Development of a Travel-Demand Model Set for the New Orleans Region

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A complete set of travel-demand models was calibrated for the New Orleans region by using the 1960 origin-destination survey. The general form of the model set was sequential, with care being taken to include transportation system characteristics in all submodels of the modeling set. Other unique features of the model set were that (a) all submodels were stratified by income quartiles; (b) the distribution model used a composite impedance that combined travel time and costs for all modes, (c) the generation model used accessibility and locational measures, and (d) the exogenous input data, required in forecasting, were limited to six data items. The calibrated models were applied to 1980 conditions, and the resulting travel estimates were compared with ground counts. This comparison indicated that the model set could produce reasonably accurate 20-year forecasts.

In 1980 the New Orleans Regional Planning Commission (RPC) decided to update its travel-demand modeling procedures to support ongoing transportation planning in the New Orleans region. A previous set of models was developed in 1972. A review of these models indicated a number of deficiencies that made them inappropriate for the current planning environment, especially with respect to the modeling of substantial new transit service and high-occupancy vehicle (HOV) incentives.

Because of limited resources available for this model update, it was necessary to use an existing home interview survey, which was taken in 1960, rather than to conduct a limited new origin-destination survey. A conservative estimate of the cost of a limited survey indicated that more than a third of the available resources would be required to conduct this survey. It was also observed that a set of models based on the 1960 survey would allow the study team to immediately make a 20-year forecast, i.e., to 1980, which could be validated by using existing ground counts.

It was judged that the available resources were sufficient to develop a set of sophisticated models that could be applied by using the standard transportation planning computer programs. An initial decision was made that the model set would be implemented by using the Urban Transportation Planning System (UTPS) developed by UMTA and FHWA. Another initial decision was that the general model structure would be the sequential model form (generation, distribution, mode choice). It was believed that this model structure gave the best assurance of successfully calibrating the model set within the resources available, and that by proper specification most of the shortcomings of a sequential model structure could be overcome or minimized.

In this paper the general philosophy and structure of the New Orleans travel-demand model set are described, and the results of applying this model set to the 1980 conditions are presented.

MODEL STRUCTURE AND PHILOSOPHY

The goals of the New Orleans travel-demand model update were to develop a model set that would include transportation system characteristics for all major travel functions, would be reasonably easy to apply in the forecast mode, and would require a minimal amount of exogenous data in the forecast mode. The goal of incorporating transportation system characteristics into all major travel function submodels (i.e., generation, distribution, and mode choice) is a fairly standard objective for a travel-demand set, but in many cases the goal is not realized. The ease-of-application goal is reasonable and obvious, but there are many urban area model sets that require extremely large amounts of computer resources and person hours to implement.

In many ways the goal of minimizing exogenous input data is the key to producing logical forecasts with a reasonable amount of resources. Model sets that require extremely detailed exogenous data simply shift the possibility for errors to other modeling efforts, impose a large expenditure of resources on other planning groups, and contribute to the phenomenon of adjusting the data so that the answer is correct. It was the objective of this study to constrain the exogenous input data to elements that are normally forecasted and can be evaluated for reasonableness by using other forecasts or by using standard reasonableness checks.

The stated goals for the New Orleans travel-demand model update led to the establishment of the following objectives:

1. The trip-generation element of the model set should include not only socioeconomic and land use data, but it should also include locational measures that describe the transportation system and the urban form of the area;
2. The distribution element of the model set should incorporate all relevant transportation system characteristics for all modes of travel;
3. The modal-choice element of the model set should be properly sensitive to transportation system characteristics, socioeconomic measures, and land use form, and the model should be applicable to planned HOV incentives;
4. All elements of the model set should be stratified by a socioeconomic characteristic that measures the wealth of the traveler;
5. The model set should require a minimal amount of exogenous data in the forecast mode, and this data should lend itself to reasonableness checks; and
6. The procedures for forecasting with the model set should use straightforward computer programs, either UTPS programs or programs compatible with the UTPS system, and these programs should be relatively easy and inexpensive to apply.

There are two general types of model forms that meet the first three objectives and that have been developed in other urban areas: direct-demand models and sequential models. The direct-demand structure is theoretically the better structure for including transportation system characteristics in all elements of the model set. For this study, though, it was believed that the resources required to calibrate a direct-demand model set would probably exceed the project's budget, and that a sequential structure could be developed to meet all the objectives. In addition, the sequential structure allowed the project to have a fallback position in the event that the initial model specifications were impossible to implement within the budget constraints (the fallback position being the standard sequential model specification).

The objective to stratify all the model elements--generation, distribution, and mode choice--by a socioeconomic characteristic that measures wealth is not a unique proposal. Most trip-generation production models use this type of stratification, and many modal-choice models also have a stratification based on wealth. The deficiency with most of these model sets is that the distribution model is not stratified by the wealth measure, and therefore there is no connectivity among the submodels with respect to the wealth measure. By performing a complete stratification by the wealth measure, the model set would have complete connectivity with respect to this measure. That is, low-wealth trip ends would be distributed by using a low-wealth impedance measure, and these person trips could then be allocated to each mode by using a low-wealth modal-choice formulation. The development of a distribution model stratified by a measure of wealth presented no theoretical or practical problems. The major impediment in the development of a fully stratified set of travel-demand models was the development of a stratified trip-generation attraction model. It was hypothesized at the beginning of the project, though, that a wealth-stratified attraction model could be developed if proper attention was given to locational variables.

The last two objectives--minimal data input and ease in application--were essential if the model set was to be frequently used in the forecasting mode. Model sets that require extremely large resources, both in person hours and computer costs, have little usefulness, regardless of their level of accuracy, because most planning organizations have constrained resources and tend to implement these expensive model sets only once every 2 or 3 years. It should be the intent of all organizations developing travel-demand models that these models can be reasonably used at least three or four times a year.

In summary, the philosophy for developing the New Orleans travel-demand model set was to (a) develop a sequential set of models completely stratified by a measure of wealth, (b) have transportation system characteristics present in each submodel, and (c) require a minimal amount of exogenous input data. Locational measures were anticipated to be significant variables in the trip-generation model, and measures representing time and cost for all modes were to be explored as independent variables for the distribution model. Care was to be taken in the development of the models to ensure a resource-efficient application methodology.

MODEL DEVELOPMENT

The final New Orleans travel-demand model set consisted of three major models--generation, distribution, and mode choice--and six auxiliary models. The study team was able to develop a model set by using only six socioeconomic and land use data items along with the normal set of transportation system data items. The following list gives a summary of the exogenous data input items:

1. Socioeconomic and land use data (at the zone level)--population, households, retail employment, nonretail employment, area of zone, and mean zonal household income;
2. Highway system data (link specific)--distance, facility type, number of lanes, and toll; and
3. Transit system data--distance (link specific), facility type (link specific), travel time for nonlocal route links, headway (route specific), and fares (interchange specific).

The use of population and households to estimate travel demand is normal. The study team would have preferred to use a more detailed classification for employment than retail and nonretail, but the base year data did not allow any finer stratification. Traffic analysis zones were used to calculate gross density measures, such as employment per acre. The mean household income of a zone was chosen as the only exogenous socioeconomic variable and was primarily used to estimate the number of households in each income quartile by zone. The project team considered whether to use income or automobile ownership as the primary socioeconomic variable. Although automobile ownership appears to have a greater effect on tripmaking and mode choice than income, automobile ownership was not chosen for the following reasons.

1. There are many variables that influence automobile ownership. Some of the obvious variables are household income, the availability and magnitude of the transit system, the structure of the city in terms of density, and general economic conditions. The use of automobile ownership as a variable would require a fairly detailed forecasting model (including the use of an income measure), which was considered to be a difficult model to calibrate.
2. There are a considerable number of independent forecasts of national and regional income levels that can be used to evaluate the income estimates used in the forecasts.
3. A recent study (1) has indicated that household trip rates are declining over time for a given level of automobile ownership. In some cases the decline is more than 30 percent in a 10-year period. This lack of temporal stability suggests that automobile ownership and trip generation may not be as firmly related as previous studies indicated.

Because the model set requires only six socioeconomic and land use data items, the effort required to develop forecasts should be minimized, thereby allowing for a more rigorous assessment of the input data.

The specification of minimal exogenous data means that this model set had to include a set of auxiliary models that would estimate values of variables that in other model sets are simply specified as required data inputs. A summary of these auxiliary models is given in Table 1. The data developed from these models include parking cost, highway terminal time, an area-type classification, the stratification of households by income quartile and family size, and network speeds. Perhaps the most important auxiliary model was the procedure to stratify zonal households by family size and income quartile. This model was calibrated by using data from the 1960 origin-destination study and the 1960 census; the model consisted of a set of stratified curves and a procedure to ensure that the regional household and population totals were balanced. The area-type model classified zones into five urban area types: central business district (CBD), CBD fringe, urban residential, suburban residential, and exurban. The technique used to assign area types to zones was developed with the aid of discriminant analysis (2) and a standard statistical computer software package (3). These area types were used in developing highway and transit link speeds. The auxiliary models also contained procedures to estimate both highway and transit link speeds. The highway network used the UTPS program UROAD speed-capacity tables, which allowed the user to specify highway speeds by area type and highway facility type. Transit speeds were developed similarly, in that local transit speeds were a function of area type and the highway facil-

Table 1. Summary of auxiliary models.

Model	Measures Estimated	Independent Variables	Estimated Measures Are Used in
Parking cost model	Daily and hourly parking cost	Employment density	Modal-choice model
Highway terminal time model	Production and attraction terminal times	Employment and population density	Modal-choice model
Area-type model	Stratification of zones into five types of areas	Employment and population density	Highway and transit speed models
Income and family size stratification model	Stratification for each zone of households by income quartile and family size	Households, population, and mean household income	Trip-generation model
Transit speed model	Peak and off-peak transit speeds for local transit routes	Area type and highway facility type	Preparation of transit networks and travel times
Highway speed model	Off-peak highway speeds	Area type and highway facility type	Preparation of highway networks and travel times

ity type. A special program was required to implement this model.

The trip-generation models were calibrated by using a combination of cross-classification analysis and regression analysis. The normal socioeconomic and land use data were used in the model, but accessibility and locational variables were also found to be significant. The accessibility measures were defined as the number of jobs or households within a given highway or transit travel time. The locational variable used was the number of jobs or households within 0.75 mile. This was interpreted as a measure of the potential of a traveler to use a nonmotorized mode, i.e., walk. Obviously, as the potential for using a nonmotorized mode is increased, the probability for using a motorized mode should decrease. It was found that for almost all of the trip-generation submodes, this locational variable had to be included in the model to obtain logical coefficients on the accessibility measures. It was also found that the accessibility and locational measures were essential in estimating attractions by income level.

A detailed description of the trip-generation model would be too long for this paper, but a short description of the final home-based work trip equations will illustrate the use of the locational and accessibility measures. The home-based work production equations are given in Table 2. There are five linear equations, one for each household size group; each contains a constant, three income quartile dummy variables, and three locational variables. The constant and dummy variables are analogous to a cross-classification model with family size and income quartiles being the independent variables. The locational variables are (a) the number of jobs (employees) within walking distance of the household, with the walking distance being defined as 0.75 mile; (b) the percentage of all jobs within 30 min of highway driving time; and (c) the percentage of all jobs within 25 min of transit travel time. The walk potential measure (i.e., employees within walking distance) will reduce the number of motorized trips as the number of employees increase, whereas the two accessibility measures will show an increase in the trip rate as the accessibility increases.

Point elasticities were calculated for each of the three locational variables for each strata of household size and income. Although these elasticities varied for each strata, in general the walk potential variable and the transit accessibility measure had the same elasticity (with, of course, opposite signs), whereas the highway accessibility elasticity was approximately 3 times as large as the other two elasticities.

To estimate home-based work attractions by income quartile, it was first necessary to estimate the employment by income quartile. The equations for estimating this employment are as follows (note that in application, estimated employees by income are normalized to total employment):

$$\text{ESTIEMP}(1) = \text{TOTEMP} \times 0.09562 + 0.025532[\text{DURAT}(1)] + 0.046435[\text{ACRAT3}(1)] \quad (1)$$

$$\text{ESTIEMP}(2) = \text{TOTEMP} \times 0.19560 + 0.021294[\text{DURAT}(2)] + 0.056881[\text{ACRAT1}(2)] \quad (2)$$

$$\text{ESTIEMP}(3) = \text{TOTEMP} \times 0.25138 + 0.073811[\text{DURAT}(3)] - 0.028823(\text{DURAT}) + 0.052197[\text{ACRAT1}(3)] \quad (3)$$

$$\text{ESTIEMP}(4) = \text{TOTEMP} \times 0.21657 - 0.004334(\text{DURAT}) + 0.042297[\text{ACRAT4}(4)] \quad (4)$$

where

ESTIEMP(i) = estimate of income i employees;
TOTEMP = total zonal employment (mean = 881.15);
DURAT(i) = ratio of income i dwelling units within 0.75 mile to employment

Table 2. Home-based work production equations.

Family Size	Constant	Income Dummy Variables[a] 1	2	3	EMPWK2[b]	PHWYACC3[c]	PTRNACC1[d]
1	0.1215	-0.20750	0.01960	-0.07919	-0.000001949	0.0040951	0.0038508
2	1.2614	-0.73882	-0.23995	-0.03878	-0.000012201	0.0040951	0.0038508
3	1.8393	-1.07462	-0.45938	-0.24010	-0.000019252	0.0040951	0.0038508
4	1.7926	-0.94112	-0.25897	-0.16738	-0.000012401	0.0040951	0.0038508
≥5	1.9193	-0.87939	-0.50307	-0.24072	-0.000014707	0.0040951	0.0038508

[a] Income dummy variables are defined as follows: 1 = lowest income quartile, 2 = medium-low income quartile, and 3 = medium-high income quartile.
[b] EMPWK2 = employees within 0.75 mile (mean = 5962.2).
[c] PHWYACC3 = percentage of regional employment within 30-min peak highway time (mean = 92.77).
[d] PTRNACC1 = percentage of regional employment within 25-min peak transit time (mean = 22.38).

within 0.75 mile (weighted means: income 1 = 0.2172, income 2 = 0.2077, income 3 = 0.1932);

DURAT = ratio of dwelling units within 0.75 mile to employment within 0.75 mile (weighted mean = 0.8082);

ACRAT1(i) = ratio of percentage of income i dwelling units within 25-min peak-hour transit time to percentage of all dwelling units within 25-min peak-hour transit time (weighted means: income 2 = 1.0449, income 3 = 0.9113);

ACRAT3(i) = same as ACRAT1(i), except for 35-min peak-hour transit time (weighted mean for income 1 = 1.1253); and

ACRAT4(i) = same as ACRAT1(i), except for 40-min peak hour transit time (weighted mean for income 4 = 0.9273).

These equations use two types of locational variables: (a) the ratio of dwelling units within walking distance (0.75 mile) to the number of employees within walking distance, and (b) the ratio of one income strata of household to all households within a given transit travel time range. These independent variables are relative variables in that they describe the mix of land use rather than the absolute value of the land use. The walk potential variable--the ratio of dwelling units to employees within walking distance--describes the mix of residential units and employment within a given area. For the lower income categories, the employment for these categories increases as the number of households in these categories increases, whereas for the highest income quartile the employment will decrease for this category when the number of total households increases. In other words, the model is showing that there is a relationship between low-income employment and low-income households, but the high-income employment tends to be in areas with little or no residential units. The accessibility variable--the ratio of one income strata of households to all households for a given transit travel time range--is always positive; that is, as the number of households for a given income group increases, the number of employees for the same income group increases.

When the number of employees for each income quartile is known, estimating home-based work attractions by income quartile is fairly simple. The equations for this model are as follows:

$$\mathrm{ESTATR}(1) = \mathrm{EMP}(1) \times \left\{1.3279 - 2.6367 \times 10^{-6} [\mathrm{DUWLK}(1)]\right\} \quad (5)$$

$$\mathrm{ESTATR}(2) = \mathrm{EMP}(2) \times \left\{1.3463 - 1.4483 \times 10^{-5} [\mathrm{DUWLK}(2)]\right\} \quad (6)$$

$$\mathrm{ESTATR}(3) = \mathrm{EMP}(3) \times \left\{1.3419 - 5.8307 \times 10^{-6} [\mathrm{DUWLK}(3)]\right\} \quad (7)$$

$$\mathrm{ESTATR}(4) = \mathrm{EMP}(4) \times \left\{1.3573 - 1.7085 \times 10^{-5} [\mathrm{DUWLK}(4)]\right\} \quad (8)$$

where

ESTATR(i) = estimated work attractions by income i employees,

EMP(i) = number of income i employees (weighted means: income 1 = 132.59, income 2 = 225.14, income 3 = 254.20, income 4 = 269.22), and

DUWLK(i) = number of income i dwelling units within 0.75 mile (weighted means: income 1 = 2604.3, income 2 = 1140.7, income 3 = 1075.6, income 4 = 1122.5).

This model is a set of linear equations that contains a constant and a locational variable--percentage of dwelling units within walking distance. The constant can be considered the average number of attractions per employee if no households are within walking distance. The locational variable has the correct sign, in that, as the number of households increases, the number of motorized work attractions decreases, but it does not contribute significantly to the trip rate; at the mean, the change in the trip rate is less than 2 percent.

The distribution model was specified as a normal gravity model. Attempts were made to use the modal-choice model equations to calculate a composite impedance by combining travel times and costs for all modes. This attempt was extremely successful for the home-based work trips, but it was not completely successful for other trip purposes. Highway travel time was thus used as the impedance measure for these other purposes. All the distribution models were stratified by income quartiles, and it was found that the low-income travelers were less sensitive to the impedance measure than were the high-income travelers. The modal-choice model was a multinomial logit model that used three modes: transit, drive alone, and group automobile. A submodel was used to split the group mode into integer automobile occupancies (two persons per automobile, three persons per automobile, and so forth). The initial modal-choice model was calibrated on a disaggregate level by using the UTPS program ULOGIT and then validated at the aggregate level. The use of integer automobile occupancies allowed the application methodology to be configured in a manner that would allow HOV incentives to be explicitly considered.

Because of the model specification, the normal forecasting procedure sequence (i.e., generation, distribution, and mode choice) was not applicable. For the New Orleans model set, the modal-choice model must be applied before distribution in order to generate the composite impedances; the general flow of the model application is shown in Figure 1. The modal probabilities, generated by the modal-choice model, can be saved and used to split the person trip distribution or, if computer time is less costly than storage, the modal-choice model can be applied again after the distribution model. Although the entire model set is fairly intricate, it does not use excessive computer resources. The central processing unit (CPU) time for the entire chain (468 traffic analysis zones) is approximately 1.5 hr on an IBM system 370 model 158.

In summary, the New Orleans travel-demand models were developed within the framework of the goals and objectives specified for the model set. The developed models are unique in that all models are stratified by income quartiles, the generation model includes accessibility and locational measures, and the home-based work distribution model uses a composite impedance measure. The goal of using transportation system characteristics in all major submodels was essentially met, although the inability to use the composite impedance measures for the nonwork trip-distribution models was somewhat disappointing. The development of six auxiliary models minimized the number of exogenous data items required for the model set, thereby reducing the effort required to apply the models and maximizing the objectivity of the forecasts.

MODEL APPLICATION RESULTS

A practical advantage of calibrating a travel-demand model set by using an old origin-destination survey was that the first forecast could use data for the present year and this forecast could be validated by using ground counts and other data sources. The New Orleans model set, which was calibrated by using the 1960 origin-destination survey, was applied for the year 1980. The resulting estimates compared quite favorably with actual ground counts and preliminary census data.

The comparison of the 1980 estimated data with observed data is given in Table 3. The number of households and the population for 1980 had been estimated before the publication of the preliminary 1980 census data, and these estimates appear to be slightly low (approximately 5 percent for households and 1 percent for population).

The Louisiana Department of Transportation and Development developed a 1978 estimate of daily vehicle miles of travel (VMT) primarily from ground counts, and this estimate is approximately 5 percent higher than the model estimates. The model overestimated transit trips by approximately 3 percent. These rather gross comparisons indicate that the model set was able to forecast trips for a 20-year time period with a reasonable degree of accuracy,

Figure 1. General model application flow diagram.

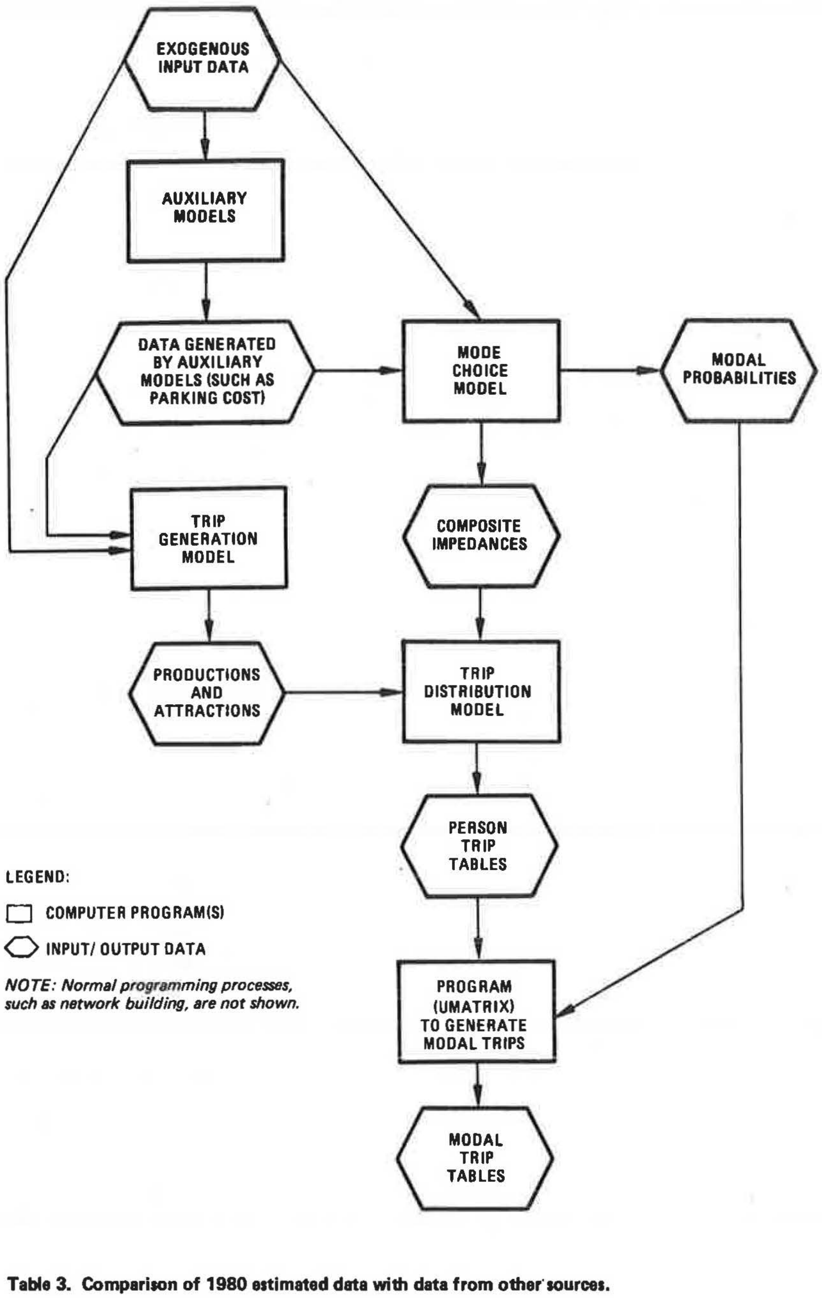

Table 3. Comparison of 1980 estimated data with data from other sources.

Item	Estimate	Data from Other Sources	Percentage Difference	Sources
Households	365,182	385,351	-5.2	Preliminary 1980 census
Population	1,064,876	1,076,171	-1.1	Preliminary 1980 census
Daily vehicle miles of travel (VMT)	7,922,045	8,325,000	-5.1	1978 estimate by Louisiana Department of Transportation and Development
Transit trips (not including school trips)	197,577	191,542	+3.1	Office of Transit Administration, city of New Orleans

although there is some indication that VMT may be slightly underestimated.

In the past 20 years there has been a significant change in travel patterns in most urban areas. The data in Table 4 present some travel measures indicative of these changes. The estimated increase in travel per person is approximately 16 percent, whereas the average trip length has increased by more than 20 percent. More significantly, the average VMT per person is estimated to have increased by approximately 100 percent during the past 20 years.

Table 4. Comparison of 1960 data with 1980 estimates.

Item	1960	1980	Percentage Change
Person trips per person	1.41	1.63	+15.6
Person trips per household	4.62	4.75	+2.6
Avg trip length (minutes of highway time)	8.44	10.36	+22.7
Daily VMT per person	3.71	7.44	+100.5
Percentage transit (total)	25.43	12.53	-50.7
Percentage transit (CBD)	54.14	36.71	-32.2
Vehicle occupancy (total)	1.477	1.480	+0.2
Vehicle occupancy (CBD)	1.487	1.365	-8.0

This growth, which represents approximately a 3.5 percent per year increase, was so substantial that growth rates from other urban areas were obtained to ascertain the reasonableness of this increase. The annual growth rate of VMT per person for the Virginia suburbs of Washington, D.C. (the counties of Arlington, Fairfax, and Prince William) was determined to be approximately 2.3 percent per year between 1968 and 1978 (4,5). This increase is not quite as large as the forecasted New Orleans increase, but it is in the same range. Transit ridership as a proportion of the total travel market decreased significantly between 1960 and 1980. The percentage of transit for the region decreased by 50 percent, whereas the percentage of transit to the CBD decreased by more than 30 percent. The model estimated only minor changes in vehicle occupancy, which was unexpected. Higher gasoline and parking costs probably account for the stable vehicle occupancies, in spite of rising incomes.

Vehicle assignments were compared with ground counts for five screen lines. In all cases the assignment volumes were lower than the ground counts. This occurred, in part, because highway assignments cannot always replicate double screen-line crossings and short (intrazonal) trips; the 1960 survey data revealed a 10 percent difference in assignment versus ground counts for one of these screen lines. The available ground counts were also simple tube counts, with no correction factor for multiaxle vehicles. The study team identified a range of errors that could be associated with the ground counts and the computer assignments, and two sets of error corrections were prepared. The ratio of assignments to ground counts for five screen lines, with the two error ranges, is given in Table 5. Perhaps the significant element of the screen-line comparisons is that the ratio of assigned volumes to ground counts are similar, which indicates that the model set estimated the distribution of travel correctly.

In summary, the New Orleans model set, calibrated on 1960 data, was used to estimate 1980 travel. This is equivalent to a 20-year forecast. The resulting travel patterns were similar to observed data, thereby providing regional planners with greater assurance that this model set could be used to forecast future travel.

Table 5. Screen-line comparisons.

Screen-Line Description	Assigned Volume to Ground Count Ratio		
	Forecast/ Ground Count	With Least Error Correction	With Highest Error Correction
Mississippi River crossings	0.870	1.086	1.206
Navigational Canal	0.746	0.930	1.034
Jefferson Parish–Orleans Parish Boundary on East Bank	0.717	0.894	0.993
Harvey Canal	0.603	0.753	0.836
Donner Canal	0.714	0.890	0.989

CONCLUSIONS

A complete set of travel-demand models was calibrated for the New Orleans region by using 1960 travel data. These models were successfully applied to 1980 conditions within a reasonable degree of accuracy, although the observed data were only available at an aggregate level. Although the physical changes in the transportation system between 1960 and 1980 were not radical (consisting primarily of a few freeway additions), the changes in aggregate travel patterns were substantial. The average VMT per person increased by approximately 100 percent, whereas the transit market share decreased by 50 percent. There was also a substantial change in economic conditions between 1960 and 1980. The consumer price index increased by more than 170 percent, whereas per capita income increased by more than 60 percent, in constant dollars. Most assuredly, changes of this magnitude would be considered significant changes for any forecast. The successful application of the model to 1980 conditions, coupled with the substantial changes in the travel patterns and economic conditions between 1960 and 1980, would imply that an appropriately specified travel-demand model set may indeed be temporarily stable (within reason), and that the use of old survey data is not appropriate in investigating travel behavior and in calibrating travel-demand models.

The calibrated travel-demand model set is fairly unique in that all submodels were stratified by income quartiles. Other noteworthy aspects of the model were the use of a composite impedance measure in the distribution model, the use of accessibility and locational factors in the trip-generation model, and the use of minimal exogenous input data.

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Estimation and Use of Dynamic Transaction Models of Automobile Ownership

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Models of automobile ownership level and type choice are described by using a dynamic transactions model structure. The functional form of the model is two-stage nested logit: the higher level in the hierarchical decision process is a decision on the type of transaction in the car market. The lower-level decision is on type of car, which is conditional on the decision to buy a car. Automobile type alternatives are defined by make, model, vintage, and body type. The model was estimated with data from the Haifa urban area in Israel. The sample consisted of a choice-based (stratified) sample of 500 households that did not buy a car in 1978 and 800 households that bought a car during the same year. Each stratum was drawn at random from the respective population of the Haifa urbanized area. The models estimated in this paper are sensitive to attributes of the type of car, household characteristics, and accessibility by public transit and private car. The models take explicit account of the transaction costs that are incurred when operating in the car market.

The purpose of this paper is to develop and test a dynamic demand model for automobiles. Understanding the demand for cars has always been an important consideration in transportation studies. In recent years the composition of the car market has become a key factor in the evaluation of energy-consumption policies. The relative roles of purchase price and usage costs in determining car choice are of interest to policy decision makers. This is especially true in a country such as Israel, where cars and fuel are taxed at high levels. Thus changes in the structure of these taxes can be used to achieve policy goals, such as increasing the share of small cars. In Israel, car purchase and use also affect the balance of payments, because almost all the cars sold and all the oil consumed are imported.

The market for private cars in Israel is characterized by two major aspects. First, the level of ownership is relatively low compared with North America and Western Europe, where a third of the households (40 percent in the major urban areas) own cars, and of these only about 6 percent (2 to 3 percent of the total population) own more than one car. Growth of the private car fleet still occurs mainly by purchase of a first car.

The second important characteristic of the Israeli car market lies in the composition of the car stock. Most of the cars in Israel are small European cars, with only a small percentage of U.S. made cars, one popular Japanese brand (Subaru), and two domestic models that are assembled in Israel. The Israeli car fleet is heterogeneous and includes scores of different makes. The typical car in Israel is older than in the United States. About 60 percent of all cars are more than 5 years old, with 20 percent more than 10 years old.

These characteristics imply that the usual categorization of cars into subcompact, compact, and so forth, used in some models of car type choice (1,2) is not valid for the Israeli market, as almost all cars fall in the subcompact category. Also, the relevant ownership levels are zero and one. Ownership of two or more cars may become of interest in the future, but any attempt to model this phenomenon now will require special data-collection efforts.

In summary, a practical model of the Israeli car market may confine itself to zero- and 1-car households; should deal with holding or purchase of all cars, new or old; and should be able to describe the determinants of growth in the market.

MODELING APPROACH

The model developed in this study is a disaggregate, dynamic transactions model for level of ownership and type of car owned. As its name implies, the decision process involved in buying or replacing a car at the household level is the model studied. The model is dynamic in the sense that level of ownership and type of car owned during the previous time period are assumed to influence decisions about transactions made during the current (modeled) time period.

The key aspects of the model developed here are as follows.

1. The model is dynamic. It uses data on previous car holdings and includes a detailed treatment of transaction costs.
2. It is a transaction model that concentrates on changes in automobile holdings.
3. It is a nested logit model of the decision to transact and then the choice of car type given a transaction.
4. It describes the Israeli market, which may be more representative of conditions in some European or developing countries than in North America in terms of type, composition, and levels of ownership.

THEORETICAL FRAMEWORK

Previous Disaggregate Automobile Ownership Models

The development of the discrete choice econometric techniques facilitated a disaggregate approach to the modeling of car ownership. The first studies dealt with level of ownership, usually as a joint decision with mode to work (3-7).

Lave and Train (1) studied the choice of new vehicles by size class. Manski and Sherman (8)