Logit Mode-Choice Models for Nonwork Trips

PETER R. STOPHER, ERIC G. OHSTROM, KENNETH D. KALTENBACH, and DONALD L. CLOUSE

ABSTRACT

Most research on logit models of mode choice has concentrated on the work trip, a fact frequently commented on by critics for some years. With the increasingly widespread adoption of the logit model as the basic mode-choice model of practical transportation planning, more logit models for nonwork purposes are being installed in travel forecasting procedures. In this paper the form that most of these models take and the assumptions on which they are based are examined. It is shown that the majority of these are not calibrated, but are updated from the work models. The inappropriateness of this is demonstrated through selected case studies, and the types of models that can be built are described. It is shown that calibration of nonwork models is feasible and presents no new problems over the work mode-choice models, and that the relative weights of cost and time components in work models are different from those found for fully calibrated nonwork models. The data requirements and calibration needs are also discussed.

Throughout most of the development of disaggregate models of mode choice, research concentrated almost exclusively on developing models of choices for the work trip. This was justified on a number of grounds, including the importance of the work trip in planning and policy decisions, and the convenience and appropriateness of the work trip for research. In this respect, it was often pointed out that collecting data on work trips presents a relatively simple and inexpensive data-collection activity; and that, because of the habitual nature of the trip, there is a greater chance that the work trip represents a rational choice of mode and that knowledge may exist about the alternatives. It is not the purpose of this paper to deliberate over these reasons or to produce evidence as to whether or not there exist foundations for them. Suffice it to say that there are published research results that cast some doubt on each of these basic assumptions and reasons, but that these still appear to have been insufficient to generate any significant change in the direction of research.

Of course the authors do not claim that there has been no research on nonwork models. There are several published papers about models for shopping trips (1-4), and a few instances of other nonwork models as well (5,6). However, the total number of such publications is insignificant in comparison with those on work trips. Furthermore, the logit model for the work trip has remained relatively simple, certainly in the perception of practicing transportation planners, whereas much of the research on nonwork models has generated more complex model forms and has tied the mode-choice models to other models in the stream, such as destination choice (trip distribution) or route choice. Given the added complexity stemming from this, the fact that most practical travel forecasters are reasonably content with existing aggregate trip-distribution models, and that aggregate versions of these more complex models are largely unknown, the few nonwork models that have been developed have largely failed, so far, to penetrate practice.

In this paper the pros and cons of substituting aggregate or disaggregate mode-choice models in the standard travel-forecasting process, as opposed to making radical changes in the modeling process and its structure, are not discussed. Rather, it is accepted that the majority of planning regions in the United States use the conventional four-step modeling process for travel forecasting, as exemplified by the Urban Transportation Planning System (UTPS) program of the U.S. Department of Transportation, and they have simply chosen to replace or update the modal-split models in this process. Also, it should be noted that the authors use the term "modal split" to refer to models that are conceptually and structurally aggregate, while using the term "mode choice" for models and procedures that are either disaggregate entirely or are based on use of disaggregate data for their development.

PRACTICAL IMPLEMENTATION

For more than two decades of modern regional transportation planning, no agreement could be reached on the form and structure of the modal-split model. It was frequently stated that, although only two types of trip-distribution models (gravity and intervening opportunity) were to be found in use, there were as many different modal-split models as there were urban areas that had completed a long-range transportation planning activity. Documentation of modal-split models tended to demonstrate the range of different types and structures of models (7,8). In the past few years this situation has changed quite dramatically. Almost every urbanized area that has updated or improved their model stream, and every area that has considered seriously the potential building of a line-haul transit service, has introduced a set of logit models of modal split. Such models are currently in use in Los Angeles and San Francisco, California; Washington, D.C.; Miami, Florida; Honolulu, Hawaii; Detroit, Michigan; Minneapolis-St. Paul, Minnesota; New Orleans, Louisiana; and San Juan, Puerto Rico, to name a few.

As noted previously, there has been considerable research on the mode-choice logit model for work trips, but relatively little for any other trip purposes. In applying logit methods to the standard travel forecasting stream, models are required to cover all purposes. In practical transportation planning, the emerging standard appears to be to use about six trip purposes for trip generation and trip distribution, but to aggregate these purposes to three or four for mode choice. In most of the cities previously mentioned, there are three models for the purposes of home-based work (HBW), home-based other (HBO), and non-home-based (NHB) trips. In one or two instances, an additional model exists for home-based school (HBS) trips, but these are more usually left as part of the HBO trips or excluded altogether, and dealt with in some other estimation procedure that includes an allocation of trips by school bus.

Clearly, then, every locality that has introduced logit models of modal split has had the need to build not only the well-researched, reasonably well-understood work trip model for HBW trips, but has also had to develop models for at least two other purposes, HBO and NHB, neither of which has been researched nor understood to any great extent. Knowledge of how to build a model for shopping trips also has not helped the definition of models for these much more aggregate purposes. For some reason, not widely reported, transportation planners and planning agencies appear to have decided that the lack of research on these models also indicates that they would not be possible to calibrate in the normal sense.

Against this situation, two primary methods have been used to build models for HBO and NHB purposes, neither of which represents true calibration (i.e., free fitting of all model parameters to current or recent data). The first method that has been used--quasi-updating--is to define the HBO and NHB models in terms of the relative coefficients found for the work trip model and to seek to determine an overall multiplying factor for the utility from the work model. This assumes that the relative weights of components of travel time, travel cost, and any user characteristics in the models are the same for all trip purposes. There is no research or other literature to support this position, but it is widely held. In some instances the models so developed are even further removed from calibration, because the work model may in some cases have been built with predetermined relationships between some of the variables. Illustrations of this are discussed later in the paper.

The second method of building the needed additional models--factoring--is to build factor models that use the zonal market shares from the work model and apply this, usually through some factoring procedure, to NHB trips. In many respects this differs from quasi-updating only in that the factor is derived by a different procedure.

One may question to what extent this treatment of nonwork trips is of any real importance. It is clear that most conventional bus systems derive most of their ridership from the peak periods, carrying primarily work and school trips. Even systems that include some form of rapid transit are still likely to carry significantly more trips in the peak period and to derive a large portion of their patronage from the work trip. Nevertheless, these statistics do not indicate that the nonwork, nonpeak trips can be dismissed and can be treated substantially less accurately than the work trips. In most large urban areas work trips represent about 20 to 25 percent of total daily trips. Home-based nonwork trips generally constitute a further 50 to 55 percent of trips, whereas NHB trips make up the balance (20 to 30 percent) of regional person trips. In a typical medium or large urban area in the United States, the transit share of the market ranges from 2 to 15 percent of all trips, and about 50 percent of this transit share comes from the work trip.

As examples of these figures, 1980 statistics for the Los Angeles region show that work trips constitute about 18 percent of daily person trips, home-based nonwork trips are about 52 percent, and NHB trips are 30 percent. The bus system carries about 3 percent of these trips, with 45 percent of transit trips being HBW trips. Overall, transit carries 7.5 percent of HBW trips, 2.4 percent of HBO trips, and 1.3 percent of NHB trips.

In Honolulu, it is estimated that 16 percent of regional trips are HBW trips, 48 percent are HBO trips (including HBS trips), with 36 percent being NHB trips. Transit carries about 14.9 percent of the HBW trips, 7.9 percent of HBO trips, and 5.4 percent of NHB trips. Because of the high use of the public bus system for HBS trips, which are included in the HBO total, Honolulu buses derive only 30 percent of their resident (not including the substantial tourist ridership in Honolulu) patronage from the work trip. If school trips are added to this, most of which also occur in the peak periods, the percentage of patronage for HBW and HBS trips becomes 53 percent. The Honolulu bus system carries 8.2 percent of the resident person trips plus an additional 29,000 tourist trips on an average weekday.

Finally, in Miami the regional split of trips among purposes is 26 percent for HBW trips, 60 percent HBO trips, and 14 percent NHB trips. The regional transit share is 4.2 percent, consisting of 7.8 percent of HBW trips, 1.7 percent of HBO trips, and 8.1 percent of NHB trips (the latter being high because of the relatively high proportion of NHB trips for Miami Beach and the high transit share of all trips in Miami Beach) (9).

ILLUSTRATIVE EXAMPLES

It is useful to see the form of the models that are produced by the alternative methods of building HBO and NHB mode-choice models. Several examples have been selected from reported models that are in current use in several different locations.

Minneapolis-St. Paul

This is one of the earliest models to have been developed and applied for regional travel forecasting (10). The coefficients for these models are given in Table 1. The ratio of out-of-vehicle time coefficients to in-vehicle time coefficients in the HBO model is exactly 2.5, and the ratio of the cost and in-vehicle time coefficients is 1.5. Neither of these ratios appears as such in the work model, although both represent values that have been stated frequently to represent the conventional wisdom of the relative values of these in logit models. Overall, these ratios appear to have been established and only the absolute values of the coefficients and the values of the modal constants were fitted to transit share data. In the NHB model the ratio of 2.5 between out-of-vehicle time and in-vehicle time is maintained, generating coefficients of -0.025 for out-of-vehicle time components and -0.01 for in-vehicle time. The cost coefficient is -0.0039, which appears as almost the same ratio as the ratio of HBW in-vehicle time to cost. Although this is not a pure example of the types described earlier, these models appear to be generally of the form of the ones that define the HBO and NHB models from the HBW models, calibrating only an overall multiplier to fit ob-observed transit shares.

Miami

The Miami model was built in 1976 and revised in 1978 (9). It was built under difficult circumstances in that no calibration data were available for constructing it. Therefore, it was built from existing trip tables, estimated modal splits, and information from other logit models, principally those for Wash-

TABLE 1 Cost and Time Coefficients of Models for Minneapolis-St. Paul

Purpose	Wait Time	Walk Time	Out-of-Vehicle Time	In-Vehicle Time	Parking Cost	Running Cost	Total Cost
HBW	−0.044	−0.030	–[a]	−0.031	–	–	−0.014
HB-nonwork	−0.020	−0.020	–[a]	−0.008	–	–	−0.012
NHB	−0.025	−0.025	–[a]	−0.0100	–	–	−0.0039

[a]Several alternative coefficients are used for out-of-vehicle time for automobile, depending on occupancy.

ington, D.C. The coefficients for these models are given in Table 2. In every case the ratio between the excess-time coefficient and the in-vehicle time coefficient is 2.5, and the ratio between the in-vehicle time coefficient and the cost coefficient is -0.3333. The cost coefficient is, in this case, the coefficient for a variable of cost divided by income.

This model is an excellent example of the first type of construction, in which the ratios among the coefficients are prespecified, and fitting of the model is concerned only with an overall factor for the model coefficients and any mode-specific constants.

New Orleans

This model was built in 1981 and incorporates some additional sophistications not apparent in the previous two models. (Note that the data for this model are from unpublished reports by Barton-Aschman Associates, Inc.) These sophistications include using different coefficients for walk time and wait time and introducing yet a further coefficient for automobile time when used as access to transit. The coefficients for these models are given in Table 3. In the HBW model the ratios between each of walk time and wait time and in-vehicle time are approximately 2.3 and 5.3; whereas the ratio between cost and in-vehicle time is 0.53. Notwithstanding these values, the model reverts to a 2.5 ratio for both walk and wait times to in-vehicle times for both the HBO and NHB models. The cost coefficients demonstrate almost exactly the same relationship to in-vehicle time as the Minneapolis models, which suggests that this model may have been used as the basis for the cost coefficient, with additional modifications being made to the cost coefficient to replicate observed transit shares more accurately.

Los Angeles I

The first Los Angeles model to be described is the one built for the Los Angeles Rapid Transit System in 1976. The time and cost coefficients for the HBW model are as follows (11): out-of-vehicle travel time/distance = 24.37, in-vehicle travel time = -0.01465, cost/income = -0.1860, and the factor = 2.332. This model, which was never adopted for regional forecasts by the local agencies, consisted of a logit work mode-choice model and a factoring procedure for nonwork trips. The factoring procedure is based on the observation that approximately 43 percent of transit trips are work trips. After estimating the HBW trips, the trip interchange totals of transit trips generated by the work model are multiplied by 2.332, which represents the inverse of the proportion of transit trips that are work trips. This is an excellent example of the second method of developing nonwork mode-choice models.

Los Angeles II

The second Los Angeles model was built in 1982. The coefficients are given in Table 4. (Note that these data are from unpublished reports for the Southern California Association of Governments by Cambridge Systematics, Inc., 1982). This model represents an exception to the previous ones, insofar as the HBO model is concerned. This model was calibrated to data, and no use was made of relationships between coefficients in the work model for devising this model. The ratio of the coefficients of excess time and in-vehicle time is 5.6 for the HBW model and 3.1 for the HBO model. In these models cost is divided by income, thus making comparison with some of the other models more difficult. However, the ratio of the cost coefficient to in-vehicle travel time is 2.01 for the HBW model and 3.17 for the HBO model.

TABLE 2 Cost and Time Coefficients of Models for Miami

Purpose	Wait Time	Walk Time	Out-of-Vehicle Time	In-Vehicle Time	Parking Cost	Running Cost	Total Cost
HBW	–	–	−0.0515	−0.0206	–	–	−0.0618
HB-nonwork	–	–	−0.0415	−0.0166	–	–	−0.0498
NHB	–	–	−0.0193	−0.0077	–	–	−0.0231

Note: The cost and time coefficients are for transit, nonbeach traffic only. Models exist for each of transit and highway for both beach and nonbeach zones. Each model contains different coefficients, but the ratios among coefficients are the same.

TABLE 3 Cost and Time Coefficients of Models for New Orleans

Purpose	Wait Time	Walk Time	Out-of-Vehicle Time	In-Vehicle Time	Parking Cost	Running Cost	Total Cost
HBW	−0.0332	−0.0769	–[a]	−0.0145	–	–	−0.0078
HB-nonwork	−0.0165	−0.0165	–[a]	−0.0066	–	–	−0.0116
NHB	−0.0328	−0.0328	−0.3048	−0.0131	–	–	−0.0047

[a]Out-of-vehicle time is for automobile only, and several coefficients exist for the occupancy levels for HBO and NHB.

TABLE 4 Cost and Time Coefficients of Models for Los Angeles (1982)

Purpose	Wait Time	Walk Time	Out-of-Vehicle Time	In-Vehicle Time	Parking Cost	Running Cost	Total Cost
HBW	-0.157	-0.0329	-0.0557	-0.0111	—	—	-0.019
HB-nonwork	—	—	-0.0746	-0.0256	—	—	-0.0293
NHB	—	—	—	—	—	—	—

Note: The NHB transit share is factored from the work modal split.

Again, these values serve primarily to demonstrate that the HBO model was calibrated freely and that the assumed values from the earlier models do not appear to be replicated by these calibrated values. This is discussed at more length later in the paper.

In this model set the NHB transit trips are estimated by multiplying the HBO share of transit trips (expressed as a fraction) by a fractional constant to determine the transit share of NHB trips. NHB trips are subdivided into other-to-work and other-to-other trips. For the former, the fractional multiplier of the HBO modal split is 0.2608, and for the latter it is 0.3431. In the event that a trip interchange has no HBO trips, the NHB transit market shares are set at 0.0182 for other-to-work trips and at 0.0156 for other-to-other trips. These values are approximately the regional modal splits for these two purposes.

The NHB model is an example of the factor model, whereas the HBO model represents one of the still-few instances of the free calibration of a model for nonwork trips.

More examples could be drawn from those that are in current use, but those documented in the preceding paragraphs provide adequate illustrations of the types of models that are in current use and that are based on the noted methods of calibration.

FULL CALIBRATION

The alternative to the foregoing procedures is to calibrate the home-based nonwork and NHB models directly from available data. As noted earlier in the paper, there appear to be certain myths surrounding full calibration of these models that have led to the preponderance of the model-fitting procedures described in the previous section of the paper. In this section two case studies are described that should expose the myths. The first of these case studies deals with what is likely to be the most common case for practical transportation planning, in which the region does not have household data that have been collected recently with calibration of logit mode-choice models in mind. Rather, the data are likely to be of the form required for updating earlier types of forecasting models. In the second case study data were collected expressly to allow calibration of logit models of mode choice for all purposes. This is closer to the ideal situation, but is likely to occur far less often than the first case.

Case Study 1

This case study is for San Juan, Puerto Rico (12). New modal-split models were to be constructed for use in a conventional UTPS-based forecasting procedure, but the modal-split models were to be aggregate logit models. The work plan for this activity did not include either time or money to permit collection of data for constructing new models. However, a data set existed that had been collected in 1977 for updating a fully conventional set of home-interview data. The data set consisted of 1,178 households, from which standard trip data for 24-hr, household demographics, and locational data had been obtained. The trip data consisted primarily of the mode of travel, the origin and destination, the time of day, and the purpose of the trip. Information existed on whether or not the household had automobiles available and how many automobiles were available. The number of licensed drivers was not included in the data.

A calibration data set was developed for mode choice by subdividing the reported trips into the purposes of HBW, HBO, NHB, and HBS. Data were compiled for each trip from the path characteristics of the highway and transit networks to represent the travel characteristics for each trip. For HBW and the HBS trips, the travel characteristics were developed from the peak networks, whereas the characteristics for HBO and NHB trips were drawn from the midday or 24-hr networks. Paths were defined for three primary mode alternatives: automobile, bus, and publico (jitney). It was assumed that access to bus was by walk only, whereas publico could be accessed by either walk or walk and bus. No distinction was obtainable in the travel characteristics for automobile based on the occupancy, except to divide the cost among the occupants. The trip characteristics obtained from the path files and zonal characteristics were walking time, waiting time, in-vehicle time, parking cost, and running cost (running cost is total out-of-pocket costs, not including parking).

The calibration was achieved by using ULOGIT in the UTPS program package. This model required that trips be deleted from the calibration file if any of the alternatives had no path and therefore no trip characteristics. From the 1,178 households, the calibration data sets consisted of 864 HBW trips, 579 HBS trips, 798 HBO trips, and 346 NHB trips. The lack of captivity data prevented removal of captives from the calibration data. The coefficients of the models are given in Table 5.

First, it may be observed that the models for all four purposes produced sensible results in terms of the signs and magnitudes of the coefficients. Hence concerns that models for nonwork trip purposes cannot be calibrated from conventional data appear to be unfounded. Second, note that the relative values of the coefficients differ from those described in the quasi-updated models. In the HBW model walking time and waiting time each have about the same coefficient, and it is more than 3 times the value of the in-vehicle time coefficient. The cost coefficient is about 0.31 of the in-vehicle time coefficient. For HBO trips, the coefficients of walking and waiting time are again similar, but are 12 times the value of the in-vehicle time. The cost coefficient is equal to the in-vehicle time coefficient in this case.

The HBS model is substantially different. In this case the in-vehicle time coefficient was so insignificant and small that the variable was not used in the final model. The walking time coefficient was

TABLE 5 Cost and Time Coefficients of Models for San Juan

Purpose	Wait Time	Walk Time	Out-of-Vehicle Time	In-Vehicle Time	Parking Cost	Running Cost	Total Cost
HBW	-0.049	-0.040	-	-0.013	-	-	-0.004
HBS	-0.053	-0.025	-	-	-0.014	-0.003	-
HBO	-0.060	-0.061	-	-0.005	-	-	-0.005
NHB	-0.119	-0.026	-	-0.010	-0.016	-0.002	-

more than twice the size of the waiting time coefficient, and is 4 times the size of the in-vehicle time coefficient for the work model. Parking cost has a coefficient that is nearly 5 times the size of running cost. The latter coefficient is about 0.2 of the work model in-vehicle travel time coefficient, and is about 0.12 of the waiting time coefficient of this HBS model. Finally, the NHB model shows a further set of different relationships. In this case walking time is weighted 4.5 times more heavily than waiting time and almost 12 times as heavily as in-vehicle time. The cost variable is again divided into the two components of parking and running cost, with the former having a coefficient that is 6 times the value of the latter, and 1.6 times the in-vehicle time coefficient. The ratio of the cost coefficient to the in-vehicle time coefficient is 0.2.

Generally, there is little support from this model for the ratios assumed in many of the noncalibrated models. The work mode-choice model exhibits coefficient relationships that are well within the range of those that have been reported in a variety of other localities. The lack of importance of in-vehicle travel time for school trips is reasonably acceptable, suggesting that, given the necessity to go to school and the relative lack of choice in school location, in-vehicle travel time is of little consequence in choosing among available travel modes. In all models both walking and waiting times are weighted much more heavily than in-vehicle travel time, although walking is considered far more onerous for HBO and NHB trips than for the other purposes.

Case Study 2

The second case study is from Honolulu, Hawaii (13). In this study data were collected expressly for calibration of a set of logit mode-choice models, although it was decided that network (aggregate) data should be used for the calibration data set. Data were collected by means of a travel diary from 1,370 households (see paper by Ohstrom et al. elsewhere in this Record), and the calibration data set was developed by geocoding the origins and destinations of the trips and again extracting the travel characteristics from the path files. The models were structured around the alternatives of automobile (with three occupancy levels), local bus, and express bus. Express bus could be accessed by walk or local bus, while local bus had walk access alone. Express bus was available for only HBW and HBS trips, and both of these purposes again used the peak transit network characteristics, with congested highway speeds, whereas midday transit network characteristics and free-flow highway conditions were used for the HBO and NHB models. As with the San Juan model, no distinction in the characteristics of multioccupant automobile trips could be obtained beyond the division of cost among the occupants. Again, the characteristics used were walking time, waiting time, in-vehicle time, parking cost, and running cost. Sociodemographic variables were also tested, but the only one found to affect the models significantly was the ratio of available vehicles to licensed drivers (minimum value of 0.0 and maximum value of 1.0). This variable was not retained in the final models because of concerns about the ability of local agencies to forecast it. Retention of the calibration values, in place of forecasts, would leave the variable as little more than a constant term.

Calibration was achieved by using the QUAIL program developed at the University of California at Berkeley (14), which permits calibration data to contain a variety of subsets of alternative modes. Therefore, the only discarded data were for any trips where only one mode had a path between a pair of zones or where the trip was totally within the zone. From the 1,370 households, the calibration data sets consisted of 458 HBW trips, 329 HBS trips, 361 HBO trips, and 277 NHB trips. In this case the data included information on captivity, and captives were excluded from the calibration data. In addition, a number of data points were lost because the network characteristics created outliers that would bias the calibration results. An outlier was defined as arising when the chosen mode had travel characteristics (times and costs) that were all inferior to those of any of the nonchosen modes and the sum of the time components was more than 20 min in excess of the worst alternative not chosen. Alternatively, if the total travel time for the chosen mode was more than 3 times the travel time of the next alternative, it was also considered an outlier. The results of the calibration are given in Table 6.

The conclusions to be drawn from these models are similar to those from the San Juan models in their essential points for this paper. Again, the results clearly show that logit models can be calibrated satisfactorily for all of the purposes. Likewise, the relative values of coefficients differ substantially from the assumed values, and show significant differences from purpose to purpose. In the HBW model walking time is weighted by 3.3 times in-vehicle time, whereas waiting time has a coefficient of 5.7 times that of in-vehicle time. Costs are split, with running cost having a coefficient that is 0.17 of in-vehicle time and parking cost a coefficient that is 0.72 of in-vehicle time. In the HBS model walking time is valued at 6.6 times in-vehicle time and waiting time is valued at 4.5 times, whereas cost is 0.47 times the in-vehicle time. In this case in-vehicle travel time did not appear in either the HBO or NHB models. This may signify a problem with the midday and uncongested networks, but it also may be a realistic reflection of behavior. For the HBO model, walking time is considered about 2.5 times as onerous as waiting time, and about 3.5 times as onerous as in-vehicle time for the work trip. Parking cost is 3.5 times as important as running cost, whereas the latter has a coefficient somewhat smaller than for the HBW model.

Finally, the NHB model shows walking time to be more than 3 times as onerous as waiting time and has cost coefficients for both parking and running costs that are almost identical to the HBO values. The

TABLE 6 Cost and Time Coefficients of Models for Honolulu

Purpose	Wait Time	Walk Time	Out-of-Vehicle Time	In-Vehicle Time	Parking Cost	Running Cost	Total Cost
HBS	-0.099	-0.068	—	-0.015	—	—	-0.007
HBO	-0.101	-0.041	—	—	-0.007	-0.002	—
NHB	-0.126	-0.040	—	—	-0.006	-0.003	—

results of the NHB and HBO models are similar to those of San Juan, and suggest a radically different weighting of coefficients to any of the noncalibrated models discussed. (It should be noted that the Honolulu models have been recalibrated subsequently, with minor changes in certain inputs, and some changes have occurred in final coefficient values.)

CONCLUSIONS

Three conclusions are in order from the cases discussed in this paper. First, planning agencies and their consultants should not conclude that the lack of reported research on nonwork models is in any way indicative of potential problems in fitting the models. Although not discussed here, it is appropriate to observe that the statistics of goodness-of-fit for the NHB models are generally inferior to those of the HBW models, which is consistent with experience in fitting trip-generation models for NHB trips. Nevertheless, the values of these statistics are adequate to indicate a useful model. This is further borne out by obtaining coefficients that are reasonable and that also show consistency between two localities described herein. The statistics for HBO models were found to be comparable with the HBW models. In all cases coefficients were found to have t-scores well in excess of 2.0 for included variables, and chi-square values were, as usual, far larger than any table values for the appropriate degrees of freedom. For details, however, the reader is referred to the original reports.

Second, although it is clearly desirable that data be collected that are designed for the purpose of calibrating logit models, it is possible to obtain adequate fits from data that may have been collected several years previously and that were not collected specifically for logit modeling. A cautionary note is appropriate to the effect that use of network-derived characteristics requires great care in path building, a topic that is too extensive to deal with in this paper.

Finally, the transferability of HBW logit-model coefficients that have been assumed in building models for other purposes is not borne out by true calibration. The relationships tend to be significantly different from those in the work models, and may exhibit variation from locality to locality. Similar local differences are also to be found among HBW models when unconstrained calibration is performed. Furthermore, not all of the travel characteristics found to be significant in work mode-choice models are significant in nonwork models. Therefore, factoring from work models, or defining a multiplier for a predefined combination of times and costs for nonwork models, is not an appropriate procedure to use.

ACKNOWLEDGMENTS

The authors would like to thank the Oahu Metropolitan Planning Organization (OMPO) for permission to use the results described for the Honolulu case study and for their active support on the presentation of this paper. The authors particularly would like to thank Cathy Arthur and Gordon Lum of OMPO for their suggestions and help both in the original work and in the documentation of the results in this paper. The authors would also like to thank the Department of Transportation and Public Works of the Commonwealth of Puerto Rico for permission to use the results described for the San Juan case study.

REFERENCES

1. T.E. Parody. Technique for Determining Travel Choices for a Model of Nonwork Travel. In Transportation Research Record 673, TRB, National Research Council, Washington, D.C., 1978, pp. 47-53.
2. T.A. Domencich and D. McFadden. Urban Travel Demand: A Behavioral Analysis. North Holland/American Elsevier, New York, 1975, Chapter 7.
3. F.S. Koppelman and J.R. Hauser. Destination Choice Behavior for Nongrocery Shopping Trips. In Transportation Research Record 673, TRB, National Research Council, Washington, D.C., 1978, pp. 157-165.
4. T.J. Adler and M.E. Ben-Akiva. Joint Choice Model for Frequency, Destination, and Travel Mode for Shopping Trips. In Transportation Research Record 569, TRB, National Research Council, Washington, D.C., 1976, pp. 136-150.
5. J. Horowitz. Disaggregate Demand Model for Nonwork Travel. In Transportation Research Record 673, TRB, National Research Council, Washington, D.C., 1978, pp. 65-71.
6. E.R. Ruiter and M.E. Ben-Akiva. Disaggregate Travel Demand Models for the San Francisco Bay Area. In Transportation Research Record 673, TRB, National Research Council, Washington, D.C., 1978, pp. 121-137.
7. M.J. Fertal et al. Modal Split: Documentation of Nine Methods for Estimating Transit Usage. Bureau of Public Roads, U.S. Department of Commerce, 1966.
8. P.R. Stopher and A.H. Meyburg. Urban Transportation Modeling and Planning. Lexington Books, Lexington, Mass., 1975, Chapter 9.
9. Kaiser Transit Group. Prime Modal Split Model Recalibration Report. Metropolitan Dade County, Miami, Fla., Dec. 1978.
10. R.H. Pratt Associates, Inc., and DTM, Inc. Development and Calibration of Mode Choice Models for the Twin Cities Area. Metropolitan Council of the Twin Cities, Minneapolis, Minn., Aug. 1976.
11. Cambridge Systematics, Inc. The Development of a Disaggregate Behavioral Work Mode Choice Model. California Department of Transportation, Sacramento, and Southern California Association of Governments, Los Angeles, Jan. 1977.

12. Schimpeler-Corradino Associates. San Juan Transportation Planning Models. Final Report. Department of Transportation and Public Works, San Juan, P.R., Sept. 1982.
13. Schimpeler-Corradino Associates. Oahu Model Update Study. Final Report, Volume II. Oahu Metropolitan Planning Organization, Honolulu, Hawaii, Dec. 1982.
14. J. Berkman; D. Brownstone and Associates. QUAIL 4.0 Programmer's Manual. Department of Economics, University of California, Berkeley, March 1979.

The opinions expressed in the paper are those of the authors, and do not necessarily reflect the position or policies of the Oahu Metropolitan Planning Organization or the Commonwealth of Puerto Rico. The authors are solely responsible for any errors or omissions in the paper.

Sequential Model of Interdependent Activity and Destination Choices

RYUICHI KITAMURA and MOHAMMAD KERMANSHAH

ABSTRACT

A sequential model of daily travel patterns that consists of activity and destination choice submodels is developed in this study. The model development takes into account the interdependencies among the choices and the constraints imposed on the movement in time and space. The empirical analysis indicates that non-home-based destination choice is critically dependent on the residence location of the individual and that activity choice is influenced only marginally by the accessibility of the origin location. As a practical and immediate modification of non-home-based destination choice models, it is proposed in this study that destination-to-home travel time be included as a factor that enables a more realistic depiction of spatial travel patterns.

In previous efforts (1,2) the authors have examined the properties of activity choice that are directly related to generation of trips and their temporal distribution over a 1-day period. The results have revealed the characteristics of time-of-day dependencies of activity choice and revealed patterns in sequencing activities in trip chains. Analysis of the dependence of activity choice on its own history indicated that activity history may be represented in a simple manner for use in travel behavior analysis. This study draws on the previous efforts and expands it by introducing the spatial dimension into its scope.

The ultimate objective of this continuing effort is to develop a practical model system that makes possible a more realistic depiction of complex daily travel behavior. The effort and the resulting models can be characterized by the following two aspects. The first is its explicit recognition and incorporation into the model structure of the fact that trips made by an individual are linked to each other. This leads to the emphasis in this study of the interdependencies among choices that underlie the entire daily travel and activity pattern. In other words, this study does not isolate a trip or a travel choice from the rest to be analyzed independently. Second, the effort acknowledges that the movement of an individual is constrained in time and space because of various factors, including the social commitments, obligations, limited transportation capabilities, and physiological needs of the individual (3-8). The constraints are most typically associated with activities that allow little scheduling flexibilities such as work, chauffeuring children to school, or having lunch during a lunch break. This study therefore emphasizes, among others, time-of-day dependencies of activities and trips.

A system of models is developed in this study. It consists of home-based and non-home-based destination choice models that incorporate the effects of trip continuity together with those of time of day. The activity choice models of this study are expanded to include, in addition to the variables used in the previous study (2), spatial factors such as the travel time between the home base and the origin activity location and the accessibility from that location.

The objective of this study is, first, to identify the extent to which destination choice is influenced by factors other than the traditional variables (i.e., the origin-destination travel time and the attributes of alternative destination locations). More specifically, the study is an endeavor to show that the location of an individual's home and the locations of alternative destinations relative to the home location critically influence non-home-based destination choice. The second objective is to identify the effects that spatial factors have on activity choice, either independently or jointly with other factors, including time of day, activity history, and socioeconomic characteristics of the