Some Contrary Indications for the Use of Household Structure in Trip-Generation Analysis

KATHIE G. MCDONALD AND PETER R. STOPHER

The variables used to predict household trip-generation rates have long been an area of concern for transportation planners; these variables included household size, number of vehicles owned, and income. However, a recent NCHRP study that used linear regression analysis has proposed that a household-structure variable would correlate more strongly with trip rates than almost any other variable, except vehicle ownership. In particular, this should improve the model significantly where it is combined with vehicle ownership and used as a substitute for household size. The results of a trip-generation analysis performed on data from the Midwest by using multiple classification analysis (MCA) in contrast to linear regression are described. The household-structure variable was tested by using both analysis of variance and MCA to determine how well the variable performs in various model structures when compared with other variables. The other variables tested were number of cars or vehicles available to the household, household size, housing type, total number of employed persons, household income, and total number of licensed drivers. It was concluded that the household-structure variable did not perform significantly better than the other variables tested.

With the increasing acceptance into practice of behavioral models for travel forecasting, recent research by the NCHRP has focused on enriching travel-forecasting models with theories and procedures from the behavioral sciences. [Note that these research results are from work done at Boston College for NCHRP Project 9-14 (New Approaches to Understanding Travel Behavior); the report is available on request from NCHRP.] One of the first potential directions examined for translation into practice is the incorporation of behavioral concepts in trip-generation modeling at the household level. As part of this research, Charles River Associates (CRA) proposed that a household-structure variable would significantly improve the performance of such a model.

This proposal was based on the premise that households with differing structures, in terms of adults, children, and personal roles, would have differing activity requirements, mobility constraints, and opportunities for trade-offs with other household members or for trip chaining. Thus proposed changes in household structure, such as an increasing percentage of single and single-parent households as well as adult households with no children, as is expected within the next decade, would have a significant effect on trip-generation rates within a population. It is argued that such a variable should add behavioral content that is lacking from traditional trip-generation models, which generally have included such variables as household size, number of vehicles owned, and income to predict household trip rates. Furthermore, a household-structure variable would be more significant in capturing changes in the future than many of the more traditional variables used.

The household-structure categories proposed were based on the age, gender, marital status, and last names of each household member. These variables determined the presence or absence of dependents within the household, the number and type of adults present, and the relationships among and of household members.

The results of an application of this household-structure variable in trip-generation analysis in a Midwest study area are described. The value of this variable is compared with other variables that were tested at this time by using multiple classification analysis (MCA) (see paper by Stopher and McDonald elsewhere in this Record). MCA is an extension of analysis of variance (ANOVA) that, for a set of classified data, expresses group means as deviations from the grand mean.

HOUSEHOLD-STRUCTURE CONCEPT

The household-structure variable defined by CRA comprises eight household categories: male and female single-person households, single-parent households, couples, nuclear families, adult families with children, adult families without children, and unrelated individuals. Age 20 was used as the cutoff to distinguish between children and adults. These categories were determined by using the method shown in Figure 1.

It was expected that these categories would have varying effects on trip rates. Adults living alone would be less mobility constrained than those adults living with children; but they would have none of the opportunities for trip coordination produced by living with other adult members. Single-parent families would have both increased mobility constraints as well as no opportunities for trip coordination, whereas couples would have the advantages of the opposite of both of these. An adult family would have further increased opportunities for trip coordination, but would perhaps differ from an adult household of unrelated individuals where individual activities would possibly be less influenced by other household members.

More specifically, when trip-generation rates are analyzed by purpose groups, differences between the trip-generation rates of these household categories would be expected. Those households with children would be expected to have a greater proportion of school trips and trips serving passengers than those households without children, whereas the latter would probably have a greater proportion of social-recreation trips.

CRA examined this household-structure concept by using Baltimore survey data with regression analysis, where the dependent variables were trip-generation rates by purpose mode, and the independent variables tested included, in addition to household structure, vehicles owned, income, number of persons older than 12, age structure of household, housing type, number of preschoolers present, number of graderschoolers present, employment status, race, population per residential acre, a city limit classification, and length of residence at that address. The trip-purpose groups defined as the dependent variables were as follows: total home-based trips, home-based work trips, home-based shopping trips, home-based personal business trips, home-based entertainment and community trips, home-based visits and social trips, and home-based service and accompany-traveler trips.

CRA concluded that the household-structure variable was significant in predicting trip frequency. It should be noted, however, that the regressions were constrained to use all independent variables to permit comparability, even though varying numbers of independent variables were highly insignificant. Potentially, intercorrelations among variables could have masked some of the true underlying relation-
Figure 1. CRA flowchart of household typology.


ships. CRA concluded that, of two commonly used
trip-generation variables—number of vehicles owned
and income—only number of vehicles owned out-per­
formed the household-structure variable.

CASE STUDY

The analysis of travel data collected in the Midwest
examined the household-structure concept. The data
were collected from a stratified random sample of
the population in seven counties. The principal
purposes of the survey were to provide

1. The means to update trip-generation rates and
modal-split models,

2. Attitudes of the population toward transpor­
tation and energy,

3. Attitudes toward possible changes in the
transit system, and

4. Preferred methods of obtaining information on
carpooling.

The data were collected by using an in-home inter­
view and a 24-hr travel diary and included the vari­
ables age, gender, possession of a driver's license,
employment status, and income of household members,
all of which were available for use in trip-genera­
tion analysis.

The final data set consisted of 2,446 house­
holds. Of these households, the average household
size was 2.9 persons per household, where less than
50 percent (1,656) of all households had two or less
persons; 60 percent (1,483) had no children; and 53
percent (1,300) were two adult person households.
In addition, almost 80 percent (1,952) of all house­
holds had at least one car available for use, and 30
percent (734) had more than one; 60 percent (1,675)
occupied single-family dwellings; and 87 percent
(2,124) of all households had at least one licensed
driver. Seventy percent (1,724) of all households
had at least one person employed, 63 percent (1,537)
had at least one person employed full-time, and 60
percent (1,468) of all households had 1980 incomes
greater than $15,000, with 14 percent (341) greater
than $35,000.

The household-structure variable defined by CRA
was derived from the data by the method shown in
Figure 2. This differs slightly from the CRA flow­
chart because of the definition of the variables
within the Southeastern Michigan Transportation
Authority (SEMTA) data set. These differences in­
clude the following: (a) the cut-off age between
children and adults is 18 years instead of 20, and
(b) relationship codes were used to distinguish be­
tween adult families without children and households
of unrelated adults; the last name of each person
was not ascertained in the survey.
Figure 2. Flowchart of household typology used in analyzing SEMTA data.

To analyze the role of the household-structure variable in trip-generation analysis, this variable and seven other variables that were also thought to play a significant role in trip-generation rates were selected from the data set. The other variables selected were car ownership, household size, housing type, licensed drivers, household income, and total number of employed persons in the household (see Table 2). These eight variables were first analyzed by using one-way ANOVAs to determine how well they performed against the household-structure variable. Subsequently, the variables were analyzed by using one-way ANOVAs to determine the effects of varying grouping strategies on the categories within each variable.

The final breakdown of the data into these household categories is given in Table 1. Almost 19 percent are single-person households, with slightly more single females than single males (2 percent). Single-parent households comprise only 6 percent, whereas couples and nuclear families comprise 21 and 20 percent, respectively. Adults with children make up slightly fewer households than those without children (14 percent compared with 17 percent), but households of unrelated individuals form the smallest category—2 percent of all households. Thirty-four households could not be classified. These included 17 single-person households where the person was younger than 18 years old.
puting individual cell means because it permits data. In addition, MCA, by using version 6, 7, or 8 different combinations of these grouped variables in deviations from the grand mean of the data set. Thus it improves on the traditional method of comparisons between related household members was examined. The most severe grouping strategy separates households with children from households without children, identifying this characteristic as the most important in trip decision making. Only single-person households are further distinguished to reflect unique trip-generation characteristics.

Other variable groupings are also given in Table 2. The model II household size grouping, which combines two- and three-person households, was examined after initial analysis indicated little difference in trip rates of these households. Income was grouped into high-, medium-, and low-income categories.

Finally, MCA (3, and paper by Stopher and McDonald elsewhere in this Record) was used to compare different combinations of these grouped variables in trip-generation analysis. MCA derives trip rates within a standard trip-generation matrix by using deviations from the grand mean of the data set. Thus it improves on the traditional method of computing individual cell means because it permits estimation of trip rates for cells that contain no data. In addition, MCA, by using version 6, 7, or 8 of the Statistical Package for the Social Sciences (SPSS) (3), is able to take into account the interactive effects between independent variables where these variables have nonzero correlations with each other. This corrects for the overestimation of adjustments from the grand mean when these correlations are ignored. This use of MCA and the cross-classification structure is different from the CRA approach, which was to use least-squares regression analysis to predict the trip-generation measures. The effects of household structure were analyzed both in terms of the additional level of variance explained by the household-structure variable as well as the level of variance explained when substituting household structure for another variable.

The models examined in trip-generation analysis are given in Table 3. It can be seen that the number of vehicles (NUMVEH) available to the household was substituted for the number of cars in some models because this variable performed significantly better across all purpose groups.

<table>
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<tr>
<th>Trip Purpose</th>
<th>No.</th>
<th>MCA Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home-based work, home-based shopping, home-based social-recreation, home-based other, and non-home-based trips</td>
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<tr>
<td>Home-based work, home-based shopping, home-based other, and non-home-based trips</td>
<td>2</td>
<td>NUMVEH, HHSIZ I, HOUSTYP</td>
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<tr>
<td>Home-based work, home-based shopping, home-based other, and non-home-based trips</td>
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<td>NUMVEH, HHSIZ II</td>
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<tr>
<td>Home-based work, home-based shopping, home-based other, and non-home-based trips</td>
<td>4</td>
<td>NUMVEH, HHSIZ II, HOUSTYP</td>
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<tr>
<td>Home-based work, home-based shopping, home-based other, and non-home-based trips</td>
<td>5</td>
<td>NUMVEH, HHSIZ II, INC80</td>
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</table>

In all three types of analysis previously discussed, trip-generation models were examined for motorized trips by specific trip purpose. Initial analyses distinguished social-recreation trips, but the final trip-purpose categories examined were home-based work, home-based shopping, home-based school, home-based other, and non-home-based trips. These final trip-purpose categories differ from the categories used by CRA that (a) do not examine non-home-based trips, and (b) break down the other category into more specific purpose groups.

**DESCRIPTION OF RESULTS**

The results of the ANOVA for ungrouped variables are given in Table 4; the results indicate that across all purpose groups the number of cars available to the household explains more variance than any other variable. This result is consistent with results obtained by CRA. Household size and housing type are the next most significant variables across all purpose groups; and whereas the number of employees in the household explains the most variation for home-based work trips, it does not perform well for all other purpose groups. Household structure and income appear to be of equal strength, although they perform better on different purpose groups. Income is most effective in explaining the total number of non-home-based trips, whereas household structure is most effective in explaining the number of home-based school trips. The licensed-driver variable ranks no better than third in explained variation for any purpose group.

The ANOVA results of the grouping strategies performed on the household-structure variable are given in Table 5. The most effective grouping is the model II grouping: single-person households, single-parent households, couples with children, and other adult households. There appears to be little difference between the travel considerations of adult families that consist of related individuals and those that consist of unrelated individuals, because there is a large increase in the F-ratio across all purpose groups when these are combined, whereas the change in the within-group differences is more modest.
Table 4. ANOVA results for ungrouped variables.

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<th>Variable</th>
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<th>HBOTH</th>
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Note: Statistics and purposes are defined in Table 4.

Table 5. ANOVA results for grouped variables.

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<th>HBSCHL</th>
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Note: Statistics and purposes are defined in Table 4.
variance is small. This contrasts with the model III grouping (single persons, families with children, and other families without children) where, although there is a large increase in the F-ratio across all purpose groups, and most particularly with home-based school trips, this is accompanied by a significant increase in the within-group variance.

The ANOVA results of the other grouped variables are also given in Table 5. It is clear that the number of cars available to the household remains the most significant variable in household trip-generation analysis. Once again, the F-scores are substantially greater across all purpose groups, even taking into account the difference in the degrees of freedom. Model II household size, which combines two- and three-person households, improves on model I household size by increasing substantially the F-ratio without increasing substantially the within-group variance. Household income (1980) is also effective in explaining trip-generation rates for all purpose groups except home-based school and home-based social, and thus may be useful when applied to specific trip-purpose models. The total number of licensed drivers, a variable that performed so poorly in earlier analyses, was not tested as a grouped variable.

The MCA results for the two sets of trip-purpose groups are given in Tables 6 and 7. From the first set of purpose groups (Table 6), the basic model consists of number of cars or vehicles available to the household and model I household size. Of the variables used as additions to this basic model, housing type clearly performs the best across all purpose groups. In addition, this model performs better than the model that uses number of cars, household structure, and housing type, where household structure is used as a substitute for household size, an alternative suggested by CRA (1). Further improvements are made by using number of vehicles available to the household instead of number of cars available.

The results of the models analyzed for the second set of trip purpose groups are given in Table 7. An initial examination of these MCA results gives the impression that the model that uses household structure, household size, and number of vehicles is the best model, particularly from an examination of the F-ratios. This is, however, a misleading impression. The F-ratio for an entire model is usually based on all main effects and interactions. If data are missing in some cells of the matrix that define the ANOVA problem, SPSS (3) is unable to calculate the interactions and computes an F-ratio on the main effects only. This F-ratio has substantially fewer degrees of freedom than one on the main effects and interactions, and therefore it must be a larger numeric value for the same significance level.

The household-structure model generated empty cells for some combinations of household structure, household size, and vehicle availability (e.g., the household structure of a couple can occur only for two-person households) and resulted in suppression of interactions in the ANOVA. The model that uses household structure is the only model in Table 7 for which this happened, and leads to an inflated F-ratio compared with all other models. When F-ratios are calculated on main effects only for the other models (as indicated by a footnote in Table 7), the F-ratios are almost all larger than those for the household-structure model. Thus the addition of household structure to the basic model of number of vehicles available to the household and household size does not improve its performance for any trip-purpose group.

Of the other variables examined as additions to the model, the total number of workers in the household improves the model for home-based work trips. Household income (1980) and the model II household-size variable are both improvements over the household-structure variable. Income is better in explaining home-based work trips and non-home-based trips, and housing type is better in explaining the other trips. Thus, unless a separate model is developed for home-based work trips by using the employment variable, the model of number of vehicles per household, household size, and housing type still remains the best approach. These conclusions support those found with the previous set of purpose groups, with the exception that the model II household size performs better than, and thus replaces, the model I household size.

CONCLUSIONS

In the trip-generation analysis of the case study data, the household-structure variable did not per-

Table 6. MCA results of set I models used in analyzing SEMTA data.

<table>
<thead>
<tr>
<th>Model</th>
<th>Statistic</th>
<th>HBWORK</th>
<th>HBSHOP</th>
<th>HBSOC</th>
<th>HBOTHR</th>
<th>NHB</th>
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<td>NUMCAR, HHSIZ I, HOUSTYP</td>
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<td>R²</td>
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<td>0.062</td>
<td>0.060</td>
<td>0.295</td>
<td>0.113</td>
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<td>35.5</td>
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</tr>
<tr>
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<td>0.060</td>
<td>0.053</td>
<td>0.298</td>
<td>0.116</td>
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Note: SIG = significance, HBSHOP = home-based shopping, HBSOC = home-based social-recreation, and the rest are defined in Table 4.
Table 7. MCA results of set II models used in analyzing SEMTA data.

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<th>HBOTH</th>
<th>NHB</th>
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<td>R²</td>
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</table>

Note: Statistics and purposes defined in Tables 4 and 6.

1 Interactions suppressed. 2 F-ratio calculated on main effects only.

The analysis reported in this paper applied traditional cross-classification models that used MCA to predict cell-by-cell trip rates. The final model consisted of number of vehicles, household size, and housing type. However, subsequent analysis not discussed in this paper has revealed that the use of an area-type variable instead of housing type may improve the models even further.

Figures 3 and 4 show the results of the automatic interaction detection (AID) analysis performed on 1973 Niagara Frontier Transportation Committee (Buffalo) and a 1974 Genesee transportation travel survey (Rochester) data for all trips and for home-based nonwork trips (4). The number of vehicles represents the first cluster. This supports both the conclusions drawn by CRA and by the authors. This is followed by number of children (usually a function of household size) and age of the oldest child. The final clusters are based on household size, vehicles per licensed driver (a function of both vehicles per household and household size), household employment status, and number of vehicles available to the household. Although the various age classifications may be a function of household structure, they may also be a function of other variables (for example, household size).

It is also pertinent to note that even had the household-structure variable performed satisfac-
Figure 3. AID analysis of Rochester survey data.

**TOTAL TRIPS/Household**

GTC (Rochester)

$R^2 = 44.1515\%$

WHERE

NUMVEH = NUMBER OF VEHICLES AVAILABLE TO THE HOUSEHOLD

NUMCHD = NUMBER OF CHILDREN PER HOUSEHOLD

NUMHH = HOUSEHOLD SIZE

AGOC = AGE OF OLDEST CHILD

VEH/DL = VEHICLES PER LICENSED DRIVER

OCCUP = OCCUPATION

EMPID = HOUSEHOLD EMPLOYMENT STATUS

LOC = LOCATION

Home Based - Non Work Trips

GTC

$R^2 = 41.9916\%$


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