Integrating EMME/2, GIS, SPSS, ALOGIT and ACCESS for Multimodal Travel Demand Model Development in a Medium-Sized Community

(Jin Ren, P.E. and Bob DenOuden at Thurston Regional Planning Council)

Introduction

Thurston Regional Planning Council (TRPC) is a medium-sized Metropolitan Planning Organization (MPO) located in Thurston County, with a population of 202,700 growing at an annual rate of 2.6% per year since 1990. Covering an area of 737 square miles, Thurston County is located at the southern end of Puget Sound in western Washington (Figure 1), and separates the urban, metropolitan Tacoma-Seattle area from the rural, timber-dependent southwest area. Included in the area is the state capital, Olympia, and Interstate-5 corridor runs right through the middle of our urban area (Figure 2). Due to these characteristics and major state employment, our region has unique socio-economic, demographic, geographic and travel characteristics.

The current regional travel demand forecasting model is based on vehicle trips only and relies on national average travel statistics. The need to develop a multi-modal travel demand model using local data is increasingly driven by the State Commute Trip Reduction Law, Travel Demand Management, traffic impact studies, regional land use and transportation policy evaluation, major transportation system investment study and funding application. These needs initiated our EMME/2 model conversion process.

It would have cost TRPC at least $1 million to hire consultants to develop a regional state-of-the-art multi-modal travel demand forecasting model, including local travel data collection and staff time. As a medium-sized MPO, TRPC certainly cannot afford such costs. Fortunately, TRPC obtained a $240,000 High Capacity Transit grant through Intercity Transit (regional transit agency) to conduct our 1998/1999 Household Travel Survey (HTS). In 1997, prior to this survey, TRPC coordinated with Washington State Department of Transportation (WSDOT) on an Interstate-5/State Route 101 origin-destination survey, which analyzed regional through/inbound/ outbound travel characteristics. As a follow-up to the HTS, TRPC coordinated with Intercity Transit and a consulting firm to conduct a transit-on-board survey designed to fit our modeling needs. The major task to use these data for regional model development falls upon the designated 1.75 full-time equivalent (FTE) TRPC transportation planning/modeling staff. A full-blown four-step model development process therefore commenced from here. A detailed scope of work was laid out with model estimation and application plans.

Although our EMME/2 Model Conversion process remains on-going, we have achieved successes in estimating and applying Household Models, Trip Generation Models and Mode Choice Models in only a few months. Besides our excellent data collection program, we attribute our successes to several factors: commitment to staff training and research, timely and appropriate software acquisition, expert advising, and most importantly, effective integration of software tools in data preparation and analysis. Based on these successes, we have great confidence in accomplishing our modeling task in one year.

This paper addresses how it is possible for a medium-size MPO with limited human resources and funding to successfully develop a state-of-the-art multi-modal travel demand forecasting model using locally collected survey data. It is focused on some useful EMME/2 features and modules, which contribute a great deal to the data preparation and integration for both model estimation and application.

Figure 1: Thurston County and Washington State

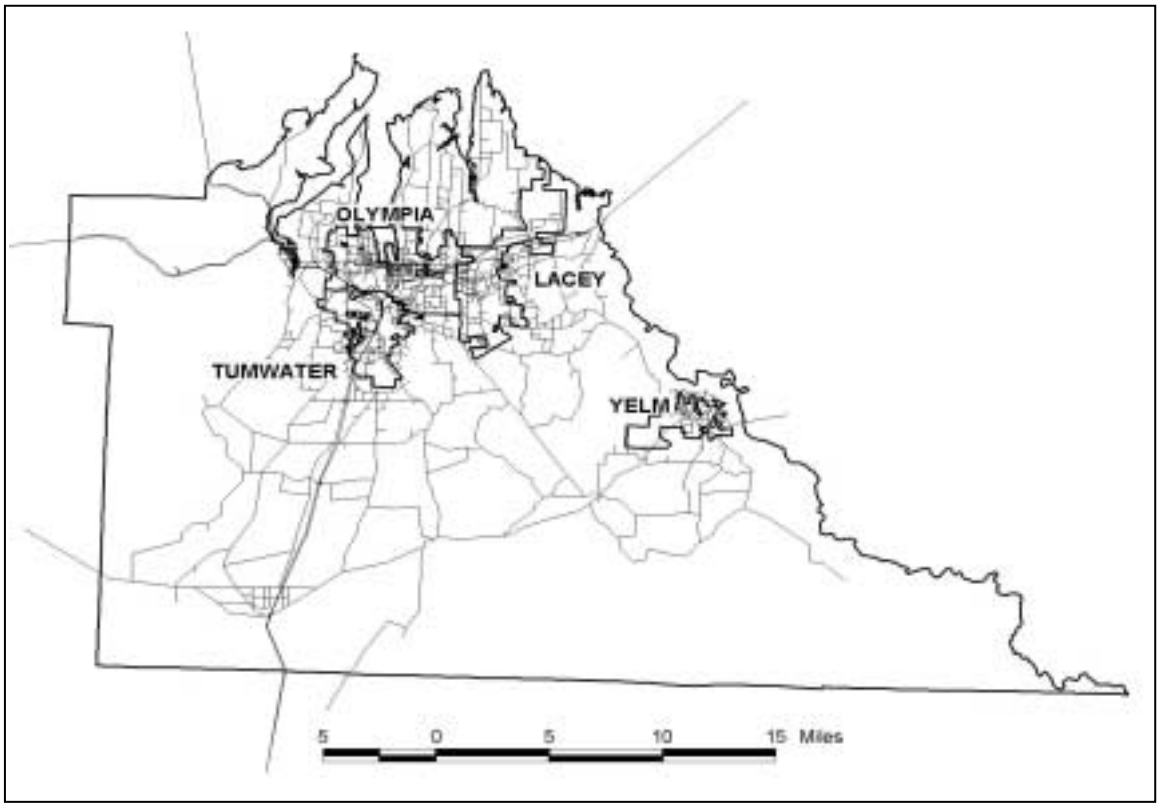

Figure 2: TRPC EMME/2 model network

Staff Training and Researching

Prior to and during the HTS data collection process, we had ample time to spend on a nation-wide literature search and staff training on the theories and methodologies of multi-modal travel demand forecasting model development. We paid special attention to the successes of public agencies, which have developed or are currently developing state-of-the-art models. We found them willing to share technical information and interested in what our medium-sized MPO is doing in terms of travel model development. The internet has helped a great deal in our information exchange and research efforts. Following is a list of public agencies used as our resources, which could be useful to you, too:

- Portland Metro, Oregon
- Mid-Willamette Valley Council of Government, Salem, Oregon
- Puget Sound Regional Council, Seattle, Washington
- Lane Council of Government, Eugene, Oregon
- Oregon Department of Transportation Modeling Section
- Baltimore MPO, Maryland
- OKI MPO, Ohio, Kentucky and Indiana
- North Central Texas Council of Government, Dallas, Texas

In regards to staff training, our efforts were focused primarily on the fundamentals of statistics and discrete choice analysis. We took individual staff knowledge and strengths (i.e. GIS Arc/Info and EMME/2) into consideration and assigned training on ALOGIT, Microsoft ACCESS and SPSS software tools accordingly. Our main goal was to know how to integrate the various data using these software tools for model estimation and application. We went through the following training and researching efforts:

- Video-taped Oregon DOT 7-Day Modeling Courses given by Mr. Peter Stopher in 1995
- Technical Specifications for the March 1998 Travel Demand Model at Portland Metro
- Ben-Akiva and Lerman's "Discrete Choice Analysis", 1985
- Travel Demand Forecasting Process for the Dallas-Fort Worth Metropolitan Area (April 1994, North Central Texas Council of Governments)
- Travel Model Development and Refinement – Trip Generation, Trip Distribution and Mode Choice (Puget Sound Regional Council, 1994 - 1997)
- OKI Household Activity and Travel Survey Report (OKI Regional Council of Government, August 1995)
- ALOGIT and SPSS Software Application Self-Training
- Access Software Application Intermediate and Advanced Courses
- EMME/2 Module Familiarization and Experimentation
- Travel Survey Manual, Cambridge Systematics, Inc., 1996

Data Collection

In addition to the collection of three sets of travel survey data, we prepared other travel demand and supply data for our modeling needs. The following briefly addresses our data collection and preparation efforts:

- 1997 I-5/SR101 Origin-Destination Travel Survey

In the South Puget Sound area, Interstate 5 and Washington State-Route 101 are the two most important regional highways carrying a combined 130,000 average daily traffic. On I-5 in Thurston County alone, there are 14 interchanges to facilitate vehicle access to and from the freeway. In 1997, TRPC joined efforts with WSDOT to conduct a regional interstate origin-destination (O-D) travel survey for two days. Video equipment was set up to capture license plates at three strategic locations going into and out of the county. Based on these license plate numbers, surveys were then sent to the vehicle owners. Meanwhile, TRPC coordinated with local jurisdictions to collect the ramp traffic counts for the same two days. This O-D survey provides regional passenger specific vehicle trip data regarding the trip purpose, travel time, modes and routes chosen, trip frequency, origin and destination, and at what interchange passenger vehicles are entering and departing Thurston County. With the origin and destination data geocoded in GIS, the survey data will help to calibrate the regional travel demand forecasting model in terms of Thurston region inbound/outbound/ through travel.

- 1998/1999 Household Travel Survey

During the fall of 1998 and winter of 1999 TRPC contracted with NuStats International to conduct a household travel survey. Recruited households in this survey recorded data on all trips that were made by all household members over an assigned two-day travel period. Travel data was collected from a total of 1,537 households, representing 3,653 people who reported a combined 25,277 trips. All household and workplace addresses were geo-coded as well as over 90% of the destination locations of trips in the survey. Data was also collected on a variety of socio-economic and demographic factors for each of the households and residents participating. In addition to data from the households who completed the survey, 950 households that were recruited but did not complete their travel assignments were added to the database for household model estimation. Data from the household travel survey has served as the backbone of our travel model estimation process, including household sub-models, trip production, mode choice and destination choice elements.

- 1999 Transit On-board Survey

Based on input from members of the modeling advisory panel, a decision was made to augment the household travel survey data collection effort with a small transit on-board survey. NuStats International was contracted to conduct this survey during the spring of 1999. Due to limited resources we opted to randomly sample routes based on ridership proportionality within Intercity Transit's designated route types. Surveys were distributed as passengers boarded the buses and collected as they exited. Surveyors on board the buses also tallied the total number of riders and kept track of the number of forms handed out. A total of 1,325 completed surveys were collected. Fifty-five percent of riders who boarded the surveyed transit runs completed a survey form. The survey was designed to match key data items collected in the household travel survey.

- T-Model2 Network Conversion and Enhancement into Multi-modal EMME/2

The existing regional travel demand forecasting model was implemented in T-Model2, which forecasts base year and future year P.M. peak hour vehicle trips on major and minor roadways. The base year 1998 model is calibrated to R-square of 0.95 with 8 North-South screenlines and 10 East-West Screenlines matching the base year traffic counts within 7% marginal errors except for one screenline with +10% overestimate. This gives us great confidence in converting the calibrated T-Model2 network into EMME/2 network, including

node x,y coordinates, from-to nodes, link length, number of lanes, posted speed, link capacity and type, as well as turn prohibitions at intersections and interchanges (Figure 2). After we calculated the conversion factor between the T-Model2 and EMME/2 network, we edited the T-Model node and link files to create an EMME/2 network batch-in file. We added volume/delay functions and travel modes (i.e. auto, bus, truck, bike, and walk) to the EMME/2 network file to enhance the multi-modal travel demand modeling capabilities.

- Updating Traffic Analysis Zone (TAZ) Structure and Transit Network Coding

Because we were updating the existing TAZ structure from 583 to 800 to meet the existing and potential modeling needs, we recoded the TAZ centroids and centroid connectors in the converted EMME/2 network. We also added separate bike paths to the EMME/2 multi-modal network for bike trip assignments and travel “skims” calculations. What is more important is that we built up to 40 regional transit lines on top of the EMME/2 highway network for A.M., Midday or P.M. peak hour periods. The EMME/2 network looks very similar to the T-Model2 network, but the network modeling capabilities are greatly enhanced from single-vehicle trip based to multi-modal travel forecasting.

- 1998 Base Year Population, Housing, and Employment by TAZ

According to Pete Swensson, TRPC Population/Employment Forecaster, TRPC staff developed estimates of population, housing, and employment for each TAZ for the base year, April 1, 1998. Housing unit estimates were developed for each of three categories: single-family, multifamily, and manufactured housing. To 1990 Census data we added building permits for each dwelling type. (TRPC has been tracking and geo-coding building permits by type since 1986.) This data then required several adjustments.

Time periods for permit tracking were selected to account for the lag between issuing the permit and completing the structure. Single family units were given a two-month lag. Multifamily units were lagged nine months in the larger cities, and three months in the small towns (recognizing that in the cities units are in large apartment complexes, but are mostly duplexes in the small towns). We used no lag for manufactured housing. To account for permits that are taken out but not completed, the April 1, 1998 totals were then adjusted to conform with official estimates from the Washington State Office of Financial Management (OFM), which fixes the annual population and employment figures for each jurisdiction for revenue allocation purposes. Household sizes and vacancy rates were combined into a population-per-dwelling factor derived from 1990 Census tract figures, and adjusted downward to conform to 1998 OFM totals. Group quarters were identified individually and surveyed by telephone to obtain population estimates.

Employment data by four-digit SIC code was obtained from the Washington State Department of Employment Security for employees covered by unemployment compensation insurance. Each employer was geo-coded and placed in a TAZ. Missing or unusable addresses were corrected in the field where possible, using a global positioning system unit. The covered employment was then "inflated" to represent total employment (i.e., to add proprietors and others not covered by unemployment compensation insurance -- about 20% of the total employment). Individual inflation rates were developed for each sector -- e.g., there are many self-employed workers in real estate, but none in government or banking. For some industries (e.g., manufacturing), the "inflated" workers were proportionately allocated to TAZs based on the location of covered workers. For other

industries (e.g., construction, where many small contractors work from home), the inflated workers were allocated to TAZs partly based on population.

- Vehicle Trip Table Expansion from Existing 483 Zones to 800 Zones

After taking care of the network conversion on the supply side, we strongly feel that on the demand side we should take advantage of the existing calibrated P.M. peak hour vehicle trip table in T-Model2. The challenge for the trip table conversion is the different TAZ structures between the two sets of models. Fortunately, 800 expanded TAZs are based on the existing 483 TAZs. We made one assumption; that the trip table expansion can be based on 800 TAZ area percentage distributions of 483 TAZs. T-Model2 has the capability of expanding the current TAZ structure to more TAZs based on the percentages of area splits, which are calculated from the regional GIS database with these two separate sets of TAZ area boundaries. Since the expanded P.M. peak hour trip table is text-based, it can be easily batched into EMME/2 as a full matrix. Then, we used the trip table to run auto assignment in EMME/2 and surprisingly found the trip distribution and assignments in EMME/2 are very similar to T-Model2 trip assignments. This fact ensures us that we are creating the auto travel "skims" from a T-Model calibrated trip table rather than from scratch. Using the T-Model2 based trip generation and peaking factors, we also created A.M. peak and Midday hour auto trip tables with R-square of 0.90 and expanded the trip tables to batch into EMME/2. By doing this, we have confidence in using EMME/2 to run peak and off-peak traffic assignments for travel "skims" to use for multimodal travel demand model estimations.

- Using EMME/2 5.34 and 5.35 to Derive Travel Skims for 21,763 Surveyed Trips

The surveyed trips are geo-coded with 100% household locations and 95% activity destination locations, but the survey does not have accurate report on travel time and distance, regardless of what travel modes were taken. Therefore, we decided not to use the reported travel time or distance for our mode choice or destination choice model estimations, but instead used the derived travel skims from EMME/2 network assignments. With the modules of 5.34 (Prepare Access and Egress Nodes for Individual Transit Trips) and 5.35 (Analyze/Assign Individual Transit Trips), it was possible for us to derive individual travel skims for each of 21,763 geo-coded survey trips. We first converted the access and egress nodes of each trip from GIS-based x,y (real-world) coordinates to the exactly same locations on EMME/2 x,y (cartesian) coordinates. We borrowed and modified EMME/2 macro trpcdisa.mac (as shown in Appendix B) to derive the travel skims for auto, transit, walk and bike for peak and off-peak hours. The travel "skims" outputs are edited in MS-Word and copied into the input file for mode choice estimation in ALOGIT.

- Area-based Land Use Data Preparation in GIS: local intersection density, mixed land use index by TAZs, x-y coordinates match-up between GIS network and EMME/2

Integration between our GIS data and EMME/2 has been an important step in our model development efforts. By geocoding locations from the household travel survey this data set could then be integrated with the rich set of spatial data we already possessed. ESRI's ArcInfo and ArcView products were used to prepare and analyze the GIS data. An Avenue script was written to calculate intersection density around given household locations. Mixed-use index was based on TRPC population forecast base year data at the TAZ level. An important step in the data integration process was the development of a set of well-

defined control points that could be used to transform EMME/2 based network data to real-world coordinate based GIS data.

- Zonal Data Preparation in EMME/2: employment density by distance, transit accessibility by transit travel time, daily and hourly parking costs, mix-use indexes and local intersection densities

Using the EMME/2 5.21 and 3.21 modules, we could respectively figure the travel distance and time by walking and transit between TAZs. Using the origin-destination travel walking distance and transit travel time, we derived the employment accessibility measures by walking distance of a quarter and one half mile and transit time by 10, 20, and 30 minutes, respectively. You can refer to walkasgn.mac (as a example for trip assignment for walk time and distance) and mdempden.mac in Appendix B for calculating the employment accessibility measures (i.e. employment "density" within 0.5 mile of walking distance to centroid). Using Olympia downtown parking pricing information and daily parking costs at state employment sites, we can input the average daily and hourly parking cost at TAZ level. All these data sets are stored in EMME/2 vector matrices and are referred to as zonal data since they are individually and directly linked to the TAZs. The mixed-use indexes and local intersection densities are calculated in the regional GIS-database for model estimation but can be input to EMME/2 as vector matrices for model application.

Taking the advice from our Modeling Advisory Panel, concurrent with the data collection and preparation we spend significant amount of time understanding and analyzing the data prior to starting model estimation. This is essential for us to adequately design the modeling structures and scope of work with discreet consideration of data limitations and trade-offs between the complexities and sufficiencies with regard to the multi-modal travel demand modeling. This also ensures effective data integration for modeling.

Software Acquisition

Thanks to agency administrative support and resource management, we were able to acquire relevant software for the regional model development at the proper time. Just for the purpose of EMME/2 model conversion, we purchased the following software: EMME/2, ALOGIT, SPSS Upgrade, and M2 Probe (An ArcView extension for integrating EMME/2 and GIS). We already had Arc/Info and ArcView as well as Microsoft Office Professional, including Access, Excel, Visual-Basic for Applications (VBA), and Word as data processing tools.

With the needed software in house, we had the full capability of analyzing and processing all data required for model estimation and application. The next challenge was to appropriately allocate 1.75 FTE for training on the software, with the knowledge that some software are extremely complex and require prior background and formal training courses. We met this challenge by appointing one staff to manage the various survey data and to analyze the statistics using SPSS, Access, and Arc/Info, and the other staff to take on logit choice modeling in ALOGIT and model application in EMME/2. The responsibilities for software maintenance and skill enhancement were thereby clearly defined.

To have better understanding of the software applications, we not only used the technical assistance from the software developers, but also worked with the survey sub-consultants and Portland Metro since they have working knowledge and experience to share with us, particularly in ALOGIT, GIS and EMME/2 macros. Frustration with software difficulties is minimized and

the time frame for becoming familiar with the software was shortened due to our efforts to learn from our peers at Salem, Oregon, Phoenix, Portland Metro, Puget Sound Regional Council, Cleveland, Cincinnati and Lane Council of Government (Eugene, Oregon).

Expert Advice

Our region is located in the Pacific Northwest with a great deal of nearby expertise in travel data collection and modeling. We are well aware of our agency's limited human resources and expertise. We also understand the importance of having expert advice to guide and expedite our major modeling process, and especially to keep it on the right track.

We formed two technical reviewing panels to meet quarterly to review and advise us on our work. The Household Travel Survey Review Panel and Modeling Advisory Panel consist of experts from public agencies and members of our consultant team. They enthusiastically participate in our quarterly meetings and concur with us that this is also a learning experience to see a medium-sized MPO developing a state-of-the-art multi-modal travel demand forecasting model. What is important to us is that they are willing to expend their time and effort to help. Appendix A lists all technical advisory members and we would like to acknowledge and appreciate their valuable professional opinions on our modeling process at this point.

Following is a summary of recommendations we have in working with expert panels:

- Keep open-ended communication with advisory members;
- Inform them of travel surveying and modeling goals and objectives in writing;
- Prepare documents, including scope of work and meeting agendas ahead of time;
- Document all stages of the model development effort through working papers in order to provide a record of the entire process;
- Record meeting minutes and listen to specifics later; and
- Follow up with recaps of meetings and additional comments and questions.

Data Integration

For the EMME/2 model conversion process, three major sets of data were categorized according to their software requirements for data processing and integration:

- Household Travel Survey/Bus On-Board Survey Data/Regional Route O-D Survey
- Geographical Information Systems Database
- EMME/2 Derived Model Data

Since these data sets were derived from different software tools, it was crucial for us to know how to effectively integrate them for both model estimation and application. Below is an example of this process; the data preparation of household auto-ownership model development.

To estimate the number of households with 0, 1, 2 or 3 or more cars in the regional traffic analysis zones, we tested the multi-nomial logit choice model estimation. Based on ALOGIT software, we included many data variables that we expected might have significant explanatory power on the household auto-ownership characteristics.

The complete HTS database (both recruited and retrieved households) included 2384 households with locations geocoded in the Thurston Regional GIS database. These households provided us with their household size, number of workers, number of vehicles owned, and incomes, which we can directly use in setting up the ALOGIT input data files.

Since the GIS database stores number of households, total and retail employment data by regional TAZs, we can calculate the mixed land use indexes by TAZ and associate them with the surveyed households. Since the regional GIS network contains the local streets and intersections, we can also calculate local intersection density within quarter, one-half and one-mile to the surveyed household locations.

As mentioned before, EMME/2 is capable of calculating other TAZ-based data such as employment density within a quarter mile, and employment accessibility to transit within 10, 20 and 30 minutes.

We effectively achieved the data formatting and integration through the following approaches and software tools (Figure 3 illustrates the logical and physical data flow by different software tools):

- The data integration was oriented for the model estimation in ALOGIT and model application in EMME/2.

- We used the intermediate data formats as text-based because EMME/2 batch-in and punch-out data are all in text-formats, as well as ALOGIT input/output data files.

- All software tools, mentioned above for EMME/2 model conversion, are capable of recognizing and storing the data in text formats.

- MS-Word and Excel can be very good data editing tools, which were used in most of our data integration steps because they are user-friendly and easily create intermediate text-based data formats.

- MS-Access acts as the "glue" that binds the whole data integration effort together.

- We were so familiar with the strengths and weaknesses of each software tool that we tried to take advantages of their strengths and avoid their weaknesses.

- All input data were subjected to quality control checks at multiple points in the process. Survey data were first checked through "automated" (logical) procedures during collection and subsequently analyzed by TRPC staff upon receipt from the consultants.

- Output results were checked for reasonableness and compared back to survey observations for goodness-of-fit at each stage of model estimation to help ensure errors in programs or data would not be propagated to future stages.

- For each subsequent ALOGIT model estimation run, we use APPLY module to verify the "choices" against the explanatory variables and compare the statistical measures for model improvements based on Root-Mean-Square-Error and number of standard deviations.

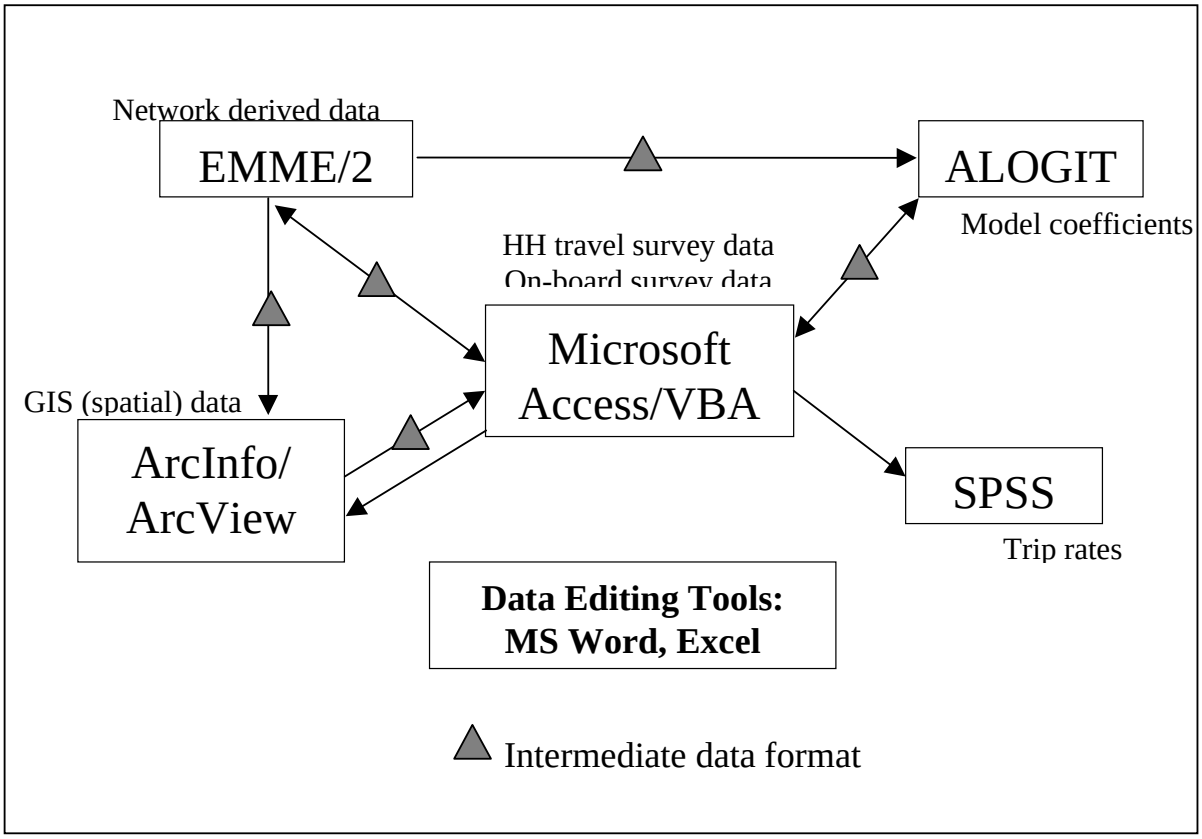

Figure 3: Data integration

Following are two typical examples of our success in data integration, through which we hope you will gain better understanding of our data integration techniques and process.

Data integration for Household Model Estimation and Application: For the household auto-ownership "choice" estimations in ALOGIT software, all the input data need to be formatted in one text-based file. As shown in Table 1, the data variables are obtained respectively from 1998/1999 HTS, GIS-Based mix-use and local intersection density calculations, and EMME/2 assignments and matrix calculations.

The final statistics of multinomial logit choice estimation are shown in Table 1 after we tested 18 different model runs in ALOGIT on many different variables using the integrated data.

Table 1:	**1998 Thurston Household Auto-Ownership LOGIT Estimation**		
		Coefficient	
0-Car Households		**Estimates**	**T-Stats**
CONSTANT	Bias Constant for 0-Car Household Utility Functions	3.578	41.5
HHSIZ	Number of Household Members (1, 2, 3 and 4+)	-1.273	-36.2
WRKRS	Number of Household Workers (0, 1, 2 and 3+)	-1.752	-42.7
INCCAT1	$5,000 - $20,000	1.964	24.9
INCCAT2	$20,001 - $35,000	-0.5912	-8.1
INCCAT3	$35,001 - $50000	-1.297	-15.1

INCCAT4	> $50,000	-2.567	-20.8
MIXUSE	Mixed land use index by TAZs (area-based density)	0.002038	19.0
INT1	local Intersections within 0.25 mile radius of households	0.02689	16.7
TOT5DEN	Total Employees within 0.5 mile of walking to centroid	0.0003972	12.9
SFHOME	Dummy Single Family Home Ownership variable	-2.76	-46.2
		Coefficient	
1-Car Households		**Estimates**	**T-Stats**
CONSTANT	Bias Constant for 1-Car Household Utility Functions	3.544	69.6
HHSIZ	Number of Household Members (1, 2, 3 and 4+)	-0.9064	-60.0
WRKRS	Number of Household Workers (0, 1, 2 and 3+)	-1.083	-59.8
INCCAT1	$5,000 - $20,000	1.705	27.1
INCCAT2	$20,001 - $35,000	0.5648	15.5
INCCAT3	$35,001 - $50000	0	0
INCCAT4	> $50,000	-0.9142	-29.4
MIXUSE	Mixed land use index by TAZs (area-based density)	0.001402	20.5
INT1	local Intersections within 0.25 mile radius of households	0.03514	41.9
TOT5DEN	Total Employees within 0.5 mile of walking to centroid	0.0002236	7.7
SFHOME	Dummy Single Family Home Ownership variable	-1.336	-37.5
		Coefficient	**Final**
2-Car Households		**Estimates**	**T-Stats**
CONSTANT	Bias Constant for 2-Car Household Utility Functions	1.739	37.9
HHSIZ	Number of Household Members (1, 2, 3 and 4+)	-0.1556	-14.8
WRKRS	Number of Household Workers (0, 1, 2 and 3+)	-0.5502	-40.1
INCCAT1	$5,000 - $20,000	0.5924	9.4
INCCAT2	$20,001 - $35,000	0.1246	3.6
INCCAT3	$35,001 - $50000	0.1133	4.5
INCCAT4	> $50,000	-0.2062	-8.2
MIXUSE	Mixed land use index by TAZs (area-based density)	0	0.0
INT1	local Intersections within 0.25 mile radius of households	0.02256	35.0
TOT5DEN	Total Employees within 0.5 mile of walking to centroid	0.0003135	11.7
SFHOME	Dummy Single Family Home Ownership variable	-0.5256	-16.2
		Coefficient	**Final**
3+Car Households		**Estimates**	**T-Stats**
CONSTANT	Bias Constant for 3-Car Household Utility Functions	0	0.0
HHSIZ	Number of Household Members (1, 2, 3 and 4+)	0	0.0
WRKRS	Number of Household Workers (0, 1, 2 and 3+)	0	0.0
INCCAT1	$5,000 - $20,000	0	0.0
INCCAT2	$20,001 - $35,000	0	0.0
INCCAT3	$35,001 - $50000	0	0.0
INCCAT4	> $50,000	0	0.0
MIXUSE	Mixed land use index by TAZs (area-based density)	0	0.0
INT1	local Intersections within 0.25 mile radius of households	0	0.0
TOT5DEN	Total Employees within 0.5 mile of walking to centroid	0	0.0
SFHOME	Dummy Single Family Home Ownership variable	0	0.0
Overall Statistics of Estimation			
Final Value of Likelihood =		-68865.2526	
"Rho-Squared" w.r.t Zero =		-104514.118	
"Rho-Squared" w.r.t Constants =		-90521.722	
Root-Mean-Square-Errors in APPLY =		878.255	
Number of *s (Difference/SD) In APPLY =		24	

We successfully implemented the household models in the 1998 EMME/2 databank, which is based on 800 TAZs with input of mix-use indexes and local intersection densities within 0.25 mile radius calculated from GIS, and total employment "density" calculated in EMME/2. We used the powerful programming features and matrix calculation capabilities of EMME/2, as are shown in the example of EMME/2 macro cwhi-sf.mac in Appendix B.

What is more convincing and interesting is that the results of auto-ownership model estimation have a very good fit to the statistics of the 1998 household travel survey expanded region-wide. Table 2 and Table 3 compare the model estimates with the survey statistics specifically for 1998 household auto-ownership forecasts in the Thurston Region. The household models of K-12 school children and workers also demonstrate good fits by the same approaches we've taken for the auto-ownership model.

Table 2: Model Estimation of 1998 Households with 0-3+ Vehicle Compared with HTS Expansion

0-3+ Vehicle HHs	1998 SF HHs	1998 MF HHs	98 HHs Total (%)	98 HHs by HTS (%)
0-Vehicle HH	710	1,932	2,462 (3.3%)	3,289 (4.1%)
1-Vehicle HH	11,781	9,759	21,540 (26.8%)	20,696 (25.8%)
2-Vehicle HH	22,544	11,780	34,324 (42.8%)	34,012 (42.4%)
3+Vehicle HH	15,947	5,765	21,712 (27.1%)	22,220 (27.7%)
Total HH	50,982	29,235	80,217 (100%)	80,217 (100%)

Table 3: Model Estimation of 98 HHs by 1-4+ Persons by 0-3+ Vehicles Compared with HTS Expansion

0-3+ Veh. By 1-4P	1998 SF HHs	1998 MF HHs	98 HHs Total (%)	98 HHs by HTS (%)
1P0V HH	507	1,176	1,683 (2.10%)	2,447(3.05%)
1P1V HH	5,775	3,619	9,394 (11.71%)	10,709 (13.35%)
1P2V HH	3,247	1,051	4,298 (5.36%)	2,567 (3.20%)
1P3+V HH	1,061	227	1,288 (1.61%)	730 (0.91%)
2P0V HH	175	608	783 (0.98%)	610 (0.76%)
2P1V HH	4,562	4,269	8,831 (11.01%)	5,992 (7.47%)
2P2V HH	9,177	4,461	13,638 (17.00%)	16,838 (20.99%)
2P3+V HH	5,527	1,810	7,337 (9.15%)	7,950 (9.91%)
3P0V HH	19	96	115 (0.14%)	185 (0.23%)
3P1V HH	909	1,106	2,015 (2.51%)	2,174 (2.71%)
3P2V HH	4,426	2,591	7,017 (8.75%)	5,952 (7.42%)
3P3+V HH	3,778	1,444	5,222 (6.51%)	5,615 (7.00%)
4P0V HH	8	51	59 (0.07%)	112 (0.14%)
4P1V HH	534	765	1,299 (1.62%)	1,813 (2.26%)
4P2V HH	5,695	3,677	9,372 (11.68%)	8,399 (10.47%)
4P3+V HH	5,581	2,284	7,865 (9.81%)	8,062 (10.05%)
Total Households	50,982	29,235	80,217 (100%)	80,217 (100%)

Data Integration and Formatting for Trip Generation Models: For the application of Trip Generation model in EMME/2, we tested two separate approaches for deriving the number of 1998 cross-classified SF and MF households by TAZs. One approach is discussed above, using the household multi-nomial logit choice models; and another is using the 1998/1999 HTS-based household cross-classification ratios directly, as shown in Tables 6-10 in Appendix C.

We took advantage of EMME/2's matrix convolution process in implementing trip production models by these two approaches. Again, the key to our success was data integration and formatting so that the individual trip production rates multiply the corresponding number of households by TAZ by trip purposes. The proposed household cross-classification schemes and rates are shown in Tables 11-17 in Appendix D. The specific steps are explained below:

- We used one full matrix (mf"tgrate") to store the trip production rates and household cross-classification ratios in a unique format:

  - Table 4 uses 1-49 origin cells to store the trip production rates corresponding sequentially to Home-Based Work, Home-Based Other, Home-Based Shopping, Home-Based School, Home-Based College, Work-Other and Other-Other household cross-classification schemes, as shown in Table 11-17; and
  - 201-424 origin cells store the household cross-classification ratios corresponding sequentially to Table 6-10.

- The 1998 SF and MF household numbers are stored in mo vector matrices.

- EMME/2 macro, sfmfhlds.mac as shown in Appendix B, is designed using matrix convolution process to multiply the household cross-classification ratios with 1998 SF households by TAZs to derive the number of cross-classified SF households by TAZs.

- Sequentially, we used a macro to combine and relocate the 1998 SF cross-classified household numbers by TAZ to 1-49 destination cells in mf"98hemp".

- Again EMME/2 macro, generate.mac as shown in Appendix B, is designed to run trip production model in matrix convolution process (refer to Larry Blain's paper of 1995 in Appendix E).

As for the second approach, after we apply the household models, we use a macro to line up the 1998 SF cross-classified household numbers by TAZs in mf"98hemp" in 1-49 destination cells and 1998 MF in 51-99 destination cells. By doing this, we are able to use generate.mac to run trip production model in matrix convolution process.

The results of these two separate trip production modeling approaches are distinctively compared in Table 5 with respect to the 1998/1999 HTS statistics. From this table, we can see that the differences between percentage distributions by purpose are very negligible.

In conclusion, our experience suggests that understanding local travel statistical data is required prior to using it for model estimation. Through our well-planned and strategic modeling approaches, we have gained good understanding of data limitations and trade-offs between sufficiency and complexity with state-of-the-art multi-modal travel model development in a medium-sized community. With effective integration of software tools for data preparation and analysis, we have also gained great confidence in estimating and applying the multinomial Logit choice models and Trip Production Models by one-way or two-way household cross-classifications. Our modeling approaches have worked great for us in a cost-effective manner. We recommend small- or medium-sized metropolitan areas, with limited funding and human resources, take these approaches for their state-of-the-art multimodal travel demand model development.

Table 4: Thurston Region Daily Trip Production Rates of All Modes and Household Cross-Classification Ratios Statistically Derived From 1998/1999 Household Travel Survey

Mf02 =mf"tgrate"		Trip/HH
TAZ	TAZ	Rates
1	1	0.02
2	1	1.25
3	1	2.38
4	1	3.6
5	2	0.85
6	2	0.88
7	2	1.28
8	2	0.67
9	2	1.89
10	2	2.2
11	2	1.89
12	2	2.05
13	2	2.98
14	2	3.03
15	2	3.28
16	2	3.07
17	2	3.48
18	2	3.5
19	2	5.73
20	2	4.77
21	3	0.43
22	3	0.44
23	3	1.21
24	3	0.81
25	3	0.7
26	3	1.44
27	3	0.92
28	3	1.14
29	3	1.39
30	3	1.52
31	3	1.43
32	3	1.03
33	3	1.38
34	4	0
35	4	1.68
36	4	2.82
37	4	3.63
38	5	0.06
39	5	0.04
40	5	0.14
41	5	0.16
42	6	0.00
43	6	0.82
44	6	1.7
45	6	2.01
46	7	0.74
47	7	1.72
48	7	2.22
49	7	3.22
201	201	0.008077
202	202	0.024735
203	203	0.005553
204	204	0.025745
205	205	0.004543
206	206	0.027764
207	207	0.009591
208	208	0.019182
209	209	0
210	210	0.030793
211	211	0.008077
212	212	0.008582
213	213	0.001514
214	214	0.019182
215	215	0.007572
216	216	0.007572
217	217	0.009086
218	218	0.015144
219	219	0.001514
220	220	0.010096
221	221	0.005048
222	222	0.02423
223	223	0.010601
224	224	0.027764
225	225	0.002524
226	226	0.039879
227	227	0.021201
228	228	0.022716
229	229	0.003534
230	230	0.116103
231	231	0.055528
232	232	0.017163
233	233	0.005048
234	234	0.009591
235	235	0.00101
236	236	0.000505
237	237	0.007572
238	238	0.021201
239	239	0.001514
240	240	0.003534
241	241	0.003029
242	242	0.030793
243	243	0.003029
244	244	0.001514
245	245	0.002019
246	246	0.076729
247	247	0.010096
248	248	0.001514
249	249	0.00101
250	250	0.014134
253	253	0.004543
254	254	0.026754
255	255	0.00101
257	257	0.005553
258	258	0.053004
259	259	0.001514
260	260	0.000505
261	261	0.002524
262	262	0.115598
263	263	0.004038
264	264	0.000505
265	265	0.040642
266	266	0.024586
267	267	0.012042
268	268	0.01154
269	269	0.014049
270	270	0.031109
271	271	0.023583
272	272	0.023081
273	273	0.000502
274	274	0.002509
275	275	0.003011
276	276	0.001505
277	277	0.002007
278	278	0.001004
279	279	0.000502
281	281	0.023081
374	374	0.036879
375	375	0.070213
376	376	0.024823
377	377	0

282	282	0.036628
283	283	0.035123
284	284	0.024084
285	285	0.015554
286	286	0.017561
287	287	0.030105
288	288	0.047165
289	289	0.010035
290	290	0.012544
291	291	0.011039
292	292	0.013046
293	293	0.007526
294	294	0.016056
295	295	0.020572
296	296	0.026593
297	297	0.006021
298	298	0.019067
299	299	0.032112
300	300	0.121927
301	301	0.004516
302	302	0.015554
303	303	0.019568
304	304	0.057702
305	305	0.005018
306	306	0.01154
307	307	0.028098
308	308	0.073256
309	309	0.001004
310	310	0.003011
311	311	0.005018
312	312	0.018565
313	313	0.001004
314	314	0.003512
315	315	0.011039
316	316	0.024084
317	317	0.002542
318	318	0.016525
319	319	0.013559
320	320	0.061017
321	321	0.002119
322	322	0.008051
323	323	0.026695
324	324	0.071186
325	325	0.000424
326	326	0.004237
327	327	0.001695

328	328	0.002542
329	329	0.000424
330	330	0.002966
331	331	0
332	332	0
333	333	0.009322
334	334	0.077966
335	335	0.017373
336	336	0.00678
337	337	0.003814
338	338	0.05678
339	339	0.037712
340	340	0.013136
341	341	0.004661
342	342	0.032627
343	343	0.003814
344	344	0.004661
345	345	0.002966
346	346	0.060593
347	347	0.001695
348	348	0.000424
349	349	0.013559
350	350	0.127966
351	351	0.033475
352	352	0.00339
353	353	0.008475
354	354	0.076695
355	355	0.00678
356	356	0.000847
357	357	0.005508
358	358	0.105932
359	359	0.002542
360	360	0.000847
361	361	0.00339
362	362	0.019915
363	363	0.003814
364	364	0
365	365	0.005508
366	366	0.031356
367	367	0.001695
368	368	0
369	369	0.030496
370	370	0.090071
371	371	0.016312
372	372	0.003546
373	373	0.002837

378	378	0.003546
379	379	0.003546
380	380	0.000709
381	381	0
382	382	0.001418
383	383	0.000709
384	384	0
385	385	0.014184
386	386	0.100709
387	387	0.023404
388	388	0.005674
389	389	0.002837
390	390	0.037589
391	391	0.053901
392	392	0.025532
393	393	0
394	394	0.017021
395	395	0.016312
396	396	0.010638
397	397	0.001418
398	398	0.012766
399	399	0.041135
400	400	0.019149
401	401	0.000709
402	402	0.01773
403	403	0.048936
404	404	0.001418
405	405	0.001418
406	406	0.00922
407	407	0.053191
408	408	0.034752
410	410	0.002837
411	411	0.07234
412	412	0.040426
413	413	0
414	414	0.000709
415	415	0.003546
416	416	0.015603
417	417	0
418	418	0
419	419	0.005674
420	420	0.024113
421	421	0.667
422	422	0.229
423	423	0.089
424	424	0.015

Table 5: 1998 Daily Trip Generation of All Modes in Two Approaches

TRIP PURPOSES	APPROACH I TRIPS	APPROACH I % TRIPS	APPROACH II TRIPS	APPROACH II % TRIPS	98 EXPANDED SURVEY %
HBW	129,783	18.1%	127,638	17.8%	18.0%
HBO	208,463	29.1%	219,252	30.6%	29.6%
HBShop	71,681	10.0%	72,209	10.1%	10.2%
HBSch	55,362	7.7%	48,788	6.8%	7.4%
HBCol	7,197	1.0%	7,197	1.0%	1.1%
W-O	87,428	12.2%	85,470	11.9%	12.1%
O-O	156,510	21.9%	156,510	21.8%	21.6%
98 Daily Total	716,424	100.0%	717,064	100.0%	100.0%
Average Person Trips/HH	8.93		8.94		8.86

APPENDIX A:

Technical Advisory Members for 1998/1999 Household Survey

- Richard Walker, Travel Forecasting Manager, Portland Metro
- Kyung-Hwa Kim, Transportation Planning Supervisor, Modeler, Portland Metro
- Joel Freeman, Modeler at PBQD Inc., sub-consultant of Household Travel Survey
- Mike Gillett, Travel Survey Manager, Oregon Department of Transportation
- Neil Kilgren, Associate Planner, Puget Sound Regional Council, WA
- Bud Reiff, Modeler at Lane Council of Government, Oregon
- Shuming Yan, Planning Engineer at Washington State DOT, Olympia Region

Technical Advisory Members for 1998 TRPC EMME/2 Model Conversion

- Richard Walker, Travel Forecasting Manager, Portland Metro
- Kyung-Hwa Kim, Transportation Planning Supervisor, Modeler, Portland Metro
- Joel Freeman, Modeler at PBQD Inc., sub-consultant of Household Travel Survey
- He-chuan Chen, Principal Travel Demand Modeler, King County, Washington
- Bud Reiff, Modeler at Lane Council of Government, Oregon
- Shuming Yan, Planning Engineer at Washington State DOT, Olympia Region
- Mushtaqur Rahman, Principal Planner/Modeler at City of Bellevue, Washington
- Faris Almemar, Planning Method Manager at Washington State DOT

APPENDIX B: EMME/2 MACROS

- Walkasgn.mac (assign walk trip for walk time and distance)
- Mdempden.mac (employment within 0.5 mile of walking distance)
- Trpcdisa.mac (Assign/Analyze individual trips of all modes)
- Cwhi-sf.mac (98 SF household auto-ownership)
- Sfmfhlds.mac (98 household cross-classifications)
- Generate.mac (98 trip productions by purposes)

```
~$>start
  Macro File Name: walkasgn.mac
  This macro assigns walk trip for walk travel time and distance skims:
  mf"walktm" and mf"walkds"
  Created by TRPC Staff in Aug. 1999
~/*************************************************************************
 ~:start
 ~?!i&32768
 ~o|295
 reports=walkasgn.rpt
 ~/
 ~/ Delete scenario 1001 if already existing
 1.22
 ~+|2|1001|~?q=1|y
 ~/
 ~/ Copy AM regional network for walk time assignment
 ~+|3|1000|1001|1998 Thurston Regional Walk Time Assignment Network|y|q
 ~/
 ~/ Prepare walk assignment using transit multi-path assignment strategy
 5.11           /Use transit assignment to obtain walk time
 ~+|2|~?q=2|2|mf91|mf"walktm"|n|||||||p|1|1|0.00|1|1.00|0.00|1.00
 ~+|0.00|n
 ~/
 ~/ Run walk assignment for walk skims
 5.31
 2
 ~/
 ~/ Compute walk distance in miles assuming 3 mph walking speed.
 3.21
 ~+|1|y|mf"walkds"|n|mf"walktm"/20|||y|1,800||1,800||2|q
 ~/
 ~/ Preparation for Walk Skims completed!
 reports=
```

```
~$>start
   Macro File Name: mdempden.mac
   This macro calculates the employment "density" within 0.5 miles of
   walking distance to the attraction zones and production zones.
   Created by TRPC staff on May 1999.
 ~/**********************************************************************
 ~:start
 ~?!i&32768
 ~o|295
 reports=mdempden.rpt
 ~/
 ~/ Initialize mf91 to default zero
 3.21
 ~+|1|y|mf91|n|0|||y|1,800||1,800||2
 q
 ~/
 ~/ Sum up the intrazonal walking distance in miles = 0.5*min(mf"walkds")
 3.21
 ~+|1|y|md"izwkds"|n|mf"walkds"*(p.eq.q)|||y|1,800||1,800||+|2
 q
 ~/
 ~/ Calculate employment "density" excluding intrazonal "density"
 3.21
 ~+|1|y|mf91|n
  (p.ne.q)*(0.max.(0.5-mf"walkds"+md"izwkds").min.(2*md"izwkds"))/
  (2*md"izwkds")*(md"attrwk"+md"attcol")
 ~+||mf"walkds"|0,1.0001,in|y|1,800||1,800||2
 q
 ~/
 ~/ Calculate employment "density" including intrazonal "density"
 3.21
 ~+|1|y|mf91|n
 mf91+(p==q)*(0.25/(md"izwkds"*md"izwkds").min.1.0)*(md"attrwk"+md"attcol")
 ~+|||y|1,800||1,800||2
 q
 ~/ Calculate employment "density" within 0.5 miles to Attraction TAZ
 3.21
 ~+|1|y|md"empden"|n|mf91|||y|1,800||1,800||+|2
 q
 ~/
 ~/ Calculate employment "density" within 0.5 miles to Production TAZ
 3.12
 ~+|4|3|md"empden"|mo"proemp"|n
 q
 ~/
 ~/ Employment Density Calculation Completed Normally.
reports=
```

```
~/*********************************************************************
~/*******       Disa module macro: TRPCDISA.MAC                  *******
~/*******       This macro will run modules 5.34 and 5.35        *******
~/*******       to obtain impedance values for individual        *******
~/*******       trips.  To use it, you must have an csv input    *******
~/*******       file with the xy coordinates of the trip origin *******
~/*******       and destination.  You will be prompted for its   *******
~/*******       name, and the names of all output files.         *******
~/*******       Latest revision:6/26/96                          *******
~/*******       Joel Freedman, Mid-Willamette Valley COG         *******
~/*******       Modified by Jin Ren at TRPC 8/99.                *******
~/*********************************************************************
~t1=~*Enter path\name of input file:
~t2=~*Enter path\name of report file for Module 5.34:
~t3=~*Enter path\name of output file for Module 5.34:
~t4=~*Enter path\name of report file for Module 5.35:
~t5=~*Enter path\name of output file for Module 5.35:
~t6=~*Auto or transit Assignment? (a or t):
reports=?
batchin=?
batchout=?
5.34                                    /enter 534
1                                       /enter trip data using batch entry
.5                                      /Maximum Distance
3                                       /Maximum number of nodes
~!e:\1998trpc\disa\trpcnode.mac         /Excluding Centroids/Freeway nodes
3                                       /Select Report and Punch
1                                       /Full Report
%t3%
%t1%
2                                       /Printer
%t2%
q                                       /Quit 534
5.35                                    /Enter 535
1                                       /Enter trip data using batch entry
10                                      /Volume
~?t6=a
20                                      /if auto assign, use 20 mph
~?t6=t
3                                       /otherwise, use 3 mph
1                                       /Dispersion parameter
.05                                     /Min access probability
~?t6=a
c
~?t6=t
bp
1                                       /Actual line headways
1                                       /same value for entire network
.5                                      /Boarding time minutes
1                                       /Same wait time factor
.25                                     /Wait time factor
1                                       /Wait time weight
1                                       /Aux transit time weight
1                                       /Boarding time weight
3                                       /Report and punch
1                                       /Full report
%t5%
%t3%
n
access egress imped inveh

2                                       /Send output to printer
%t4%
5                                       /End
```

```
~o|256       /Clear Screen
~/*************************************************************************
~/* TRPC Auto Ownership Model for SF Households                           *
~/* Usage:  ~< cwhi-sf.mac                                                *
~/* Modified by Jin Ren, TRPC, WA, Sept. 1999 from cwhi.mac               *
~/* Steve Perone, Metro PDX Or, 1995                                      *
~/*************************************************************************
~?!m=000     / Test for proper starting place
~+:~/ Error - Macro must be started from the main menu:~$>end
~?!i&32768   / If switch 15 (dialog echo mode) is off
~o=39        / Set Screen echo and pause off
~t6=2
c=calling macro: cwhi-sf.mac
~/ Calculate worker/size/income Cross-classifcations for SF Households
~<mf-sfwhi.mac
~p=2004      / Check operating system
~?p=1        / Unix System
~!rm cwhi-sf.rpt
~?p=2        / DOS System
~!delete cwhi-sf.rpt
/ Delete the old report file anyway.
~!del cwhi-sf.rpt
reports=cwhi-sf.rpt
/
/ Initialize cwhi working matrices
~+:3.21:1:y:mf91:y:c0whi:0 car whi matrix:~?q=1:y:0::q
~+:3.21:1:y:mf92:y:c1whi:1 car whi matrix:~?q=1:y:0::q
~+:3.21:1:y:mf93:y:c2whi:2 car whi matrix:~?q=1:y:0::q
~+:3.21:1:y:mf94:y:c3whi:3 car whi matrix:~?q=1:y:0::q
/ *************************************************************************
~x=1         / Initalize HHSIZE variable
~y=0         / Initalize Worker # variable
~r4=1        / Income Counter
~z=0         / Initalize whi position counter
/             Define Income Coefficents in t0 used as %1% %2% %3%
/
3.21         / Matrix Calculations
~o|256       / Clear Screen
~/ ************************************************************************
~/ ********* Calculating Utility Portion C[0-3+]W[0-3+]H[1-4]I[1-4] ***********
~/ ************************************************************************
~/
~:util_loop
~/
~/ Income Coefficients r1=c0, r2=c1, r3=c2
~?r4=1         / income 1
~+|~r1=1.964|~r2=1.705|~r3=.5924
~?r4=2         / income 2
~+|~r1=-.5912|~r2=.5648|~r3=.1246
~?r4=3         / income 3
~+|~r1=-1.297|~r2=0.00|~r3=.1133
~?r4=4         / income 4
~+|~r1=-2.567|~r2=-.9142|~r3=-.2062
~+:1:y:mo95:y:utc0:0 Car util for %y% worker whi's:~?q=1:y:
~+:exp(3.578 -1.273*%x% -1.752*%y% +%r1% +.002038*mo"mixuse" +.02689*mo"locint"
+.0003972*mo"totden" -2.760)
~+:::n:%t6%
~/
~+:1:y:mo96:y:utc1:1 Car util for %y% worker whi's:~?q=1:y:
~+:exp(3.544 -.9061*%x% -1.083*%y% +%r2% +.001402*mo"mixuse" +.03514*mo"locint"
+.0002236*mo"totden" -1.336)
~+:::n:%t6%
~/
~+:1:y:mo97:y:utc2:2 Car util for %y% worker whi's:~?q=1:y:
~+:exp(1.739 -.1556*%x% -.5502*%y% +%r3% +.000*mo"mixuse" +.02256*mo"locint"
+.0003135*mo"totden" -.5256)
~+:::n:%t6%
~/
~+:1:y:mo98:y:utc3:3 Car util for %y% worker whi's:y:
~+:1  :::n:%t6%
~/
~+:1:y:mo99:y:utsum:cwhi utility Sum for 0 worker whi's:~?q=1:y:
~+:mo95 + mo96 + mo97 + mo98  :::n:%t6%
~+:~%:~%:~%             /Shift income parameters for next loop
~o|256        /Clear Screen
~/ ************************************************************************
~/ ********* Probability and Car Ownership Estimate **************************
~/ ************************************************************************
~/ Evaluating c[0-3] for W%y%H%x%I%r4%
~+:~z+1:~t1=%%%z%%%
~+:1:y:mf"c0whi":n:mo"utc0"/mo"utsum" * mf"whi":::y:all:%t1%::%t6%
```

```
~+:1:y:mf"c1whi":n:mo"utc1"/mo"utsum" * mf"whi":::y:all:%t1%::%t6%
~+:1:y:mf"c2whi":n:mo"utc2"/mo"utsum" * mf"whi":::y:all:%t1%::%t6%
~+:1:y:mf"c3whi":n:mo"utc3"/mo"utsum" * mf"whi":::y:all:%t1%::%t6%
~/ ********* whi MATRIX POSITION = %z% of 52 ********************************
~/
~r4+1          /Increment HH-Income [1-4] and Reset Income Parameters r1,r2,r3
~?!r4=5        /Repeat loop util whi combinations are exhausted [w0h1i1...w3h4i4]
~$util_loop
~+:~x+1:~r4=1      /Increment HH-Size [1-4]
~?!x=5             /Repeat loop util hi combination are exhausted [h1i1...h4i4]
~$util_loop
~?z=16             /Set 1 Worker whi Parameters Use Household Group [1-4]
~+:~y=1:~x=1:~r4=1
~?z=32             /Set 2 Worker whi Parameters Use Household Group [2-4]
~+:~y=2:~x=2:~r4=1
~?z=44             /Set 3 Worker whi Parameters Use Household Group [3-4]
~+:~y=3:~x=3:~r4=1
~?z<52
~$util_loop
~o|256       /Clear Screen
~/ ******************************************************************************
~/ *************** Summary Statistics ******************************************
~/ ******************************************************************************
~/ Total Cars by group[c0-c3]
~+:1:y:ms90:y:c0:Total 0-Car whi:~?q=1:y::mf"c0whi":::n:+:+:2
~+:1:y:ms91:y:c1:Total 1-Car whi:~?q=1:y::mf"c1whi":::n:+:+:2
~+:1:y:ms92:y:c2:Total 2-Car whi:~?q=1:y::mf"c2whi":::n:+:+:2
~+:1:y:ms93:y:c3:Total 3+Car whi:~?q=1:y::mf"c3whi":::n:+:+:2
~+:1:y:ms94:y:csum:Sum of Car Ownership:~?q=1:y::ms"c0"+ms"c1"+ms"c2"+ms"c3":::2
q  /Exit to Main Menu
~/ Calculate SF Person/Car Cross-Classifications for SF households
~<mfsf1p0c.mac
~/
~/ 1998 Thurston Household Auto-Ownership Model for SF Household Completed Normally.
```

```
/SFMFHLDS.MAC -
/1998/1999 SF and MF Households Cross-Classificatio by HIA, WHI, WHA, WHV and Kids
/By Jin Ren, TRPC, August 1999.
reports=sfmfhlds.rpt
~/
3.23
~/ SF Households cross-classifications
~+|1|mo"98sfhh"|*|mf"tgrate"|n||+|mf"98hemp"|n|y|*|201,424||201,424|||y|2|q
~/
3.23
~/ MF Households Cross-classifications
~+|1|mo"98mfhh"|*|mf"tgrate"|n||+|mf"98hemp"|n|y|*|501,724||501,724|||y|2|q
reports=
```

```
~$>start
   Macro File Name: generate.mac
   This macro runs trip generation matrix convolution process to produce trip
   production for each zone by purpose.
     Input:  mf"98hemp" mf"tgrate"
     Output: mf"tgvect"
   Created by TRPC staff in Nov. 1998
 ******************************************************************************
 ~:start
 ~?!i&32768
 ~o|295
 ~z=%o%
 ~o=39
 ~/ generate.mac
 ~/
 ~/ This macro multiplies the household and employment data in
 ~/ hhemp by the coefficients in rates.  The resulting productions
 ~/ and attractions are columns in tgvect.
 ~/ Created by TRPC staff, Aug. 1999.
 ~/
 reports=?
 3.23
 ~+|1|mf"98hemp"||mf"tgrate"|n|||mf"tgvect"|n
 ~+|y|*|1,100||1,7|||y|2|generate.rpt
 q
 ~o=%z%
 ~/ Trip Generation Calculation Completed Normally.
```

Appendix C: Household Cross-Classification Ratios derived from the total household survey samples broken up by the following household characteristics as shown in Table 6-10:

Table 6 (HIA): Household Size (1, 2, 3, 4+), Household Income (<$20K, 20K-35K, 35K-50, >$50K), and Age Group of Head of Households (15-24, 25-55, 56-65, >66)

Hhsize	Income	Age 1	Age 2	Age 3	Age 4
1	1	0.008077	0.024735	0.005553	0.025745
1	2	0.004543	0.027764	0.009591	0.019182
1	3	0	0.030793	0.008077	0.008582
1	4	0.001514	0.019182	0.007572	0.007572
2	1	0.009086	0.015144	0.001514	0.010096
2	2	0.005048	0.02423	0.010601	0.027764
2	3	0.002524	0.039879	0.021201	0.022716
2	4	0.003534	0.116103	0.055528	0.017163
3	1	0.005048	0.009591	0.00101	0.000505
3	2	0.007572	0.021201	0.001514	0.003534
3	3	0.003029	0.030793	0.003029	0.001514
3	4	0.002019	0.076729	0.010096	0.001514
4	1	0.00101	0.014134	0	0
4	2	0.004543	0.026754	0.00101	0
4	3	0.005553	0.053004	0.001514	0.000505
4	4	0.002524	0.115598	0.004038	0.000505

Table 7 (WHI): Household Workers (0,1, 2, 3+), Household Size (1, 2, 3, 4+), and Household Income Groups (<$20K, 20K-35K, 35K-50, >$50K)

Workers	Hhsize	Income 1	Income 2	Income 3	Income 4
0	1	0.040642	0.024586	0.012042	0.01154
0	2	0.014049	0.031109	0.023583	0.023081
0	3	0.000502	0.002509	0.003011	0.001505
0	4	0.002007	0.001004	0.000502	0
1	1	0.023081	0.036628	0.035123	0.024084
1	2	0.015554	0.017561	0.030105	0.047165
1	3	0.010035	0.012544	0.011039	0.013046
1	4	0.007526	0.016056	0.020572	0.026593
2	2	0.006021	0.019067	0.032112	0.121927
2	3	0.004516	0.015554	0.019568	0.057702
2	4	0.005018	0.01154	0.028098	0.073256
3	3	0.001004	0.003011	0.005018	0.018565
3	4	0.001004	0.003512	0.011039	0.024084

Table 8 (WHA): Household Workers (0, 1, 2, 3+), Household Size (1, 2, 3, 4+), and Age Group of Head of Households (15-24, 25-55, 56-65, >66)

Workers	Hhsize	Age 1	Age 2	Age 3	Age 4
0	1	0.002542	0.016525	0.013559	0.061017
0	2	0.002119	0.008051	0.026695	0.071186
0	3	0.000424	0.004237	0.001695	0.002542
0	4	0.000424	0.002966	0	0
1	1	0.009322	0.077966	0.017373	0.00678
1	2	0.003814	0.05678	0.037712	0.013136
1	3	0.004661	0.032627	0.003814	0.004661
1	4	0.002966	0.060593	0.001695	0.000424
2	2	0.013559	0.127966	0.033475	0.00339
2	3	0.008475	0.076695	0.00678	0.000847
2	4	0.005508	0.105932	0.002542	0.000847
3	3	0.00339	0.019915	0.003814	0
3	4	0.005508	0.031356	0.001695	0

Table 9 (WHV): Household Workers (0, 1, 2, 3+), Household Size (1, 2, 3, 4+), and Household Vehicles Owned (0, 1, 2, 3+)

Workers	Hhsize	Veh 0	Veh 1	Veh 2	Veh 3+
0	1	0.030496	0.090071	0.016312	0.003546
0	2	0.002837	0.036879	0.070213	0.024823
0	3	0.000000	0.003546	0.003546	0.000709
0	4	0.000000	0.001418	0.000709	0.000000
1	1	0.014184	0.100709	0.023404	0.005674
1	2	0.002837	0.037589	0.053901	0.025532
1	3	0.000000	0.017021	0.016312	0.010638
1	4	0.001418	0.012766	0.041135	0.019149
2	2	0.000709	0.017730	0.048936	0.001418
2	3	0.001418	0.009220	0.053191	0.034752
2	4	0.000000	0.002837	0.072340	0.040426
3	3	0.000000	0.000709	0.003546	0.015603
3	4	0.000000	0.000000	0.005674	0.024113

Table 10 (KID):Household K-12 School Student (0, 1, 2, 3+)

Student	Ratios
0	0.667
1	0.229
2	0.089
3+	0.015

Appendix D: Proposed Trip Rates for Production Models

Note: All trip rates shown are for one-day person trip productions based on Day 1 results from the household travel survey.

Home-Based Work productions

Table 11: HBW rates

Workers	HBW trip production rate
0	0.02
1	1.25
2	2.38
3+	3.60

Home-Based Shop productions

Table 12: HBshop rates

	Workers in HH			
Persons in HH	0	1	2	3+
1	0.43	0.44		
2	1.21	0.81	0.70	
3	1.44*	0.92	1.14	1.39
4+	1.52*	1.43	1.03	1.38

Home-Based School productions

Table 13: HBSchool rates

Students in HH	HBSchool trips
0	0.00
1	1.68
2	2.82
3+	3.63

Home-Based College productions

Table 14: HBCollege rates

Persons Aged 18-24	HBCollege trips
0	0.02
1	0.54
2	0.65
3+	2.33

Home-Based Other productions

Table 15: HBOther rates

	Vehicles			
Persons in HH	0	1	2	3+
1	0.85	0.88	1.28	0.67
2	1.89*	2.20	1.89	2.05
3	2.98*	3.03	3.28	3.07
4+	3.48*	3.50	5.73	4.77

Other-Other productions

Table 16: Other-Other rates

Persons in HH	Other-Other trips
1	0.74
2	1.72
3	2.22
4+	3.22

Work-Other productions

Table 17: Work-Other rates

workers	Work-Other trips
0	0.00
1	0.82
2	1.70
3+	2.01

* Since these classification cells represent a small number of households in the sample the trip rate values were “smoothed” using a modified multiple classification analysis (MCA) procedure.

Appendix E: Selected Readings or References

Anas, A. "Discrete Choice Theory, Information Theory, and the Multinomial Logit and Gravity Models." Transportation Research B, 17 (1983), pp. 13-23.

Ben Akiva, M., Lerman, S.R., "Discrete Choice Analysis: Theory and Application to Travel Demand," MIT Press, Cambridge, MA, 1985.

Blain, L., Puget Sound Regional Council, "Cross-Classification and Linear Regression Using Matrix Convolution," presented at the 10th Annual EMME/2 Users Conference, November 1995.

Cambridge Systematics, Inc., "Travel Survey Manual," prepared for U.S. Department of Transportation, June 1996.

Cambridge Systematics, Inc., "Data Collection in the Portland, Oregon Metropolitan Area," prepared for U.S. Department of Transportation, April 1996.

Daly, A., "Estimating Choice Models Containing Attraction Variables," Transportation Research B, Vol. 16B, No. 1, pp. 5-15, Pergamon Press Ltd., 1982.

Daly A., "Estimating 'Tree' Logit Models," Transportation Research B, Vol. 21B, No. 4, pp. 251-267, Pergamon Journals Ltd., 1987.

DKS Associates, "Travel Model Development and Refinement – Trip Generation," prepared for the Puget Sound Regional Council, 1994.

DKS Associates, "Travel Model Development and Refinement – Phase Two: Trip Distribution and Mode Choice," prepared for the Puget Sound Regional Council, 1994.

Freedman, J., Davidson, W., Schlappi, M. and Hunt, JD, "Comparing Stratified Cross-Classification and Logit-Based Trip Attraction Models," presented at the 7th National Conference on Transportation Planning Practice held in Boston MA, March 1999.

Forinash, C. and F. Koppelman, "Application and Interpretation of Nested Logit Models of Intercity Mode Choice." Transportation Research Record 1413, Transportation Research Board, National Research Council (1993), pp. 98-106.

Pearson, D. F., "Urban Travel in Texas: An Overview of Travel Surveys," Research Report 1099-1 prepared for Texas Department of Transportation, April 1993.

Pearson, D. F. and G. B. Dresser, "Evaluation of Urban Travel Survey Methodologies," Research report 1235-10, prepared for Texas Department of Transportation, October 1994.

Portland Metro, "Technical Specifications for the march 1998 Travel Demand Model," March 1998.

Portland Metro, "The Application of Conical Delay Functions: The Portland Approach," February 1990.

PBQD, Inc. and RST International, "Washington State Ferries Travel Forecasting Methodology Report," prepared for Washington State Ferries, May 1996.

PBQD, Inc. and Kittelson Associates, Inc, "Travel Demand Model Development and Application Guidelines," prepared for Oregon Department of Transportation, Planning Section, Transportation Planning Analysis Unit, June 1995.

Puget Sound Council of Governments, "Household Travel Surveys, 1985-1988 Puget Sound Region," June 1990.

Sobel, K.L. "Travel Demand Forecasting by Using the Nested Multinomial Logit Model," Transportation Research Record 775, Transportation Research Board, National Research Council (1980), pp. 48-55.

Southworth, F. "Calibration of Multinomial Logit Models of Mode and Destination Choice," Transportation Research B, 15 (1981), pp. 315-325.

Zimowski, M., Tourangeau, R., Ghadialy, R. and Pedlow, S., "Nonresponse in Household Travel Surveys," prepared for Federal Highway Administration, October 1997.