PAPER

Long-Distance Trip Generation Modeling Using ATS

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ABSTRACT

This paper demonstrates how the 1995 American Travel Survey (ATS) may be used to develop a long-distance, non-business trip generation model using a cross-classification approach.

INTRODUCTION

Trip generation is the decision to travel for a specific purpose. In traditional four-step travel demand forecasting, trip generation modeling is the first analytic process undertaken to determine travel demand in terms of trip rates or total trips. In urban models, the study region is divided into sub-areas called transportation analysis zones (TAZs). The number of trips produced from each TAZ is determined by relating characteristics of the population within the TAZ to travel demand. Trips are generally considered to originate at residential facilities. However, depending on the purpose of the model, non-residential facilities may also be treated as trip producers. Urban long-range travel demand forecasting trip generation models typically distinguish between business and social needs for travel.

Two approaches have been explored for estimating the number of trips generated from TAZs and non-residential land use, namely regression models and cross-classification models. Traditionally, these models are aggregate in nature, but may be specified to determine the trip-making propensity of individuals or households. Regression models have been formulated as simple and multivariate linear and non-linear forms and use a variety of socioeconomic and demographic characteristics to determine the propensity to travel. Examples of the typical variables used in residential regression models include income, vehicle availability, and household type (age, life cycle, etc.). Regression analysis is commonly used for non-residential facilities. The Institute of Transportation Engineers publishes a trip generation handbook that contains regression models for a wide variety of land uses (*1*). This manual presents for each land use a few different regression equations based on different variables. For instance, the number of trips generated from child-care facilities may be related to the number of staff, the floor space, etc. Recently, researchers have focused on developing Poisson regression models to provide more realistic estimates of trips (*2*).

Cross-classification (category) models have been more widely used for long range residential trip generation analysis to overcome some of the inherent problems with regression analysis. Cross-classification models were explored in the late 1960s in a study sponsored by the FHWA (*3*). Similar to regression-based approaches, cross-classification models relate characteristics of households to demand for travel. However, no functional form of this relationship is presumed. Information from travel surveys is used to forecast future numbers of trips. Cross-classification models differ in the number and type of individual and household characteristics that are related to travel demand. As noted by Sheppard (1986), regression models tend to be good describers but not good predictors because assumptions about travel behavior may not hold and because of problems with multicolinearity of variables. Further, category analysis works best for independent variables that can only take on discrete values (*4*) The trip generation model developed in this study is a cross-classification model for metropolitan and non-metropolitan areas.

As metropolitan areas continue to grow, and the nature of travel continues to change in the Information Age, state and metropolitan transportation agencies are faced with planning for transportation facilities (highways, airports, intercity rail, etc.) that serve longer distance travel. Urban models generally concentrate on shorter trips (under 60 mi). Transportation literature generally refers to long-distance travel as intercity travel (*5*). In the late 1980s, Koppelman and Hirsh proposed a behavioral framework for intercity travel demand forecasting that grouped the travel decision process into four interrelated decision categories: trip generation, destination choice, mode choice, and “at destination” decisions. Koppelman’s work also explored the data requirements for intercity travel demand forecasting (*6*, *7*).

The literature is quite sparse on statewide travel demand forecasting for long-distance travel. Until 1995, very little data characterizing long-distance travel flows and travel behavior existed for planners to use in travel demand modeling at the statewide level. The American Travel Survey (ATS), conducted by the Bureau of Transportation Statistics (BTS) in 1995 represents the only national database of long-distance passenger travel information collected by the federal government since the 1977 National Travel Survey (NTS). The ATS serves as the primary data source for this investigation in long-distance trip generation analysis.

The ATS is a sample of 80,000 households. Each household was interviewed four times during the year to determine the number and nature of long-distance trips taken by individuals in the household. Information contained in the ATS includes origin and destination of each reported trip, as well as the mode, purpose, duration, travel party type and size, and accommodation at the destination. The ATS also contains demographic information about the trip maker and the household, such as age, race, sex, income, primary economic activity, and household size and composition. Data in the ATS may be summarized by state and metropolitan area, although users are cautioned to consider sampling error.

Three public-use microdata files have been developed from the ATS: a household trip file, a person-trip file, and a demographic file. The household trip file contains one record for each trip taken by a household during the sample year. A record in the person-trip files provides characteristics of each individual person in the household who took a trip. So if three people in a household of five people take one trip, there is one record in the household file and three records in the person-trip file. The demographic file contains summary information about each sample household’s travel behavior over the course of the entire survey year. The demographic and household trip files were used in this analysis of trip generation.

The ATS survey design was based on retired panels from the Bureau of the Census's Current Population Survey which reflected 1980 standard metropolitan statistical area boundaries. Geographic references for the origin and destination of each trip in the household trip file include

- Census region code and name (NE, NW, S, W);
- Census division code and name ;
- State code, name, and postal abbreviation; and
- Metropolitan area code and name.

In addition, foreign country codes are provided for trips outside the United States.

The literature on intercity travel demand forecasting models generally distinguishes between business and non-business trip purposes. The ATS actually describes 12 purposes for taking a long-distance trip. This study focuses on non-business trip purposes assuming that the decision to travel for business purposes is different from the decision to travel for other purposes. However, we recognize that the decision process, and consequently the model structure, may in fact be different for trips made for recreational purposes as opposed to trips made to visit friends or relatives or for personal business. A trip in the ATS is considered to be for business reasons if the reason cited was "business, combined business/pleasure, convention, conference, or seminar." Trips made for all other purposes reported in the ATS are used to develop the long-distance trip generation model here.

METHODOLOGY

In urban cross-classification models, the goal is to estimate the number of trips generated from a TAZ that is a sub-area of a study region. Characteristics of the TAZ used in the estimation process are the number of households and the average income of those households in a TAZ. In this long-distance cross-classification model, the goal is to estimate the number of trips generated from metropolitan and non-metropolitan areas using information on income and number of households within these areas. Statewide totals for long-distance trips may be obtained by applying the metropolitan model to each metropolitan area in a state and to the non-metropolitan area and summing the results of each application.

Household income reported in the ATS is categorical data. Respondents indicated if household income was less than $10,000, between $10,000 and $14,999, between $15,000 and $24,999, etc. Median income is used throughout this model instead of mean income because of the categorical nature of the reported income data. So, with this cross-classification model, if we know the median income of and number of households in a metropolitan statistical area (MSA), we are able to estimate the total number of long-distance non-business trips generated from the MSA.

Another reason for determining median MSA income is based on the timeliness of the ATS survey. Since the ATS was conducted in 1995, income reported by households is in terms of 1995 dollars. Cross-classification models require information on the percent of households that fall within certain income categories in an area (i.e., MSA). Typically, census data are used to construct this information. However, census information is in terms of 1990 household incomes. Converting 1990 dollars to 1995 dollars is not a problem. Determining if the same proportion of households fall within each income category is. For example, if we use the 1990 census data to determine that 33 percent of the households in the San Antonio MSA fall into a low-income category, we cannot with any certainty assume that 33 percent of the households in the San Antonio MSA fall into the low-income category in 1995. If an area experiences an economic downturn or increased urban sprawl (more middle- to high-income families moving out of the urbanized area) the percentage of low-income households may actually increase. Consequently, in this study ATS data are used to determine the percentage of households within each income category in an MSA and non-metropolitan areas.

An impact of using the ATS data is that income may not be modeled as a continuous variable. In all of the following charts and tables that summarize information using median MSA or non-metropolitan income, there are discrete values reported. This may impact the future utility of the model when median income may be determined from another source. Some of the graphs show a best fit polynomial equation for the data to aid in interpolation. Even though a cited advantage of cross-classification models is that they do not presume a functional form (contrary to regression models), the limits of the data encourage the use of these polynomials.

Model development follows that described for the urban trip cross-classification model in Garber and Hoel (*8*). Individual steps in the analysis are described below.

Step 1: For each MSA and each non-metropolitan area, determine the percentage of households that fall into each income category. Three income categories are used in this study. Households in the low-income category have reported a household income below $25,000. The medium-income category contains all households with income between $25,000 and $40,000. The high-income category contains households with income greater than $40,000. The low-income group encompasses reported ATS income categories 1 to 3, the medium-income group encompasses reported ATS income categories 4 to 5, and the high-income group encompasses reported ATS income categories 6 to 12.

After the median income of each MSA and non-metropolitan area was calculated from the ATS data, the percentage of households in each income category was determined for each MSA and non-metropolitan area. There are many metropolitan areas with the same median income (due to the categorical nature of ATS income data), each having a somewhat different proportion of low-, medium-, and high-income households. An example of the variation in the proportion of low-income households within metropolitan areas is shown in Figure 1*a*. The 95 percent confidence interval around each of these sample points also is graphed.

An example of how to interpret a sample point is given for the Detroit, Mich., prime metropolitan statistical area (PMSA) whose median income was determined from the ATS data to be $45,000. The percent of low-income (<$25,000) households is 33.4 ± 6.33. The large variation apparent in this graph is due to the small sample size of the ATS. The largest variation for the low-income category is in the Tallahassee, Florida, MSA where the percent low-income households is 49.9 ± 44.3. The largest variation for the medium-income category is in the Bakersfield, California, MSA where the percentage medium-income households is 47 ± 42.6. The largest variation in the high-income category is in Stockton–Lodi, California, MSA where the percentage of high-income households is 47.6 ± 41.0. The least variation in all income categories is in the Santa Barbara-Santa Monica–Lompac, California, MSA where there are zero percent low- and medium-income households and 100 percent high-income households.

The same type of variation in individual data points also is found for the non-metropolitan areas.

To simplify the data for modeling purposes, the average percent of households for MSAs and non-metropolitan areas with the same median income was determined along with the 95 percent confidence interval. This information is graphed (Figures 1*b* and 1*c*) with the best-fit polylines. Notice that the 95 percent confidence intervals are larger from metropolitan areas with lower (<$20,000) and higher (>$60,000) median incomes. The confidence intervals are reasonable for non-metropolitan areas whose median income is less than $50,000. The information shown in these graphs conforms to intuition. As the median income of an MSA or non-metropolitan area increases, the proportion of low-income households decreases. Conversely, as the median income of an MSA or non-metropolitan area increases, the proportion of high-income households increases.

To assure statistical validity of this information, the number of observations within category is important. Tables 1 and 2 show the number of households that fall within each income class in each MSA and non-metropolitan area with a particular median income. A cell size of at least 20 is desirable.

Insufficient sample size (<20) is evident in one cell of Table 1. Only 17 households with income between $25,000 and $45,000 were interviewed in MSAs whose median income was $12,500.

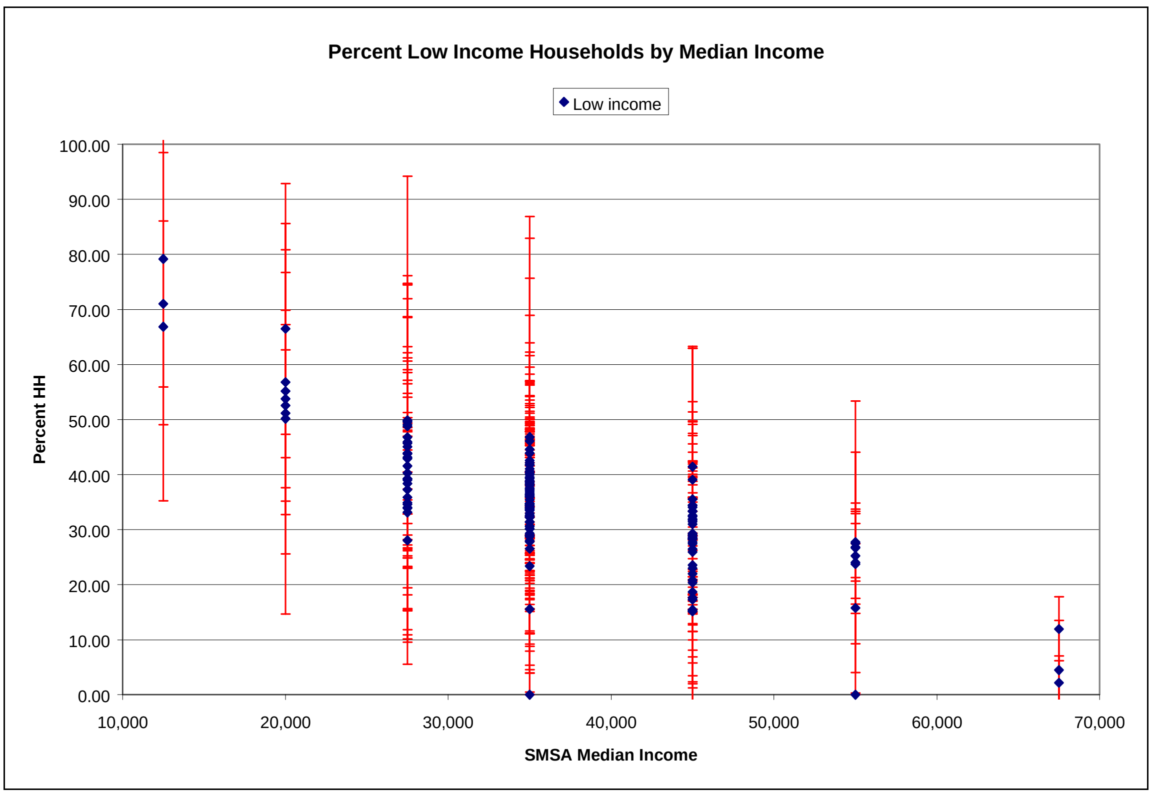

FIGURE 1(a) Percent low income households by median MSA income, individual sample points.

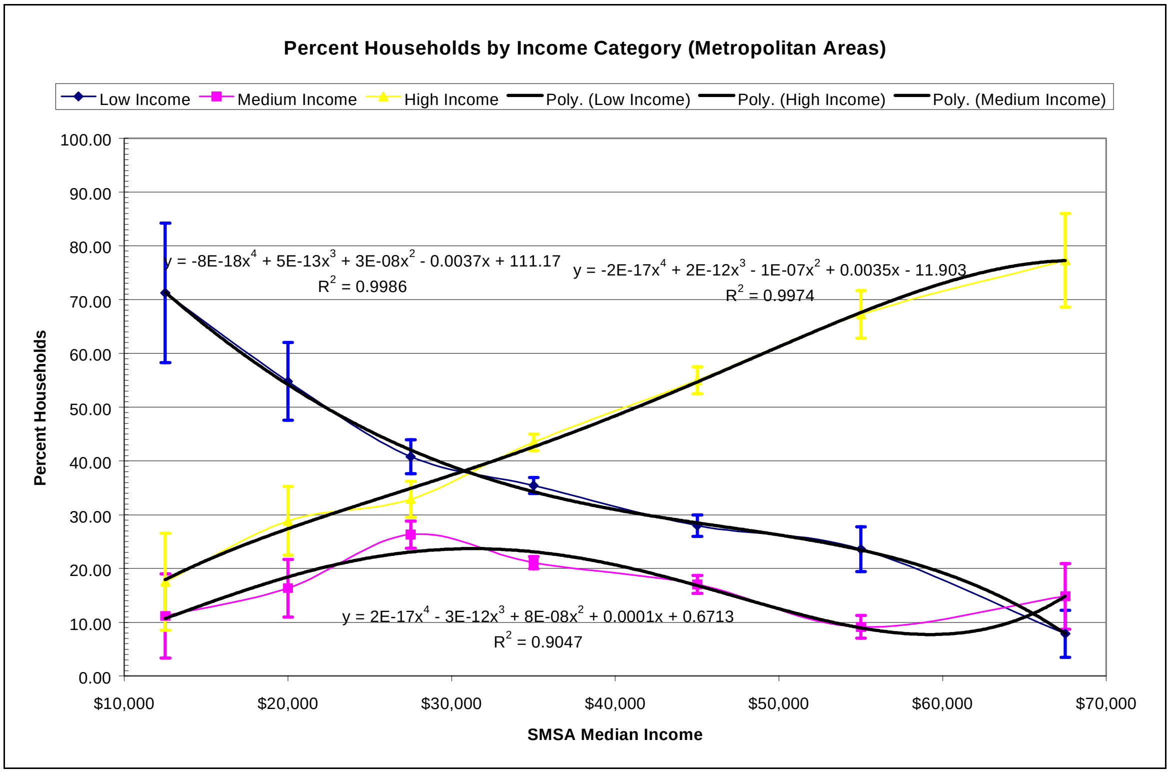

FIGURE 1(b) Percent households by income category, metropolitan areas.

TABLE 1 Sample Size in Metropolitan Areas

Sample Size (Metropolitan Areas)			
	Income Category		
Median Income	**Low Income**	**Medium Income**	**High Income**
$12,500	70	17	34
$20,000	214	89	163
$27,500	1,067	676	1,096
$35,000	4,740	3,149	7,337
$45,000	1,869	1,294	4,297
$55,000	289	137	812
$67,500	26	38	152
Total	8,275	5,400	13,891

Cell interpretation: 70 households whose income was less than $25,000 were interviewed in MSAs whose median income is $12,500.

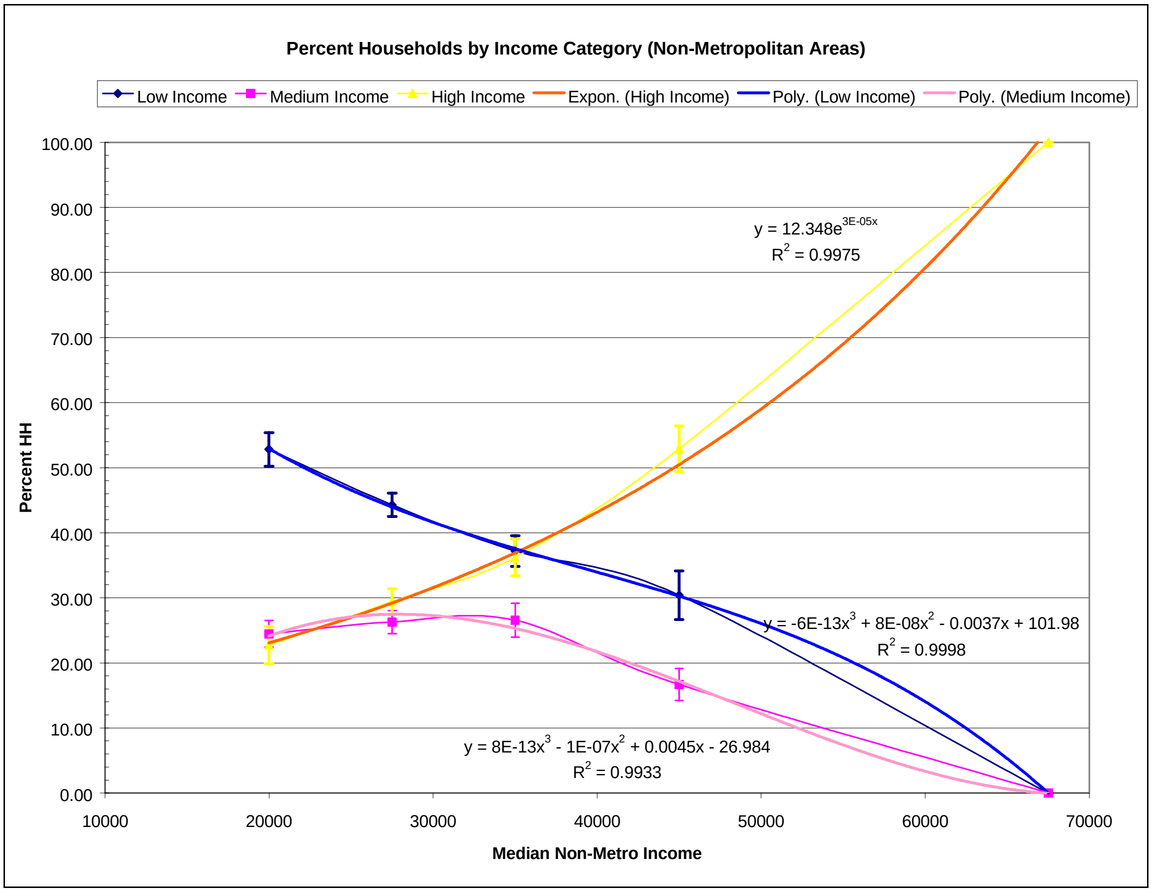

FIGURE 1(c) Percent households by income category, non-metropolitan areas.

Insufficient sample size (<20) is evident in three cells of Table 2. Non-metropolitan areas with median income above $45,000 should not be investigated using this cross-classification model.

Step 2: Households by Household Type by Income Category. Urban cross-classification models generally stratify household trips by the number of available

TABLE 2 Sample Size in Non-metropolitan Areas

Sample Size (Non-Metropolitan Areas)			
Income Category			
Median Income	**Low Income**	**Medium Income**	**High Income**
$20,000	2,359	1,303	1,329
$27,500	4,900	3,177	4,004
$35,000	2,576	1,866	3,196
$45,000	438	272	860
$67,500	0	0	3
Total	10,273	6,618	9,392

Cell interpretation: 2,359 households whose income was less than $25,000 were interviewed in non-metropolitan areas whose median income is $12,500.

vehicles based on the assumption that the more vehicles available to the household, the more trips the household will generate. For analysis of long-distance non-business travel, which is more multi-modal in nature, a decision was made to evaluate the relationship between household type and the number of trips. Originally, the presence or absence of children in the household and the relationship among household members was assumed to influence the number of long-distance non-business trips generated.

Household type information from the ATS was aggregated into 5 categories from the original 16 reported in the ATS databases for this analysis. Married couple family households with children present includes ATS household type categories 1 to 3. Married couple family households without children include household type category 4. Single-parent household with children present includes categories 5 to 7 and 9 to 11. Family or non-family households without children include categories 8, 12, 13, and 15, and non-family households not living alone include categories 14 and 16.

Figures 2*a* and 2*b* show the percentage of households by household type and income category. Although the low-, medium-, and high-income categories introduced above are based on ranges in household income, specific values for low-, medium-, and high-median MSA and non-metropolitan income are used to apply model. Vertical lines drawn for low income equal to $20,000, medium income equal to $35,000, and high income equal to $50,000 are shown on these graphs.

The largest variation in the percentage households is found in MSAs with very low median income ($20,000) and MSAs with very high median income (>$60,000). Non-metropolitan areas generally have lower median incomes than metropolitan areas. The

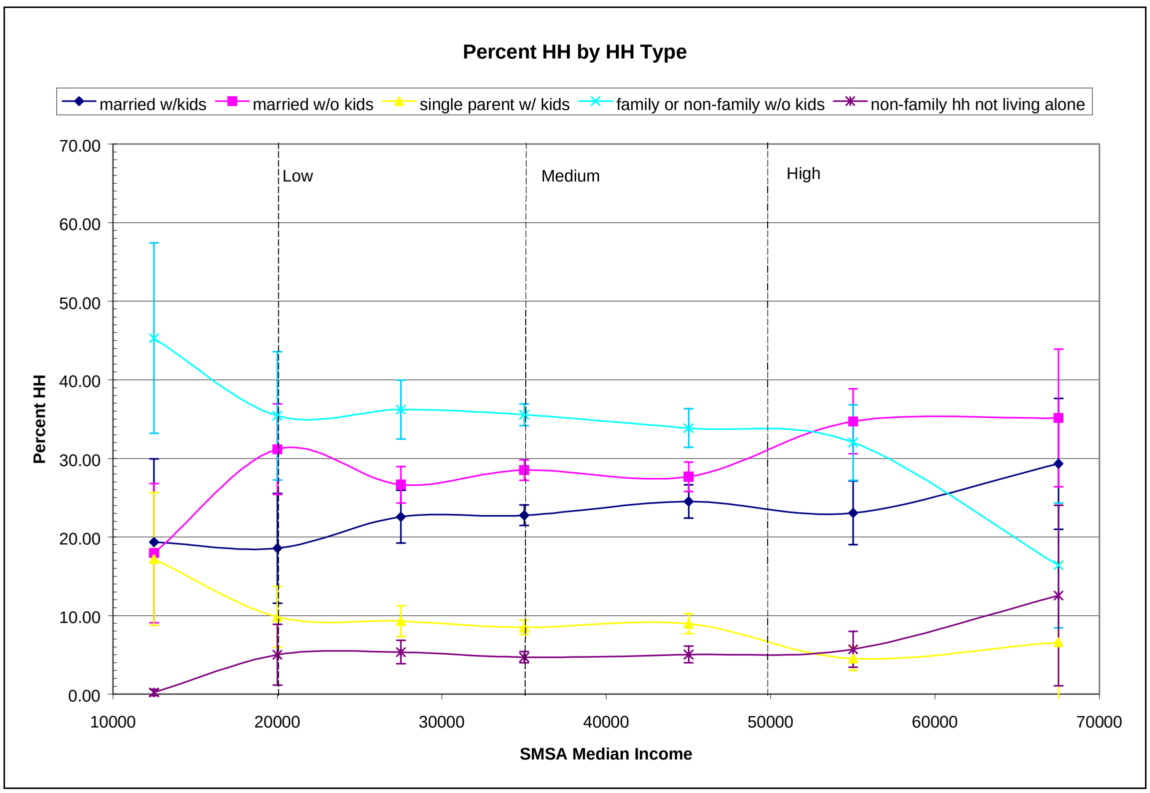

FIGURE 2(*a*) Percent households by household type, metropolitan areas.

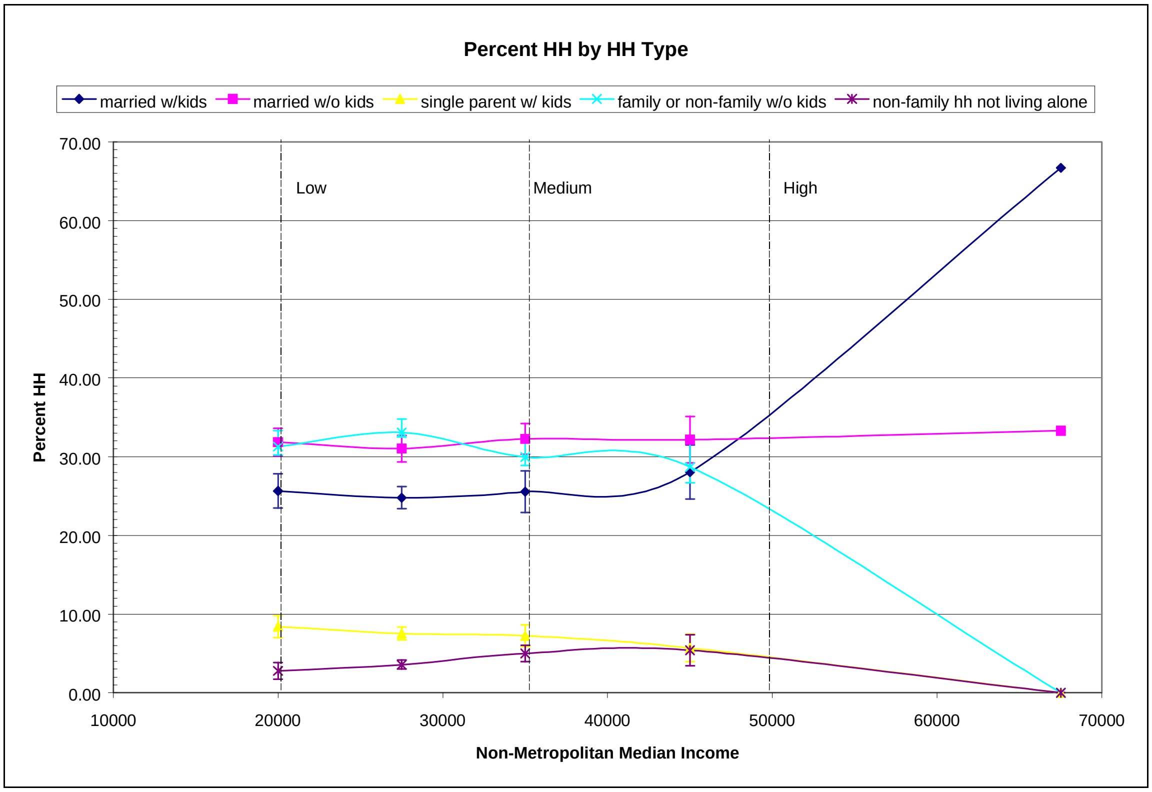

FIGURE 2(b) Percent households by household type, non-metropolitan areas.

percentage of households in non-metropolitan areas in the high income category is not reliable information in this model.

The sample size for each household type by MSA and non-metropolitan median income is shown in Table 3.

Insufficient sample size (<20) is evident in four cells of Table 3. These cells represent households consisting of single parents with children as well as non-family

TABLE 3 Unweighted Sample Size Includes Households Reporting No Long-Distance Non-Business Trips

Sample Size—Metropolitan Households					
	Household Type				
Median Income	Married w/Kids	Married w/o Kids	Single Parent w/Kids	Family or Non-Family w/o Kids	Non-Family HH Not Living Alone
$ 12,500	24	29	19	48	1
$ 20,000	93	157	35	159	22
$ 27,500	648	917	195	975	104
$ 35,000	3638	5094	879	5027	588
$ 45,000	1824	2357	457	2463	359
$ 55,000	293	463	47	393	42
$ 67,500	65	89	8	41	13
Total	6585	9106	1640	9106	1129

Cell interpretation: 24 households whose members were married with children were interviewed in MSAs whose median income is $12,500.

households not living alone in MSAs with median income of $12,500 and $67,500. In general, these two household types have the smallest sample size over all income ranges.

Sample size is insufficient for all household types in non-metropolitan areas with median income of $67,500 (Table 4). As in metropolitan areas, households consisting of single parents with children as well as non-family households not living alone have the smallest sample size over all income ranges.

The total number of households included in the demographic file in metropolitan areas is 27,566 and in non-metropolitan areas is 26,283. The total metro/non-metro sample of households in the ATS demographic file is 53,849. The nearly equal sample size of households in metropolitan and non-metropolitan areas raises concern that that metropolitan long-distance trips may not be well represented in the survey since a greater proportion of households are in metropolitan areas. In the ATS, non-metropolitan area means any metropolitan area with less than 250,000 in population plus non-urban areas. Still, due to the sampling methodology, with each state having roughly the same number of households sampled, there probably is an overrepresentation of non-metropolitan areas.

Step 3: Trips per household by household type and income category. The final information needed to estimate the total number of long-distance non-business trips generated by an MSA or non-metropolitan area is the average number of trips per household by household type and income category. This information is shown in Figures 3*a* and 3*b*.

In metropolitan areas, the 95 percent confidence interval around household trip rates is much larger for MSAs with low (<u><</u>$20,000) or high (<u>></u>$57,500) median income. For example, household trip rates for married families without children living in a MSA with a median income of $12,500 range between 3.2 to 13.5. However, the 95 percent confidence interval for married families without children living in a MSA with a median income of $35,000 is 5.4 to 6.2 non-business trips per household per year. In non-metropolitan areas, except for non-family households not living alone, the 95 percent

TABLE 4 Unweighted Sample Size Includes Households Reporting No Long-Distance Non-Business Trips

Sample Size—Non-Metropolitan Households					
	Household Type				
Median Income	**Married w/Kids**	**Married w/o Kids**	**Single Parent w/Kids**	**Family or Non-Family w/o Kids**	**Non-Family HH Not Living Alone**
$20,000	1162	1897	274	1559	99
$27,500	3031	4336	621	3725	368
$35,000	2106	2662	405	2172	293
$45,000	438	549	82	437	64
$67,500	2	1	0	0	0
Total	6739	9445	1382	7893	824

Cell interpretation: 1,162 households whose members were married with children were interviewed in the non-metropolitan areas whose median income is $20,000. No state has a non-metropolitan area with a median household income of $55,000.

confidence interval around non-business household trip rates is approximately ±1 trip (or less) per year when the median income of the non-metropolitan area is less than $40,000.

In general, households in non-metropolitan areas on average generate more long-distance non-business trips per year than their counterpart households in metropolitan areas. The presence of children in married households does not significantly impact the average long-distance non-business trip rate (Table 5).

RESULTS

The trip generation model developed above may be used to estimate the number of long-distance, non-business trips in metropolitan and non-metropolitan areas. An example of how to use this model is given for the Binghamton, New York, MSA. Input information required to apply the model is median income and number of households. Binghamton's median income is $45,000 and the metropolitan area contains 67,567 households.

The first step is to determine the percentage of households in each income category using Figure 1*b*. The percentage of low-income households is 28 percent, medium income households is 17 percentage, and high-income households is 56 percent. (This total, over 100 percent, reflects rounding.)

The second step is to determine the percentage of households for each household type and each income class using Figure 2*a*.

Figure 3*a* is used to determine the trip rates for households in different household type and income categories. The trip rates are shown in the table below.

Finally, all of this information is put into the following equation to determine the total number of trips generated by each income group.

$$P_{ij} = HH \cdot I_i(\%) \cdot T_{ij}(\%) \cdot (P_{hh})_{ij} \qquad (1)$$

where

HH = number of households in the metropolitan or non-metropolitan area
$I_I(\%)$ = percentage of households in MSA or non-MSA with income level *i* (low, medium, or high)
$T_{ij}(\%)$ = percentage of households in income level *i* with and household type *j* (*j* = married with kids, married without kids, etc.)
$(P_{hh})_{ij}$ = average number of trips generated by householders with income level *i* with and household type *j*

Step 4 shows the results of these calculations for each income category and household type. The first cell is calculated as follows:

$$P_{l,1} = 67{,}567 \cdot 0.28 \cdot 0.18 \cdot 5.21 = 17{,}368$$

The total number of long-distance, non-business trips for the Binghamton, NY MSA calculated from this model is 324,789. The estimate from the ATS for Binghamton is 337,468 with a standard error of 174,937.

TABLE 5 Average Trips Per Household

	Household Type				
Average Trips per Household	**Married w/Kids**	**Married w/o Kids**	**Single Parent w/Kids**	**Family or Non-Family w/o Kids**	**Non-Family HH Not Living Alone**
Metropolitan Households ($20,000–$55,000)	5.2 (0.21)	5.7 (0.41)	2.7 (0.43)	3.5 (1.06)	6.2 (0.76)
Non-Metropolitan Households ($20,000–$45,000)	6.3 (0.63)	6.5 (0.37)	3.8 (0.50)	4.0 (0.67)	7.2 (1.93)

Note: Certain median income ranges were eliminated from these averages because of insufficient sample size.

An example of the non-metropolitan trip generation model is given for Maine. The median income for non-metropolitan Maine is $27,500 and there are 494,023 households in non-metropolitan Maine. The first step is to determine the percentage of households in each income category using Figure 1*c*. The percent of low-income households in 44 percent, medium-income households is 26 percent and high-income households is 29 percent.

The second step is to determine the percent of households for each household type and each income class using Figure 2*b*.

Figure 3B is used to determine the trip rates for households in different household type and income categories. The trip rates are shown in the table below.

Step 2: Distribution of Household Types for Each Income Category						
	Household Type					
	1	2	3	4	5	TOTAL
Low Income ($20K)	18	31	10	35	5	99
Medium Income ($35K)	23	28	8	36	5	100
High Income ($50K)	24	32	6	34	5	101

Step 3: Trips per Household for Each Income-Household Type Category					
	Household Type				
	1	2	3	4	5
Low Income ($20K)	5.1	5.6	2.3	2.6	7
Medium Income ($35K)	5.6	5.9	3.4	3.4	6
High Income ($50K)	5.1	5.7	2.7	4.6	6

Step 4: Total Number of Trips in MSA (Binghamton, New York)					
$P_{l,1}$	17,368	$P_{m,1}$	14,795	$P_{h,1}$	46,313
$P_{l,2}$	32,843	$P_{m,2}$	18,976	$P_{h,2}$	69,016
$P_{l,3}$	4,351	$P_{m,3}$	3,124	$P_{h,3}$	6,130
$P_{l,4}$	17,216	$P_{m,4}$	14,059	$P_{h,4}$	59,178
$P_{l,5}$	6,622	$P_{m,5}$	3,446	$P_{h,5}$	11,351
P_L =	78,400	P_M =	54,400	P_H =	191,989

Finally, all of this information is put into equation (1) to determine the total number of trips generated by each income group.

The table below shows the results of these calculations for each income category and household type. The first cell is calculated as follows:

$$P_{l,1} = 494{,}023 \cdot 0.44 \cdot 0.26 \cdot 5.4 = 305{,}188$$

The total number of long-distance, non-business trips for non-metropolitan Maine calculated from this model is 2,554,534. The estimate from the ATS for non-metropolitan Maine is 2,286,650 with a standard error of 166,713.

Step 2: Distribution of Household Types for Each Income Category						
	Household Type					
	1	2	3	4	5	TOTAL
Low Income ($20K)	26	32	8	31	3	100
Medium Income ($35K)	25	32	7	30	4	98
High Income ($50K)	35	32	4	23	4	98

Step 3: Trips per Household for Each Income-Household Type Category					
	Household Type				
	1	2	3	4	5
Low Income ($20K)	5.4	6.4	3.2	3.4	6.2
Medium Income ($35K)	6.8	7.0	3.8	3.8	6.2
High Income ($50K)	5.8	6.2	3.0	4.2	5.2

Step 4: Total Number of Trips Generated by Non-Metropolitan Area					
$P_{l,1}$	305,188	$P_{m,1}$	218,358	$P_{h,1}$	290,831
$P_{l,2}$	445,174	$P_{m,2}$	287,719	$P_{h,2}$	284,241
$P_{l,3}$	55,647	$P_{m,3}$	34,167	$P_{h,3}$	21,490
$P_{l,4}$	229,108	$P_{m,4}$	146,428	$P_{h,4}$	138,396
$P_{l,5}$	40,431	$P_{m,5}$	31,855	$P_{h,5}$	37,249
P_L =	1,075,547	P_M =	718,527	P_H =	772,207

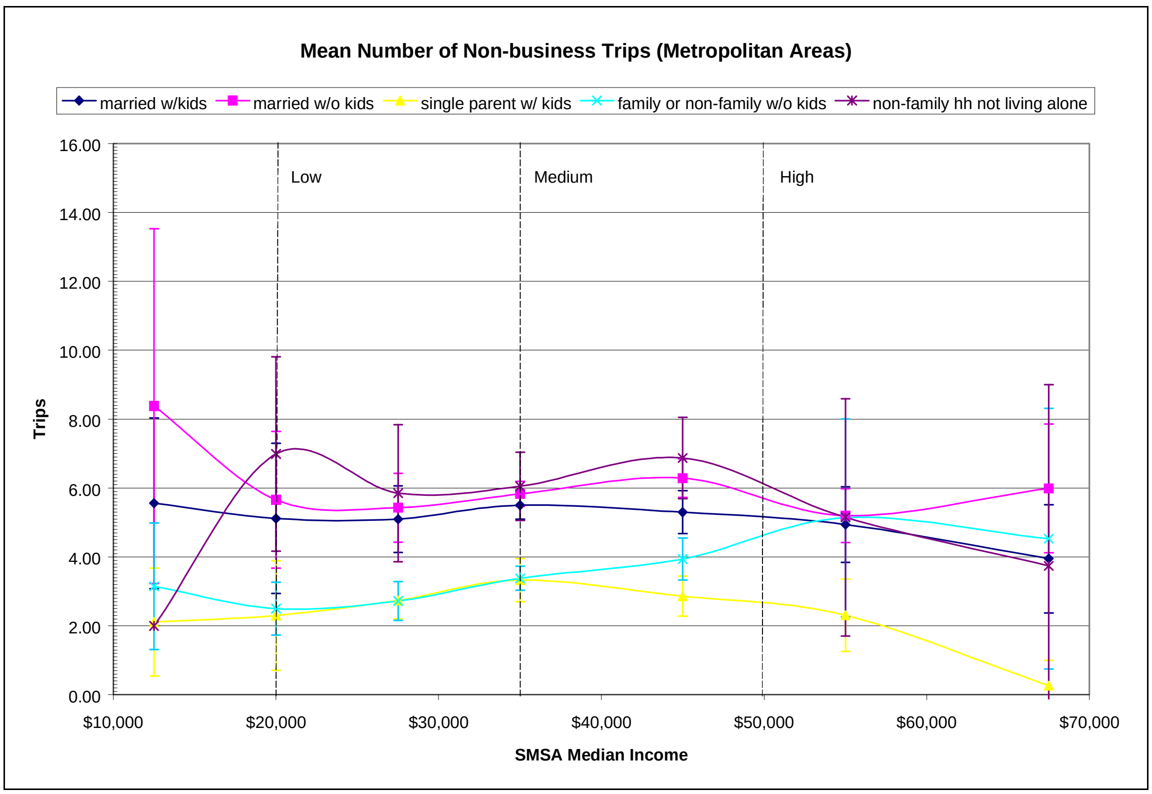

FIGURE 3(a) Mean number of non-business trips by household type, metropolitan areas.

CONCLUSIONS

This paper demonstrates how a cross-classification model for long-distance non-business trip generation may be developed using data from the 1995 ATS. This model may be used by states and metropolitan areas to estimate the number of long-distance trips that will be generated during a year.

This is a very simple cross-classification model based on two variables. Future work investigates the use of other information to determine the propensity for non-business

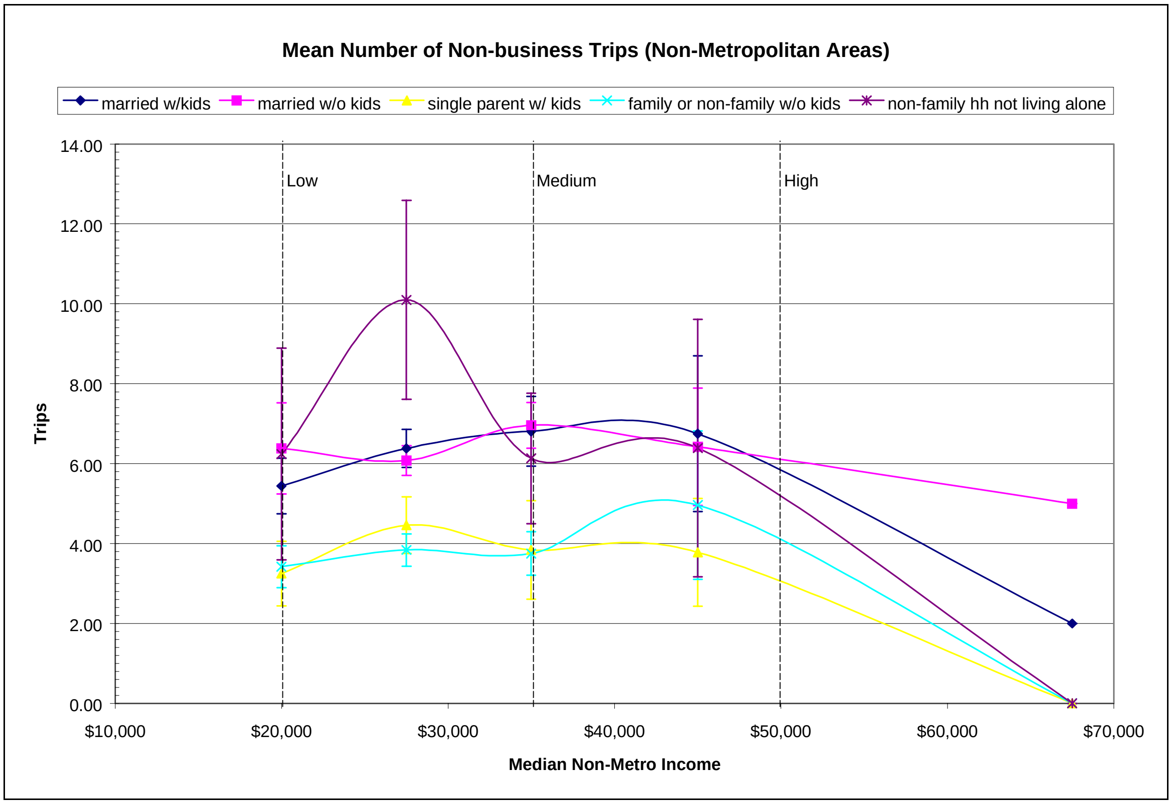

FIGURE 3(b) Mean number of non-business trips by household type, non-metropolitan areas.

travel. Particularly, stratification of households by age of the householders will be investigated. Transferability of trip generation models has been a problem in urban modeling. This research effort investigated the development of individual trip generation models for different geographic regions as well as for different population sizes. The results of these efforts will be reported in forthcoming papers.

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