measure estimation as well as reporting systems that enable the Metropolitan Council to monitor the performance of the regional transportation system over time. The refinement of the Development Framework concepts, the specification of detailed performance measures, and the operationalizing of the measures are currently under way as part of phase 2 of this project.

SUMMARY

The performance measure study for the Metropolitan Council of the Twin Cities area has illustrated the usefulness of multimodal performance measures with a regional planning orientation. The measures developed for the Metropolitan Council include many of the more traditional highwayand transit-supply-oriented measures that have been applied in performance reviews throughout the country. However, the highlight of this study is that it has also produced performance measures that reach beyond the supply characteristics to relate the supply of transportation and the attainment of planning objectives.

Three types of measures have been developed for the Metropolitan Council to meet their many needs: The first type was designed to assess attainment of regional planning objectives, the second was designed to evaluate performance with respect to specific policies, and the third was designed to provide an overall picture of the state of transportation in the region. In all, roughly 200 measures were necessary to satisfy the needs implied by the many types of applications that the Metropolitan Council can make of the measures in performance review; each type of use requires a different type of measure.

Although a large number of performance measures were presented to the Metropolitan Council, a methodology for their use was also developed that results in a practical, straightforward, and comprehensible program for performance review. The methodology ensures that there is a performance measure appropriate to each need.

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Disaggregate Model of Mode Choice in Intercity Travel

ALAN GRAYSON

The development of a policy-sensitive model of mode choice in intercity travel is discussed. The disaggregate logit model is based on the National Travel Survey of 1977, supplemented by service information from industry guides. Automobile, air, bus, and rail market shares are estimated from information on cost, travel time, frequency, terminal access, automobile availability, and trip purpose. By all measures, the model performs well. It is applicable on a national, regional, or route-by-route level. Forecasts are performed for a variety of national and regional scenarios.

This report summarizes the results of a recent project to develop a policy-sensitive behavioral model of mode choice in intercity travel. The approach is based on the economic theory of consumer behavior embodied in the logit statistical model. The model is calibrated with data from the National Travel Survey of 1977, supplemented by common-carrier service information for selected routes.

The purpose of this project is to develop a research tool to forecast the impact of transportation policies and controls on national patterns of intercity travel. These policies include gasoline pricing, modernization of the Interstate Highway System, air traffic control, interstate common-carrier pricing and service, etc., as well as general concern for competition and efficiency, energy conservation, regional equality, and other broad goals that intercity travel may impinge on. The government needs reliable forecasting techniques to weigh various policy alternatives.

The disaggregate, cross-sectional logit model of mode choice in intercity travel employed is based on a sample of intercity trips from a given period. The sample includes information for each trip on the attributes on each mode, characteristics of the travel party, and the mode chosen. The logit model is used to estimate the relative importance of different explanatory variables determining mode choice. In the base situation, the observed distribution of modal attributes is matched with the observed mode split. In alternate scenarios, changing the values of these variables yields a different mode split. The causal relationship between mode choice and the predictor variables specified in the model is based on a specific conception of the choice grounded in consumer behavior theory and experience with mode choice in urban contexts. The disaggregate logit model views transportation demand as demand for the "best" mode from each traveler's point of view, rather than demand for a specific mode per se (cf., time series multiple regression models of intercity travel). The "derived-demand" assumption in the model emphasizes competition among modes; the model is not concerned with changes in total demand.

What are the elements of an ordinary traveler's logit utility function when he or she evaluates an intercity travel mode? Four measurable factors that the traveler considers are cost, travel time, frequency of service, and terminal access. For each of these variables, the data only approximate what is believed to be the "actual" element of the subjective utility function, but each is a reasonable and useful approximation.

Modal attributes become observable as the circumstances of the trip are defined. Obviously, for instance, there is no one universal cost for air travel; the cost depends on the circumstances. Some circumstances are determined for all trips prior to mode choice. These circumstances may involve decisions too, but it is assumed that these decisions are made prior to mode choice in order to simplify the problem.

It is assumed that automobile ownership, destination, and travel party membership are determined prior to mode choice. It is also assumed that the decisionmaker considers all available alternatives, has perfect information about their attributes, and bears all costs. Some exceptions to these rules, e.g., business travelers, are isolated through stratification described below.

By making these assumptions about the circumstances of the trip, the values of the attributes of each mode become less and less ambiguous. At some point, a single value has been defined for, say, the cost of air travel. The attributes to be considered (cost, travel time, frequency of service, and terminal access) are admittedly biased toward the economic and the measurable. This choice is conditioned by the available data. Variables are specified according to how they might matter to the decisionmaker. To illustrate, a traveler has no inherent interest in the frequency of common-carrier service between Boston and Washington, but he or she may know that arrival at Washington National Airport must be by 9:00 and the closest earlier arrival is 8:13. So from the traveler's point of view, frequency itself is meaningless; but the reciprocal of frequency, the average waiting time at the destination between actual embarkment and the "ideal" preferred time of embarkment, is important.

So far only modal attributes and the assumptions that define these attributes have been considered. But many characteristics of the travel party itself affect mode choice. There are several ways in which characteristics of the travel party or its members might be modeled: The characteristics might be used to scale a modal attribute, foreclose an alternative, enter the utility function as a dummy variable, or stratify the data. Examples of scaling in this model include multiplication of common-carrier fare by travel-party size to yield common-carrier cost and multiplication of travel time by family income, following the hypothesis that the value of time varies linearly with income. The lack of automobile availability forecloses automobile as an alternative. Stratification was preferred to intercept dummy variables to avoid the assumption of equal slope coefficients and allow the testing of behavioral hypotheses. Stratification was employed for trip purpose and annual automobile use, but not for routes or regions, since the basic principles of mode choice decisionmaking were not thought to vary by route or by region.

This introduction is intended as an outline of the general considerations behind the structure of this model of mode choice in intercity travel. The utility function remains simple to reflect a simple decision-making process. Most characteristics of the travel party are manifested through stratification or elimination of alternatives to leave the behavioral assumptions of the model clear and challengeable.

MODEL DEVELOPMENT

The core of the model of mode choice in intercity travel is information on several attributes of each mode: cost, travel time, frequency, and access. The goal of this analysis has been to gather this information for a sample of trips within the 1977 National Travel Survey (NTS) and create a working forecasting model with broad geographic applicability.

The NTS collected information on all trips of 100 miles or more made by members of 20 000 households during 1977. This represents a sample of about 1 in every 4000 intercity trips.

The NTS contains no information on the frequency of common-carrier service for the trip. The information on travel time (number of days en route) is too imprecise to be useful. The information on cost (transportation cost for common-carrier trips) tells nothing about automobile trips and modes not chosen and is also apparently unreliable. As for access, there are data on the distance from place of residence to common-carrier terminals.

There are two methods of estimating intercity cost, travel time, and frequency of service: as a function of distance and region or of origin and destination. The first method is somewhat imprecise, obscuring differences among different routes and different stages of the trip (e.g., access and line haul). The second method is more precise, but it involves secondary data collection (e.g., looking up the number of flights between New York and Washington). It is applicable only to trips originating and terminating in standard metropolitan statistical areas (SMSAs) because only geographic coding by SMSA is available.

Following Stopher (1,2), a per-mile estimate of automobile cost and travel time was used together with estimates of common-carrier service attributes collected for specific routes from industry guides. As will be seen later, there is evidence that per-mile estimates of common-carrier attributes may be sufficiently accurate. The origin-destination approach required selection of specific routes within the national sample. Models based on selected routes are accurate only to the extent that the decision process of travelers along these routes (the subjective utility function, which is estimated in the logit model) is the same as the decision process elsewhere. Clearly, the mean value and distribution of modal attributes will be different for the sample as a whole. But there is no reason to believe a priori that the basic decision process will be different.

The model was calibrated for samples based on two different sets of routes: a sample of 1658 trips along 46 routes that were the most heavily sampled in the NTS (generally corresponding to the routes with the most person trips) and a sample of 1062 trips along 41 routes representing the greatest number of passenger miles. The first sample comprises New York to Boston, Hartford, Albany, Syracuse, Philadelphia, Washington, Chicago, and Miami; Los Angeles to San Diego, Bakersfield, Santa Barbara, Phoenix, Las Vegas, San Francisco, and Sacramento; San Francisco to Fresno, Salinas, Sacramento, Reno, and San Diego; and 26 other routes. The second sample includes New York to Boston, Philadelphia, Washington, Miami, Chicago, Dallas, Las Vegas, San Francisco, and Los Angeles; Los Angeles to San Diego, Phoenix, Las Vegas, Santa Barbara, San Francisco, Sacramento, Seattle, Honolulu, Dallas, Chicago, Washington, and Boston; Chicago to Honolulu, San Francisco, Las Vegas, Phoenix, Miami, Tampa, and Washington; San Francisco to Honolulu, San Diego, Sacramento, Reno, Washington, and Boston; Miami to Washington, Philadelphia, and Boston; Washington to Philadelphia, Orlando, and San Diego; and Dallas to Houston.

For both samples, information was collected on coach fare, fastest line-haul time, and trips per week for each common-carrier mode along each route as of June 1977. Common-carrier cost was defined as coach fare multiplied by travel party size. "Waiting time" was defined as one-half the average number of hours between common-carrier departures, i.e., the reciprocal of frequency. Travel time was defined as fastest line-haul time. Access was defined as distance to common-carrier terminals. A unit of access based on cost or time would have been preferable, being a better estimate of subjective utility, but the data would only allow an arbitrary transformation based on some assumed access speed or cost per mile.

Estimates of automobile cost and travel time were based on a U.S. Bureau of the Census-generated distance estimate called Place Identification, Characteristics and Area, Direction and Distance (PICADAD). Although only origin and destination SMSA information was released by the Census Bureau, the original survey included origin and destination addresses. Knowing the geographic location of every significant "place" in the United States, the Census Bureau calculated exact straight-line distance. The final PICADAD estimate was the straight-line distance scaled by an elaborate system of estimated "circuity factors" documented in the Census report, Travel During 1977. This measure of distance was found to be more reliable than traveler estimates or atlas listings. Minor adjustments were made in PICADAD distances by different modes to make them comparable. Automobile travel time was defined as PICADAD distance multiplied by an assumed average speed of 50 mph. This is in-car time. After consulting information on 1977 gasoline cost and fleet fuel economy, automobile cost was defined as distance times \$0.05/mile (gasoline plus maintenance costs) plus \$25/350 miles (overnight costs) plus toll costs. This formula may seem arbitrary, but experience with the model has shown that reasonable modifications of each component have little effect on coefficient estimates or forecasts. Intercity mode choice is not very sensitive to minor changes in automobile costs.

The basic utility function is defined in simple terms. It is a linear combination of cost, line-haul time, waiting time, and access for each mode.

In certain obvious cases some modes were eliminated as alternatives (i.e., assigned a probability of zero). In 1977 there was no rail service to Las Vegas, so the rail alternative was eliminated for trips to and from Las Vegas. On several other routes, the only rail service was connecting service between routes served once daily. A train trip from Cleveland to Columbus, for instance, would take 40 h 25 min (via Chicago), while a bus trip would last 2 h 50 min. Rail trips along these routes were also eliminated as alternatives. Automobile, bus, and rail travel was precluded for trips to Honolulu. Automobile was eliminated as an alternative if the travel party did not own a car, or if no member held a driver's license. Finally, air, bus, and rail were eliminated as alternatives for outdoor recreational trips. Because these destinations were not served by common carriers and automobile storage space was necessary for equipment and luggage, virtually every sampled outdoor recreational trip was an automobile trip. Almost all of the few exceptions were children traveling by bus in large groups. Captive Honolulu and outdoor recreation trips were retained in the sample so that it would not be necessary to adjust forecasts for these two groups. All the categories of eliminated alternatives together represent 9 percent of total alternatives.

The factors of automobile availability (automobile ownership and possession of a driver's license) and outdoor recreation (one category of trip purpose) represent the first allowance for characteristics of the travel party. Other relevant characteristics that do not preclude alternatives but still affect the choice will be discussed later.

The data below summarize the simple model of mode choice outlined so far:

$$U_m = aC_m + bYT_m + cY/2F_m + dYA_m + e_m \quad (1)$$

where

U_m = "utility" of mode M,
a, b, c, d, e_m = coefficients to be estimated,
C_m = cost of mode M,
T_m = travel time of mode M,
F_m = frequency of mode M (average departures per hour),
A_m = access of mode M (miles to common carrier terminal),
Y = family income/2000,
N = number of observations,
L = log-likelihood value,
L_0 = pre-calibration log-likelihood value,
$\rho^2 = 1 - L/L_0$, a measure of goodness of fit,

and

P_{AUTO} = 0 for (1) (2),
P_{AIR} = 0 for (4),
P_{BUS} = 0 for (2) (4), and
P_{RAIL} = 0 for (2) (3) (4) [(1) = the household owned no car, or no member of the travel party held a driver's license; (2) = Honolulu-San Francisco, Honolulu-Los Angeles, Honolulu-Chicago; (3) = Las Vegas-Los Angeles, Las Vegas-Chicago, Las Vegas-New York, Los Angeles-Bakersfield, Knoxville-Chattanooga (no service); Cleveland-Pittsburgh, Cleveland-Columbus, Cincinnati-Columbus, Charlotte-Columbia, Los Angeles-Bakersfield (connection); and (4) = outdoor recreation trips].

There are four modal attributes and four classes of trips where alternatives have been eliminated.

Figure 1 shows the results of calibration of the logit model for the two samples derived from the NTS. The coefficients represent the traveler's subjective weighting of each unit of a service attribute. The ratio of these coefficients repre-

Figure 1. Model I.

$$U_m = aC_m + bYT_m + cY/2F_m + dYA_m + e_m$$

Group I			Group II		
N = 1658			N = 1062		
a = -0.0161	(- 5.65)	(COST)	a = - 0.0036	(- 4.22)	(COST)
b = -0.0240	(-12.66)	(TIME)	b = - 0.0050	(-11.63)	(TIME)
c = -0.0055	(- 1.81)	(WAIT)	c = - 0.0050	(- 1.37)	(WAIT)
d = -0.0007	(- 1.66)	(ACCESS)	d = - 0.0005	(- 1.05)	(ACCESS)
e_{AIR} = -2.700	(-14.60)		e_{AIR} = -0.582	(- 2.03)	
e_{BUS} = -2.552	(-14.32)		e_{BUS} = -2.728	(- 8.75)	
e_{RAIL} = -3.027	(-16.86)		e_{RAIL} = -2.1850	(- 7.55)	
L = -932.6, L_0 = -1338.0, ρ^2 = .303			L = -585.5, L_0 = -861.9, ρ^2 = .321		
82.7% correctly classified			76.4% correctly classified		

(pseudo t-ratios in parentheses)

sents the relative importance of the units. The quotient of the time (income hours) and access (income miles) coefficients, for example, represents an imputed time expenditure equivalent to each mile of access. The t-ratio determines whether each coefficient is statistically significant. The ρ^2 statistic is a measure of goodness of fit, how well the model explains observed choice. As a rule of thumb, ρ^2 values above 0.2 represent an excellent fit.

In both samples, every coefficient has the expected sign. This is uncommon in logit models of mode choice. The cost and time coefficients in both samples are statistically significant. The wait and access coefficients are significant at the 0.05 level (one-tailed test) in the first sample, statistically insignificant in the second sample. The goodness-of-fit measures are unusually large. By prevailing standards of logit mode choice modeling, this model appears effective.

The marginal significance of access is perhaps attributable to the fact that many trips, especially business trips, do not originate at home. Also, a specific value of access distance may encompass wide variations in access time and cost, depending in part on the access mode. Similarly, a specific "wait" value represents quite different scheduling delays. Even if there is only one train per day from San Francisco to Sacramento that arrives at 2:40 p.m., this represents no inconvenience to the traveler who wants to arrive at 2:40 p.m.

All of the common carriers show constant terms significantly different from the automobile base. Even when the effects of cost, line-haul time, and waiting time are allowed for, automobile is still favored. Factors omitted from the model (e.g., use of a car at destination, instant free egress, convenience in carrying luggage, etc.) in aggregate strongly favor automobile use. In the first sample differences among the common carriers are small, but in the second sample, where longer trips predominate, air travel is much less disadvantageous (relative to automobile travel) than bus or rail travel. The values of the constant terms relative to the coefficients of the modal attributes seem substantial.

The values of the attribute coefficients are smaller for the second sample than the first. The second sample included more long trips, and each trip was weighted by distance. If either of these factors is eliminated, the coefficients assume intermediate values. Longer trips are associated with more expense, more time, and less frequency. One interpretation of this phenomenon is that the difference between $10 and $11 is subjectively greater than the difference between $100 and $101. The model as specified assumes the contrary, constant marginal utility.

Much of the research through this section has been directed toward reducing the complex phenomenon of intercity mode choice to a tractible one embodied in a simple model based on explicit assumptions. The next section examines the consequences of varying some of these assumptions.

MODEL VARIATIONS

The fundamental assumption in the basic model outlined above is that all travel parties "think the same way," i.e., they all perceive and weight each modal attribute according to the same utility function. This is no more than a fiction, but the success of the basic model suggests that it is not absolutely necessary to include a large number of traveler characteristics in the model to produce a workable result.

Some of the traveler characteristics included in the basic model deserve closer examination. The value of time clearly varies with family income; the explanatory power of the model improves markedly when line-haul time, frequency, and access are scaled accordingly. Yet it seems unlikely that different family subgroups (e.g., husband, wife, husband-wife, parent-children, children, and complete family) manifest the same relationship between family income and the value of time. However, stratifying by subgroup to incorporate travel party would strain data resources and weaken the behavioral framework. It was thought that much of the residual variation in the value of time was captured by another variable: trip purpose. For instance, business trips tend to be associated with lone travelers and a characteristic relationship between family income and the value of time. Trip purpose is also important in its own right.

The NTS enumerates nine different trip purposes but these resolve themselves into four basic categories: business, social, entertainment, and outdoor recreation. Virtually all outdoor recreation trips were by automobile, so this trip purpose was incorporated into earlier models by eliminating alternatives. The components of the remaining groups are (a) business and convention (business), (b) visiting relatives or friends and personal and family affairs (social), and (c) entertainment and sightseeing (entertainment).

Model II stratifies the first sample by trip purpose and calibrates each subsample separately. The most prominent characteristic (Figure 2) is the submodels' similarity to each other and to Model I. The attribute coefficients remain the same order of magnitude. Each common carrier displays a large, statistically significant negative coefficient compared with automobile. The goodness-of-fit is uniform.

Differences seem to conform to common-sense perceptions of trip purpose. The cost coefficient is much higher for business travel than other travel. One might expect that cost would be a less important factor in business travel because often the business, not the traveler, pays for the trip. But it is also true that the business, not the traveler, chooses the mode. If the business makes the mode choice, it is no more likely to downgrade travel costs (for which it is paying) than it is to downgrade the value of the traveler's time (for which it is probably paying). (This assumes that the business is a decision-making entity distinct from the traveler.) Moreover, business travel may entail greater actual costs than coach fare model estimates indicate. Also, per-mile automobile reimbursement far exceeds out-of-pocket costs. The model probably underestimates business travel costs relative to other trip purposes, causing a larger cost coefficient.

The travel time coefficient is much smaller, although still negative, for entertainment trips. This is hardly surprising, since sightseeing travelers may actually value time spent en route, unlike destination-oriented business and social travelers. For some travelers, getting there is half the fun. The extreme case of travel for the sake of travel are trips by railroad afficionados, who may not even disembark at the destination before returning.

The waiting time (frequency) coefficient is not statistically significant for entertainment and social travelers. Only business travelers are likely to have to arrive at a destination at a specific time of day. For business travelers, waiting time is comparable with travel time. Others traveling on weekends or on vacation can be more flexible.

Access (i.e., distance from home to common-carrier terminal) appears to be less important to business travelers, probably because many business trips originate outside the home.

The air constant is smaller for business trips than others. Some of the factors making air travel less attractive than automobile travel (e.g., use of the car at the destination and convenience in carrying luggage) are not important to business travelers. The bus coefficient is smaller for entertainment trips. This may be attributable to nonscheduled bus package tours or charters for sightseeing trips that reduce the cost and inconvenience of bus travel. Charter trips account for about one-sixth of all intercity bus travel. The cost of these trips may be significantly overestimated in the model, which is based on scheduled bus tariffs.

Although they bear the proper signs, the modal attribute coefficients in the entertainment model are not statistically significant. This is perhaps attributable to the unusually small sample size, less than 200 trips. Only seven of these trips were by air and only eight were by rail.

Coefficient differences for stratified samples cannot always be explained in behavioral terms. The ability to do this provides additional confidence in the model.

The next travel party characteristic to be considered is a function of the number of miles driven by each travel party member annually. The hypothesis is that, if the travel party contains no one who drives a great deal, driving will be perceived as a burden and the group would be more likely to travel by common carrier. Some people (e.g., the elderly or students) hold driver's licenses and have access to automobiles but are generally reluctant to drive. There is some circularity in this definition, but, for most people, intercity mileage is a small percentage of the total.

The basic variable is the annual mileage of the most experienced driver in the travel party. There are many different ways in which the variable might be incorporated into the model. It was decided to stratify the model, isolating those trips made by travel parties without any heavy drivers. The median mileage for licensed drivers is about 20 miles/day. This was chosen as the threshold. About 15 percent of the sampled trips included only light drivers, or only light drivers and non-drivers, owning cars.

Model III (Figure 3) is a calibration of the base model for the subsample of light drivers. The results are somewhat confusing, since the supposed aversion to cars can interact with the wait and access variables whose automobile values are zero and common-carrier values positive. The model clearly has less explanatory power when calibrated for this group. But the common-carrier modal constants are only about half as large here. Driving experience does seem to have some effect on the set of intangibles embodied in the modal coefficients, including driving attitudes. But the relationship is difficult to model accurately.

Some other readily available variables whose

Figure 2. Model II. $U_m = aC_m + bYT_m + cY/2F_m + dYA_m + e_m$

BUSINESS		SOCIAL		ENTERTAINMENT	
N = 550		N = 717		N = 191	
a = -0.0328	(- 4.06)	a = -0.0111	(- 2.62)	a = -0.0111	(- 1.03)
b = -0.0200	(- 5.55)	b = -0.0238	(- 8.01)	b = -0.0079	(- 1.22)
c = -0.0244	(- 2.54)	c = -0.0090	(- 1.51)	c = -0.0030	(0.56)
d = -0.0006	(- 1.04)	d = -0.0016	(- 1.55)	d = -0.0015	(- 0.89)
e_{AIR} = -1.313	(- 3.66)	e_{AIR} = -3.166	(-11.49)	e_{AIR} = -3.435	(- 5.98)
e_{BUS} = -3.159	(-8.57)	e_{BUS} = -3.016	(-11.47)	e_{BUS} = -1.797	(- 3.69)
e_{RAIL} = -2.461	(-7.15)	e_{RAIL} = -2.828	(-10.97)	e_{RAIL} = -3.288	(- 6.35)
ρ^2 = .299		ρ^2 = .306		ρ^2 = .301	

Figure 3. Model III. $L_m = aC_m + bYT_m + cY/2F_m + YA_m + e_m$

LIGHT DRIVERS			TOTAL		
N	233		N	1658	
a	-0.0129	(- 1.96)	a	-0.0161	(- 5.65)
b	-0.0167	(- 3.49)	b	-0.0240	(-12.66)
c	-0.0246	(- 2.15)	c	-0.0055	(- 1.81)
d	-0.0003	(- 0.39)	d	-0.0007	(- 1.66)
e_{AIR}	-1.995	(- 5.19)	e_{AIR}	-2.700	(-14.60)
e_{BUS}	-1.137	(- 3.30)	e_{BUS}	-2.552	(-14.32)
e_{RAIL}	-1.253	(- 3.62)	e_{RAIL}	-3.027	(-16.86)
ρ^2	.140		ρ^2	.303	

relationship to mode choice in intercity travel might be significant, aside from those considered above, include the automobile needs (e.g., journey to work) of household members not in the travel party, the existence of secondary destinations along the travel route, the gasoline mileage and condition of available family automobiles, the availability of non-household drivers and vehicles, general discounts based on travel party composition, etc.

As was mentioned above, much of the data for the model was collected from outside the NTS. This limited the data base to trips along a relatively small set of routes. To extend the model to the national sample and make it applicable to intercity travel in general, it is necessary to generate service information from the NTS itself.

A first effort toward this goal was made by regressing cost and time for air and bus service against distance, and replacing the actual values with the fitted values. R^2 was 0.97 or above in each case and the regression coefficients were in accord with prior expectations. By using the fitted values in the model, the logit coefficients were largely unchanged and goodness of fit actually improved slightly. These results make a national model of mode choice in intercity travel appear feasible.

This section was intended to explore some of the ways in which the basic model can be modified and strengthened by relaxing some of the assumptions inherent in the model. Stratification by trip purpose seems to be a simple and instructive adjunct to the basic model. The next section reverts to the basic model to demonstrate its applications to forecasting and policymaking.

APPLICATIONS

The model of mode choice in intercity travel developed here can be applied to a wide range of forecasting problems. Basically, a forecast of mode shift can be derived for any posited change in circumstances by changing the values of affected variables in the model and reestimating what choices would be made under the new circumstances. A change in highway speed limits, for example, would manifest itself through different automobile travel times and bus travel times. Forecasts will be accurate if the model explains observed behavior well and if the posited changes have a clear, direct effect on elements of the model (and an insignificant effect on factors omitted from the model).

The means of estimating changes in modal demand is the "success matrix." The logit model yields the probability of choosing each mode for each trip in the sample. The success matrix is the product of the choice matrix, with ones for the mode chosen and zeros for all other modes, and the matrix of estimated probabilities. If the model is applied to a different set of values, e.g., higher automobile and bus travel times, the sum of all the estimated probabilities will change. The ratio of the new sum to the old sum is the forecast.

To illustrate possible applications, various scenarios were applied to the model by using the first sample that included 46 routes chosen on the basis of sampled trips. The model is used here to estimate the change in the number of trips (not passengers or passenger miles) on these 46 routes (which are by no means representative of all intercity travel in the United States) for different modes, assuming that total demand remains constant. These caveats should be kept in mind as the forecasts are examined.

Table 1 shows the impact of six different scenarios on mode choice. The figures generally conform to common-sense expectations about what the effects of the posited scenarios might be. Perhaps the most important finding is the minimal mode shift arising from a significant gasoline price rise. Of course, the real price of gasoline has risen by more than 50 percent since the sample was taken in 1977.

Forecasting can also be applied to particular corridors (Table 2). The latter group of scenarios is applied to the corridor between Sacramento and San Diego, including San Francisco and Los Angeles. The third column suggests that the low present speed limit, partly justified on fuel economy grounds, might be a spur to air travel and therefore have perverse effects on fuel savings. In general, travel time appears to be a very important factor in mode choice.

The model can also be applied to specific routes. For 10 routes, the sample size is more than 200 trips. Samples of this size could support reasonably precise forecasting. Because most of this large-sample data became available only recently, route-by-route results cannot be reported here.

Elasticities were derived for the complete sample as well as for the Northeast and Southwest Corridors (Table 3). Unlike reported elasticities for many other intercity travel models, these are consistent with expectations. The cost elasticities, for instance, are all less than one. As expected, automobile travel is more sensitive to travel time than cost changes. Rail sensitivity to frequency changes seems fairly high, but apparently this is

Table 1. Impact analysis: group 1.

	Scenario					
Mode	1[a]	2[b]	3[c]	4[d]	5[e]	6[f]
Automobile	−1%	−2%	−0.3%	−2%	−0.1%	+0.1%
Air	+7%	+5%	−0.3%	−5%	−0.4%	+0.1%
Bus	−2%	+4%	−0.4%	+27%	+2.3%	+0.2%
Rail	−2%	+4%	+7.4%	−4%	−0.5%	−2.4%

[a]Family income rises 10 percent.
[b]Gasoline costs rise 50 percent.
[c]Frequency of rail service outside the northeast doubles.
[d]80-mph speed limit for buses.
[e]Bus fares decline by 10 percent.
[f]Rail fares rise by 10 percent.

Table 2. Impact analysis: Southwest Corridor.

	Scenario			
Mode	1[a]	2[b]	3[c]	4[d]
Automobile	−1%	−7%	+4%	−0.4%
Air	+4%	+19%	−19%	−0.7%
Bus	+3%	+20%	+7%	−1.1%
Rail	+3%	+17%	−9%	+18.2%

[a]Two cents per mile toll for automobiles.
[b]Two-h increase in automobile travel time.
[c]70-mph speed limit for automobiles and buses.
[d]Rail frequency triples.

Table 3. Elasticities for group 1 and corridors.

Mode	Cost	Time	Wait	Access
Group 1				
Automobile	−0.076	−0.303	0.0	0.0
Air	−0.618	−0.159	−0.048	−0.107
Bus	−0.321	−1.101	−0.054	−0.061
Rail	−0.373	−0.251	−0.463	−0.100
Northeast Corridor				
Automobile	−0.112	−0.555	0.0	0.0
Air	−0.538	−0.163	−0.031	−0.108
Bus	−0.267	−0.954	−0.022	−0.062
Rail	−0.315	−0.825	−0.050	−0.059
Southwest Corridor				
Automobile	−0.072	−0.292	0.0	0.0
Air	−0.359	−0.164	−0.023	−0.141
Bus	−0.311	−0.209	−0.038	−0.070
Rail	−0.361	−0.335	−0.419	−0.168

less true in the Northeast Corridor where service is already competitive. On the other hand, travel time is a more important factor in rail demand in the Northeast.

As noted above, these sensitivity analyses can be performed for any scenario affecting model variables. The model is sensitive to changes in various costs, travel time, frequency, income, access, service availability, and automobile ownership. With little additional effort, the changes in demand can be expressed in policy-relevant terms such as energy saved, tax revenues earned, change in vehicle miles of travel, and change in transportation expenditures.

Various technical improvements, such as sample expansion and sensitivity to total demand, have been undertaken to expand the applicability and usefulness of the model. Even in current form, it can be a useful forecasting and policy tool.

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Interactive UTPS: Implementation Under a Timesharing Environment

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This paper reports on the development of interactive computer programs for the Urban Mass Transportation Administration's Urban Transportation Planning Systems (UTPS). The programs, originally designed to run under an IBM 360 or 370 OS environment, were executed under a conversational monitor system (CMS) timesharing environment. The aim was to reduce turnaround time and explore future interactive capabilities of the programs. Interactive versions of programs INET, UPATH, UPSUM, ULOAD, UROAD, NAG, UMATRIX, UFIT, and ULOGIT were developed. The paper describes the process involved in creating CMS exec programs to control the program compilation and data set manipulation without any job control steps. Each UTPS program exec is described along with other supporting software that was developed. Finally, a summary of the problems encountered in transforming the software and data files from CS to CMS is presented.

This paper summarizes the development of an interactive version of several Urban Transportation Planning System (UTPS) computer programs. UTPS is a collection of computerized and manual techniques to aid planners in the assessment of urban transportation systems. It was developed and maintained by