Life-Cycle Concept: A Practical Application to Transportation Planning

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ABSTRACT

The usefulness of the family life-cycle concept in trip-generation procedures is examined. A life-cycle classification scheme is constructed after consideration of important components and data availability. The Automatic Interaction Detector program is used to determine which variables are important in affecting the number of trips taken by a household. These variables are then calculated in light of published census tract information. The stages in the classification scheme are designed to be compatible with census categories, thus ensuring the usefulness of the scheme. Trip-generation tables based on stage in the life cycle and vehicle ownership are developed by using data from the 1973 Niagara Frontier Transportation Committee home-interview survey. These tables are compared with trip-generation tables based on household size and vehicle ownership. Analysis of variance is used to compare the life-cycle-based scheme and the household-size-based scheme. The applicability and replicability of the life-cycle-based trip-generation tables are also tested by using data from the 1974 Rochester, New York, home-interview survey. Results indicate that the life-cycle-based trip-generation procedure produces accurate results and has several advantages over other procedures. An example of an application at the town level in Albany County is briefly described.

One of the most profound recent changes in American society has been the rapid evolution of alternative living styles and family types. The proportion of single-head and single-person households has nearly doubled in the past decade alone, and the average size of the family has fallen sharply. These trends, well established in the literature of demographics and confirmed in the 1980 census, are likely to have widespread and far-reaching effects on family activity patterns and travel, and therefore it is incumbent on transportation planners to quantify and understand them.

In this paper the usefulness of the family life-cycle concept in the trip-generation phase of transportation planning is evaluated. The concept of life cycle as used in this paper refers to household structure or composition. Different structures are reflected in life-cycle stages, and a household passes through various stages as it evolves. Although not all households take the same path through these various stages, the concept has the ability to take into account structural changes in families and households more accurately than traditional variables (i.e., number of persons in a household, income), and this ability could possibly lead to better trip-generation models. Many researchers have examined the usefulness of the family life-cycle concept and have generally found it to be an important factor in explaining travel behavior (1-9). However, recent papers have cast doubts on its usefulness (10-12), and the issue deserves further examination.

The practical applications of the life-cycle concept to trip-generation procedures are stressed in this paper. The primary purpose here is to demonstrate that a useful life-cycle classification scheme can be developed and applied in trip-generation tables, where only readily available tract-level census data are required as input. A streamlined life-cycle classification scheme using readily available data is desirable for its practicality and usefulness. Because of the wide availability of published census information, development of a classification scheme is focused on the identification of stages that are compatible with census household categories. In this way trip-generation tables based on these life-cycle stages are easy to use, because of the ready availability of published tract-level census data.

Rather than establish stages of a life-cycle classification scheme based on a priori notions, the data in this paper rely on a computerized explanatory data analysis program known as the Automatic Interaction Detector (AID) to determine which life-cycle variables influence the number of household trips and how these variables should be arranged in a classification scheme. An examination of AID results can indicate which variables are important in explaining the variation of the dependent variable, and thus can provide insight into which variables should be considered as components of a life-cycle classification scheme. Once these ideal components of a classification scheme are identified, they are evaluated in light of available census tract information.

Data from the 1973 Niagara Frontier Transportation Committee (NFTC) home-interview survey in the Buffalo, New York, region are used in developing the life-cycle classification scheme and the trip-generation tables. Trip rates are developed for home-based work, home-based nonwork, non-home-based, and total trips; the primary focus of this paper is on total trips. The 1974 Genesee Transportation Council (GTC) home-interview survey in the Rochester, New York, region is used as a check on the life-cycle classification and trip rates developed from the NFTC data. Although use of GTC data is not a final test of replicability of the results, it provides a preliminary screening process to help judge the accuracy of the life-cycle-based procedure. The trip-generation tables based on life-cycle classification are tested for significance by using analysis of variance (ANOVA). Significance levels are then compared with those of trip-generation tables based on household size.

It should be noted that cross-classification tables based on income and automobile ownership are currently in favor for use in trip generation (13). Although automobile ownership is considered in the trip-generation tables (as described later in the paper), two problems preclude consideration of income here. The first is that trip-generation tables based on income require constant updating to account for inflation. The consumer price index is often used for this purpose, but an index more sensitive to changes in transportation costs may be more appropriate. The second problem is that this paper is based on data gathered in home-interview surveys, which have high nonresponse rates for income questions (more than 35 percent in both surveys used here). Consequently, no comparisons of results from life-cycle-based and income-based classifications are possible.

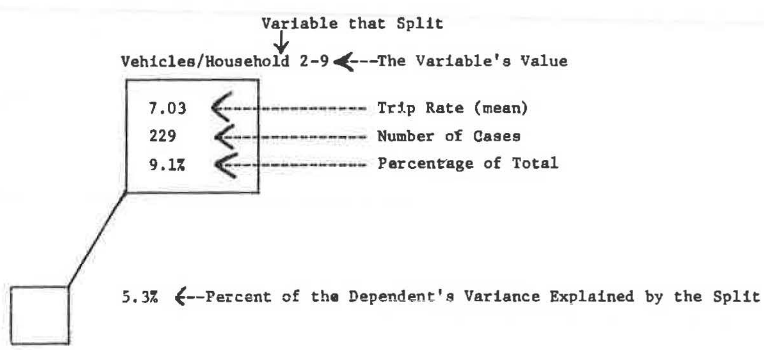
AID AND IDEAL COMPONENTS

As mentioned previously, there has been a considerable amount of research addressing the family life-cycle concept, and most researchers have found it to be an important factor in explaining travel behavior (1-9). A consensus has not yet emerged concerning the components of a family life-cycle classification scheme. In this paper potential components of a classification scheme are examined along with other demographic variables by using the AID program. AID is a sequential search procedure that divides the data set into subgroups through a number of binary splits based on the ability of the independent variables to account for the variation of a dependent variable (14). From the series of binary splits, a "tree" with various branches can be developed. In contrast to statistical methods such as multiple regression, the use of AID does not require assumptions concerning such factors as linearity.

The 1973 NFTC (Buffalo) and 1974 GTC (Rochester) travel surveys were used in the AID analysis. The analysis was done at the household level, and four dependent variables were used: total number of trips, home-based work trips, home-based nonwork trips, and non-home-based trips. Independent variables include all demographic and structural variables available or readily synthesized from the existing data. Figure 1 shows how to read an AID tree and also lists the independent variables.

Figure 2 shows the AID tree for overall trips in the NFTC region. The box in the far left is the starting point (level 0) for the AID analysis; it contains all 1,963 households that average 7.9 trips per day. The first splitting variable is vehicle ownership. The top box on level 1 represents multiple-vehicle households, and these 774 households average 11.56 trips per day. In the bottom box on level 1 are the 1,189 households with zero or one vehicle; they average 5.56 trips per day. This partitioning of the data set into two groups according to level of vehicle ownership accounts for 17.5 percent of the total variation in household trips. An additional 1 percent is accounted for by splitting the multivehicle households into two groups based on occupation of the household head. The coefficient of determination (R^2) for the entire tree is 0.401. The uppermost box in the right-hand side contains eight white collar multivehicle households with six or seven children; these households average nearly 29 daily trips. The lowest box in the tree contains 310 households with no vehicle; these households average fewer than two daily trips.

Interpreting an AID tree is more an art than a science. It certainly appears that vehicle ownership has a strong effect on travel behavior. Household size, vehicle availability, and age of oldest child each accounts for at least 2 percent of the total variation in household trips. Occupation and number of children appear less important. A complete set of



INDEPENDENT VARIABLES USED IN AID:

Age of household head	free	10 year groupings (under 25, 35-34, etc., to over 65
Age of oldest child	free	None, 1-5, 6-10, 11-15, 16-20, 21+
Employment status of head	free	Various
Presence of spouse	free	Present, not
Employment status of spouse	free	various
Number of children	Monotone	Actual number
Number in household	Monotone	Actual number
Occupation of head	free	various
Number of vehicles	Monotone	Actual number
Income	Monotone	Various groupings in data set
Vehicles per licensed driver	Monotone	Actual number
Education	Free	various
Race	free	White, black, other
Presence of relatives (other than spouse or child)	free	Present, not
Presence of non-relatives	free	Present, not
Location	free	Urban, suburban, rural

Note: Free variables may break in any fashion; monotone variables are ordered and must break following that order (i.e., a split of two children and 0-1 or ≥ 2 children is not possible). See report by Ugolik and McDesmott (14) for more details.

FIGURE 1 Directory to AID trees.

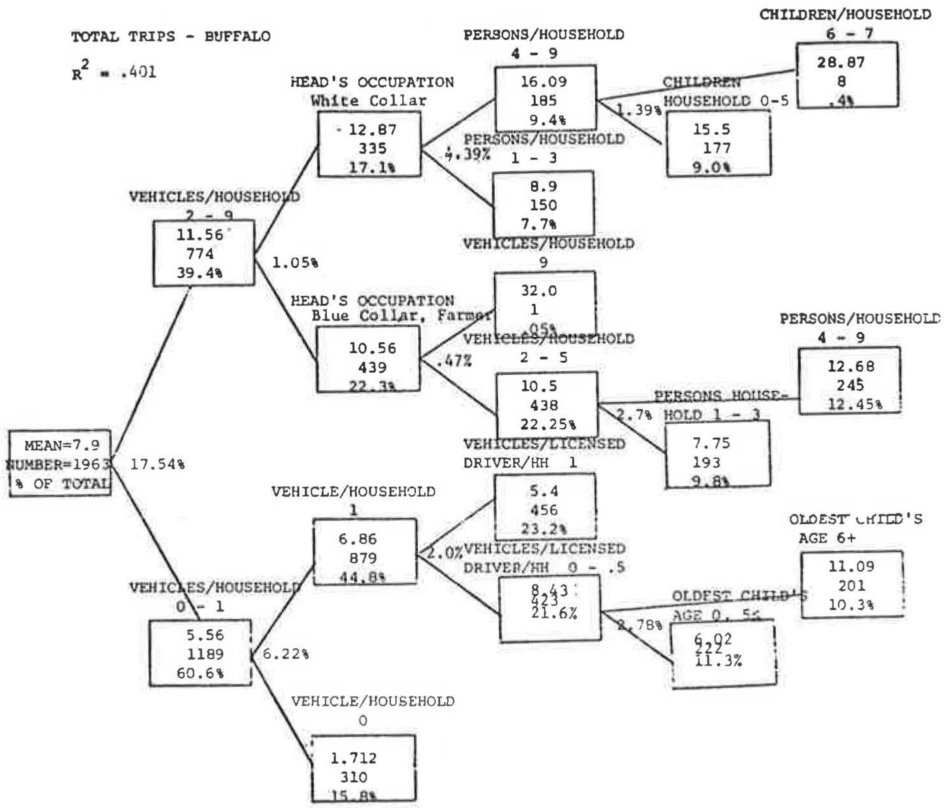


FIGURE 2 AID tree.

AID trees for both regions and for all trip purposes is contained in a report by Boyle and Chicoine (15); the results in terms of important variables are summarized in Table 1. Vehicle ownership, household size, and presence and age of children emerge from the AID analysis as important factors that affect the number of household trips. The importance of vehicle ownership indicates that it should be taken into account in developing trip-generation tables. Consequently, these will be cross-classification tables based on (a) stage in the life cycle and vehicle ownership and (b) household size and vehicle ownership. In terms of ideal components of a family life-cycle classification scheme, consideration should be given to the presence and ages of children.

CENSUS DATA AND A FAMILY LIFE-CYCLE CLASSIFICATION SCHEME

A major purpose of this paper is to develop a classification scheme using as input published tract-level census data. The availability of such data ensures the widest possible use of the scheme in trip-generation procedures. Thus published 1980 census information was examined (16) and appropriate household categories sought for use in constructing a family life-cycle classification. With the AID findings in mind, a breakdown of households by presence and ages of children was particularly sought, without particular success. Several alternate classification schemes were drawn up; details may be

TABLE 1 Important Variables by Trip Type

Trip Type	Variable	Categories Indicated by AID Analysis
All trips	Number of vehicles	0, 1, ≥2
	Vehicles per licensed driver	0-0.5, ≥1; or 0, ≥0.3
	Number of persons	0-3, ≥4
	Number of children	0-1, ≥2
	Age of oldest child	None or 1-5, ≥6
Home-based work trips	Employment status of spouse	Full-time or part-time, not employed, or no spouse
	Employment status of head	Full-time or part-time, not employed
	Age of oldest child	None or 1-20, ≥21; or none or 1-15, ≥16
	Number of persons	1-2, ≥3; or 1, ≥2
Home-based nonwork trips	Number of persons	1-3, ≥4
	Age of oldest child	11-20, none or 1-10 or ≥21; or none or 1-5, ≥6
	Vehicles per licensed driver	0, ≥0.3
	Location	Urban-rural, suburban; or urban, suburban–outer ring
Non-home-based trips	Number of vehicles	0, 1, ≥2
	Employment status of head	Full-time, part-time, or unemployed
	Employment status of spouse	Full-time, part-time, or unemployed
	Age of head	17-54, ≥55; or 17-44, ≥45
	Occupation of head	Categories unclear

found elsewhere (15). After some consideration, the following census-compatible family life-cycle classification scheme was selected:

1. Singe-person households,
2. Households of unrelated persons without children,
3. Families with children younger than 18 years old, and
4. Families without children or families with the youngest child older than 18 years old.

Census information did not include the age of the oldest child, and so the presence of children is a major component of this life-cycle classification scheme. It should be noted that this classification does not differentiate between single-parent and two-parent households. AID results indicated that the presence of a spouse is not a significant element in determining the number of household trips.

DEVELOPMENT AND ANALYSIS OF TRIP-GENERATION TABLES

Trip-generation tables are prepared by using data from the NFTC survey. Two sets of tables are developed: the first is based on stage in the life cycle and vehicle ownership, and the second is based on household size and vehicle ownership. Mean trip rate, standard deviation, and number of observations are presented in each cell. The trip-generation tables for overall trips in the NFTC region are given in Table 2. Detailed tables by trip purpose may be found elsewhere (15). Table 4, discussed later in this paper, gives trip rates for all trip purposes and for both classification schemes in both NFTC and GTC regions.

With number of household trips as the dependent variable, a two-way ANOVA was run by using vehicle ownership and either the life-cycle or the household-size classification as the two independent variables. Because examination of the data indicated unequal variances, the Welch statistic was used to determine F-values and tail probabilities. The Welch statistic was chosen because it is approximately distributed as an F-statistic and does not assume equality of variances (17,18). Although tail possibilities are directly comparable, F-values are not because their level of significance is based on the degrees of freedom. Therefore, F-values resulting from the ANOVAs are examined in general terms.

The data in Table 2 also give the results of the ANOVAs. For overall household trips, the F-values are comparable, although slightly higher for the family-size-based classification. Standard deviations are similar for both schemes. These findings also apply to other trip types [see Table 4 and the report by Ugolik and McDermott (15)]. There is no indication that a significant improvement is obtained by use of one scheme instead of the other. Thus either classification scheme may be considered valid as an analytical tool for use in examining differences in travel behavior.

APPLICATION OF TRIP RATES TO GTC REGION

Another method of comparing the two classification

TABLE 2 Trip Rates, All Trips, NFTC

Life Cycle Stage		Vehicle Ownership 0	1	2	3+	Household Size	Vehicle Ownership 0	1	2	3
1	$\bar{x}$	0.9	3.3	3.3	3.0	1	0.9	3.3	3.3	3.0
	s	1.4	2.5	2.5	—		1.4	2.5	2.5	--
	n	144	105	6	1		144	105	6	1
2	$\bar{x}$	2.2	5.2	8.1	18.6	2	1.4	4.9	6.9	8.2
	s	2.5	5.1	5.7	10.6		2.1	4.2	3.7	5.4
	n	17	16	16	5		82	315	136	13
3	$\bar{x}$	3.6	9.4	13.0	16.0	3	3.3	7.4	9.1	10.6
	s	4.1	6.9	7.8	7.8		2.6	5.4	5.4	5.5
	n	69	396	359	81		35	151	144	43
4	$\bar{x}$	1.4	5.2	8.3	10.8	4+	3.4	9.8	13.8	15.4
	s	2.1	4.1	5.1	5.3		4.6	7.1	7.8	7.5
	n	79	362	228	78		48	308	323	108

Welch Statistic:			Welch Statistic:		
	F-Value	137.46		F-Value	146.65
	Tail Probability	0.0000		Tail Probability	0.0000
	Degrees of Freedom	14,105		Degrees of Freedom	14,182

$\bar{x}$ = mean trip rate
s = the standard deviation of the mean rate
n = number of households

Life Cycle Stages
(1) Single person households
(2) Households of unrelated persons without children
(3) Families with children under 16 years old
(4) Families with no children or with youngest child at least 18 years old

schemes is to apply each to a different data set and compare the results. The data set from the GTC home-interview survey was used to do this. The number of GTC households in each cell is given in Table 3. Trip rates from Table 2 were applied to these household distributions, and the resulting numbers of trips in all cells were summed to obtain total calculated GTC trips for each classification scheme. These are compared with the actual number of GTC trips:

1. Actual number of GTC trips (sample only) = 18,920;
2. Calculated number of GTC trips using life-cycle-based method = 18,739; and
3. Calculated number of GTC trips using household-size-based method = 18,246.

Although one application certainly is not conclusive, it is interesting that use of the life-cycle-based trip table produced a total number of trips within 1 percent of the actual number, whereas use of the household-size-based trip table produced a total number of trips 3.5 percent less than the actual number.

TABLE 3 Distribution of GTC Households by Cell

	Vehicle Ownership			
	0	1	2	≥3
Stage in life cycle				
1	281	259	18	2
2	32	36	38	12
3	126	365	474	119
4	81	341	245	84
Household size				
1	281	259	18	2
2	118	347	194	23
3	46	123	170	48
≥4	75	272	393	144

Note: Life-cycle stages are 1 = single-person households, 2 = households of unrelated persons without children, 3 = families with children younger than 18 years old, and 4 = families with no children or with youngest child at least 18 years old. Total number of GTC households = 2,513.

COMPARISON OF NFTC AND GTC TRIP RATES

The final test of the life-cycle-based trip-generation tables also concerns their applicability to other areas. If the trip rates could be applied to several different data sets where the actual number of trips is known, this would indicate whether use of these trip rates produced consistently accurate results. Because only one other data set is used here, variations in household distribution among cells may mask differences in trip rates. A better way of testing the accuracy of the trip-generation tables is to derive a set of tables from the GTC data and compare the trip rates in each cell between the two regions. This can serve as a preliminary test of whether the life-cycle-based trip rates are replicable. For this test, all trip types are considered [see report by Ugolik and McDermott (15) for detailed data].

The data in Table 4 present the trip-generation tables by classification scheme, by region, and by type of trip. For the life-cycle-based tables, trip rates in each cell were examined for differences between the two regions. Those cells with greater than a 10 percent difference were tested to determine whether the difference was statistically significant. Only 6 cells (out of 52) were found to have trip rates different at a significance level of 0.05 in the two regions:

1. Total trips, stage 1 (single person), no vehicle;
2. Total trips, stage 4 (families without children), no vehicle;
3. Home-based nonwork trips, stage 1 (single person), one vehicle;
4. Home-based work trips, stage 3 (families with children), no vehicle;
5. Home-based work trips, stage 4 (families without children), no vehicle (trip rates also different at a significance level of 0.01); and
6. Non-home-based trips, stage 4 (families without children), three or more vehicles.

The NFTC trip rates are generally replicable using GTC data. Although the results cannot be used to proclaim the replicability of the life-cycle-based trip rates, these preliminary indications are promising.

Related to the concerns of accuracy and replicability is the issue of the stability of trip rates over time. One study of differences between the results of home-interview surveys conducted in the NFTC region (1962 and 1973), and the GTC region (1963 and 1974) indicates that trip rates tend to be stable over time, at least for an 11-year period (19). The question of the stability of trip rates in the post-energy-crises era remains to be answered.

TRAVEL PROJECTIONS: ALBANY COUNTY

An interesting application of the life-cycle-based trip-generation procedure was carried out by using town-level data in Albany County. Projections of 1990 town households, broken down by life-cycle stage, were made by using 1970 and 1980 data and previous New York State Department of Transportation forecasts (20). The life-cycle-based trip-generation procedure was then used to forecast the number of trips generated in 1990 in each town under two scenarios. The first scenario held the number of households in each town constant at the 1980 level, thus measuring solely the effects of changes in household structure. The second scenario allowed the number of households to grow to the levels forecast for each town, thus measuring the actual number of trips expected in 1990. Results indicate that the number of trips shows an 11 percent increase in 1990 over 1980, with a 13 percent growth in number of households. When the number of households is held constant, changes in household structure produce a 2.3 percent decrease in the number of trips in 1990 compared with 1980. These results suggest that, if present trends continue, changes in household structure will dampen the increase in travel expected with an increase in number of households.

CONCLUSIONS

The concept of family life cycle has been used to construct trip-generation tables based on a life-cycle classification scheme developed in this paper. The stages in the classification scheme are developed in such a way as to require only published tract-level census data as input. Important components of a life-cycle classification scheme were not assumed a priori, but were determined through use of the AID program. Results from AID were evaluated in light of available census information, leading to a scheme in which the presence of children is emphasized more than ages of children. By designing life-cycle stages to be compatible with census categories, the practical usefulness of these life-cycle-based trip-generation tables has been ensured.

TABLE 4 Trip Rates

LIFE CYCLE CLASSIFICATION	Buffalo (1973) 0	1	2	3+	Rochester (1974) 0	1	2	3+
TOTAL TRIPS (Vehicles/Household)								
Life cycle 1	.9	3.3	-	-	1.1	3.2	5.3*	-
Life cycle 2	2.2*	5.2*	8.1*	-	3.0	7.6	9.1	14.8*
Life cycle 3	3.6	9.4	13.0	16.0	2.8	9.2	13.0	16.5
Life cycle 4	1.4	5.2	8.3	10.8	2.2	5.6	7.6	11.6
ANOVA WELCH STATISTIC F-VALUE	137.46				144.97			
TAIL-PROBABILITY	0.0000				0.0000			
HOME-BASED NON-WORK TRIPS								
1	.5	1.6	-	-	.6	1.3	2.8*	-
2	1.1*	2.1*	3.7*	-	1.5	3.7	4.7	6.4*
3	1.9	5.7	7.9	9.2	1.8	5.6	7.9	10.1
4	.9	2.9	4.0	5.2	1.1	3.0	3.6	4.6
ANOVA WELCH STATISTIC F-VALUE	90.05				96.33			
TAIL-PROBABILITY	0.0000				0.0000			
HOME-BASED WORK TRIPS								
1	.3	.8	-	-	.4	.9	.8*	-
2	.7*	1.9*	2.0*	-	.9	2.3	2.2	4.2*
3	1.2	1.8	2.4	3.7	.8	1.9	2.5	3.3
4	.5	1.3	2.4	3.3	.9	1.4	2.4	3.8
ANOVA WELCH STATISTIC F-VALUE	72.35				73.08			
TAIL-PROBABILITY	0.0000				0.0000			
NON-HOME BASED TRIPS								
1	.2	.9	-	-	.2	1.0	1.8*	-
2	.4*	1.4*	2.5*	-	.5	1.8	2.2	4.3*
3	.6	2.0	2.7	3.3	.2	1.7	2.7	3.2
4	.1	1.0	2.0	2.3	.2	1.2	1.7	3.3
ANOVA WELCH STATISTIC F-VALUE	37.90				37.02			
TAIL-PROBABILITY	0.0000				0.0000			

FAMILY SIZE CLASSIFICATION	Buffalo (1973) 0	1	2	3+	Rochester (1974) 0	1	2	3+
TOTAL TRIPS (Vehicles/Household)								
Family size 1	.9	3.3	-	-	1.1	3.2	5.3*	-
Family size 2	1.4	4.9	6.9	8.2*	2.0	5.5	6.8	8.9*
Family size 3	3.3	7.4	9.1	10.6	3.0	7.2	9.6	10.6
Family size 4+	3.4	9.8	13.8	15.4	3.4	10.1	13.8	16.7
ANOVA WELCH STATISTIC F-VALUE	146.65				156.63			
TAIL-PROBABILITY	0.0000				0.0000			
HOME-BASED NON-WORK TRIPS								
1	.5	1.6	-	-	.6	1.3	2.8*	-
2	.9	2.8	2.9	3.8*	1.0	2.9	3.0	3.2*
3	1.8	3.9	5.2	5.3	1.6	3.9	4.9	4.8
4+	1.6	6.1	8.3	8.6	2.4	6.3	8.5	9.5
ANOVA WELCH STATISTIC F-VALUE	95.12				101.95			
TAIL-PROBABILITY	0.0000				0.0000			
HOME-BASED WORK TRIPS								
1	.3	.8	-	-	.4	.9	.8*	-
2	.4	1.1	2.2	2.8*	.8	1.4	2.1	2.7*
3	1.4	1.8	2.0	2.7	1.1	1.7	2.6	3.3
4+	1.1	1.9	2.6	3.9	.8	2.0	2.6	3.8
ANOVA WELCH STATISTIC F-VALUE	80.47				75.21			
TAIL-PROBABILITY	0.0000				0.0000			
NON-HOME BASED TRIPS								
1	.2	.9	-	-	.2	1.0	1.8*	-
2	.2	1.1	1.8	1.7*	.2	1.2	1.7	3.1*
3	.1	1.8	2.0	2.7	.4	1.6	2.1	2.8
4+	.8	1.9	2.9	3.0	.2	1.8	2.7	3.5
ANOVA WELCH STATISTIC F-VALUE	39.60				36.33			
TAIL-PROBABILITY	0.0000				0.0000			

- = Empty cells or cell count very small (under 10)

* = Cell Size ≤ 30

Life Cycle Stages

(1) Single person households
(2) Non-related person households without children
(3) Families with children under 18 years old
(4) Families with no children or families with youngest child over 18 years old

The explanatory power, accuracy, and replicability of the life-cycle-based trip-generation tables were tested by various means. ANOVA showed that the life-cycle-based scheme is comparable in terms of F-values to a scheme based on household size (with vehicle ownership being a second independent variable for both schemes). When applied to data from the GTC region, the life-cycle-based trip-generation table produced a more accurate number of total trips than did the household-size-based trip-generation table. Life-cycle-based trip rates were also shown to be replicable using GTC data.

The advantage of a life-cycle-based trip-generation procedure over regression models lies in its simplicity and its ability to handle non-numeric values. It is preferable to a procedure based on family size because it explicitly addresses family structure and thus takes intrahousehold interactions into account. Finally, a life-cycle-based procedure uses readily available data; an income-based procedure is vulnerable to high nonresponse rates if a noncensus data source is used, and such a scheme must be constantly adjusted to account for the effects of inflation.

It is anticipated that critiques of this paper will focus on the difficulty in forecasting household structure, the usefulness of the census tract as the basic areal unit for travel analysis, and the justification for changing established trip-generation procedures. Each of these points deserves to be addressed. First, the question of the pattern of family structure in the future needs further investigation and cooperation with demographers and sociologists so that accurate means to forecast household structure can be developed or put into more widespread use. Related to this, the sensitivity of the life-cycle-based procedure to the projections of future household and family structure needs to be investigated. Second, as noted previously, use of the census tract as the basic areal unit of analysis ensures the availability of the necessary data.

Finally, although it has been demonstrated in this paper that use of the family life-cycle concept in trip generation is practical and produces accurate results, the main justification for this procedure is based on theoretical considerations. The premise behind this investigation is that the family life-cycle concept holds the potential to improve the trip-generation process by increasing its sensitivity to household structure. Consequently, this analytical tool should improve the ability of the transportation analyst to account directly for underlying factors that influence travel behavior.

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