  402  445 0 505 44
120 9203 2 2  538   91   21    1   35   34   0  498  180  181 0 209 26
121 5781 3 3  197   70    9   16   14   31   0  245  148   89 0 147 30
12210107 2 2  133  167   94    0   59   14   0 2745 1007  996 01089 19
12310653 2 2  115  168   89    0   58   21   0 1402  363  509 0 438  7
12410641 3 3  342  586  142    2  391   51   0 3169 1141 1150 01138 19
125 8709 3 3  313  677  131    8  479   59   0 3530 1214 1281 01172100
12613790 1 1  295 1716  608    0 1020   88   0 3054  916 1202 01445 12
12715675 2 2 1576  328  137    0  174    6  11 2326  870  915 0 478  0
128 9959 2 2  395  267   85    7  158   17   0  958  377  377 0 479 27
12911214 1 1  250  701  234    0  428   39   0 4391 1860 1728 0 895 46
```

```
13012382 3 3  111  426    34    0  148  243   1  351   46  138 0  31  0
13113844 1 1  107 1129   125    0  997    7   0 1462  321  575 0 205  6
132  500 1 1    8 1600    81    0 1519    0   0  819  100  298 0 205  6
133  500 1 1    1 2240    91    0 2149    0   0  408  100  149 0 205  6
134  500 1 1    0 2143    81    0 2062    0   0  412  138  150 0 205  6
13516315 1 1   64  935    50    0  866   18   1  412  119  150 0 290  8
13614018 1 1  168 1607   451    1 1083   49  23 2533  793  997 01024  3
13712283 1 1  292  424    52    0  371    1   0  281   84  102 0 155  0
13810528 1 1  590  843   125    5  588  116   9 1548  504  561 0 668 24
13910538 1 1  697  935   179    0  687   69   0 3096  991 1121 01023 14
14012752 1 1  279 1927   190   75 1621   23  18 1126  341  408 0 570  8
14114193 1 1 1592 2303   658    6 1417  122 100 7792 2788 2917 03166 74
14211854 1 1    5 4084    72    0 4007    5   0  824  248  300 0 684  8
14311854 1 1    5 4030    95    0 3931    4   0  660  196  240 0 684  8
14416633 1 1   54 1589   243    0 1173    3 170 1731  548  629 0 442  0
14514592 1 1  143 1278   200    0 1050   28   0  989  316  360 0 388 16
14611407 1 1   49 1282   193    6 1066   17   0  563  222  204 0 316  5
14714664 1 1   73  929   321    3  597    8   0 1407  435  509 0 833  8
14812656 1 1   61  400    24    1  341   34   0  141   26   51 0 119  0
14910369 1 1   44 1207    64    0 1134    9   0 1126  351  408 0 198  0
15012215 1 1   29 3224   185    0 3034    2   3  844  235  306 0 500  0
15111907 1 1   62 2423   271    0 2131   21   0 1072  334  390 01099  7
15211854 1 1    2 2533   122    0 2337    4  70  659  212  240 0 684  8
15311854 1 1    3 1459   124    0 1333    2   0 1484  446  539 0 684  8
15415102 1 1    1 1644   125    0 1510    1   8  563  249  204 0 148  0
15515102 1 1    3  978    64    0  912    1   1  281   96  102 0 148  0
15612623 1 1  132 2837   312    0 2498   27   0 2195  718  806 0 804 13
15711705 1 1  133 4575   341    0 4221   13   0 1150  391  422 0 748 14
15810968 1 1   43 6207   320    0 5876    8   3 1723  501  555 0 778  7
15914878 1 1    8 4501   256    0 4244    1   0  920  334  296 0 507 12
16010048 1 1  493  606   150    0  406   48   2 1800  551  637 0 674 32
16114878 1 1   16 4117   347    0 3757   13   0  849  304  274 0 507 12
16212224 1 1   30 6439   289    0 6138    3   9 1607  479  518 0 498 14
16311705 1 1    8 4347   215    1 3990    6 135 1359  440  499 0 748 14
16412730 1 1  100 3149   213    0 2870   66   0  836  261  310 0 601  6
165 9659 1 1 1477  628    94    5  467   46  16 2808 1043 1150 0 888108
16610395 1 1   49  424    69    1  305   49   0  732  227  272 0 876 39
16710395 1 1   49 3196   172    1 2980    7  36 1568  504  582 0 876 39
16810834 1 1   12 3247   204    0 3011   14  18  986  325  366 0 468  0
16910834 1 1    2 3834   197    0 3577    4  56  634  207  235 0 468  0
17010834 1 1   13 3633   108    0 3338    2 185  423  162  157 0 468  0
17111200 1 1    9 5025   230    0 4780    3  12  553  173  198 0 440 31
17211200 1 1   18 8206   555    0 7609   42   0 1272  400  454 01013 31
173 8618 1 1  340  610    75    3  514    5  13  800  229  322 0 302 21
17411200 1 1    8 5000   334    0 4664    2   0  940  296  336 0 749 31
17511272 1 1   48 3902   217    2 3681    2   0  705  232  262 0 244  0
17612357 1 1   18 3780   195    0 3504    9  72  423  153  157 0 227  0
17710585 1 1  133 3840   223    3 3446   98  70 3875 1326 1438 01484 29
17811809 1 1   85  564    81    0  457   10  16  523  173  192 0 177 17
17910860 1 1  320 3024   260    1 2726   19  18 2091  683  768 0 474 27
18010297 1 1   85 1153   128    3  960   34  28 1126  399  408 0 743 25
18110267 2 2 1185  629   326    0  213   79  11 3488 1213 1344 01448 39
18210601 1 1  109 1624   368    2 1238   16   0 1407  512  509 0 571 20
18310965 1 1  629  745   344    0  332   69   0 5628 1846 2038 02290 68
184 9269 2 2  725 1246   439    0  632  168   7 6473 2156 2344 02314133
185 8558 2 2  412  402   236    1  120   42   3 2706  851  982 0 942 89
186 9259 2 2 4241  837   214  239  338   45   1 1665  587  604 0 902 50
18710184 2 2  271  809   277    0  493   39   0 2011  671  730 0 866 34
18810749 1 1  104 1286    90    2 1164   15  15 2460  816  892 0 203  0
189 8556 1 1  165 1177    62   26  979   95  15  621  224  225 0 236 33
```

```
19012163 1 1  188 2509  312    0 2164   32   1 1523  522  553 0 973 33
19112648 1 1   69 2660  169  143 2201   17 130 2116  686  768 0  29  0
19211179 1 1   38 4132  286  153 3664   29   0  952  250  358 0 794 10
19312513 1 1   58 8028  456    0 7569    3   0 1959  526  738 01465  6
19412513 1 1  242 9817  797    5 8886  115  14 4413 1111 1661 01465  6
19511425 1 1   26 1396  165    0 1213    0  18  552  218  200 0 339  7
19610720 1 1  127 2244  163    4 2068    9   0 1005  354  365 0 514 23
19712241 1 1  233 1850  384    3 1313   16 134 1765  583  640 01128 13
198 9266 2 2  301  505  249    5  165   20  66 2115  705  767 0 838 21
19912402 1 1  446 3135 1336    3 1696  100   0 4954 1683 1797 02632 11
20011195 1 1   51  660  206    1  446    7   0  762  231  276 0 291 14
20112881 2 2 3361  925  380   60  447   35   3 3097  889 1192 01421 29
20214694 1 1   78 1261  250    5  720    7 279 1385  388  533 0 644 17
20320185 1 1   63  921  242    0  465    6 208 1318  413  507 0 580  0
20414417 1 1  178 2137  232    1 1883   20   1 2691  832 1022 0 798  0
20511052 1 1  544  646  339    1  272   34   0 3116 1075 1293 01166 96
20611938 1 1   17 2423   80    0 2062   33 248 1008  281  383 0 355  0
20711810 1 1   96 3403   96    0 3301    6   0 1034  318  393 0 573  0
20814592 1 1 1245  396  165    0  183   38  10 2872 1284 1192 01179 10
20911565 1 1   97 2598  127    0 2450   17   4 2069  614  786 0 326  0
21011606 1 1   55 1774  370    0 1388   16   0 1581  456  600 0 538  0
21111394 1 1  204  897  295    0  578   24   0 2768  764 1065 01020 12
21210441 1 1  108  657  113    0  498   46   0  996  302  383 0 386 10
21311919 1 1  358  657  101    4  547    5   0 1227  284  472 0 557 24
21416192 1 1   47  319   70   12  231    6   0  593  138  228 0 243  6
21513207 1 1  886  624  128    0  435   61   0  859  234  331 0 350 15
21612588 1 1  201  279  172    0  100    7   0 1520  482  585 0 623 17
21710565 1 1   31  628   48    0  566    5   9  536   94  206 0 106  9
21812389 1 1  369  614  147    2  447   17   1 1197  399  461 0 488  0
21911479 1 1   35  305   86    0  189   30   0 1079  317  415 0 401 11
220 8625 1 1  354  609  186   49  335   20  19 1782  464  686 0 562 42
221 8285 1 1  164  609   64    0  467   77   1  593  135  228 0 197  0
22212930 1 1   67  634  231    0  385   18   0  963  271  371 0 407  8
22310135 1 1   28  601  103    0  496    2   0  687  159  264 0 195  0
22411685 1 1   74 4443  223    1 4065   18 136 1501  421  570 0 980 14
22511685 1 1  126 5069  256    0 4667    6 140 1010  295  383 0 980 14
22614242 1 1    6 4577  167    0 4410    0   0  538  162  189 0 365 12
22714242 1 1   88 4548  260    3 4142   10 133  493  163  173 0 365 12
22815517 1 1   88 1607  303    0 1286   17   1 1935  608  723 0 928  7
22911343 1 1   69  599  126    0  468    5   0  437  144  168 0 195  6
23011374 1 1   91  626   92    0  531    3   0  323   82  124 0 100 10
23112938 1 1   55  615   98    3  471   43   0  537  115  207 0 185  0
23210916 1 1  303  612  115   24  441   32   0  883  127  340 0 365  0
23311921 1 1  159  901  110    0  648   70  73 1451  447  543 0 461  0
23413747 1 1   43 1069  181    0  857    0  31 1935  625  723 0 421  0
23513250 1 1   39 1084   49    0 1031    4   0 1210  467  452 0 118  0
23611612 1 1 4759 1187  487   57  461  176   6 5796 2256 2400 02340 59
23710977 1 1   99  521  119  102  261   39   0  174   44   65 0 132  7
23813629 1 1   12  632   64    0  568    0   0  242   90   90 0 106  0
23915041 1 1   23  368   63    0  303    2   0  484  156  181 0 275  0
24022210 1 1  295 1633  220    1 1366   16  30  968  317  362 0 610  0
24123288 1 1   94 2065   64  371 1476   10 144 2419  777  904 0 508  0
242 9682 1 1   71 5601  281    0 5302    9   9  867  242  304 0 185  9
24311574 1 1  348 1257  142    3 1017   47  48  900  265  374 0 390  7
24412027 1 1    0 3187   68    0 2971    0 148  438  121  154 0 389 14
24512027 1 1  106 3467  160    0 3295   12   0  590  165  207 0 389 14
246    0 1 1  240 1580    0    0 1461    2 128    1    1    0 0   0  0
24735293 1 1   21 2269  195    0 1944    2 128  968  283  362 0 157  0
248    0 1 1    2 5581    0    0 5565   16   0    1    1    0 0   0  0
24916913 1 1  129 5581  331    0 5234   16   0 1693  512  633 01033  8
```

250	6225	1	1	22	295	21	0	273	1	0	68	22	25	0	11	0
251	14696	1	1	115	1861	586	0	1202	73	0	3871	1281	1447	0	1478	25
252	20936	1	1	82	406	248	0	157	1	0	1451	460	543	0	705	0
253	9296	1	1	114	337	186	0	141	10	0	1935	635	723	0	57	0
254	14203	2	2	343	802	383	0	403	16	0	2661	820	995	0	1476	24
255	10157	2	2	252	221	64	0	136	14	7	726	223	271	0	353	10
256	8938	2	2	658	602	157	8	294	50	93	3821	1152	1470	0	1492	72
257	8120	2	2	425	313	56	16	199	41	1	1501	377	578	0	664	62
258	8415	2	2	216	107	25	0	69	13	0	1990	588	766	0	688	54
259	9770	2	2	213	340	107	1	200	31	1	1973	544	759	0	745	12
260	11813	2	2	251	319	77	0	225	17	0	983	374	378	0	432	12
261	9652	2	2	630	163	43	0	64	56	0	899	668	346	0	428	28
262	12189	1	1	457	319	234	0	49	36	0	1257	478	495	0	657	5
263	12682	1	1	376	640	515	2	86	37	0	3059	1426	1204	0	2167	55
264	10782	1	1	277	943	187	1	683	48	24	1427	442	511	0	396	7
265	14183	1	1	70	355	161	0	191	3	0	666	212	238	0	272	0
266	11924	1	1	98	1860	201	3	1651	5	0	1046	327	374	0	525	0
267	12548	1	1	90	3270	250	1	2993	14	12	761	232	272	0	376	0
268	13041	1	1	297	5333	511	5	4617	70	130	4182	1324	1657	0	2247	45
269	11602	1	1	389	1541	216	4	1270	48	3	2912	927	1154	0	2006	111
270	11602	1	1	1916	2731	401	41	2078	191	20	4934	1563	1873	0	3432	111
271	11602	1	1	0	564	28	0	515	4	17	243	56	96	0	167	111
272	11161	1	1	5	5535	425	2	4937	8	163	2835	887	1123	0	441	17
273	11902	1	1	20	3383	268	1	3109	5	0	951	293	340	0	634	14
274	13761	1	1	176	2939	299	1	2626	7	6	1522	457	545	0	496	7
275	12466	1	1	214	2031	231	0	1794	6	0	856	714	337	0	587	0
276	14571	1	1	220	417	76	23	300	18	0	769	194	303	0	338	0
277	0	5	5	34	991	3	0	988	0	0	5	1	2	0	0	0
278	9416	2	2	304	346	46	28	258	14	0	300	110	118	0	104	6
279	14703	3	3	1800	1014	268	4	727	15	0	713	243	281	0	450	8
280	11302	2	2	553	327	95	2	154	75	1	1257	463	495	0	675	47
281	12897	2	2	125	200	96	0	102	2	0	1614	628	635	0	712	7
282	8988	2	2	470	382	141	5	165	71	0	2026	663	797	0	687	5
283	10134	2	2	463	1185	176	3	912	63	31	3920	980	1543	0	1076	41
284	12688	2	2	54	241	93	2	111	11	24	468	100	184	0	208	0
285	13180	2	2	269	1498	268	20	1188	22	0	2474	729	974	0	810	14
286	14264	2	2	315	304	37	0	261	6	0	150	57	59	0	102	0
287	10114	5	5	2353	757	50	0	668	14	25	399	106	145	0	227	0
288	13729	1	1	39	999	210	0	697	5	87	2138	749	841	0	468	0
289	12982	1	1	28	1280	87	0	1185	8	0	285	71	102	0	153	0
290	11505	1	1	2	2560	182	0	2378	0	0	1332	385	477	0	127	0
291	11505	1	1	0	3916	195	0	3719	2	0	667	200	239	0	127	0
292	11161	1	1	0	2818	176	0	2640	0	2	533	160	211	0	441	17
293	12590	1	1	621	1277	212	1	1042	20	2	2100	634	869	0	715	34
294	13752	1	1	1	3643	224	0	3318	5	96	1658	513	657	0	576	10
295	10523	1	1	23	7394	396	3	6881	21	93	2692	841	884	0	573	23
296	10523	1	1	5	5591	106	0	5485	0	0	465	127	153	0	240	23
297	10523	1	1	8	7541	197	2	7330	12	0	1107	307	364	0	573	23
298	9039	1	1	3	3477	75	0	3385	17	0	272	77	89	0	594	30
299	11896	1	1	133	3494	175	0	3297	22	0	1052	286	389	0	753	25
300	11869	1	1	2	3840	118	0	3685	0	37	654	179	242	0	753	25
301	11869	1	1	8	3630	182	0	3446	2	0	621	165	229	0	753	25
302	12721	1	1	26	3634	223	0	3406	5	0	710	187	262	0	544	0
303	12510	1	1	190	752	159	0	568	25	0	1654	458	600	0	369	0
304	12661	1	1	1233	1111	284	0	738	85	4	3649	1003	1324	0	1413	21
305	11952	1	1	19	2924	175	0	2749	0	0	713	190	263	0	90	0
306	11952	1	1	11	4866	210	0	4652	4	0	623	167	230	0	90	0
307	9050	1	1	14	990	26	0	964	0	0	147	33	54	0	43	0
308	11903	1	1	21	2809	146	0	2646	10	7	1977	755	720	0	705	7
309	9050	1	1	22	664	34	0	614	16	0	186	35	68	0	43	0

```
 31011093 1 1     5 2935  169    0 2763    3   0  675  227  246 0 705  7
 31113778 1 1    29 1532  110    0 1419    3   0  486   97  177 0  87  0
 31212665 1 1    31 1937  201    0 1726   10   0  645  190  235 0 392  0
 31312070 1 1     5 3734  176    0 3553    5   0  749  244  273 0 907  0
 31413635 1 1    48 2784  262    0 2522    0   0 1289  309  470 0 203  0
 31520388 1 1    74 1655  503    0 1111   10  31 2942  878 1158 01046 11
//UMODEL.SYSIN DD *
  **  FLINT  **  CALIBRATION FILE TO BE USED FOR ULOGIT ** WORK TRIPS
&PARAM ZONES=364 &END
&OPTION &END
&SELECT &END
&DATA
 1 P       1    5  1 1              ZONE NUMBER
 2 P       6   10  2 1              INCOME                  $/YEAR
 3 P      11   12  3 1              TERMINAL TIME  P        MINUTES
 4 A      13   14  4 1              TERMINAL TIME  A        MINUTES
 5 A      15   19  5 1              EMPLOYMENT              PERSONS
 6 A      20   24  6 1              TOTAL ACRES             ACRES
 7 P      25   29  7 1              RESIDENTIAL ACRES       ACRES
 8 A      30   34  8 1              INDUSTRIAL ACRES        ACRES
 9 A      35   39  9 1              UNDEVELOPED ACRES       ACRES
10 A      40   44 10 1              RETAIL WHOSL ACRES      ACRES
11 A      45   48 11 1              RECREATIONAL ACRES      ACRES
12 P      49   53 12 1              POPULATION              PERSONS
13 P      54   58 13 1              DWELLING UNITS          UNITS
14 P      59   63 14 1              RES LABOR FORCE         PERSONS
15 A      64   65 15 1              PARKING COSTS           CENTS
16 P      66   69 16 1              AUTO OWNERSHIP          AUTOS/ZN
17 P      70   72 17 1              ZERO AUTOS              FAMILIES
18 X    1001                        TIMEDA                  MINUTES
19 X    2001                        TRNS TIME               MINUTES
20 X    2002                        TRNS RUN TIME           MINUTES
21 X    2003                        TRNS WAIT TIME          MINUTES
22 X    3001                        HGWY SKIM DIST          MILES
23 H       1    4                   ORIGIN ZONE
24 H       5    8                   DESTINATION ZONE
25 H      10   10                   WDA                     TRIPS
26 H      11   11                   WONE                    TRIPS
27 H      12   12                   WTWO                    TRIPS
28 H      13   13                   WTHREE                  TRIPS
29 H      14   14                   TRANSIT                 TRIPS
30 P*             18               POP PER DU              POP/DU
31 P*             19               POP PER ACRE            POP/ACRE
32 X*                               TRNS FARE               CENTS
33 A*             20               EMPLY                   EMP/100
34 P*             21               POP                     POP/100
35 P*             22               AUTOS PER POP           AUTO/POP
36 P*             23               PENTILE                 PENT
37 X*                               TIME1                   MINUTES
38 X*                               TIME2                   MINUTES
39 X*                               TIME3                   MINUTES
40 X*                               COSTDA                  CENTS
41 X*                               COST1                   CENTS
42 X*                               COST2                   CENTS
43 X*                               COST3                   CENTS
44 X*                               WTRNS TIME              MINUTES
45 X*                               EXCESS                  MINUTES
46 X*                               TTR                     MIN/MIN
99999
/*
```

2.2 Program listing used to calibrate a logit model

```
 X MSGLEVEL=1,CLASS=L,REGION=290K
// EXEC ULOGIT,TIME=30,REGION=290K,
//     J1='DSN=CWORK,VOL=SER=008693',UNITJ1=TAPE
//ULOGIT.FT11F001 DD &J1,UNIT=TAPE,LABEL=(13,SL),DISP=(OLD,KEEP)
//ULOGIT.SYSIN DD *
&SELECT
    FIT(WDA=A1*TIMEDA+B1*PENTILE+A BIAS),
    FIT(WONE=A1*TIME1),
    FIT(WTWO=A1*TIME2+B3*POP PER ACRE+P2 BIAS),
    FIT(WTHREE=A1*TIME3+C4*COST3+P3 BIAS),
    FIT(TRANSIT=A5*WTRNS TIME+B5*AUTOS PER POP+T BIAS),
    VALUE(A1=0.0),VALUE(A5=0.0),
    VALUE(B1=0.0),VALUE(B3=0.0),
    VALUE(B5=0.0),VALUE(C4=0.0),
    REPORT=1,2,3,6,8 &END
/*
```

2.3 Program listing used to perform the mode-split process

```
X MSGLEVEL=1,CLASS=L,REGION=290K
// EXEC PGM=IEBGENER
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD UNIT=TAPE,VOL=(PRIVATE,RETAIN,SER=003721),
//     DSN=WORKTT,LABEL=(11,SL),DISP=(OLD,KEEP)
//SYSUT2 DD UNIT=SYSUTS,DSN=&WTRIPS,DISP=(NEW,PASS),
//     SPACE=(TRK,(20,20))
//SYSIN DD DUMMY
/*
// EXEC PGM=IEBGENER
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD UNIT=TAPE,VOL=(PRIVATE,RETAIN,SER=005299),
//     DSN=F78HSKT,LABEL=(5,SL),DISP=(OLD,PASS)
//SYSUT2 DD UNIT=SYSUTS,DSN=&&HWYSKIM,DISP=(NEW,PASS),
//     SPACE=(TRK,(20,20))
//SYSIN DD DUMMY
/*
// EXEC PGM=IEBGENER
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD UNIT=TAPE,VOL=(PRIVATE,RETAIN,SER=005299),
//     DSN=FHSKMD,LABEL=(10,SL),DISP=(OLD,PASS)
//SYSUT2 DD UNIT=SYSUTS,DSN=&&HSKMD,DISP=(NEW,PASS),
//     SPACE=(TRK,(20,20))
//SYSIN DD DUMMY
/*
// EXEC PGM=IEBGENER
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD UNIT=TAPE,VOL=(PRIVATE,RETAIN,SER=005299),
//     DSN=FLSUMEX,LABEL=(11,SL),DISP=(OLD,KEEP)
//SYSUT2 DD UNIT=SYSUTS,DSN=&&PTSKIM,DISP=(NEW,PASS),
//     SPACE=(TRK,(20,20))
//SYSIN DD DUMMY
/*
// EXEC USERCODE,PROGRAM=UMODEL
//USERCODE.SYSIN DD *
./ CHANGE LIST=ALL,NAME=UMODEL
./ NUMBER INSERT=YES,SEQ1=442000,NEW1=442001,INCR=1
      REAL*4 WDA/0.0/,WONE/0.0/,WTWO/0.0/,WTHREE/0.0/,TRNS/0.0/,
     1       PENT/0.0/,INC/0.0/,EMP/0.0/,TIMEDA/0.0/,TIME1/0.0/,
     2       TIME2/0.0/,TIME3/0.0/,WTRAN/0.0/,COST3/0.0/,PPA/0.0/,
     3       NUMDA/0.0/,NUM1/0.0/,NUM2/0.0/,NUM3/0.0/,NUMT/0.0/,
     4       WTRP/0.0/,APP/0.0/,DEN/0.0/
C       INITIALIZE TRIP TABLES
      TABSO(1)=0.0
      TABSO(2)=0.0
      TABSO(3)=0.0
      TABSO(4)=0.0
      TABSO(5)=0.0
      TETAB(1,1)=0.0
      TETAB(2,1)=0.0
      TETAB(3,1)=0.0
      TETAB(1,2)=0.0
      TETAB(2,2)=0.0
      TEPERS(1)=0.0
C       GIVE VALUES TO INDEPENDANT VARIABLES
      INC=X(2)
      EMP=X(5)/100
      PPA=X(12)/X(6)
```

```
      COST3=((X(22)*.10)+X(15))/4+.06
      APP=X(16)/X(12)
      TIMEDA=X(18)
      TIME1=TIMEDA+1.1
      TIME2=TIMEDA+2.1
      TIME3=TIMEDA+3.7
      WTRAN=1.5*(X(19)-X(20)-X(21))+X(20)+2*X(21)
      IF(X(20).EQ.0) WTRAN=500
      WTRP=X(23)
      IF(INC.LT.4960) PENT=1
      IF(INC.GE.4960.AND.INC.LT.7520) PENT=2
      IF(INC.GE.7520.AND.INC.LT.9920) PENT=3
      IF(INC.GE.9920.AND.INC.LT.12000) PENT=4
      IF(INC.GE.12000) PENT=5
C.....EVALUATE NUMERATORS
      NUMDA=EXP(-.262*TIMEDA+.101*PENT+1.529)
      NUM1=EXP(-.262*TIME1)
      NUM2=EXP(-.262*TIME2-.011*PPA-1.076)
      NUM3=EXP(-.262*TIME3+.074*COST3-1.448)
      NUMT=EXP(-.081*WTRAN+.007*APP-.831)
      IF(X(20).EQ.0) GO TO 100
C.....MODAL SPLIT (ALL FIVE MODES)
      DEN=NUMDA+NUM1+NUM2+NUM3+NUMT
      WDA=(NUMDA/DEN)*WTRP
      WONE=(NUM1/DEN)*WTRP
      WTWO=(NUM2/DEN)*WTRP
      WTHREE=(NUM3/DEN)*WTRP
      TRNS=(NUMT/DEN)*WTRP
      GO TO 200
C.....MODAL SPLIT (FOUR MODES-NO TRANSIT)
  100 DEN=NUMDA+NUM1+NUM2+NUM3
      WDA=(NUMDA/DEN)*WTRP
      WONE=(NUM1/DEN)*WTRP
      WTWO=(NUM2/DEN)*WTRP
      WTHREE=(NUM3/DEN)*WTRP
C.....LOAD TRIP TABLES
  200 TABSO(1)=WDA
      TABSO(2)=WONE
      TABSO(3)=WTWO
      TABSO(4)=WTHREE
      TABSO(5)=TRNS
      TETAB(1,1)=TABSO(1)
      TETAB(2,1)=TABSO(2)
      TETAB(3,1)=TABSO(3)
      TETAB(1,2)=TABSO(4)
      TETAB(2,2)=TABSO(5)
      TEPERS(1)=WTRP
      TEPERS(2)=WTRP
/*
// EXEC UMODEL,TIME=30,REGION=290K,
//     J1='DSN=&&HWYSKIM,SPACE=(CYL,(1,1))',
//     J2='DSN=&&PTSKIM,SPACE=(CYL,(1,1))',
//     J3='DSN=&&HSKMD,SPACE=(CYL,(1,1))',
//     J4='DSN=&&WTRIPS,SPACE=(CYL,(1,1))',
//     J9='DSN=WORK2,VOL=SER=007670',UNITJ9=TAPE
//UMODEL.FT19F001 DD &J9,UNIT=TAPE,LABEL=(16,SL),DISP=(NEW,KEEP)
```

```
//UMODEL.A1 DD *
  1 6682 5 5 1260   88    27     1   30   30    0  634  351  244 0 272234
  2 5266 5 5 1051   55     2     2   32   19    0   11    5   425  27  7
  3 7465 5 5 2855   41     1     1   25   11    3  181  135  7075  77 83
  .
  .              data as used in program listing 2.1
  .
30412661 1 1 1233 1111   284     0  738   85    4 3649 1003 1324 01413 21
30511952 1 1   19 2924   175     0 2749    0    0  713  190  263 0  90  0
30611952 1 1   11 4866   210     0 4652    4    0  623  167  230 0  90  0
307 9050 1 1   14  990    26     0  964    0    0  147   33   54 0  43  0
30811903 1 1   21 2809   146     0 2646   10    7 1977  755  720 0 705  7
309 9050 1 1   22  664    34     0  614   16    0  186   35   68 0  43  0
31011093 1 1    5 2935   169     0 2763    3    0  675  227  246 0 705  7
31113778 1 1   29 1532   110     0 1419    3    0  486   97  177 0  87  0
31212665 1 1   31 1937   201     0 1726   10    0  645  190  235 0 392  0
31312070 1 1    5 3734   176     0 3553    5    0  749  244  273 0 907  0
31413635 1 1   48 2784   262     0 2522    0    0 1289  309  470 0 203  0
31520388 1 1   74 1655   503     0 1111   10   31 2942  878 1158 01046 11
//UMODEL.SYSIN DD *
  **  FLINT  **  MODAL SPLIT2 - FIVE MODES ** WORK TRIPS
&PARAM ZONES=364,TABOUT=5,TESUM=3,2,
       NAME01='DRIVE ALONE',NAME02='1 PASS',NAME03='2PASS',
       NAME04='3+ PASS',NAME05='TRANSIT' &END
&OPTION &END
&SELECT REPORT=4,I=1,-315,J=1,-315,PRINT=1,-315 &END
&DATA
 1 P       1     5  1 1          ZONE NUMBER
 2 P       6    10  2 1          INCOME                  $/YEAR
 3 P      11    12  3 1          TERMINAL TIME  P        MINUTES
 4 A      13    14  4 1          TERMINAL TIME  A        MINUTES
 5 A      15    19  5 1          EMPLOYMENT              PERSONS
 6 A      20    24  6 1          TOTAL ACRES             ACRES
 7 P      25    29  7 1          RESIDENTIAL ACRES       ACRES
 8 A      30    34  8 1          INDUSTRIAL ACRES        ACRES
 9 A      35    39  9 1          UNDEVELOPED ACRES       ACRES
10 A      40    44 10 1          RETAIL WHOSL ACRES      ACRES
11 A      45    48 11 1          RECREATIONAL ACRES      ACRES
12 P      49    53 12 1          POPULATION              PERSONS
13 P      54    58 13 1          DWELLING UNITS          UNITS
14 P      59    63 14 1          RES LABOR FORCE         PERSONS
15 A      64    65 15 1          PARKING COSTS           CENTS
16 P      66    69 16 1          AUTO OWNERSHIP          AUTOS/ZN
17 P      70    72 17 1          ZERO AUTOS              FAMILIES
18 X    1001                     TIMEDA                  MINUTES
19 X    2001                     TRNS TIME               MINUTES
20 X    2002                     TRNS RUN TIME           MINUTES
21 X    2003                     TRNS WAIT TIME          MINUTES
22 X    3001                     HGWY SKIM DIST          MINUTES
23 T    4001                     WORK TRIP TABLE
99999
/*
```

APPENDIX 3

ULOGIT REPORTS

MODEL 1 - Two Mode Model

```
----------------------------ULOGIT  07JUL77 ---------------------------

                          ULOGIT   REPORT  1                    PAGE    4

           F O R M U L A   A N D   C O E F F I C I E N T

                        S P E C I F I C A T I O N S


THE COMPOSITE DISUTILITY EXPRESSIONS ARE:

A MODE                        = A2            * LANDUSE
                              + B2            * EMPLY
                              + A BIAS

TRNS MODE                     = A1            * TTRW
                              + B1            * INPENT
                              + C1            * POP PER ACRE


THE  6 COEFFICIENTS TO BE ESTIMATED ARE:

COEFFICIENT          INITIAL    LOWER    UPPER   BOUND
NO. NAME              VALUE     BOUND    BOUND    TYPE
--- ------------     -------   -------  -------  -----
  1 A1                 0.0                        NONE
  2 B1                 0.0                        NONE
  3 C1                 0.0                        NONE
  4 A2                 0.0                        NONE
  5 B2                 0.0                        NONE
  6 A BIAS             0.0                        NONE
```

MODEL 1 - Two Mode Model

```
----------------------------ULOGIT  07JUL77 ----------------------------
                           ULOGIT   REPORT  2                    PAGE    5
                 S T A T I S T I C A L   S U M M A R Y
              O F   I N D E P E N D E N T   V A R I A B L E S

THE VARIABLES USED FOR CALIBRATION ARE:

VARIABLE                         STANDARD   LARGEST  SMALLEST
NO. NAME                 MEAN       DEV.     VALUE     VALUE  UNITS
--- ------------      -------   --------  --------  --------  -----
  1 LANDUSE              1.60       0.77      3.00      1.00  CLASS

  2 EMPLY               16.21      26.59    169.52      0.0   EMP/100

  3 TTRW                 7.15       3.17     10.00      1.08  MIN/MIN

  4 INPENT               3.89       1.02      5.00      1.00  PENTILE

  5 POP PER ACRE        12.77      20.28    299.11      0.0   POP/ACRE


CORRELATION MATRIX OF INDEPENDENT VARIABLES:

          1         2         3         4
 2  -0.1843
 3   0.4459  -0.0920
 4   0.1929   0.0221   0.3441
 5  -0.3808   0.0392  -0.2867   0.0063

LOG13 6000 (INFORMATION): THE TOTAL NUMBER OF OBSERVATIONS READ
                          FROM THE CALIBRATION FILE IS         21220
                          THE TOTAL NUMBER OF SELECTED RECORDS
                          FROM THE CALIBRATION FILE IS         21220
                          THE TOTAL NUMBER OF
                          POSITIVE (WEIGHTED) VALUES IS        21220

LOG16 6070 (INFORMATION): COEFFICIENT CALIBRATION PROCEDURE ENDED
           BECAUSE OF NO IMPROVEMENT ALONG LINE.
```

MODEL 1 - Two Mode Model

```
----------------------------ULOGIT  07JUL77 ----------------------------

                         ULOGIT   REPORT  3                    PAGE    6

           F I N A L   C O E F F I C I E N T   V A L U E S

THE RESULTS OF THE COEFFICIENT CALIBRATION ARE:

COEFFICIENT              FINAL  STANDARD     T-   GRADIENT  LOWER   UPPER
NO. NAME                 VALUE     ERROR  RATIO  (IF BND.)  BOUND   BOUND
--- ------------ --------  --------  -----  ---------  -----   -----
  1  A1                 1.1217    0.1034  10.85
  2  B1                 0.1881    0.0799   2.35
  3  C1                 0.0212    0.0051   4.13
  4  A2                -0.3775    0.2141  -1.76
  5  B2                 0.0100    0.0024   4.16
  6  A BIAS             0.4714    0.3868   1.22


THE INITIAL VALUE OF THE LOGLIKELIHOOD WAS -0.14709E 05,
WHILE THE FINAL VALUE WAS -0.63663E 03 AFTER  9 ITERATIONS.

THE LOGLIKELIHOOD WITH ALL ZERO COEFFICIENTS IS -0.14709E 05,
WHILE BY INCLUDING PURE ALTERNATIVE EFFECTS IT IS -0.78178E 03.
THE LARGEST LOGLIKELIHOOD FOR THESE DATA AND ANY MODEL  0.0

TEST OF EQUAL PROBABILITY HYPOTHESIS IS  0.2814E 05
WITH   6 DEGREES OF FREEDOM.

TEST OF ALTERNATIVE DEPENDENT PROBABILITY HYPOTHESIS IS   290.3
WITH   5 DEGREES OF FREEDOM.

PSEUDO R-SQUARE = .957


MATRIX OF APPROXIMATE CORRELATION COEFFICIENTS
FOR COEFFICIENTS NOT AT BOUNDS:

COEF.   1       2       3       4       5       6
 2   -0.265
 3    0.140  -0.284
 4    0.038   0.119  -0.242
 5    0.183   0.058  -0.059   0.060
 6    0.496   0.292   0.275  -0.587  -0.057
```

MODEL 1 - Two Mode Model

```
---------------------------ULOGIT  07JUL77 ---------------------------

                         ULOGIT   REPORT  6                   PAGE    7

      O B S E R V E D   V S .   E S T I M A T E D   T O T A L S

                  F O R   E A C H   A L T E R N A T I V E

                                                STD.   CORR.  CORR.    NO.
ALTERNATIVE    OBSERVED   ESTIMATED  RESIDUAL   COEF.  RATIO  CELLS
-----------    --------   ---------  --------   -----  -----  -----
A MODE          21092.0     21018.2     6.294  0.001  0.012     19

TRNS MODE         128.0       145.9    -1.520  0.010  0.010     18




---------------------------ULOGIT  07JUL77 ---------------------------

                         ULOGIT   REPORT  8                   PAGE    8

               T A B L E   O F   E L A S T I C I T I E S

                        ELASTICITY FOR ALTERNATIVE:
                        A MODE          TRNS MODE
NO. NAME
--- ----               ------------   ------------
 1  LANDUSE            D  0.745E-04   C -0.603
 2  EMPLY              D -0.201E-04   C  0.162
 3  TTRW               C  0.995E-03   D  -8.02
 4  INPENT             C  0.906E-04   D -0.731
 5  POP PER ACRE       C  0.335E-04   D -0.270

PROBABILITIES AT AVERAGE VALUES OF VARIABLES ARE:

                           1.000          0.000

NOTE:  D INDICATES A DIRECT ELASTICITY WHILE
       C INDICATES A CROSS ELASTICITY.

ELASTICITIES ARE EVALUATED AT THE AVERAGE (WEIGHTED) VALUE
OF THE VARIABLE VALUES AS LISTED IN REPORT  2.

LOG26 8100 (INFORMATION): PROCESSING ENDED FOR &SELECT NUMBER  1

LOG26 7000 (INFORMATION): THERE WERE172936 EXTRA BYTES
                          OF CORE ALLOTTED FOR TABLES

SINOFF 6700 (INFORMATION): ULOGIT   ENDED AT 15.09.46 (RETURN CODE=  0)
```

MODEL 2 - Two Mode Model

```
----------------------------ULOGIT  07JUL77 ----------------------------
                            ULOGIT   REPORT  1                    PAGE    4

            F O R M U L A   A N D   C O E F F I C I E N T

                       S P E C I F I C A T I O N S

THE COMPOSITE DISUTILITY EXPRESSIONS ARE:

A MODE                        = A2           * HWY COST
                              + B2           * INPENT
                              + A BIAS

TRNS MODE                     = A1           * TTRW
                              + B1           * RETAIL WHOLESALE ACRES
                              + C1           * POP PER ACRE

THE  6 COEFFICIENTS TO BE ESTIMATED ARE:

COEFFICIENT          INITIAL    LOWER     UPPER   BOUND
NO. NAME               VALUE    BOUND     BOUND    TYPE
--- ------------     -------  -------   -------   -----
  1 A1                0.0                          NONE
  2 B1                0.0                          NONE
  3 C1                0.0                          NONE
  4 A2                0.0                          NONE
  5 B2                0.0                          NONE
  6 A BIAS            0.0                          NONE
```

MODEL 2 - Two Mode Model

```
----------------------------ULOGIT  07JUL77 ----------------------------
                                ULOGIT   REPORT  2                   PAGE    5
                    S T A T I S T I C A L   S U M M A R Y
                 O F   I N D E P E N D E N T   V A R I A B L E S

THE VARIABLES USED FOR CALIBRATION ARE:

VARIABLE                         STANDARD   LARGEST  SMALLEST
NO. NAME                 MEAN      DEV.      VALUE     VALUE   UNITS
--- ------------      -------  --------  --------  --------   -----
  1 HWY COST             0.77      0.66      4.80      0.10   $

  2 INPENT               3.89      1.02      5.00      1.00   PENTILE

  3 TTRW                 7.15      3.17     10.00      1.08   MIN/MIN

  4 RETAIL WHOLE        37.63     42.82    243.00       0.0   ACRES
    SALE ACRES
  5 POP PER ACRE        12.77     20.28    299.11       0.0   POP/ACRE


CORRELATION MATRIX OF INDEPENDENT VARIABLES:

          1          2          3          4
  2   0.2038
  3   0.2962     0.3441
  4   0.0639     0.0799     0.0887
  5  -0.0075     0.0063    -0.2867    -0.2532

LOG13 6000 (INFORMATION): THE TOTAL NUMBER OF OBSERVATIONS READ
                          FROM THE CALIBRATION FILE IS          21220
                          THE TOTAL NUMBER OF SELECTED RECORDS
                          FROM THE CALIBRATION FILE IS          21220
                          THE TOTAL NUMBER OF
                          POSITIVE (WEIGHTED) VALUES IS         21220

LOG16 6070 (INFORMATION): COEFFICIENT CALIBRATION PROCEDURE ENDED
             BECAUSE OF NO IMPROVEMENT ALONG LINE.
```

MODEL 2 - Two Mode Model

```
---------------------------ULOGIT  07JUL77 ---------------------------

                          ULOGIT   REPORT  3                   PAGE    6

          F I N A L   C O E F F I C I E N T   V A L U E S


THE RESULTS OF THE COEFFICIENT CALIBRATION ARE:

COEFFICIENT             FINAL  STANDARD      T-   GRADIENT  LOWER  UPPER
NO. NAME                VALUE     ERROR   RATIO  (IF BND.)  BOUND  BOUND
--- ------------ --------  --------  -----  ---------  -----  -----
  1  A1                0.9934    0.0724   13.72
  2  B1                0.0059    0.0021    2.81
  3  C1                0.0259    0.0049    5.23
  4  A2                1.5765    0.1273   12.39
  5  B2                0.1629    0.0749    2.18
  6  A BIAS           -1.9359    0.3166   -6.11


THE INITIAL VALUE OF THE LOGLIKELIHOOD WAS -0.14709E 05,
WHILE THE FINAL VALUE WAS -0.65161E 03 AFTER  8 ITERATIONS.

THE LOGLIKELIHOOD WITH ALL ZERO COEFFICIENTS IS -0.14709E 05,
WHILE BY INCLUDING PURE ALTERNATIVE EFFECTS IT IS -0.78178E 03.
THE LARGEST LOGLIKELIHOOD FOR THESE DATA AND ANY MODEL  0.0

TEST OF EQUAL PROBABILITY HYPOTHESIS IS  0.2811E 05
WITH   6 DEGREES OF FREEDOM.

TEST OF ALTERNATIVE DEPENDENT PROBABILITY HYPOTHESIS IS   260.3
WITH   5 DEGREES OF FREEDOM.

PSEUDO R-SQUARE = .956


MATRIX OF APPROXIMATE CORRELATION COEFFICIENTS
FOR COEFFICIENTS NOT AT BOUNDS:

COEF.    1       2       3       4       5       6
 2     0.070
 3     0.147   0.246
 4     0.315   0.154  -0.061
 5     0.128   0.016   0.207  -0.278
 6     0.487   0.255   0.210   0.089  -0.624
```

MODEL 2 - Two Mode Model

```
----------------------------ULOGIT  07JUL77 ----------------------------

                             ULOGIT   REPORT  6                  PAGE    7

     O B S E R V E D   V S .   E S T I M A T E D   T O T A L S

               F O R   E A C H   A L T E R N A T I V E

                                            STD.   CORR.   CORR.    NO.
ALTERNATIVE   OBSERVED  ESTIMATED  RESIDUAL  COEF.   RATIO   CELLS
-----------   --------  ---------  --------  -----   -----   -----
A MODE         21092.0    20999.8     7.495  0.001   0.018      24

TRNS MODE        128.0      165.9    -3.063  0.007   0.016      23
```

```
----------------------------ULOGIT  07JUL77 ----------------------------

                             ULOGIT   REPORT  8                  PAGE    8

               T A B L E   O F   E L A S T I C I T I E S

                    ELASTICITY FOR ALTERNATIVE:
                    A MODE        TRNS MODE
NO. NAME
--- ----          ------------  ------------
 1  HWY COST      D -0.524E-03  C    1.21
 2  INPENT        D -0.273E-03  C  0.633
 3  TTRW          C  0.306E-02  D  -7.10
 4  RETAIL WHOLE  C  0.958E-04  D -0.222
 5  POP PER ACRE  C  0.142E-03  D -0.330

PROBABILITIES AT AVERAGE VALUES OF VARIABLES ARE:

                         1.000         0.000

NOTE:  D INDICATES A DIRECT ELASTICITY WHILE
       C INDICATES A CROSS ELASTICITY.

ELASTICITIES ARE EVALUATED AT THE AVERAGE (WEIGHTED) VALUE
OF THE VARIABLE VALUES AS LISTED IN REPORT  2.

LOG26 8100 (INFORMATION): PROCESSING ENDED FOR &SELECT NUMBER   1

LOG26 7000 (INFORMATION): THERE WERE172936 EXTRA BYTES
                          OF CORE ALLOTTED FOR TABLES

SINOFF 6700 (INFORMATION): ULOGIT   ENDED AT 15.01.50 (RETURN CODE=  0)
```

MODEL 2-A - Two Mode Model

```
----------------------------ULOGIT  07JUL77 ---------------------------
                            ULOGIT  REPORT  1                 PAGE    4
           F O R M U L A   A N D   C O E F F I C I E N T
                        S P E C I F I C A T I O N S

THE COMPOSITE DISUTILITY EXPRESSIONS ARE:

A MODE                       = A2             * INPENT
                             + B2             * EMPLY
                             + A BIAS

TRNS MODE                    = A1             * TTRW


THE  4 COEFFICIENTS TO BE ESTIMATED ARE:

COEFFICIENT         INITIAL     LOWER     UPPER  BOUND
NO. NAME              VALUE     BOUND     BOUND   TYPE
--- -----------     -------   -------   -------  -----
  1 A1                0.0                         NONE
  2 A2                0.0                         NONE
  3 B2                0.0                         NONE
  4 A BIAS            0.0                         NONE
```

MODEL 2-A - Two Mode Model

```
---------------------------ULOGIT  07JUL77 ---------------------------
                           ULOGIT   REPORT  2                 PAGE    5
               S T A T I S T I C A L   S U M M A R Y
           O F   I N D E P E N D E N T   V A R I A B L E S

THE VARIABLES USED FOR CALIBRATION ARE:

VARIABLE                       STANDARD   LARGEST  SMALLEST
NO. NAME                MEAN       DEV.     VALUE     VALUE  UNITS
--- ------------     -------   --------  --------  --------  -----
  1 INPENT              3.89       1.02      5.00      1.00  PENTILE

  2 EMPLY              16.21      26.59    169.52      0.0   EMP/100

  3 TTRW                7.15       3.17     10.00      1.08  MIN/MIN


CORRELATION MATRIX OF INDEPENDENT VARIABLES:

        1         2
 2   0.0221
 3   0.3441   -0.0920

LOG13 6000 (INFORMATION): THE TOTAL NUMBER OF OBSERVATIONS READ
                          FROM THE CALIBRATION FILE IS          21220
                          THE TOTAL NUMBER OF SELECTED RECORDS
                          FROM THE CALIBRATION FILE IS          21220
                          THE TOTAL NUMBER OF
                          POSITIVE (WEIGHTED) VALUES IS         21220

LOG16 6070 (INFORMATION): COEFFICIENT CALIBRATION PROCEDURE ENDED
             BECAUSE OF NO IMPROVEMENT ALONG LINE.
```

MODEL 2-A - Two Mode Model

```
---------------------------ULOGIT  07JUL77 ---------------------------

                            ULOGIT   REPORT  3                  PAGE    6

            F I N A L    C O E F F I C I E N T    V A L U E S


THE RESULTS OF THE COEFFICIENT CALIBRATION ARE:

COEFFICIENT              FINAL  STANDARD      T-    GRADIENT  LOWER  UPPER
NO. NAME                 VALUE     ERROR   RATIO  (IF BND.)  BOUND  BOUND
--- ------------ -------- -------- -----  ---------  -----  -----
  1  A1                1.0049    0.0875   11.48
  2  A2                0.3245    0.0756    4.29
  3  B2                0.0086    0.0026    3.33
  4  A BIAS           -2.2969    0.3346   -6.86


THE INITIAL VALUE OF THE LOGLIKELIHOOD WAS -0.14709E 05,
WHILE THE FINAL VALUE WAS -0.64863E 03 AFTER  8 ITERATIONS.

THE LOGLIKELIHOOD WITH ALL ZERO COEFFICIENTS IS -0.14709E 05,
WHILE BY INCLUDING PURE ALTERNATIVE EFFECTS IT IS -0.78178E 03.
THE LARGEST LOGLIKELIHOOD FOR THESE DATA AND ANY MODEL  0.0

TEST OF EQUAL PROBABILITY HYPOTHESIS IS  0.2812E 05
WITH   4 DEGREES OF FREEDOM.

TEST OF ALTERNATIVE DEPENDENT PROBABILITY HYPOTHESIS IS   266.3
WITH   3 DEGREES OF FREEDOM.

PSEUDO R-SQUARE = .956


MATRIX OF APPROXIMATE CORRELATION COEFFICIENTS
FOR COEFFICIENTS NOT AT BOUNDS:

COEF.   1       2       3       4
  2   0.207
  3   0.133 -0.020
  4   0.505 -0.680 -0.095
```

MODEL 2-A - Two Mode Model

```
----------------------------ULOGIT  07JUL77 ----------------------------

                    ULOGIT   REPORT  6                      PAGE    7

     O B S E R V E D   V S .   E S T I M A T E D   T O T A L S

               F O R   E A C H   A L T E R N A T I V E

                                           STD.   CORR.  CORR.    NO.
ALTERNATIVE    OBSERVED  ESTIMATED  RESIDUAL  COEF.  RATIO  CELLS
-----------    --------  ---------  --------  -----  -----  -----
A MODE          21092.0    21010.3     6.725  0.001  0.008     16

TRNS MODE         128.0      154.3    -2.155  0.009  0.006     15
```

```
----------------------------ULOGIT  07JUL77 ----------------------------

                    ULOGIT   REPORT  8                      PAGE    8

              T A B L E   O F   E L A S T I C I T I E S

                    ELASTICITY FOR ALTERNATIVE:
                    A MODE          TRNS MODE
NO. NAME
--- ----           ------------  ------------
 1  INPENT         D -0.388E-03  C   1.26
 2  EMPLY          D -0.430E-04  C  0.140
 3  TTRW           C  0.221E-02  D  -7.19

PROBABILITIES AT AVERAGE VALUES OF VARIABLES ARE:

                         1.000          0.000

NOTE:  D INDICATES A DIRECT ELASTICITY WHILE
       C INDICATES A CROSS ELASTICITY.

ELASTICITIES ARE EVALUATED AT THE AVERAGE (WEIGHTED) VALUE
OF THE VARIABLE VALUES AS LISTED IN REPORT  2.

LOG26 8100 (INFORMATION): PROCESSING ENDED FOR &SELECT NUMBER  1

LOG26 7000 (INFORMATION): THERE WERE173336 EXTRA BYTES
                          OF CORE ALLOTTED FOR TABLES

SINOFF 6700 (INFORMATION): ULOGIT   ENDED AT 20.54.55 (RETURN CODE=  0)
```

MODEL 2-B - Two Mode Model

```
---------------------------ULOGIT  07JUL77 ---------------------------
                           ULOGIT   REPORT  1                  PAGE    4
           F O R M U L A   A N D   C O E F F I C I E N T
                        S P E C I F I C A T I O N S

THE COMPOSITE DISUTILITY EXPRESSIONS ARE:

A MODE                    = A2          * HWY COST
                          + B2          * INPENT
                          + A BIAS

TRNS MODE                 = A1          * WTR TIME
                          + B1          * RETAIL WHOLESALE ACRES
                          + C1          * POP PER ACRE

THE  6 COEFFICIENTS TO BE ESTIMATED ARE:

COEFFICIENT        INITIAL    LOWER    UPPER   BOUND
NO. NAME             VALUE    BOUND    BOUND    TYPE
--- -----------    -------  -------  -------   -----
  1 A1             0.0                          NONE
  2 B1             0.0                          NONE
  3 C1             0.0                          NONE
  4 A2             0.0                          NONE
  5 B2             0.0                          NONE
  6 A BIAS         0.0                          NONE
```

MODEL 2-B - Two Mode Model

```
----------------------------ULOGIT  07JUL77 ---------------------------
                               ULOGIT   REPORT  2                   PAGE    5
                S T A T I S T I C A L   S U M M A R Y
             O F   I N D E P E N D E N T   V A R I A B L E S

THE VARIABLES USED FOR CALIBRATION ARE:

VARIABLE                          STANDARD   LARGEST  SMALLEST
NO. NAME               MEAN       DEV.       VALUE      VALUE  UNITS
--- ------------    -------   --------   --------   --------   -----
  1 HWY COST           0.77       0.66       4.80       0.10  $

  2 INPENT             3.89       1.02       5.00       1.00  PENTILE

  3 WTR TIME         289.13     216.07     500.00      20.50  MINUTES

  4 RETAIL WHOLE      37.63      42.82     243.00       0.0   ACRES
    SALE ACRES
  5 POP PER ACRE      12.77      20.28     299.11       0.0   POP/ACRE


CORRELATION MATRIX OF INDEPENDENT VARIABLES:

           1          2          3          4
 2    0.2038
 3    0.3863     0.3141
 4    0.0639     0.0799     0.0903
 5   -0.0075     0.0063    -0.2391    -0.2532

LOG13 6000 (INFORMATION): THE TOTAL NUMBER OF OBSERVATIONS READ
                          FROM THE CALIBRATION FILE IS          21220
                          THE TOTAL NUMBER OF SELECTED RECORDS
                          FROM THE CALIBRATION FILE IS          21220
                          THE TOTAL NUMBER OF
                          POSITIVE (WEIGHTED) VALUES IS         21220

LOG16 6070 (INFORMATION): COEFFICIENT CALIBRATION PROCEDURE ENDED
             BECAUSE OF NO IMPROVEMENT ALONG LINE.
```

MODEL 2-B - Two Mode Model

```
---------------------------ULOGIT  07JUL77 ---------------------------

                           ULOGIT   REPORT  3                   PAGE   6

          F I N A L   C O E F F I C I E N T   V A L U E S

THE RESULTS OF THE COEFFICIENT CALIBRATION ARE:

COEFFICIENT.           FINAL  STANDARD     T-   GRADIENT  LOWER  UPPER
NO. NAME               VALUE     ERROR  RATIO  (IF BND.)  BOUND  BOUND
--- ------------ --------  --------  -----  ---------  -----  -----
 1  A1              0.0128    0.0011  11.84
 2  B1              0.0052    0.0020   2.55
 3  C1              0.0180    0.0050   3.62
 4  A2              1.9438    0.1403  13.85
 5  B2              0.0433    0.0734   0.59
 6  A BIAS         -4.1861    0.2854 -14.67


THE INITIAL VALUE OF THE LOGLIKELIHOOD WAS -0.14709E 05,
WHILE THE FINAL VALUE WAS -0.69487E 03 AFTER  7 ITERATIONS.

THE LOGLIKELIHOOD WITH ALL ZERO COEFFICIENTS IS -0.14709E 05,
WHILE BY INCLUDING PURE ALTERNATIVE EFFECTS IT IS -0.78178E 03.
THE LARGEST LOGLIKELIHOOD FOR THESE DATA AND ANY MODEL  0.0

TEST OF EQUAL PROBABILITY HYPOTHESIS IS  0.2803E 05
WITH   6 DEGREES OF FREEDOM.

TEST OF ALTERNATIVE DEPENDENT PROBABILITY HYPOTHESIS IS   173.8
WITH   5 DEGREES OF FREEDOM.

PSEUDO R-SQUARE = .953


MATRIX OF APPROXIMATE CORRELATION COEFFICIENTS
FOR COEFFICIENTS NOT AT BOUNDS:

COEF.   1       2       3       4       5       6
 2    0.098
 3    0.097   0.262
 4    0.702   0.148  -0.009
 5   -0.012   0.031   0.142  -0.201
 6    0.097   0.237   0.188   0.014  -0.832
```

MODEL 2-B - Two Mode Model

```
---------------------------ULOGIT  07JUL77 ---------------------------

                        ULOGIT   REPORT  6                  PAGE    7

      O B S E R V E D   V S .   E S T I M A T E D   T O T A L S

                F O R   E A C H   A L T E R N A T I V E

                                             STD.   CORR.  CORR.    NO.
ALTERNATIVE   OBSERVED  ESTIMATED  RESIDUAL  COEF.  RATIO  CELLS
-----------   --------  ---------  --------  -----  -----  -----
A MODE         21092.0    20992.0     7.697  0.001  0.006     21

TRNS MODE        128.0      178.4    -3.856  0.006  0.006     20
```

```
---------------------------ULOGIT  07JUL77 ---------------------------

                        ULOGIT   REPORT  8                  PAGE    8

              T A B L E   O F   E L A S T I C I T I E S

                     ELASTICITY FOR ALTERNATIVE:
                     A MODE         TRNS MODE
NO. NAME
--- ----            ------------  ------------
 1  HWY COST        D -0.195E-02  C    1.50
 2  INPENT          D -0.219E-03  C  0.168
 3  WTR TIME        C  0.481E-02  D  -3.69
 4  RETAIL WHOLE    C  0.253E-03  D -0.194
 5  POP PER ACRE    C  0.300E-03  D -0.230

PROBABILITIES AT AVERAGE VALUES OF VARIABLES ARE:

                           0.999          0.001

NOTE:  D INDICATES A DIRECT ELASTICITY WHILE
       C INDICATES A CROSS ELASTICITY.

ELASTICITIES ARE EVALUATED AT THE AVERAGE (WEIGHTED) VALUE
OF THE VARIABLE VALUES AS LISTED IN REPORT  2.

LOG26 8100 (INFORMATION): PROCESSING ENDED FOR &SELECT NUMBER  1

LOG26 7000 (INFORMATION): THERE WERE172936 EXTRA BYTES
                          OF CORE ALLOTTED FOR TABLES

SINOFF 6700 (INFORMATION): ULOGIT   ENDED AT 21.50.48 (RETURN CODE=  0)
```

MODEL 3

Five Mode Model for Work Trips

```
----------------------------ULOGIT  07JUL77 ----------------------------
                         ULOGIT   REPORT  1                    PAGE    5
           F O R M U L A   A N D   C O E F F I C I E N T
                         S P E C I F I C A T I O N S

THE COMPOSITE DISUTILITY EXPRESSIONS ARE:

WDA                            = A1             * HGWY SKIM TIME
                               + B1             * PENTILE
                               + A BIAS

WONE                           = A1             * HONE
                               + B2             * EMPLY

WTWO                           = A1             * HTWO
                               + B3             * RLF PER ACRE

WTHREE                         = A1             * HTHREE
                               + B4             * AUTOS PER POP

TRANSIT                        = A5             * WTRNS TIME
                               + B5             * ZERO AUTOS

THE  8 COEFFICIENTS TO BE ESTIMATED ARE:

COEFFICIENT           INITIAL     LOWER     UPPER   BOUND
NO. NAME                VALUE     BOUND     BOUND    TYPE
--- ------------      -------   -------   -------   -----
  1 A1                  0.0                          NONE
  2 B1                  0.0                          NONE
  3 A BIAS              0.0                          NONE
  4 B2                  0.0                          NONE
  5 B3                  0.0                          NONE
  6 B4                  0.0                          NONE
  7 A5                  0.0                          NONE
  8 B5                  0.0                          NONE
```

MODEL 3

Five Mode Model for Work Trips

```
----------------------------ULOGIT  07JUL77 ----------------------------
                              ULOGIT   REPORT  2                   PAGE    6
                 S T A T I S T I C A L   S U M M A R Y
              O F   I N D E P E N D E N T   V A R I A B L E S

THE VARIABLES USED FOR CALIBRATION ARE:

VARIABLE                        STANDARD   LARGEST  SMALLEST
NO. NAME               MEAN       DEV.      VALUE     VALUE  UNITS
--- ------------    -------   --------  --------  --------  -----
  1 HGWY SKIM TI      18.24       8.96     70.00      2.00  MINUTES
    ME
  2 PENTILE            3.91       0.97      5.00      1.00  PENT

  3 HONE              19.32       8.99     71.10      3.10  MINUTES

  4 EMPLY             35.66      48.28    163.99      0.0   EMP/100

  5 HTWO              20.32       9.00     72.10      4.10  MINUTES

  6 RLF PER ACRE       5.69       7.49    100.59      0.0   RLF/ACRE

  7 HTHREE            21.93       8.96     73.70      5.70  MINUTES

  8 AUTOS PER PO       0.98      11.47    253.00      0.0   AUTO/POP
    P
  9 WTRNS TIME       266.00     211.53    500.00     22.00  MINUTES

 10 ZERO AUTOS        61.12      70.44    328.00      0.0   FAMILIES



CORRELATION MATRIX OF INDEPENDENT VARIABLES:

         1         2         3         4         5         6         7
         8         9
 2    0.1640
 3    0.9970    0.1693
 4    0.1510   -0.0680    0.1524
 5    0.9967    0.1696    0.9992    0.1524
 6    0.0366    0.0664    0.0380   -0.1416    0.0379
 7    0.9971    0.1626    1.0003    0.1518    0.9992    0.0362
 8   -0.0126   -0.0883   -0.0123   -0.0104   -0.0123   -0.0365   -0.0125
 9    0.3335    0.3287    0.3349   -0.0588    0.3348   -0.1332    0.3340
     -0.0185
10   -0.1946   -0.6326   -0.1923    0.0413   -0.1922    0.0853   -0.1945
      0.1468   -0.3047

LOG13 6000 (INFORMATION): THE TOTAL NUMBER OF OBSERVATIONS READ
                          FROM THE CALIBRATION FILE IS          10165
                          THE TOTAL NUMBER OF SELECTED RECORDS
                          FROM THE CALIBRATION FILE IS          10165
                          THE TOTAL NUMBER OF
                          POSITIVE (WEIGHTED) VALUES IS         10165

LOG16 6070 (INFORMATION): COEFFICIENT CALIBRATION PROCEDURE ENDED
           BECAUSE OF NO IMPROVEMENT ALONG LINE.
```

MODEL 3

Five Mode Model for Work Trips

```
----------------------------ULOGIT  07JUL77 ----------------------------

                            ULOGIT   REPORT  3                      PAGE    7

          F I N A L    C O E F F I C I E N T    V A L U E S

THE RESULTS OF THE COEFFICIENT CALIBRATION ARE:

COEFFICIENT            FINAL  STANDARD      T-   GRADIENT  LOWER  UPPER
NO. NAME               VALUE     ERROR   RATIO  (IF BND.)  BOUND  BOUND
--- ------------ ---------  --------   -----  ---------  -----  -----
  1 A1              0.3460    0.0234   14.81
  2 B1             -0.0830    0.0300   -2.76
  3 A BIAS         -1.7602    0.1278  -13.77
  4 B2             -0.0024    0.0007   -3.61
  5 B3              0.1225    0.0145    8.47
  6 B4              1.5972    0.2370    6.74
  7 A5              0.1207    0.0083   14.47
  8 B5             -0.0007    0.0013   -0.55

THE INITIAL VALUE OF THE LOGLIKELIHOOD WAS -0.16360E 05,
WHILE THE FINAL VALUE WAS -0.53323E 04 AFTER  9 ITERATIONS.

THE LOGLIKELIHOOD WITH ALL ZERO COEFFICIENTS IS -0.16360E 05,
WHILE BY INCLUDING PURE ALTERNATIVE EFFECTS IT IS -0.53464E 04.
THE LARGEST LOGLIKELIHOOD FOR THESE DATA AND ANY MODEL  0.0

TEST OF EQUAL PROBABILITY HYPOTHESIS IS  0.2206E 05
WITH   8 DEGREES OF FREEDOM.

TEST OF ALTERNATIVE DEPENDENT PROBABILITY HYPOTHESIS IS   28.26
WITH   4 DEGREES OF FREEDOM.

PSEUDO R-SQUARE = .674


MATRIX OF APPROXIMATE CORRELATION COEFFICIENTS
FOR COEFFICIENTS NOT AT BOUNDS:

COEF.    1        2        3        4        5        6        7        8
 2   -0.039
 3    0.282   -0.918
 4    0.093   -0.046    0.231
 5   -0.193    0.008    0.071    0.216
 6   -0.506    0.025   -0.043    0.149    0.245
 7    0.955   -0.019    0.273    0.124   -0.156   -0.460
 8   -0.065   -0.160    0.142    0.023    0.030    0.047   -0.253
```

MODEL 3

Five Mode Model for Work Trips

```
--------------------------ULOGIT  07JUL77 --------------------------

                          ULOGIT   REPORT  6                 PAGE    8

      O B S E R V E D   V S .   E S T I M A T E D   T O T A L S

              F O R   E A C H   A L T E R N A T I V E

                                            STD.   CORR.  CORR.    NO.
ALTERNATIVE   OBSERVED  ESTIMATED  RESIDUAL   COEF.  RATIO  CELLS
-----------   --------  ---------  --------   -----  -----  -----
WDA             8784.0     8749.9     0.986  0.002  0.009     19

WONE             946.0      815.7     4.763  0.000  0.002     10

WTWO             219.0      324.5    -5.971  0.001  0.004      8

WTHREE           130.0      152.3    -1.819  0.001  0.000      3

TRANSIT           86.0      110.3    -2.519  0.006  0.029     24
```

```
--------------------------ULOGIT  07JUL77 --------------------------

                          ULOGIT   REPORT  8                 PAGE    9

          T A B L E   O F   E L A S T I C I T I E S

                   ELASTICITY FOR ALTERNATIVE:
                   WDA           WONE           WTWO
                   WTHREE        TRANSIT
NO. NAME
--- ----           ------------  ------------   ------------
 1  HGWY SKIM TI   D -0.729      C   5.58       C   5.58
                   C   5.58      C   5.58
 2  PENTILE        D  0.375E-01  C -0.287       C -0.287
                   C -0.287      C -0.287
 3  HONE           C  0.551      D  -6.13       C  0.551
                   C  0.551      C  0.551
 4  EMPLY          C -0.692E-02  D  0.770E-01   C -0.692E-02
                   C -0.692E-02  C -0.692E-02
 5  HTWO           C  0.188      C  0.188       D  -6.84
                   C  0.188      C  0.188
 6  RLF PER ACRE   C  0.186E-01  C  0.186E-01   D -0.679
                   C  0.186E-01  C  0.186E-01
 7  HTHREE         C  0.487E-01  C  0.487E-01   C  0.487E-01
                   D  -7.54      C  0.487E-01
 8  AUTOS PER PO   C  0.100E-01  C  0.100E-01   C  0.100E-01
                   D  -1.55      C  0.100E-01
 9  WTRNS TIME     C  0.232E-10  C  0.232E-10   C  0.232E-10
                   C  0.232E-10  D  -32.1
10  ZERO AUTOS     C -0.308E-13  C -0.308E-13   C -0.308E-13
                   C -0.308E-13  D  0.425E-01


PROBABILITIES AT AVERAGE VALUES OF VARIABLES ARE:

                       0.884         0.082          0.027
                       0.006         0.000

NOTE:  D INDICATES A DIRECT ELASTICITY WHILE
       C INDICATES A CROSS ELASTICITY.

ELASTICITIES ARE EVALUATED AT THE AVERAGE (WEIGHTED) VALUE
OF THE VARIABLE VALUES AS LISTED IN REPORT  2.

LOG26 8100 (INFORMATION): PROCESSING ENDED FOR &SELECT NUMBER  1

LOG26 7000 (INFORMATION): THERE WERE170620 EXTRA BYTES
                          OF CORE ALLOTTED FOR TABLES

SINOFF 6700 (INFORMATION): ULOGIT   ENDED AT 18.26.01 (RETURN CODE=  0)
```

MODEL 4

Five Mode Model for Work Trips

```
---------------------------ULOGIT  07JUL77 ---------------------------

                          ULOGIT   REPORT  1                       PAGE    5

            F O R M U L A   A N D   C O E F F I C I E N T

                         S P E C I F I C A T I O N S

THE COMPOSITE DISUTILITY EXPRESSIONS ARE:

WDA                        = A1               * TIMEDA
                           + B1               * PENTILE
                           + A BIAS

WONE                       = A1               * TIME1

WTWO                       = A1               * TIME2
                           + B3               * POP PER ACRE
                           + P2 BIAS

WTHREE                     = A1               * TIME3
                           + C4               * COST3
                           + P3 BIAS

TRANSIT                    = A5               * WTRNS TIME
                           + B5               * AUTOS PER POP
                           + T BIAS


THE 10 COEFFICIENTS TO BE ESTIMATED ARE:

COEFFICIENT          INITIAL    LOWER    UPPER   BOUND
NO. NAME               VALUE    BOUND    BOUND    TYPE
--- ------------     -------  -------  -------   -----
  1 A1                0.2620                      NONE
  2 B1               -0.1010                      NONE
  3 A BIAS           -1.5290                      NONE
  4 B3                0.0110                      NONE
  5 P2 BIAS           1.0760                      NONE
  6 C4               -0.0740                      NONE
  7 P3 BIAS           1.4480                      NONE
  8 A5                0.0810                      NONE
  9 B5               -0.0070                      NONE
 10 T BIAS            0.8310                      NONE
```

MODEL 4

Five Mode Model for Work Trips

```
---------------------------ULOGIT  07JUL77 ---------------------------

                          ULOGIT   REPORT  2                   PAGE    6
                S T A T I S T I C A L   S U M M A R Y

            O F   I N D E P E N D E N T   V A R I A B L E S

THE VARIABLES USED FOR CALIBRATION ARE:

VARIABLE                            STANDARD   LARGEST  SMALLEST
NO. NAME                   MEAN       DEV.      VALUE     VALUE  UNITS
--- ------------        -------   --------   --------  --------  -----
  1 TIMEDA                18.24       8.96      70.00      2.00  MINUTES

  2 PENTILE                3.91       0.97       5.00      1.00  PENT

  3 TIME1                 19.32       8.99      71.10      3.10  MINUTES

  4 TIME2                 20.32       9.00      72.10      4.10  MINUTES

  5 POP PER ACRE          15.06      19.79     268.69      0.00  POP/ACRE

  6 TIME3                 21.93       8.96      73.70      5.70  MINUTES

  7 COST3                  1.02       3.63      19.36      0.08  CENTS

  8 WTRNS TIME           266.00     211.53     500.00     22.00  MINUTES

  9 AUTOS PER PO           0.98      11.47     253.00       0.0  AUTO/POP
    P


CORRELATION MATRIX OF INDEPENDENT VARIABLES:

          1         2         3         4         5         6         7
          8
 2   0.1640
 3   0.9970    0.1693
 4   0.9967    0.1696    0.9992
 5   0.0412    0.0709    0.0430    0.0432
 6   0.9971    0.1626    1.0003    0.9992    0.0421
 7   0.0579    0.0565    0.0585    0.0585    0.5053    0.0583
 8   0.3335    0.3287    0.3349    0.3348   -0.1324    0.3340   -0.0716
 9  -0.0126   -0.0883   -0.0123   -0.0123   -0.0366   -0.0125   -0.0112
    -0.0185

LOG13 6000 (INFORMATION): THE TOTAL NUMBER OF OBSERVATIONS READ
                          FROM THE CALIBRATION FILE IS         10165
                          THE TOTAL NUMBER OF SELECTED RECORDS
                          FROM THE CALIBRATION FILE IS         10165
                          THE TOTAL NUMBER OF
                          POSITIVE (WEIGHTED) VALUES IS        10165

LOG16 6070 (INFORMATION): COEFFICIENT CALIBRATION PROCEDURE ENDED
            BECAUSE OF NO IMPROVEMENT ALONG LINE.
```

MODEL 4

Five Mode Model for Work Trips

```
----------------------------ULOGIT  07JUL77 ---------------------------

                            ULOGIT   REPORT  3                   PAGE    7

           F I N A L   C O E F F I C I E N T   V A L U E S

THE RESULTS OF THE COEFFICIENT CALIBRATION ARE:

COEFFICIENT            FINAL  STANDARD     T-   GRADIENT  LOWER  UPPER
NO. NAME               VALUE     ERROR  RATIO  (IF BND.)  BOUND  BOUND
--- ------------ --------- --------- -----  ---------  -----  -----
 1  A1              0.2620    0.0219  11.95
 2  B1             -0.1010    0.0295  -3.43
 3  A BIAS         -1.5290    0.1218 -12.55
 4  B3              0.0110    0.0048   2.27
 5  P2 BIAS         1.0760    0.0971  11.08
 6  C4             -0.0740    0.0148  -5.02
 7  P3 BIAS         1.4480    0.1161  12.47
 8  A5              0.0810    0.0070  11.58
 9  B5             -0.0070    0.0039  -1.80
10  T BIAS          0.8310    0.3283   2.53


THE INITIAL VALUE OF THE LOGLIKELIHOOD WAS -0.52428E 04,
WHILE THE FINAL VALUE WAS -0.52428E 04 AFTER  1 ITERATIONS.

THE LOGLIKELIHOOD WITH ALL ZERO COEFFICIENTS IS -0.16360E 05,
WHILE BY INCLUDING PURE ALTERNATIVE EFFECTS IT IS -0.53464E 04.
THE LARGEST LOGLIKELIHOOD FOR THESE DATA AND ANY MODEL  0.0

TEST OF EQUAL PROBABILITY HYPOTHESIS IS  0.2223E 05
WITH  10 DEGREES OF FREEDOM.

TEST OF ALTERNATIVE DEPENDENT PROBABILITY HYPOTHESIS IS   207.2
WITH   6 DEGREES OF FREEDOM.

PSEUDO R-SQUARE = .680



MATRIX OF APPROXIMATE CORRELATION COEFFICIENTS
FOR COEFFICIENTS NOT AT BOUNDS:

COEF.    1       2       3       4       5       6       7       8
       1       2       3       4       5       6       7       8
 2  -0.046
 3   0.241 -0.940
 4  -0.003  0.020 -0.019
 5  -0.223 -0.005  0.049 -0.593
 6  -0.012  0.024 -0.025  0.010 -0.005
 7  -0.488  0.019 -0.041  0.000  0.202 -0.321
 8   0.732 -0.014  0.159 -0.004 -0.162 -0.017 -0.357
 9  -0.098 -0.035  0.013 -0.003  0.024 -0.002  0.048 -0.072
10   0.331 -0.063  0.150  0.003 -0.044  0.011 -0.136 -0.364
    -0.065
```

MODEL 4

Five Mode Model for Work Trips

```
---------------------------ULOGIT  07JUL77 ---------------------------

                           ULOGIT   REPORT  6                   PAGE    9

      O B S E R V E D   V S .   E S T I M A T E D   T O T A L S

              F O R   E A C H   A L T E R N A T I V E

                                          STD.   CORR.   CORR.    NO.
ALTERNATIVE  OBSERVED  ESTIMATED  RESIDUAL  COEF.   RATIO   CELLS
-----------  --------  ---------  --------  -----   -----   -----
WDA            8784.0     8727.7     1.617  0.002   0.008      15

WONE            946.0      958.9    -0.439  0.000   0.001       7

WTWO            219.0      217.7     0.086  0.001   0.000       3

WTHREE          130.0      128.9     0.099  0.002   0.010       6

TRANSIT          86.0      118.4    -3.119  0.010   0.033      22


---------------------------ULOGIT  07JUL77 ---------------------------

30SEP80  16.46.42          ULOGIT   REPORT  8                   PAGE   10

              T A B L E   O F   E L A S T I C I T I E S

                     ELASTICITY FOR ALTERNATIVE:
                     WDA              WONE             WTWO
                     WTHREE           TRANSIT
NO. NAME
--- ----           ------------     ------------     ------------
  1  TIMEDA        D -0.619         C   4.16         C   4.16
                   C   4.16         C   4.16
  2  PENTILE       D  0.511E-01     C -0.344         C -0.344
                   C -0.344         C -0.344
  3  TIME1         C  0.485         D  -4.58         C  0.485
                   C  0.485         C  0.485
  4  TIME2         C  0.114         C  0.114         D  -5.21
                   C  0.114         C  0.114
  5  POP PER ACRE  C  0.353E-02     C  0.353E-02     D -0.162
                   C  0.353E-02     C  0.353E-02
  6  TIME3         C  0.704E-01     C  0.704E-01     C  0.704E-01
                   D  -5.68         C  0.704E-01
  7  COST3         C -0.928E-03     C -0.928E-03     C -0.928E-03
                   D  0.748E-01     C -0.928E-03
  8  WTRNS TIME    C  0.629E-07     C  0.629E-07     C  0.629E-07
                   C  0.629E-07     D  -21.5
  9  AUTOS PER PO  C -0.200E-10     C -0.200E-10     C -0.200E-10
                   C -0.200E-10     D  0.686E-02

PROBABILITIES AT AVERAGE VALUES OF VARIABLES ARE:

                          0.871            0.096            0.021
                          0.012            0.000

NOTE:  D INDICATES A DIRECT ELASTICITY WHILE
       C INDICATES A CROSS ELASTICITY.

ELASTICITIES ARE EVALUATED AT THE AVERAGE (WEIGHTED) VALUE
OF THE VARIABLE VALUES AS LISTED IN REPORT  2.

LOG26 8100 (INFORMATION): PROCESSING ENDED FOR &SELECT NUMBER  1

LOG26 7000 (INFORMATION): THERE WERE166248 EXTRA BYTES
                          OF CORE ALLOTTED FOR TABLES

SINOFF 6700 (INFORMATION): ULOGIT   ENDED AT 16.54.27 (RETURN CODE=  0)
```

MODEL 5

Five Mode Model for Work Trips

```
---------------------------ULOGIT  07JUL77 ---------------------------
                           ULOGIT   REPORT  1                 PAGE    5
           F O R M U L A   A N D   C O E F F I C I E N T
                     S P E C I F I C A T I O N S

THE COMPOSITE DISUTILITY EXPRESSIONS ARE:

WDA                        = A1          * PENTILE
                           + B1          * COSTDA

WONE                       = B2          * COST1
                           + BIAS1

WTWO                       = B3          * COST2
                           + BIAS2

WTHREE                     = A4          * POP PER ACRE
                           + B4          * COST3

TRANSIT                    = A5          * TTR
                           + B5          * TRNS FARE
                           + C5          * AUTOS PER POP

THE 11 COEFFICIENTS TO BE ESTIMATED ARE:

COEFFICIENT          INITIAL    LOWER     UPPER   BOUND
NO. NAME               VALUE    BOUND     BOUND    TYPE
--- ------------     -------  -------   -------   -----
  1 A1                 0.0                         NONE
  2 B1                 0.0                         NONE
  3 B2                 0.0                         NONE
  4 BIAS1              0.0                         NONE
  5 B3                 0.0                         NONE
  6 BIAS2              0.0                         NONE
  7 A4                 0.0                         NONE
  8 B4                 0.0                         NONE
  9 A5                 0.0                         NONE
 10 B5                 0.0                         NONE
 11 C5                 0.0                         NONE
```

MODEL 5

Five Mode Model for Work Trips

```
----------------------------ULOGIT  07JUL77 ----------------------------

                            ULOGIT   REPORT  2                   PAGE    6

                  S T A T I S T I C A L   S U M M A R Y

               O F   I N D E P E N D E N T   V A R I A B L E S


THE VARIABLES USED FOR CALIBRATION ARE:

VARIABLE                         STANDARD   LARGEST  SMALLEST
NO. NAME                MEAN       DEV.      VALUE     VALUE  UNITS
--- ------------     -------   --------  ---------  --------  -----
  1 PENTILE             3.91       0.97       5.00      1.00  PENT

  2 COSTDA             63.35      47.61     330.00      7.00  CENTS

  3 COST1              33.67      23.81     167.00      5.50  CENTS

  4 COST2              25.10      15.89     114.00      6.33  CENTS

  5 POP PER ACRE       15.07      19.78     268.69      0.00  POP/ACRE

  6 COST3              21.84      11.90      88.50      7.75  CENTS

  7 TTR                 5.03       1.99       7.00      1.19  MIN/MIN

  8 TRNS FARE          19.30      17.41      35.00      0.0   CENTS

  9 AUTOS PER PO        0.45       0.18       2.45      0.0   AUTO/POP
    P



CORRELATION MATRIX OF INDEPENDENT VARIABLES:

         1         2         3         4         5         6         7
         8
 2   0.2367
 3   0.2365    0.9986
 4   0.2385    0.9987    0.9994
 5   0.0699    0.1427    0.1425    0.1429
 6   0.2367    0.9994    0.9996    1.0002    0.1424
 7   0.3354    0.2308    0.2302    0.2311   -0.1766    0.2306
 8  -0.3175   -0.3616   -0.3616   -0.3606    0.1196   -0.3621   -0.8916
 9   0.0810    0.0628    0.0620    0.0634   -0.0979    0.0611    0.0762
    -0.0722

LOG13 6000 (INFORMATION): THE TOTAL NUMBER OF OBSERVATIONS READ
                          FROM THE CALIBRATION FILE IS          10165
                          THE TOTAL NUMBER OF SELECTED RECORDS
                          FROM THE CALIBRATION FILE IS          10165
                          THE TOTAL NUMBER OF
                          POSITIVE (WEIGHTED) VALUES IS         10165

LOG16 6050 (INFORMATION): COEFFICIENT CALIBRATION PROCEDURE ENDED
           BECAUSE THE MARGINAL LINE INCREASE IS ZERO (OPTIMALITY).
```

MODEL 5

Five Mode Model for Work Trips

```
----------------------------ULOGIT  07JUL77 ----------------------------

                             ULOGIT   REPORT  3                   PAGE    7

           F I N A L   C O E F F I C I E N T   V A L U E S

THE RESULTS OF THE COEFFICIENT CALIBRATION ARE:

COEFFICIENT               FINAL  STANDARD      T-   GRADIENT  LOWER  UPPER
NO. NAME                  VALUE     ERROR   RATIO  (IF BND.)  BOUND  BOUND
--- ------------ --------  ---------   -----   ---------  -----  -----
  1  A1                 -0.3294    0.0266 -12.40
  2  B1                  0.0146    0.0026   5.65
  3  B2                  0.0272    0.0053   5.11
  4  BIAS1               0.9714    0.1063   9.14
  5  B3                  0.0498    0.0090   5.52
  6  BIAS2               2.1111    0.1559  13.54
  7  A4                  0.0407    0.0079   5.18
  8  B4                  0.1566    0.0107  14.67
  9  A5                  1.3294    0.1439   9.24
 10  B5                  0.0031    0.0138   0.23
 11  C5                 -0.1500    0.6023  -0.25

THE INITIAL VALUE OF THE LOGLIKELIHOOD WAS -0.16360E 05,
WHILE THE FINAL VALUE WAS -0.54299E 04 AFTER  9 ITERATIONS.

THE LOGLIKELIHOOD WITH ALL ZERO COEFFICIENTS IS -0.16360E 05,
WHILE BY INCLUDING PURE ALTERNATIVE EFFECTS IT IS -0.53464E 04.
THE LARGEST LOGLIKELIHOOD FOR THESE DATA AND ANY MODEL  0.0

TEST OF EQUAL PROBABILITY HYPOTHESIS IS  0.2186E 05
WITH   11 DEGREES OF FREEDOM.

TEST OF ALTERNATIVE DEPENDENT PROBABILITY HYPOTHESIS IS  -166.9
WITH    7 DEGREES OF FREEDOM.

PSEUDO R-SQUARE = .668


MATRIX OF APPROXIMATE CORRELATION COEFFICIENTS
FOR COEFFICIENTS NOT AT BOUNDS:

COEF.    1       2       3       4       5       6       7       8
        1       2       3       4       5       6       7       8
  2    0.040
  3    0.092   0.962
  4    0.829  -0.044  -0.118
  5    0.088   0.851   0.828  -0.004
  6    0.543  -0.163  -0.137   0.489  -0.470
  7    0.170  -0.119  -0.109   0.160  -0.096   0.123
  8    0.492   0.688   0.686   0.364   0.610   0.149  -0.357
  9    0.037  -0.061  -0.058   0.038  -0.051   0.033   0.015  -0.023
 10    0.167   0.398   0.392   0.109   0.348   0.018  -0.020   0.344
      -0.700
 11    0.033   0.108   0.106   0.018   0.094  -0.003  -0.010   0.089
      -0.071  -0.451
```

MODEL 5

Five Mode Model for Work Trips

```
---------------------------ULOGIT  07JUL77 ---------------------------

                           ULOGIT   REPORT  6                  PAGE   9

      O B S E R V E D   V S .   E S T I M A T E D   T O T A L S

              F O R   E A C H   A L T E R N A T I V E

                                            STD.  CORR.  CORR.    NO.
ALTERNATIVE   OBSERVED   ESTIMATED   RESIDUAL  COEF.  RATIO   CELLS
-----------   --------   ---------   --------  -----  -----   -----
WDA             8784.0      8685.5      2.808  0.003  0.008      15

WONE             946.0       944.3      0.058  0.000  0.003      12

WTWO             219.0       218.9      0.009  0.002  0.001       6

WTHREE           130.0       217.5     -6.060  0.000  0.002      13

TRANSIT           86.0        86.4     -0.048  0.009  0.009      16


---------------------------ULOGIT  07JUL77 ---------------------------

                           ULOGIT   REPORT  8                  PAGE  10

             T A B L E   O F   E L A S T I C I T I E S

                  ELASTICITY FOR ALTERNATIVE:
                  WDA           WONE          WTWO
                  WTHREE        TRANSIT
NO. NAME
--- ----          ------------  ------------  ------------
 1  PENTILE       D  0.161      C  -1.13      C  -1.13
                  C  -1.13      C  -1.13
 2  COSTDA        D -0.115      C  0.807      C  0.807
                  C  0.807      C  0.807
 3  COST1         C  0.843E-01  D -0.831      C  0.843E-01
                  C  0.843E-01  C  0.843E-01
 4  COST2         C  0.264E-01  C  0.264E-01  D  -1.22
                  C  0.264E-01  C  0.264E-01
 5  POP PER ACRE  C  0.660E-02  C  0.660E-02  C  0.660E-02
                  D -0.607      C  0.660E-02
 6  COST3         C  0.368E-01  C  0.368E-01  C  0.368E-01
                  D  -3.38      C  0.368E-01
 7  TTR           C  0.512E-02  C  0.512E-02  C  0.512E-02
                  C  0.512E-02  D  -6.68
 8  TRNS FARE     C  0.459E-04  C  0.459E-04  C  0.459E-04
                  C  0.459E-04  D -0.599E-01
 9  AUTOS PER PO  C -0.516E-04  C -0.516E-04  C -0.516E-04
                  C -0.516E-04  D  0.674E-01

PROBABILITIES AT AVERAGE VALUES OF VARIABLES ARE:

                         0.875         0.092          0.021
                         0.011         0.001

NOTE:  D INDICATES A DIRECT ELASTICITY WHILE
       C INDICATES A CROSS ELASTICITY.

ELASTICITIES ARE EVALUATED AT THE AVERAGE (WEIGHTED) VALUE
OF THE VARIABLE VALUES AS LISTED IN REPORT  2.

LOG26 8100 (INFORMATION): PROCESSING ENDED FOR &SELECT NUMBER  1

LOG26 7000 (INFORMATION): THERE WERE166076 EXTRA BYTES
                          OF CORE ALLOTTED FOR TABLES

SINOFF G700 (INFORMATION): ULOGIT   ENDED AT  9.35.56 (RETURN CODE=  0)
```

MODEL 6

Five Mode Model for Non-Work Trips

```
---------------------------ULOGIT  07JUL77 ---------------------------
                          ULOGIT   REPORT  1                   PAGE    5
           F O R M U L A   A N D   C O E F F I C I E N T
                        S P E C I F I C A T I O N S

THE COMPOSITE DISUTILITY EXPRESSIONS ARE:

NWDA                         = A1            * HGWY SKIM TIME
                             + B1            * PENTILE

NWONE                        = A1            * HONE
                             + BIAS2

NWTWO                        = A1            * HTWO
                             + BIAS3

NWTHREE                      = A1            * HTHREE
                             + B4            * POP PER DU

TRANSIT                      = A5            * WTRNS TIME
                             + B5            * AUTOS PER POP
                             + BIAS


THE  8 COEFFICIENTS TO BE ESTIMATED ARE:

COEFFICIENT         INITIAL    LOWER    UPPER   BOUND
NO. NAME              VALUE    BOUND    BOUND    TYPE
--- ------------    -------  -------  -------   -----
  1 A1                0.0                        NONE
  2 B1                0.0                        NONE
  3 BIAS2             0.0                        NONE
  4 BIAS3             0.0                        NONE
  5 B4                0.0                        NONE
  6 A5                0.0                        NONE
  7 B5                0.0                        NONE
  8 BIAS              0.0                        NONE
```

MODEL 6

Five Mode Model for Non-Work Trips

```
---------------------------ULOGIT  07JUL77 ---------------------------

                           ULOGIT   REPORT  2                  PAGE    6

                     S T A T I S T I C A L   S U M M A R Y

             O F   I N D E P E N D E N T   V A R I A B L E S


THE VARIABLES USED FOR CALIBRATION ARE:

VARIABLE                          STANDARD   LARGEST  SMALLEST
NO. NAME                  MEAN      DEV.      VALUE     VALUE  UNITS
--- ------------       -------  --------  --------  --------  -----
  1 HGWY SKIM TI         12.64      7.50     95.00      2.00  MINUTES
    ME
  2 PENTILE               3.78      1.05      5.00      1.00  PENT

  3 HONE                 12.83      7.50     95.20      2.20  MINUTES

  4 HTWO                 13.02      7.51     95.40      2.40  MINUTES

  5 HTHREE               13.21      7.52     95.60      2.60  MINUTES

  6 POP PER DU            2.97      1.48     28.76      0.10  POP/DU

  7 WTRNS TIME          298.79    210.81    500.00     25.50  MINUTES

  8 AUTOS PER PO          0.87     10.21    253.00      0.0   AUTO/POP
    P


CORRELATION MATRIX OF INDEPENDENT VARIABLES:

          1         2         3         4         5         6         7
  2   0.0128
  3   0.9959    0.0112
  4   0.9963    0.0162    1.0003
  5   0.9964    0.0198    0.9997    1.0031
  6   0.0196    0.0856    0.0216    0.0238    0.0261
  7   0.0577    0.2461    0.0579    0.0594    0.0608    0.0627
  8   0.0078   -0.0660    0.0078    0.0079    0.0080   -0.0549   -0.0397

LOG13 6000 (INFORMATION): THE TOTAL NUMBER OF OBSERVATIONS READ
                          FROM THE CALIBRATION FILE IS         15268
                          THE TOTAL NUMBER OF SELECTED RECORDS
                          FROM THE CALIBRATION FILE IS         15268
                          THE TOTAL NUMBER OF
                          POSITIVE (WEIGHTED) VALUES IS        15268

LOG16 6070 (INFORMATION): COEFFICIENT CALIBRATION PROCEDURE ENDED
             BECAUSE OF NO IMPROVEMENT ALONG LINE.
```

MODEL 6

Five Mode Model for Non-Work Trips

```
---------------------------ULOGIT  07JUL77 ---------------------------

                      ULOGIT   REPORT  3                      PAGE    7

          F I N A L   C O E F F I C I E N T   V A L U E S

THE RESULTS OF THE COEFFICIENT CALIBRATION ARE:

COEFFICIENT            FINAL  STANDARD     T-   GRADIENT  LOWER  UPPER
NO. NAME               VALUE     ERROR  RATIO  (IF BND.)  BOUND  BOUND
--- ------------ --------  --------  -----  ---------  -----  -----
 1  A1              0.2103    0.0189  11.14
 2  B1             -0.0349    0.0141  -2.48
 3  BIAS2          -0.0204    0.0559  -0.37
 4  BIAS3           0.8192    0.0586  13.99
 5  B4              0.1853    0.0196   9.45
 6  A5              0.0155    0.0021   7.33
 7  B5             -0.0061    0.0041  -1.48
 8  BIAS            5.4663    0.2773  19.72

THE INITIAL VALUE OF THE LOGLIKELIHOOD WAS -0.24573E 05,
WHILE THE FINAL VALUE WAS -0.20118E 05 AFTER  7 ITERATIONS.

THE LOGLIKELIHOOD WITH ALL ZERO COEFFICIENTS IS -0.24573E 05,
WHILE BY INCLUDING PURE ALTERNATIVE EFFECTS IT IS -0.20094E 05.
THE LARGEST LOGLIKELIHOOD FOR THESE DATA AND ANY MODEL  0.0

TEST OF EQUAL PROBABILITY HYPOTHESIS IS   8909.
WITH   8 DEGREES OF FREEDOM.

TEST OF ALTERNATIVE DEPENDENT PROBABILITY HYPOTHESIS IS  -48.70
WITH   4 DEGREES OF FREEDOM.

PSEUDO R-SQUARE = .181


MATRIX OF APPROXIMATE CORRELATION COEFFICIENTS
FOR COEFFICIENTS NOT AT BOUNDS:

COEF.   1        2       3       4       5       6       7       8
 2    0.058
 3   -0.008   0.936
 4   -0.072   0.889   0.892
 5   -0.136   0.892   0.898   0.866
 6    0.797   0.052  -0.001  -0.052  -0.103
 7   -0.025  -0.015  -0.013  -0.011  -0.010   0.000
 8    0.741   0.222   0.173   0.117   0.070   0.303  -0.094
```

MODEL 6

Five Mode Model for Non-Work Trips

```
---------------------------ULOGIT  07JUL77 ---------------------------

                          ULOGIT   REPORT  6                   PAGE    8

        O B S E R V E D   V S .   E S T I M A T E D   T O T A L S

                 F O R   E A C H   A L T E R N A T I V E

                                              STD.   CORR.  CORR.   NO.
ALTERNATIVE    OBSERVED  ESTIMATED  RESIDUAL  COEF.  RATIO  CELLS
-----------    --------  ---------  --------  -----  -----  -----
NWDA             5841.0     5690.5     2.523  0.000  0.001      6

NWONE            4897.0     4879.9     0.297  0.000  0.000      6

NWTWO            2027.0     2021.9     0.122  0.000  0.000      5

NWTHREE          2440.0     2578.5    -2.997  0.001  0.003     12

TRANSIT            63.0       77.1    -1.692  0.002  0.007     16
```

```
---------------------------ULOGIT  07JUL77 ---------------------------

                          ULOGIT   REPORT  8                   PAGE    9

                 T A B L E   O F   E L A S T I C I T I E S

                     ELASTICITY FOR ALTERNATIVE:
                     NWDA           NWONE           NWTWO
                     NWTHREE        TRANSIT
NO. NAME
--- ----            ------------   ------------   ------------
 1  HGWY SKIM TI    D  -1.66       C  0.997       C  0.997
                    C  0.997       C  0.997
 2  PENTILE         D  0.824E-01   C -0.495E-01   C -0.495E-01
                    C -0.495E-01   C -0.495E-01
 3  HONE            C  0.870       D  -1.83       C  0.870
                    C  0.870       C  0.870
 4  HTWO            C  0.366       C  0.366       D  -2.37
                    C  0.366       C  0.366
 5  HTHREE          C  0.467       C  0.467       C  0.467
                    D  -2.31       C  0.467
 6  POP PER DU      C  0.925E-01   C  0.925E-01   C  0.925E-01
                    D -0.457       C  0.925E-01
 7  WTRNS TIME      C  0.909E-03   C  0.909E-03   C  0.909E-03
                    C  0.909E-03   D  -4.62
 8  AUTOS PER PO    C -0.104E-05   C -0.104E-05   C -0.104E-05
                    C -0.104E-05   D  0.529E-02

PROBABILITIES AT AVERAGE VALUES OF VARIABLES ARE:

                          0.375          0.322          0.134
                          0.168          0.000

NOTE:  D INDICATES A DIRECT ELASTICITY WHILE
       C INDICATES A CROSS ELASTICITY.

ELASTICITIES ARE EVALUATED AT THE AVERAGE (WEIGHTED) VALUE
OF THE VARIABLE VALUES AS LISTED IN REPORT  2.

LOG26 8100 (INFORMATION): PROCESSING ENDED FOR &SELECT NUMBER   1

LOG26 7000 (INFORMATION): THERE WERE170804 EXTRA BYTES
                          OF CORE ALLOTTED FOR TABLES

SINOFF 6700 (INFORMATION): ULOGIT   ENDED AT 18.36.34 (RETURN CODE=  0)
```

MODEL 7

Five Mode Model for Non-Work Trips

```
-------------------------ULOGIT  07JUL77 --------------------------
                         ULOGIT   REPORT  1                   PAGE    5
        F O R M U L A   A N D   C O E F F I C I E N T
                    S P E C I F I C A T I O N S

THE COMPOSITE DISUTILITY EXPRESSIONS ARE:

NWDA                           = A1           * PENTILE
                               + B1           * COSTDA

NWONE                          = B2           * COST1
                               + BIAS1

NWTWO                          = B3           * COST2
                               + BIAS2

NWTHREE                        = A4           * POP PER ACRE
                               + B4           * COST3

TRANSIT                        = A5           * TTR
                               + B5           * TRNS FARE
                               + C5           * AUTOS PER POP

THE 11 COEFFICIENTS TO BE ESTIMATED ARE:

COEFFICIENT         INITIAL    LOWER     UPPER    BOUND
NO. NAME              VALUE    BOUND     BOUND     TYPE
--- ------------    -------   -------   -------   -----
  1 A1              -0.0209                        NONE
  2 B1               0.0268                        NONE
  3 B2               0.0478                        NONE
  4 BIAS1            0.1045                        NONE
  5 B3               0.0773                        NONE
  6 BIAS2            0.6939                        NONE
  7 A4               0.0035                        NONE
  8 B4               0.1107                        NONE
  9 A5               1.0503                        NONE
 10 B5               0.1255                        NONE
 11 C5               4.3451                        NONE
```

MODEL 7

Five Mode Model for Non-Work Trips

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---------------------------ULOGIT  07JUL77 ---------------------------

                          ULOGIT   REPORT  2                 PAGE    6

                 S T A T I S T I C A L   S U M M A R Y

             O F   I N D E P E N D E N T   V A R I A B L E S

THE VARIABLES USED FOR CALIBRATION ARE:

VARIABLE                         STANDARD   LARGEST  SMALLEST
NO. NAME                 MEAN      DEV.      VALUE     VALUE  UNITS
--- ------------      -------  --------  --------  --------  -----
  1 PENTILE              3.78      1.05      5.00      1.00  PENT

  2 COSTDA              40.42     39.20    430.00      7.00  CENTS

  3 COST1               22.21     19.61    217.00      5.50  CENTS

  4 COST2               17.46     13.08    147.33      6.33  CENTS

  5 POP PER ACRE        11.14     16.83    278.29      0.00  POP/ACRE

  6 COST3               16.10      9.80    113.50      7.75  CENTS

  7 TTR                  5.69      1.75      7.00      1.31  MIN/MIN

  8 TRNS FARE           18.26     17.48     35.00      0.0   CENTS

  9 AUTOS PER PO         0.45      0.21      2.45      0.0   AUTO/POP
    P


CORRELATION MATRIX OF INDEPENDENT VARIABLES:

         1         2         3         4         5         6         7
         8
 2    0.1026
 3    0.1023    0.9987
 4    0.1050    0.9999    0.9989
 5    0.0552    0.2153    0.2149    0.2153
 6    0.1027    1.0006    0.9991    1.0004    0.2147
 7    0.2631   -0.0224   -0.0235   -0.0217   -0.3017   -0.0251
 8    0.2404    0.1316    0.1315    0.1321   -0.2474    0.1311    0.7816
 9    0.1326    0.0241    0.0237    0.0260   -0.0726    0.0234   -0.0287
     -0.0020

LOG13 6000 (INFORMATION): THE TOTAL NUMBER OF OBSERVATIONS READ
                          FROM THE CALIBRATION FILE IS          15268
                          THE TOTAL NUMBER OF SELECTED RECORDS
                          FROM THE CALIBRATION FILE IS          15268
                          THE TOTAL NUMBER OF
                          POSITIVE (WEIGHTED) VALUES IS         15268

LOG16 6050 (INFORMATION): COEFFICIENT CALIBRATION PROCEDURE ENDED
                  BECAUSE THE MARGINAL LINE INCREASE IS ZERO (OPTIMALITY).
```

MODEL 7

Five Mode Model for Non-Work Trips

```
---------------------------ULOGIT  07JUL77 ---------------------------

                           ULOGIT   REPORT  3                   PAGE     7

          F I N A L    C O E F F I C I E N T    V A L U E S

THE RESULTS OF THE COEFFICIENT CALIBRATION ARE:

COEFFICIENT              FINAL  STANDARD     T-   GRADIENT  LOWER   UPPER
NO. NAME                 VALUE     ERROR  RATIO  (IF BND.)  BOUND   BOUND
--- ------------  --------  --------  -----  ---------  -----   -----
  1  A1            -0.0209    0.0123  -1.70
  2  B1             0.0268    0.0020  13.75
  3  B2             0.0478    0.0039  12.36
  4  BIAS1          0.1045    0.0463   2.26
  5  B3             0.0773    0.0060  12.99
  6  BIAS2          0.6938    0.0508  13.66
  7  A4             0.0035    0.0015   2.35
  8  B4             0.1108    0.0073  15.26
  9  A5             1.0508    0.1111   9.46
 10  B5             0.1838    0.2056   0.89
 11  C5             4.3457    0.7905   5.50

THE INITIAL VALUE OF THE LOGLIKELIHOOD WAS -0.20049E 05,
WHILE THE FINAL VALUE WAS -0.20049E 05 AFTER  2 ITERATIONS.

THE LOGLIKELIHOOD WITH ALL ZERO COEFFICIENTS IS -0.24573E 05,
WHILE BY INCLUDING PURE ALTERNATIVE EFFECTS IT IS -0.20094E 05.
THE LARGEST LOGLIKELIHOOD FOR THESE DATA AND ANY MODEL  0.0

TEST OF EQUAL PROBABILITY HYPOTHESIS IS   9048.
WITH  11 DEGREES OF FREEDOM.

TEST OF ALTERNATIVE DEPENDENT PROBABILITY HYPOTHESIS IS   90.91
WITH   7 DEGREES OF FREEDOM.

PSEUDO R-SQUARE =  .184



MATRIX OF APPROXIMATE CORRELATION COEFFICIENTS
FOR COEFFICIENTS NOT AT BOUNDS:

COEF.    1        2        3        4        5        6        7        8
        1        2        3        4        5        6        7        8
 2    0.564
 3    0.610   0.968
 4    0.802   0.501   0.432
 5    0.594   0.942   0.943   0.481
 6    0.546   0.164   0.157   0.563  -0.015
 7    0.072  -0.089  -0.091   0.092  -0.088   0.111
 8    0.732   0.946   0.945   0.630   0.920   0.288  -0.162
 9    0.179   0.227   0.226   0.158   0.220   0.075  -0.017   0.233
10    0.033   0.055   0.056   0.024   0.054   0.006  -0.006   0.053
     -0.065
11    0.273   0.377   0.377   0.229   0.367   0.094  -0.007   0.376
     -0.721   0.083
```

MODEL 7

Five Mode Model for Non-Work Trips

```
---------------------------ULOGIT  07JUL77 ---------------------------

                          ULOGIT   REPORT  6                    PAGE    9

      O B S E R V E D   V S .   E S T I M A T E D   T O T A L S

              F O R   E A C H   A L T E R N A T I V E

                                                STD.   CORR.  CORR.    NO.
ALTERNATIVE    OBSERVED  ESTIMATED  RESIDUAL  COEF.  RATIO  CELLS
-----------    --------  ---------  --------  -----  -----  -----
NWDA             5841.0     5728.2     1.888  0.001  0.001      7

NWONE            4897.0     4885.0     0.209  0.003  0.003      9

NWTWO            2027.0     2023.9     0.073  0.000  0.000      5

NWTHREE          2440.0     2540.2    -2.179  0.000  0.000     10

TRANSIT            63.0       71.3    -1.037  0.003  0.014     19


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              T A B L E   O F   E L A S T I C I T I E S

                     ELASTICITY FOR ALTERNATIVE:
                     NWDA           NWONE          NWTWO
                     NWTHREE        TRANSIT
NO. NAME
--- ----             ------------   ------------   ------------
 1  PENTILE          D  0.491E-01   C -0.298E-01   C -0.298E-01
                     C -0.298E-01   C -0.298E-01
 2  COSTDA           D -0.674       C  0.410       C  0.410
                     C  0.410       C  0.410
 3  COST1            C  0.341       D -0.720       C  0.341
                     C  0.341       C  0.341
 4  COST2            C  0.181       C  0.181       D  -1.17
                     C  0.181       C  0.181
 5  POP PER ACRE     C  0.658E-02   C  0.658E-02   C  0.658E-02
                     D -0.329E-01   C  0.658E-02
 6  COST3            C  0.297       C  0.297       C  0.297
                     D  -1.49       C  0.297
 7  TTR              C  0.764E-04   C  0.764E-04   C  0.764E-04
                     C  0.764E-04   D  -5.98
 8  TRNS FARE        C  0.429E-04   C  0.429E-04   C  0.429E-04
                     C  0.429E-04   D  -3.36
 9  AUTOS PER PO     C  0.251E-04   C  0.251E-04   C  0.251E-04
                     C  0.251E-04   D  -1.97

PROBABILITIES AT AVERAGE VALUES OF VARIABLES ARE:

                          0.378          0.322          0.134
                          0.167          0.000

NOTE:  D INDICATES A DIRECT ELASTICITY WHILE
       C INDICATES A CROSS ELASTICITY.

ELASTICITIES ARE EVALUATED AT THE AVERAGE (WEIGHTED) VALUE
OF THE VARIABLE VALUES AS LISTED IN REPORT  2.

LOG26 8100 (INFORMATION): PROCESSING ENDED FOR &SELECT NUMBER   1

LOG26 7000 (INFORMATION): THERE WERE166080 EXTRA BYTES
                          OF CORE ALLOTTED FOR TABLES

SINOFF 6700 (INFORMATION): ULOGIT   ENDED AT 16.10.38 (RETURN CODE=  0)
```

APPENDIX 4

GLOSSARY OF VARIABLES

4.1 List of Variables Used in the Two-Mode Models

A MODE - A dependendent variable describing mode of travel. If this variable has a value of one, the trip is made by automobile mode. For any other value, another mode is used.

DESTINATION ZONE - The zone in which the trip ends.

DWELLING UNITS - The number of dwelling units in the production zone of the trip.

EMPLOYMENT - The number of individuals employed in the attraction zone of the trip.

EMPLY - The number of individuals employed in the attraction zone of the trip divided by 100.

EXCESS TIME - That portion of transit travel time (minutes) associated with walking to and from the transit stop and waiting at the transit stop for the vehicle to arrive.

HIGHWAY SKIM TREE - Total travel time (minutes) by automobile mode. This value includes in-vehicle time along with parking and un-parking time.

HWY DIST - Travel distance (miles) for the automobile mode.

HWY COST - Out-of-pocket travel cost (based on a 10 cents per mile cost) for the automobile mode.

INCOME - Median zonal income ($/year) for the production zone of the trip.

INDUSTRIAL ACRES - The number of industrial acres in the attraction zone of the trip.

INPENT - A five level classification of income groups based on 1975 median zonal income for the production zone. The following classification was used in the model.

Category	Median Zonal Income
1	$ 0 - 4960
2	4961 - 7520
3	7521 - 9920
4	9921 - 12,000
5	+ 12,000

LANDUSE - A three level classification scheme to define the type of landuse of the producton zone, where 1 = urban land use, 2 = suburban land use and 3 = rural land use.

ORIGIN ZONE - The zone in which the trip began.

OT MODE - A dependent variable describing mode of travel. If this variable has a value of one, the trip is by transit during off peak periods. For any other value, another mode is selected.

POPULATION - The number of individuals residing in the production zone of the trip.

POP - The number of individuals residing in the production zone of a trip divided by 100.

POP PER ACRE - The number of individuals per acre residing in the production zone of a trip.

POP PER DU - The average household size in a zone associated with the production zone of the trip.

PT MODE - A dependent variable describing the mode of travel. If this variable has a variable of one, the trip is made by transit during the peak period. For other values, the trip is by an alternate mode or occurred during off-peak time periods.

RECREATIONAL ACRES - The number of cultural and recreational acres in the attraction zone of the trip.

RESIDENTIAL ACRES - The number of residential acres in the production zone of the trip.

RETAIL WHOLESALE ACRES - The number of retail, wholesale, government, and educational acres in the attraction zone of the trip.

TERMINAL TIME A - The time spent (minutes) parking or un-parking for the auto mode in the attraction zone of the trip.

TERMINAL TIME P - The time spent (minutes) in parking or un-parking for the auto mode in the production zone of the trip.

TOTAL ACRES - The size (acres) of the attraction zone of the trip.

TRNS MODE - A dependent variable describing the mode of travel. If this variable has a value of one, the trip is by transit. For any other value, another mode is used. The transit made included all peak and off-peak transit trips.

TRNS RUN TIME - The in-vehicle travel time (minutes) for the transit mode.

TRNS SKIM TREE - The total travel time in minutes by the transit mode. The transit travel time consists of walk time plus wait time plus in-vehicle time. For zones unconnected by transit, the transit travel time is designated by a value of 16,384 minutes.

TRNS WAIT TIME - The time spent waiting for transit (minutes).

TTR - The travel time ratio computed as [travel time by transit]/[travel time by automobile]. The travel time ratio was constrained to a maximum value of 7, which indicates a zone pair unconnected by transit travel. (Note for unconnected zone pairs, the travel time by transit was 16,384 minutes).

TTRW - The weighted travel time ratio computed as [weighted travel time by transit/[weighted travel time automobile]. The weighted travel time ratio was constrained to a maximum value of 10, which indicates a zone pair unconnected by transit travel.

UNDEVELOPED ACRES - The number of agricultural, undeveloped, water and right-of-way acres in the production zone of a trip.

WAUTO TIME - The weighted time (minutes) for travel by the automobile mode. The weight time consists of the in-vehicle time plus 2 times the un-parking and parking times. This variable recognizes that one minute of parking/un-parking time has a higher disutility than one minute of in-vehicle time.

WTR TIME - The weighted time (minutes) for travel by the transit mode. The weighted time consists of the in-vehicle time plus 1.5 times the walk time plus 2 times the wait time. The maximum value for this variable is 500 minutes, which represents a zone pair unconnected by transit. This variable recognizes that one minute of wait and walk time has a higher disutility than one minute of in-vehicle travel time.

ZONE NUMBER - The number of the production zone of the trip. There are 315 zones in this study area, all of which are internal zones.

4.2 List of Variables Used in the Five-Mode Models for Work Trips

AUTO OWNERSHIP - The total number autos owned in the production zone of the trip.

AUTOS PER POP - A density variable indicating the number of automobiles owned divided by the population in the production zone of the trip.

COSTDA - Out-of-pocket travel cost (cents) for the drive alone automobile mode. This cost includes a distance cost (10 cents per vehicle mile) plus parking costs in the attraction zone of the trip.

COST1 - The out-of-pocket travel costs per vehicle occupant (cents) for the one passenger automobile mode. This variable includes a distance cost (10 cents per vehicle mile) plus parking costs in the attraction zone of the trip. The costs are assumed divided equally amongst both vehicle occupants.

COST2 - The out-of-pocket travel costs per vehicle occupant (cents) for the two passenger automobile mode. This variable includes a distance cost (10 cents per vehicle mile) plus a parking cost in the attraction zone of the trip. The costs are assumed divided equally amongst all three vehicle occupants.

COST3 - The out-of-pocket travel costs per vehicle occupant (cents) for the three or more passenger automobile mode. This variable includes a distance cost (10 cents per vehicle mile) plus a parking cost in the attraction zone of the trip. The costs are assumed divided equally amongst all vehicle occupants.

DESTINATION ZONE - The zone in which the trip ends.

DWELLING UNITS - The number of dwelling units in the production zone of the trip.

EMPLOYMENT - The number of individuals employed in the attraction zone of the trip.

EMPLY - The number of individuals employed in the attraction zone of the trip divided by 100.

EXCESS - The portion of transit travel time (minutes) associated with walking to and from the transit stop and waiting at the transit stop for the vehicle to arrive.

HGWY SKIM DIST - Travel distance (miles) for the automobile modes.

HGWY SKIM TIME - See TIMEDA

HONE - See TIME1

HTWO - See TIME2

HTHREE - See TIME3

INCOME - Meidan zonal income ($/year) for the production zone of the trip.

INDUSTRIAL ACRES - The number of industrial acres in the attraction zone of the trip.

ORIGIN ZONE - The zone in which the trip began.

PARKING COSTS - The average zonal cost for parking in the attraction zone of the trip. With the exception of five zones in downtown Flint, most parking costs were zero.

PENTILE - A five level classification of income groups based on 1975 median zonal income for the production zone. The following classification scheme was used in the model.

Category	Median Zonal Income
1	$ 0 - 4960
2	4961 - 7520
3	7521 - 9920
4	9921 - 12,000
5	+ 12,000

POPULATION - The number of individuals residing in the production zone of the trip.

POP - The number of individuals residing in the production zone of a trip divided by 100.

POP PER ACRE - The number of individuals per acre residing in the production zone of a trip.

POP PER DU - The average household size in a zone associated with the production zone of the trip.

RECREATIONAL ACRES - The number of cultural and recreational acres in the attraction zone of the trip.

RESIDENTIAL ACRES - The number of residential acres in the production zone of the trip.

RES LABOR FORCE - The number of workers (work force) in the production zone of the trip.

RETAIL WHOSL ACRES - The number of retail, wholesale, government, and educational acres in the attraction zone of the trip.

RLF PER ACRE - The resident-labor work force divided by the number of acres in the production zone of the trip.

TERMINAL TIME A - The time spent (minutes) parking or un-parking for the auto modes in the attraction zone of the trip.

TERMINAL TIME P - The time spent (minutes) in parking or un-parking for the auto modes in the production zone of the trip.

TIMEDA - The travel time (minutes) for the automobile mode for the drive alone trips. This variable includes in-vehicle time plus parking and un-parking time.

TIME1 - The travel time (minutes) for the one passenger automobile mode for work trips. This variable consists of the TIMEDA travel time plus a 1.1 minute time "penalty" for picking up the passenger.

TIME2 - The travel time (minutes) for the two passenger automobile mode for work trips. This variable consists of the TIMEDA travel time plus a 2.1 minute time "penalty" for picking up the two passengers.

TIME3 - The travel time (minutes) for the three or more passenger automobile mode for work trips. This variable consists of the TIMEDA travel time plus a 3.7 minute time "penalty" for picking up the passengers.

TOTAL ACRES - The size (acres) of the production zone of the trip.

TRANSIT - A dependent variable describing mode of travel. If this variable has a value one, the trip is by transit (for work purposes). For any other value, another mode is selected.

TRNS FARE - The cost (cents per trip) associated with travel by transit.

TRNS RUN TIME - The in-vehicle travel time (minutes) for the transit mode.

TRNS TIME - The total travel time in minutes by the transit mode. The transit travel time consists of walk time plus wait time plus in-vehicle time. For zones unconnected by transit, the travel time is designated by a value of 16,384 minutes.

TRNS WAIT TIME - The time spent waiting for transit (minutes).

TTR - The travel time ratio computed as [travel time by transit]/[travel time by automobile]. The travel time ratio was constrained to a maximum value of 7, which indicates a zone pair unconnected by transit travel.

UNDEVELOPED ACRES - The number of agricultural, undeveloped, water and right-of-way acres in the production zone of a trip.

WDA - A dependent variable describing mode of travel. If this variable has a value of one, the trip is by the "drive-alone" automobile mode (for work purposes). For any other value, another mode is used.

WONE - A dependent variable describing mode of travel. If this variable has a value of one, the trip is by the "one passenger" (in addition to the driver) automobile mode (for work purposes). For any other value, another mode is used.

WTWO - A dependent variable describing mode of travel. If this variable has a value of one, the trip is by the "two passenger" automobile mode (for work purposes). For any other value, another mode is used.

WTHREE - A dependent variable describing mode of travel. If this varialbe has a value of one, the trip is by the "three or more passenger" automobile mode (for work purposes). For any other value, another mode is used.

WTRNS TIME - The weighted time (minutes) by the transit mode. The weighted time consists of the in-vehicle time plus 1.5 times the walk time plus 2 times the wait time. The maximum value for this variable is 500 minutes, which represents a zone pair unconnected by transit. This variable recognizes that one minute of wait and walk time has a higher disutility than one minute of in-vehicle travel time.

ZERO AUTOS - The number of zero auto families in the production zone of a trip. This variable is used a measure of the number of "captive" transit riders.

ZONE NUMBER - The zone number of the production zone of the trip.

4.3 List of Variables Used in the Five-Mode Models for Non-Work Trips

AUTO OWNERSHIP - See List 4.2

AUTOS PER POP - See List 4.2

COSTDA - See List 4.2

COST1 - See List 4.2

COST2 - See List 4.2

COST3 - See List 4.2

DESTINATION ZONE - See List 4.2

DWELLING UNITS - See List 4.2

EMPLOYMENT - See List 4.2

EXCESS - See List 4.2

HGWY SKIM DIST - See List 4.2

INCOME - See List 4.2

INDUSTRIAL ACRES - See List 4.2

NWDA - A dependent variable associated with the "drive-alone" automobile mode of travel for non-work trips. If this variable has a value of one, the trip is made by the drive-alone automobile mode. For any other value, another mode is used.

NWONE - A dependent variable associated with the "one passenger" automobile mode of travel of non-work trips. If this variable has a value of one, the trip is made by the one-passenger auto mode. For any other value, another mode is used.

NWTWO - A dependent variable associated with the "two-passengers" automobile mode of travel for non-work trips. If this variable has a value of one, the trip is made by the two-passengers automobile mode. For any other value, another mode is used.

NWTHREE - A dependent variable associated with the "three-passengers" automobile mode of travel for non-work trips. If this variable has a value of one, the trip is made by the "three-or-more passengers" automobile mode. For any other value, another mode is used.

ORIGIN ZONE - See List 4.2

PARKING COSTS - See List 4.2

PENTILE - See List 4.2

POPULATION - See List 4.2

POP - See List 4.2

POP PER ACRE - See List 4.2

POP PER DU - See List 4.2

RECREATIONAL ACRES - See List 4.2

RESIDENTIAL ACRES - See List 4.2

RES LABOR FORCE - See List 4.2

RETAIL WHOLESALEACRES - See List 4.2

TERMINAL TIME A - See List 4.2

TERMINAL TIME P - See List 4.2

TIMEDA - The travel time (minutes) for the drive-alone automobile mode for non-work trips. This variable includes in-vehicle time plus parking and un-parking times.

TIME1 - The travel time (minutes) for the one-passenger automobile mode for non-work trips. This variable consists of the TIMEDA travel time plus a 0.2 minute time "penalty" for picking up the passenger.

TIME2 - The travel time (minutes) for the two-passengers automobile mode for non-work trips. This variable consists of the TIMEDA travel time plus a 0.4 minute time "penalty" for picking up the two passengers.

TIME3 - The travel time (minutes) for the three-or-more passengers automobile mode for non-work trips. This variable consists of the TIMEDA variable plus a 0.6 minute time "penalty" for picking up the passengers.

TOTAL ACRES - See List 4.2

TRANSIT - A dependent variable associated with travel by bus mode for non-work trips. If the value of this variable is one, the trip is by the transit mode, for any other value, another mode is used.

TRNS FARE - See List 4.2

TRNS TIME - See List 4.2

TRNS RUN TIME - See List 4.2

TRNS WAIT TIME - See List 4.2

TTR - See List 4.2

WTRNS TIME - See List 4.2

ZERO AUTOS - See List 4.2

ZONE NUMBER - See List 4.2

APPENDIX 5

MODEL FORMULATION

This Appendix illustrates the model formulations for all of the models developed in this study. The formulations are given in terms of the utility of using each mode.

MODEL 1
Two Mode Model

AUTO = EXP(0.3775 * LANDUSE - 0.0100 * EMPLY - 0.4714)

TRANSIT = EXP(-1.1217 * TTRW - 0.1881 * INPENT - 0.0212 * POP PER ACRE)

MODEL 2
Two Mode Model

AUTO - EXP(-1.5765 * HWY COST - 0.1629 * INPENT + 1.9359)

TRANSIT - EXP(-.9934 * TTRW - 0.0059 * RETAIL WHOLESALE ACRES - 0.0259 * POP PER ACRE)

MODEL 2-A
Two Mode Model

AUTO = EXP(-0.3245 * INPENT - 0.0086 * EMPLY + 2.2969)

TRANSIT = EXP(-1.0049 * TTRW)

MODEL 2-B
Two Mode Model

AUTO = EXP(-1.9438 * HWY COST - 0.0433 * INPENT + 4.1861)

TRANSIT = EXP(-0.0128 * WTR TIME - 0.0052 * RETAIL WHOLESALE ACRES - 0.0180 * POP PER ACRE)

MODEL 3
Five Mode Model for Work Trips

WDA = EXP(-0.3460 * HGWY SKIM TIME + 0.0830 * PENTILE + 1.7602)
WONE = EXP(-0.3460 * HONE + 0.0024 * EMPLY)
WTWO = EXP(-0.3460 * HTWO - 0.1225 * RLF PER ACRE)
WTHREE = EXP(-0.3460 * HTHREE - 1.5972 * AUTOS PER POP)
TRANSIT = EXP(-0.1207 * WTRNS TIME + 0.0007 * ZERO AUTOS)

MODEL 4
Five Mode Model for Work Trips

WDA = EXP(-0.2620 * TIMEDA + 0.1010 * PENTILE + 1.5290)
WONE = EXP(-0.2620 * TIME1)
WTWO = EXP(-0.2620 * TIME2 - 0.0110 * POP PER ACRE - 1.0760)
WTHREE = EXP(-0.2620 * TIME3 + 0.0740 * COST3 - 1.4480)
TRANSIT = EXP(-0.0810 * WTRNS TIME + 0.0070 * AUTOS PER POP - 0.8310)

MODEL 4 ADJUSTED

Five Mode Model for Work Trips

WDA = EXP(-0.2620 * TIMEDA + 0.1010 * PENTILE + 1.5290)
WONE = EXP(-0.2620 * TIME1)
WTWO = EXP(-0.2620 * TIME2 - 0.0110 * POP PER ACRE - 1.0760)
WTHREE = EXP(-0.2620 * TIME3 + 0.0740 * COST3 - 1.4480)
TRANSIT = .54 * EXP(-0.0810 * WTRNS TIME + 0.0070 * AUTOS PER POP - 0.8310)

MODEL 5

Five Mode Model for Work Trips

WDA = EXP(0.3294 * PENTILE - 0.0146 * COSTDA)
WONE = EXP(-0.0272 * COST1 - 0.9714)
WTWO = EXP(-0.0498 * COST2 - 2.1111)
WTHREE = EXP(-0.0407 * POP PER ACRE - 0.1566 * COST3)
TRANSIT = EXP(-1.3294 * TTR - 0.0031 TRNS FARE + 0.1500 * AUTOS PER POP)

MODEL 6

Five Mode Model for Non-Work Trips

NWDA = EXP(-0.2103 * HGWY SKIM TIME + 0.0349 * PENTILE)
NWONE = EXP(-0.2103 * HWONE + 0.0204)
NWTWO = EXP(-0.2103 * HTWO - 0.8192)
NWTHREE = EXP(-0.2103 * HTHREE - 0.1853 * POP PER DU)
TRANSIT = EXP(- 0.0155 * WTRNS TIME + 0.0061 * AUTOS PER POP - 5.4663)

MODEL 7

Five Mode Model for Non-Work Trips

NWDA = EXP(0.0209 * PENTILE - 0.0268 * COSTDA)
NWONE = EXP(-0.0478 * COST1 - 0.1045)
NWTWO = EXP(-0.0773 * COST2 - 0.6938)
NWTHREE = EXP(-0.0035 * POP PER ACRE - 0.1108 * COST3)
TRANSIT = EXP(-1.0508 * TTR - 0.1838 TRNS FARE - 4.3457 * AUTOS PER POP)

APPENDIX 6 - AUTO-OCCUPANCY SURVEY

INTRODUCTION

The use of auto-occupancy studies to monitor transportation demands and to evaluate various transportation programs has gained wide-spread use in recent years. With the increased demand for higher occupancy vehicle modes, a need to measure the impacts of carpooling, vanpooling, and other ridesharing activities has resulted. There is thus a need to develop travel estimates for these ridesharing programs and to plan for the future impacts of these programs, especially in the light of energy shortfalls. Auto-occupancy surveys may be used to monitor transportation characteristics of existing facilities and to re-define estimates of the future travel demand.

Data collected in an auto-occupancy survey is typically obtained through the use of a sampling technique. The surveys are based on the premise that the sample population will retain the same characteristics of the total population group. As the sample size increases, information about the population becomes more complete. However, an increase in sampling costs also occurs. In practice, a need exists to achieve a balance between the "cost" and the "completeness" of the information obtained in sampling. This balance is dependent on the available resources and requirements of the individual agency. Overall, the utilization of sampling surveys for obtaining information on a population group is quite extensive.

To follow the various steps performed to achieve an apropriate auto-occupancy survey tool and plan, this section has been presented in the following format:

I. Review of State-of-the-Art

II. Recommended Auto-Occupancy Survey Tool and Plan

III. References

The details of these sections follow.

I. Review of State-of-the-Art

In all vehicle-occupancy studies, it is generally recognized that only a sample of actual vehicles on a facility needs to be observed. The sample should be representative of the total population of vehicles using the facility, and the sample size should be determined through the use of statistical techniques. The survey should be performed for the distinct period under question. For example, if peak period occupancy levels are desired, the survey should only be performed during peak periods.

- Sample Size Determination

Several approaches to determining a sample size which represents the actual population exist. The most common method to use is the standard statistical formula [1] for determining a sample size. In this method, the sample size is derived as follows:

$$N = \frac{Z_a^2}{D^2} p(1-p)$$

Where N = sample size (vehicles)

Z_a = 100 "a" percent point of the standard normal distribution

$a = (1 + \lambda)/2$: λ = confidence level

D = permitted error

p = probability that an observation will have a given occupancy level.

In determining the required minimum sample size, the value of "p" represents a critical factor. This value (for each mode vs. total of the modes) can be obtained prior to the study by trial observation on a selected ratio. A one-hour trial observation may be sufficient. The proportions of each mode from the trial observation is then used to calculate a sample size for each mode. Typically, the largest value will be selected as the required sample size. Following the survey, the sample size should be checked based on the new values of "p". If found inadequate, an additional sample will be necessary.

Where values of "p" are not available or cannot be obtained in advance of the study, a "p" = 0.50 value can be used to determine the sample size. Using this value for "p" would identify the most conservative estimate of the minimum sample size. Values of "p" other than 0.50 would result in smaller sample sizes requirements. The sample size (using "p" $\leq$ 0.50) is determined by:

$$N \leq \frac{(Z_a)^2\ (0.25)}{D^2}$$

For example, assume λ = 95% and D = 2%

$$a = \frac{(1 + \lambda)}{2} = \frac{1 + 0.95}{2} = 0.975$$

Z_a (using normal distribution tables) = 1.96

$$N \leq \frac{(1.96)^2\ (0.25)}{(0.02)^2} \leq 2401 \text{ vehicles}$$

This approach will result in the minimum required sample size. In some cases, however, the sample size may be difficult to obtain in a single data collection period and will require additional days of data collection [2].

For some cases, it may be determined unreasonable to recount the same vehicles on successive days [3]. An alternative procedure uses a "finite population correction" (fpc) factor which accounts for the fact that most occupancy surveys actually observe a very high percentage of the total population (during the survey period) and allows the sample size to be adjusted accordingly. In such a case, the fpc factor is applied to the variance which results in a smaller sample size required for study [4].

Although the use of a fpc factor will result in smaller sample sizes than the previous approach, it has not gained widespread acceptance. This approach, however, was used in an auto-occupancy study conducted in the City of Seattle [3].

A third sampling technique, which was recently evaluated by the Federal Highway Administration, was based on a research effort performed by the firm of Peat, Marwick, Mitchell, and Co. [5]. In this approach, the sample size is calculated similar to the standard statistical method except for the following differences:

1. Sampling plans are stated in terms of "link days" of survey. (Each site is surveyed for one link-day).
2. The standard deviation used in the formula typically incorporates the effects of season of year, day of the season, and time of day.

The second factor is considered significant since many research efforts have shown that the time period factors will significantly affect the average occupancy rate [2,3,5,6,7,9].

The sample size formula is of the form [8]:

$$N = \frac{Z^2(SO)^2}{(DOCC)^2}$$

Where N = sample size (link-days)

Z = normal variate for the $(1-\lambda)$ level of confidence

λ = confidence level

SO = composite standard deviation of average occupancy

$DOCC$ = acceptable difference between the estimated average occupancy and the true value, and

$$SO = (SOL^2 + SOS^2 + SOW^2)^{1/2}$$

SO, the composite standard deviation depicts the standard deviation of the auto-occupancy rate at a location. Past research efforts have shown that the auto occupancy rate is affected significantly by the time occurrence of the survey. To account for time variations, various time-related standard deviation factors are combined to provide a composite standard deviation, SO. These various time-related standard deviation factors are:

SOL = standard deviation of average occupancy across link-days within a season

SOS = standard deviation of average occupancy across seasons

SOW = standard deviation of average occupancy across time periods during the day as a result of short-counts.

Representative ranges have been developed to reflect these differences in auto-occupancy rates by time period [5,8]. These ranges may be used to obtain a preliminary estimate of the required sample size. After the initial survey is completed, however, actual variances should be used to check the adequacy of the sample size and to compute the sample size for future occupancy surveys.

This approach has been tested by several metropolitan planning organizations throughout the U.S. [6,7]. The results indicate that the sampling plan is a reliable and cost-effective tool for determining auto occupancy rates.

This approach provides a fairly comprehensive determination of the required sample size. It is favorable for use in regional-type metropolitan areas, and has been shown to be reliable and cost-effective.

- Sites Required for Study

Since all roadways cannot be sampled in an auto-occupancy survey, it is necessary that a number of routes be selected to represent the area under study. In most studies [2,3,5-8], the functional classification of the highway is the primary consideration in determining feasible survey points. The following are several highway classification schemes and their characteristics.

For major urban areas, a functional highway classification scheme may be [2]:

- Freeway
- Freeway Entrance/Exit Ramps
- Arterial

This scheme allows for the study of the major travel routes in the area. It is highly favorable for CBD areas where extensive use of these routes exist. Selection of study points is based on the study purpose and the general assessment of routes representative of the area's travel characteristics.

A second classification scheme [3] uses combinations of the following criteria to assure that the sites selected are representative of the area's facilities. These criteria were:

- Facility type: a mix of expressways, expressway ramps, and arterials, and both suburban and central city facilities;
- Traffic volume: variety of volumes within a reasonable range;
- Level of transit service: a range from no direct commuter transit service to excellent transit service; and
- Land use characteristics: a mix of densities at suburban and central city locations, at varying distances from a CBD.

This approach is favorable for an areawide and regionwide study. Many variables which are used require their characteristics to be generalized in defining study routes. A significant amount of subjective evaluation is required to select the survey routes based on these divisions. Links are usually selected by a team of planners and engineers.

A third approach is to select locations on the basis of functional classification and traffic volume [6,7]. One particular sampling plan used the following classifications on a regional basis:

- Freeway
- Arterial, > 35,000 vehicles ADT
- Arterial, < 35,000 vehicles ADT

In this classification scheme, traffic volumes are used to categorize arterials as major or minor roadways. The classification can be further sub-categorized by urban and rural locations. Survey links are selected on a random basis by placing all roadway links into one of the three categories.

This plan is reliable for medium to large metropolitan areas. It reduces much of the subjective evaluation by individuals in selecting link classifications.

II. Recommended Auto-Occupancy Survey Tool and Plan

Based on a review of the state-of-the-art and the survey needs of the MDOT, a survey tool has been recommended for use by MDOT in measuring auto-occupancy levels. It is envisioned that the data obtained from this survey tool will assist in accomplishing the following objectives:

1. Evaluate the effectiveness of short-range transportation programs.
2. Study the energy utilization of highway travel.
3. Study transportation-related air pollution.
4. Validate urban transportation planning models; and
5. Monitor general trends in traffic and travel characteristics.

The first step in the development of a monitoring program is to define specific objectives. A general goal of determining regional occupancy rates will be of little value unless more specific objectives are defined.

For instance, a determination of the amount of variation in occupancy rates at a specific location before and after the initiation of a high-vehicle-occupancy incentive project is a well defined objective. The objectives should be defined at the outset of the survey.

Once specific objectives have been defined, the selection of sites at which occupancy levels are to be monitored should be made. The required minimum sample size is determined from the earlier formula, i.e.:

$$N = \frac{Z^2(SO)^2}{(DOCC)^2}$$

In computing the standard deviation, SO, representative ranges are [5,8]:

SOL - 0.057 - 0.069

SOS - 0.011 - 0.019

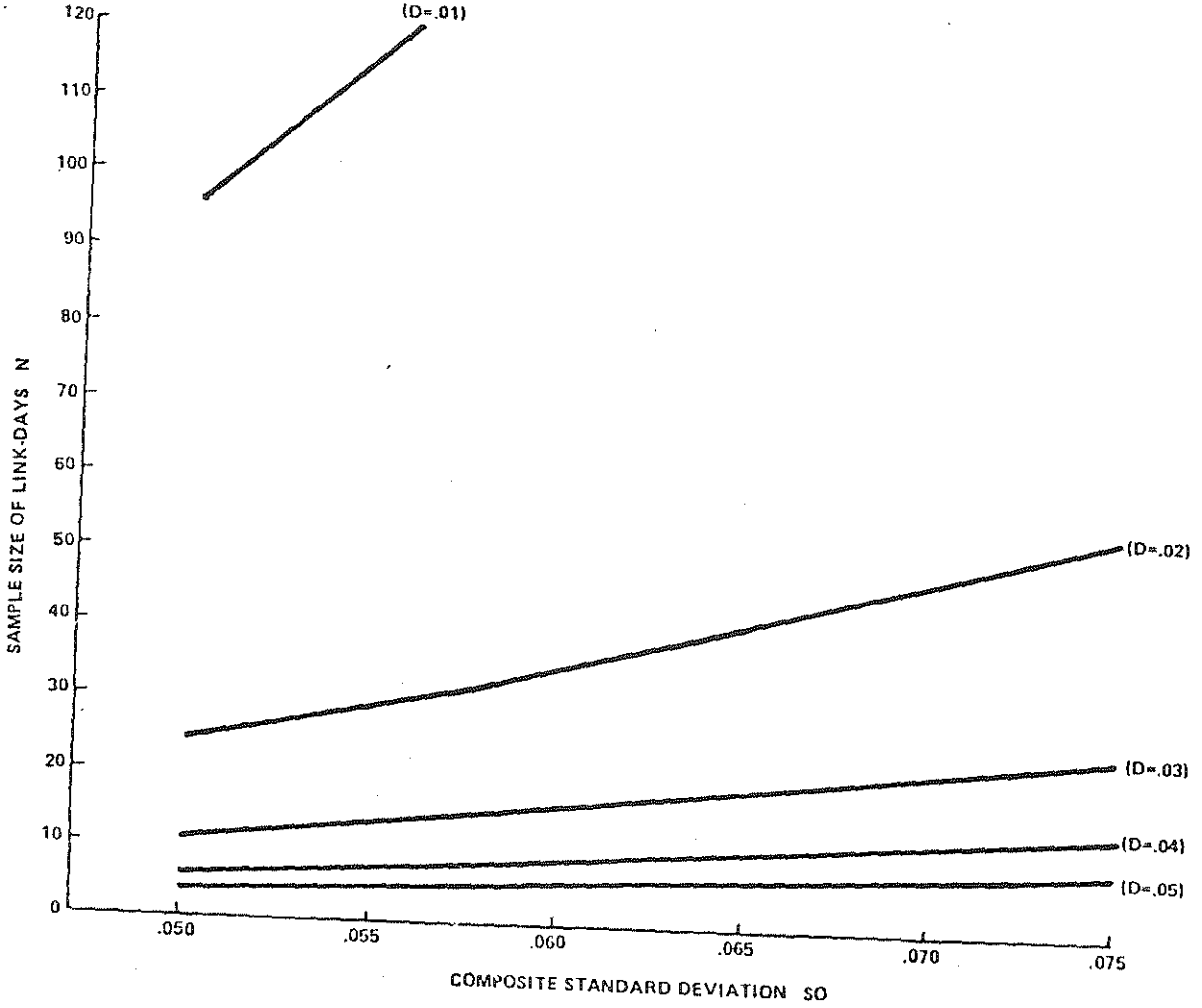
SOW - 0.012 - 0.022

Dependent on the expected variation of the results, values within any part of the range may be selected. Figure 6.1 may also be used to approximate the sample size as a function of the composite standard deviation, SO, and the permitted error. As survey data is obtained, more representative variance data may be used.

The output of the sample size formula will be in the form of "link-day". It is interpreted as a one-day survey at "x" link locations. Thus, an output of five link-days will result in a one-day survey (of bidirectional traffic movements) at five locations.

To compute "link-days" of survey, the breakdown of locations should be:

Figure 6.1 - Sample Sizes for Estimating Regional Average Occupancy Within Tolerance "D" with 95 Percent Confidence



Source: FHWA Case Study in the following States (Fall 1979):
Eastern & Western States: Kentucky, Maryland, Oregon, and West Virginia
Central States: Iowa, Michigan, and South Dakota.

- Freeway
- Arterial: > 35,000 vehicles ADT
- Arterial: < 35,000 vehicles ADT

Survey locations may be further sub-categorized on an urban vs. rural basis. The sites are randomly selected from a list of sites fitting the classifications given above.

These locations should be field-checked to find an appropriate location from which to conduct the survey. Field surveyors should be in a position of good visibility and one which is clear of the roadway. The data collectors should be fairly inconspicuous to minimize interference with the normal traffic flow. Finally, if the survey is to be conducted during hours of darkness, it is helpful to select a site which has a bright light across the roadway from the observer. The resultant silhouettes inside the vehicles allow for greater accuracy.

Data collection is fairly straightforward. Typical characteristics are:

1. Survey Period

   Monitoring of traffic should occur during the following time periods:

   7:00 - 9:00 A.M.
   11:00 - 1:00 P.M.
   2:00 - 6:00 A.M.

2. Sampling Plan

   Each lane in each direction is counted for a period of 10 or 15 minutes followed by a five minute interval to record the counts and reset the counter to zero, if used. After the counter is reset, the next lane is counted in this manner, a single observer is able to collect occupancy data at a site.

3. Vehicle Occupancy Definitions

The following definitions are recommended to be used in defining the vehicle occupancy characteristics:

- One person passenger vehicles. These include non-commercial pick-up trucks, vans, and private auto and taxis.
- Two person passenger vehicles.
- Three person passenger vehicles.
- Passenger vehicles carrying four or more passengers.

Commercial vehicles and trucks are not surveyed.

4. Data Summary Sheet

A recommended data summary sheet is shown in Figure 6.2.

Some sites may require more than one observer. This need is a function of traffic volume and may also be related to the degree of visibility of the vehicle occupants. For most sites, the best way to determine if more observers are needed is to schedule one observer for the site and subsequently find out whether there was any particular difficulty in keeping up with the traffic flow. If there was difficulty, two observers should be assigned, and they should divide the lanes of traffic between them. In these cases, values on the both count sheets have to be summed to obtain occupancy figures for the total flow.

Some of the sites selected may be freeways, freeway ramps, or other State highways. When these sites are to be monitored, it is recommended that the local State Patrol office be contacted and notified of the planned counts. This helps prevent unnecessary explanations to individual officers and allows data recorders to collect data with fewer interruptions.

Figure 6.2

AUTO OCCUPANCY STUDY

TIME: ______ A.M. / P.M.

VISIBILITY OF OCCUPANTS (Good, fair, poor, very poor): ______

WEATHER CONDITION (Clear, overcast, raining): ______

DAY: ______ DATE: ______

NAME: ______

LOCATION: ______

TIME	VEHICLE WITH 1 OCCUPANT	VEHICLE WITH 2 OCCUPANTS	VEHICLE WITH 3 OCCUPANTS	VEHICLE WITH 4 OCCUPANTS	VEHICLE WITH FIVE OR MORE OCCUPANTS

INCLUDE MOTORCYCLES AND PICKUPS.
DO NOT INCLUDE BUSES OR HEAVY COMMERCIAL TRUCKS.

COMMENT ON ANY PARTICULAR PROBLEMS

______

______

In reviewing the data findings, caution should be exercised in defining the standard deviation. For example, a summary of statistics may show the average auto occupancy for a period as 1.293, with a standard deviation of .650. On first inspection, this appears to be an abnormally high value for the standard deviation. However, the standard deviation is a measure of the amount of variation of the occupancies of each individual vehicle, as opposed to the standard error of the mean. Thus, the true value of 0.650 is not unreasonable.

Recent findings from a study developed as part of the Highway Performance Monitoring System, formulated the following findings in regards to vehicle occupancy rates. These characteristics should be studied in evaluating the survey findings (9).

> "Table 6.1 provides the average vehicle occupancy for rural and urban areas and by functional class of highway. There are several results which tend to agree with previous studies:
>
> 1. Vehicle occupancies are higher in rural areas than in urban areas. The higher occupancy is likely due to the longer trip lengths and the larger proportion of non-work trip purposes occurring on rural systems.
> 2. Vehicle occupancies are lower in the rural portion of the Central States as compared with the Eastern and Western States. This is likely due to the lower population density. Also, data collection in the fall quarter versus the summer quarter and in 1979 versus another year may have resulted in lower vacation travel and therefore, lower vehicle occupancies.
> 3. Vehicle occupancies are higher on weekends than on weekdays. This is likely due to the larger proportion of trips for the purposes of recreation, visit friends and relatives, and shopping. When Saturday and Sunday data are added to Monday through Friday data, the daily average vehicle occupancy is increased 12 percent. (The average factor was 1.12 with a range of 1.07 to 1.33).
> 4. Vehicle occupancies vary among functional classes of highway with the highest functional classes having the highest vehicle occupancies. This is likely due to the longer trip

Table 6.1 - Average Vehicle Occupancy

RURAL	Interstate	Other Principal Arterials	Minor Arterials	Major Collectors	Minor Collectors	Total
Eastern & Western States						
Rural Average	2.11	1.98	1.71	1.69	1.77	1.93
Range (by State)	1.86-2.39	1.94-2.06	1.51-1.94	1.58-2.24	1.53-1.98	1.85-1.99
Central States						
Rural Average	1.85	1.80	1.65	1.84	1.58	1.83
Range (by State)	1.85	1.62-2.01	1.59-1.70	1.64-2.24	1.54-1.62	1.65-2.06

URBAN	Interstate	Other Freeways and Expressways	Other Principal Arterials	Minor Arterials	Collectors	Total
All States						
Urban (5000+Pop.)	1.76	1.54	1.56	1.53	1.59	1.59
Range (by State & Urban Pop. Size)	1.52-2.21	1.36-1.74	1.35-1.79	1.29-1.71	1.38-1.82	1.47-1.73

Source: FHWA Case Study in the following States (Fall 1979):
Eastern & Western States: Kentucky, Maryland, Oregon, and West Virginia
Central States: Iowa, Michigan, and South Dakota.

lengths taking place on these facilities. However, collectors and minor arterials still have a fairly high vehicle occupancy since they carry not only local trips, but also the beginning and ending portions of high occupancy long trips.

5. The variation in vehicle occupancy among the different population sizes of urban areas was small and not significantat at the national level.

6. On a daily basis, the afternoon time period provides a good representation of the 24-hour daily vehicle occupancy. Where monitoring of work travel is also important, a split shift covering the morning peak period, as well as the afternoon off-peak and peak periods was generally successful in providing data for both purposes."

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