Baltimore Region Model Application Auto Availability Estimation
Using 2001 National Household Travel Survey

Introduction

Approximately every 5 years, the United States Department of Transportation (USDOT) conducts a national household survey that is used to measure demographic and household travel characteristics to evaluate national policies and assist researchers in understanding emerging travel trends. The USDOT allows states, local jurisdictions and Metropolitan Planning Organizations (MPOs) to purchase additional local samples. The additional local samples can be used by local planning agencies in evaluating and understanding community transportation issues and increase the national sample.

The Baltimore Regional Transportation Board (BRTB), the designated MPO for the Baltimore metropolitan area, agreed to participate in the 2001 National Household Travel Survey (NHTS) as an add-on. The BRTB felt the survey was a unique opportunity to collect household travel observations that could assist in developing travel models used in policy analysis and development of long range transportation plans.

Baltimore NHTS Dataset

The BRTB contracted with the USDOT selected add-on consultant and designated the Baltimore Metropolitan Council (BMC), staff to the MPO, to manage the project and evaluate the observed data. Approximately 3,500 households participated in the one day travel survey (3,121 weekday and 325 weekend) reporting household and household member demographic characteristics and the household travel activity such as mode, purpose, destination, and time of day. The observed dataset records were evaluated and verified. A trip linking process was developed linking reported trips of serve passenger, change means of travel, and stop for gas.

The observed weekday records have been used to estimate total person and vehicle trip rates, trips by purpose, and household, vehicle and person miles of travel. The average household in the Baltimore region generates 8.45 person trips with 7.59 being motorized. Household person travel is comprised of 19% work, 58% non-work, and 23% non-home-based. To accomplish these weekday activities, the average household generates 63.3 miles of travel. Travel per capital was estimated at 25.4 miles with a person trip length of 7.5 miles on average.

Numerous household and household member demographic characteristics along with household location influence travel choices. The availability of a household motorized vehicle is one such variable. Developing models to estimate vehicle availability is the topic for the remainder of the paper.

Household Motorized Vehicle

The existing Baltimore travel model, used in such analysis as air quality conformity and plan development, was estimated considering household vehicle availability. The existing cross class trip generation model and nested logit mode share model both consider household vehicle availability influence on household travel choices.

An analysis of the NHTS data set considering the effects of household vehicle availability indicates the need to estimate and forecast household vehicle choice. Average household person trips stratified by vehicle availability are estimated at:

- 5.05 for zero vehicle households
- 6.05 for one vehicle households
- 10.66 for two vehicle households
- 11.65 for three or more vehicle households

The number of household licensed drivers and household size affect the above rates. Average household person trip rates considering vehicle availability and licensed drivers were estimated as follows:

- 4.99 for vehicles or drivers equal zero
- 8.62 for vehicles equal drivers
- 10.20 for vehicles greater than drivers
- 10.13 for vehicles less than drivers

It is clear that understanding the household vehicle availability and relationships between licensed drivers and vehicle availability would be important for consideration in forecasting travel demand. At first glance looking at regional household vehicle characteristics, one might conclude that household vehicle availability has reached saturation and there would be no need for a sophisticated approach in estimating household vehicles. The Baltimore region household vehicle average has increased from 1.57 in 1990 to 1.59 in 2000, based on Census estimates. In the Baltimore region, 75% of households have at least one vehicle for every licensed driver. The remaining quarter of households have either no vehicle or fewer vehicles than licensed drivers. These households would be more transit captive or have located in environments that allow for travel alternatives other than the vehicle. A need for a vehicle model to understand the location of this quarter of the households is needed in such analysis as Environmental Justices, modifying land use patterns to allow for different transportation choices, and accurate transit forecasts.

The 2000 Census estimates 14% (139,600) of the households in the Baltimore region have no vehicle available, down from 1990 levels of 141,400. In 2000 Baltimore City households comprised 66% of region's zero vehicle households. Comparing 1990 levels to 2000, Baltimore City was the only jurisdiction that reported fewer zero vehicle households (11,500), while suburban jurisdictions increased the number of zero vehicle households. The suburban jurisdiction of Baltimore (4,400) and Anne Arundel (1,900) counties, which boarder Baltimore City, had the greatest absolute increase in zero vehicle households. There were most likely incidents of City residents purchasing a vehicle and suburban residents eliminating a vehicle, maybe due to age or disability, but there was migration between the City and surrounding suburban jurisdictions. A vehicle availability model that would be sensitive to variables that allow for these changes is desirable.

Vehicle Availability Model

There are numerous reasons to conduct household travel surveys in order to understand the travel choices of a household thus justifying the expense of a travel survey. A justification for the need of household survey data is an analysis of vehicle availability models using 2000 Census data compared to household survey data. Models constructed with household survey data with a known location, allow for inclusion of other variables that influence vehicle choice.

Public Use Microdata Sample (PUMS)

PUMS is a standard Census product containing the household/person responses from the Census long form. The 5 percent sample for the Baltimore region contains 50,621 individual household records contained in 22 Public Use Microdata Areas (PUMAs). The Census Bureau maintains confidentiality using the PUMAs with a definition of containing at least 100,000 persons. Advantages of a large disaggregate sample size are offset with limits on the ability to apply other location reference datasets. As an example, households in Carroll County (suburban rural county northwest of downtown Baltimore) is contained within one entire PUMA, since the county has a total population of 151,700. If we believed land use or accessibility variables might help explain household vehicle choice, we would have to apply the variable to every record. The variable might not be uniform for each household within the county.

Using the disaggregate PUMS 2000 data set for the Baltimore region, logit models were estimated for the choice of zero, one, two, and three plus vehicles. A model for each household size (1, 2, 3, 4+) using household income and household labor force (household size of 4+ included an additional variable of non-workers) was estimated in order to reduce some aggregation error. Household income was stratified into four groups:

1) Household income less than $10,000
2) Household income between $10,000-$30,000
3) Household income between $30,000-$40,000
4) Household income greater than $40,000

Table 1 contains the results of model estimation.

National Household Travel Survey (NHTS)

In a similar fashion, four logit models, one for each household size, were estimated using NHTS 3,500 household records. Reported household income was grouped into the same ranges as stated above and revealed household labor force for each household were used. Results of these models are shown in Table 2.

The NHTS model and 2000 PUMS model have comparable results. The NHTS model constant are larger compared to the PUMS model especially for households with three and four plus members.

Model Application

A data set of households stratified by the needed variables was prepared for the 1,151 Baltimore region TAZs using the 2000 Census Transportation Planning Package (CTPP). Table 1-075 stratifies households by size (4), income (11), and workers (4) was used TAZ level. Household income group was converted from the 11 groups to the 4 groups used in the estimation.

The two vehicle availability models were applied to the TAZ household data set. The results of the estimation using the PUMS and NHTS derived models and the 2000 Census estimate are displayed in Table 3 for the regional stratified by income group. Both models seem to replicate the regional observed data.

Table 3
Baltimore Region Auto Availability

		Zero	One	Two	Three+
2000 Census	Income Group 1	5.2%	3.7%	0.6%	0.0%
	Income Group 2	6.0%	13.5%	3.9%	0.6%
	Income Group 3	1.2%	6.5%	4.1%	0.6%
	Income Group 4	2.0%	12.3%	29.1%	10.5%
2000 PUMS Model	Income Group 1	4.2%	3.7%	0.4%	0.0%
	Income Group 2	8.2%	17.5%	5.7%	0.6%
	Income Group 3	1.0%	4.4%	3.8%	0.7%
	Income Group 4	1.5%	11.1%	27.7%	9.3%
2001 NHTS Model	Income Group 1	4.9%	3.2%	0.3%	0.0%
	Income Group 2	7.9%	17.6%	6.0%	0.5%
	Income Group 3	0.6%	4.2%	4.3%	0.8%
	Income Group 4	0.4%	9.2%	29.4%	10.7%

As stated previously Baltimore City has the highest share of zero vehicle households. Results of the two models compared to 2000 Census data for Baltimore City is contained in Table 4. Both models seem to under predict the number zero vehicles within the City. There appears to be some geographic bias. However, there are other factors influencing the household vehicle choice.

Table 4
Baltimore City Vehicle Availability

	Zero	One	Two	Three+
2000 Census	35.8%	39.9%	19.3%	5.0%
2000 PUMS Model	22.7%	43.1%	27.6%	6.6%
2001 NHTS Model	23.1%	40.8%	29.0%	7.1%

Built Environment

Researchers and practitioners have discovered relationships between transportation choices and the built environment (density, diversity, and design). These measures have been both quantitatively and qualitatively estimated. Individually, these measures might not directly impact choice, but collectively several research projects have demonstrated their importance in effecting transportation choice. Although the impacts might be relatively small, the environmental community has identified the inclusion of these measures as potential analysis tools in developing long range transportation plans. It is believed that inclusion of density, diversity, and design would provide measures and results of policy changes in land use decisions that could lead to different transportation network alternatives.

Transit Cooperative Research Program (TCRP), Report 95, Chapter 15 defines the 3 D's as follows:

- **Density**, which relates to concentration or compactness of development, measured by the number of opportunities (activities, jobs, places to live, or combinations) located within a given geographic space.
- **Diversity** or "Land Use Mix," which relates to the extent and nature of the mix of uses, and the balance, or compatibility, of the uses with each other.
- **Design**, which refers to the way in which the various uses are combined, linked and presented on a site, and the results in terms of ease of access, use, and attractiveness.

BMC staff using the Maryland Department of Planning (MDP) land use land coverage files, BMC Master Establishment File (MEF), and the power of GIS has developed measures of the built environment. Measures of accessibility to jobs using either the transit network or highway network have also been developed from the BMC travel demand model. These indices and calculation have been estimated at the TAZ level and joined with the NHTS dataset. Probabilities of household vehicle availability have been estimated considering these additional variables.

Additional TAZ Variables for Consideration

A TAZ mean entropy index (land use balance) was developed using the MDP land use and land cover database. The MDP polygon dataset was converted to hectares and aggregated form 21 categories to 6 categories (residential, commercial, public, institutional, industrial, and other). The entropy is a measure of zonal land use balance and can be described as the summation of the proportion of developed land uses with a neighborhood. The TAZ mean entropy averages the entropy score for each hector within a TAZ based on the following formula:

Mean Entropy = $\sum_k \frac{\sum_j \left(\frac{P_{jk} X \ln(P_{jk})}{\ln(J)} \right)}{K}$

where k= Number of Actively Developed Hectares in Tract and P_{jk} = Proportion of Use Type j within a Half m Mile Radius of Development Area Surrounding the kth Hectare.

Using the MDP land use and land cover database converted to the hector level a dissimilarity index was developed. The dissimilarity is a measure of zonal land use mixing and can be described as the contrast between a land use unit and its adjacent land area. The index is based on "points" awarded to a land unit based on the dissimilarity of its land use from those of its neighboring units.

Dissimilarity = $\sum_i^8 \frac{X_{ik}}{8}$

where X_{ik} = 1 if a land use unit differs from a neighboring unit, otherwise X_{ik} =0

An opportunities index was developed using the MEF, developed for the ES-202 employment and wages file, which contains employment location, number of employees, and Standard Industrial Classification (SIC). The opportunities index is a measure of the abundance and variety of neighborhood resources that can be reached on foot. The index consists of a weighted sum of the commercial, civic, cultural, educational and recreational opportunities available within a ¼ mile radius of a household.

Opportunities = $\sum_{O_{i=1}}^{O_n} \frac{W_i * S_i}{D_i}$

where:
O_i is an Opportunity within ¼ mile of a household
W_i is an Importance weight for the Opportunity
S_i is a Size factor where small=1, medium=2, large=3
D_i is the Distance from the household to the Opportunity

The Walkability Index is a measure of the relative ease with which a person can travel on foot within the immediate neighborhood of their household. The index is based on "points" awarded to a household based on the types of road intersections within a ¼ mile radius.

The equation for the index is:

Walkability = $\sum_{i=1}^{n} I_i$

where:
I_i = ½ for 3-way intersections ,
½ for 4-way intersections involving a principal roadway, or
1 for 4-way intersections without a principal roadway;
n = the number of intersections within a ¼ mile radius of the household;
A principal roadway is a walkable major arterial or freeway.

Density calculations of households and employment were also developed for each TAZ. Density is developed summing the land use within 1 mile radius of the centroid of each TAZ. For TAZ that are bisected with the 1 mile radius a proportion of that TAZs land use is considered. The 1 mile radius eliminates the bias to smaller zones.

Calculation of accessibility of cumulative opportunities and gravity were developed using highway and transit skims (in and out of vehicle time) from the travel demand model. For each TAZ the amount of employment that can be reached within 15, 30 and 45 minutes of total transit time and 30 and 60 minutes of highway time were cumulated for each originating TAZ. A gravity function based on the total employment and travel time using highway or transit to all destinations was developed.

Total Employment Gravity = $\sum \frac{E_j}{e^{0.2T_{ij}}}$

Where E_j is the total employment at each destination and T_{ij} is the travel time between origin and destination using either transit or highway network.

Modified NHTS Auto Availability Model

The above indices and calculations were added to the NHTS survey database. Probability models were estimated using the base model (household income group and labor force) with the addition of each land use index or TAZ accessibility in order to evaluate the impact of each variable. This first analysis was also completed using all household survey records regardless of household size. Table 5 displays the model results. The model constants, coefficients, rho squared and t-statistic are shown for the model considering household income group and labor force. The table then shows the results considering the base model with the inclusion of each land use index or associability variable added individually not cumulatively.

Model Application – Land Use

Using the same 2000 CTPP database of households for each TAZ, the final model structure including some of the above land use and accessibility variables was applied. Table 6 contains the share of household vehicle availability for Baltimore City. The additional variables help explain household choice of zero vehicles.

Table 6
Baltimore City Vehicle Availability

	Zero	One	Two	Three+
2000 Census	35.8%	39.9%	19.3%	5.0%
2000 PUMS Model	22.7%	43.1%	27.6%	6.6%
2001 NHTS Model	23.1%	40.8%	29.0%	7.1%
2001 NHTS Plus Land Use	30.0%	51.1%	17.3%	1.6%

Conclusion

Auto availability models can be constructed using Census PUMS and local survey data. There are advantages in using local survey data due to the known location of the household. Other administrative database or variables describing the location surroundings of the household survey record can be appended to the local survey database. This information can assist in understanding the household variables that effect travel choices.

Table 1
Auto Availability Model Estimated from 2000 PUMS

		Zero Vehicle	One Vehicle	Two Vehicle	Three or More Vehicle
One Person Households	Income Group	-0.85262			
		-29.6			
	Labor Force	-0.89473			
		-17.9			
	Alternative-specific Constant	1.197105			
		20.6			
	Rho-squared	0.31			
Two Persons Households	Income Group	-1.32935	-0.693		
		-38.0	-30.7		
	Labor Force	-0.31658	-0.48486		
		-7.3	-18.0		
	Alternative-specific Constant	2.389088	2.001046		
		26.1	27.8		
	Rho-squared	0.32			
Three Persons Households	Income Group	-1.72842	-1.11034	-0.30447	
		-26.8	-20.4	-5.6	
	Labor Force	-1.04704	-1.02995	-0.74163	
		-15.4	-20.2	-17.5	
	Alternative-specific Constant	6.347817	5.598077	3.042084	
		28.9	27.1	14.6	
	Rho-squared	0.21			
Four or More Persons Households	Income Group	-1.57479	-1.07907	-0.11358	
		-29.5	-22.4	-2.4	
	Labor Force	-0.27833	-0.37204	-0.80052	
		-5.0	-8.2	-21.6	
	Non-Worker	0.372906	0.263155	-0.03199	
		10.0	8.1	-1.1	
	Alternative-specific Constant	3.670245	3.281698	2.62478	
		15.1	14.7	12.3	
	Rho-squared	0.23			

Table 2
Auto Availability Model Estimated from 2001 NHTS

		Zero	One	Two	Three or More
One Person Households	Income Group	-1.2393			
		-10.6			
	Labor Force	-0.39022			
		-2.1			
	Alternative-specific Constant	1.689872			
		8.4			
	Rho-squared	0.35			
Two Persons Households	Income Group	-1.98247	-0.78162		
		-11.8	-9.2		
	Labor Force	-0.15313	-0.39488		
		-0.9	-4.0		
	Alternative-specific Constant	3.320067	1.98953		
		9.2	7.8		
	Rho-squared	0.38			
Three Persons Households	Income Group	-2.75286	-1.60262	-0.71428	
		-7.6	-6.2	-3.0	
	Labor Force	-1.067	-1.13962	-0.77395	
		-3.2	-4.7	-4.3	
	Alternative-specific Constant	8.843446	7.171367	4.533636	
		7.8	7.0	4.7	
	Rho-squared	0.26			
Four or More Persons Households	Income Group	-2.52022	-1.82584	-0.17065	
		-2.5	-1.8	-0.2	
	Labor Force	-1.3918	-0.84611	-1.21697	
		-1.4	-0.8	-1.2	
	Non-Worker	0.165144	0.095483	-0.30279	
		0.2	0.1	-0.3	
	Alternative-specific Constant	7.952698	6.211587	4.228497	
		8	6.2	4.2	
	Rho-squared	0.35			

Table 5
Auto Availability Model Estimated from 2001 NHTS with Additional Variables

NHTS Survey

	Zero	One	Two	Three or More
Income	-2.19919	-0.98869	-0.26662	
	-18.7	-10.8	-2.9	
Labor Force	-1.50349	-1.57734	-0.86649	
	-12.5	-17.1	-10.9	
Alternative-specific Constant	7.90173	6.303146	3.281185	
	21.5	18.3	9.5	
Rho-squared	0.27			
Entropy	8.780009	6.235378	3.111765	
	14.2	13.9	8.2	
Alternative-specific Constant	3.076958	3.037996	1.696385	
	6.3	7.6	4.4	
Rho-squared	0.30			
Dissimilarity	8.593064	7.263918	3.57216	
	10.2	10.5	5.7	
Alternative-specific Constant	5.668486	4.498956	2.442294	
	13.5	11.9	6.6	
Rho-squared	0.28			
Opportunities	0.000606	0.000527	0.000339	
	11.0	9.7	6.4	
Alternative-specific Constant	6.812921	5.41983	2.728096	
	18.0	15.3	7.8	
Rho-squared	0.30			
Walkability	0.097703	0.066462	0.03504	
	16.6	13.1	7.3	
Alternative-specific Constant	5.44171	4.981635	2.633243	
	13.9	13.9	7.4	
Rho-squared	0.32			
Household Density	0.608234	0.417543	0.220449	
	18.2	14.7	8.3	
Alternative-specific Constant	4.828721	4.629475	2.503391	
	12.0	12.8	7.0	
Rho-squared	0.33			

NHTS Survey

	Zero	One	Two	Three or More
Income	-2.19919	-0.98869	-0.26662	
	-18.7	-10.8	-2.9	
Labor Force	-1.50349	-1.57734	-0.86649	
	-12.5	-17.1	-10.9	
Alternative-specific Constant	7.90173	6.303146	3.281185	
	21.5	18.3	9.5	
Rho-squared	0.27			
Total Employment Density	0.101903	0.080479	0.05319	
	11.0	8.9	6.0	
Alternative-specific Constant	6.822171	5.68161	2.848867	
	18.0	16.1	8.1	
Rho-squared	0.30			
LN(Cumulitivy Opportunity 45 Transit)	0.339071	0.151222	0.064939	
	9.4	11.3	6.3	
Alternative-specific Constant	4.073047	4.833982	2.711434	
	7.1	13.2	7.6	
Rho-squared	0.29			
LN(Cumulitivy Opportunity 60 Highway)	2.254332	1.233757	0.493667	
	9.7	9.0	4.5	
Alternative-specific Constant	-25.3195	-11.7224	-3.90259	
	-7.4	-5.8	-2.4	
Rho-squared	0.28			
LN(Gravity Transit Time)	0.582278	0.304345	0.1303	
	16.0	14.7	7.6	
Alternative-specific Constant	3.775608	4.560779	2.6417	
	8.2	12.5	7.4	
Rho-squared	0.32			
LN(Gravity Highway Time)	0.582278	0.304345	0.1303	
	16.0	14.7	7.6	
Alternative-specific Constant	3.775608	4.560779	2.6417	
	8.2	12.5	7.4	
Rho-squared	0.32			