Transit Trip Distribution Model for Multimodal Subarea Focusing

STEPHEN M. HOWE, YEHUDA GUR, AND DAVID L. KURTH

This paper describes the development of a model for distribution of transit person trips, separately from automobile trips, as an integral component of a multimodal subarea focusing methodology. The extension of subarea focusing to multimodal transportation planning is reviewed. The components of the multimodal transportation analysis process, particularly the interaction between disaggregate mode choice estimation and mode-specific trip distribution, are then described. Transit trip distribution model theory and design are then presented, featuring the simultaneous distribution of distinct transit trip classes. An analysis of observed travel patterns supports hypothesized differences between segments of the travel market. Calibration results show a high degree of accuracy in estimated trip patterns and subsequent transit assignment and, therefore, point to greater precision in assessing the effects of transit-oriented actions.

In the past five years the North Central Texas Council of Governments (NCTCOG) has invested heavily in the development of a refined travel forecasting methodology, designed specifically for detailed subregional planning. The methodology is designed to answer many of the planning needs that arise from increased emphasis on (a) transportation system management strategies for more efficient short-term use of existing facilities, (b) transportation control measures for improvement of air quality, and (c) analysis of alternative major transit investments at the subregional or corridor level. To integrate the various evaluation and decision-making processes into one consistent, efficient work effort, NCTCOG relies heavily on macrosimulation models analogous to the Urban Transportation Planning System (UTPS).

The NCTCOG methodology was first implemented in the form of the thoroughfare analysis process (TAP), which was designed for highway planning at the subregional level (1-4). The extension of subarea focusing to multimodal analysis was undertaken in response to Urban Mass Transportation Administration (UMTA) guidelines of 1976, which require rigorous analysis of alternatives in support of proposed major transit investments. A fully operational feature of the new Multimodal Transportation Analysis Process (MTAP) is the focusing of transit networks. The design of MTAP and the calibration and validation of the models for the evaluation of proposed transitway technologies and alignment along Dallas' North Central Expressway are documented in a forthcoming report (5).

MTAP

The transit trip-distribution model described in this paper could be presented as a stand-alone development effort. In reality, however, this work was an integral part of the overall MTAP development effort. This section provides a brief overview, with particular attention to the challenges posed by subarea focusing and the rationale behind the model structure ultimately adopted.

MTAP features that pertain specifically to transit analysis include the following:

1. Incorporation of the UTPS program INET to use TAP's detailed highway networks in construction of compatible transit networks;
2. Computerized construction of transit approach links;
3. Specification of transit access and egress impedances in the form of frequency distributions, rather than zonal averages, to permit explicit treatment of intrazonal variation;
4. Preparation of stripped transit skim trees, to reflect line-haul impedances only (i.e., those impedance components that have little or no intrazonal variation);
5. Specification of trip maker characteristics in the form of frequency distributions, again to permit sampling of intrazonal variation;
6. Disaggregate mode choice estimation, driven by Monte Carlo sampling and weighting of individual trips; and
7. Distribution of transit person trips, separately from automobile vehicle trips, and explicit treatment of distinct transit trip classes.

Design

The overall MTAP design is schematically presented in Figure 1. The zonal and network master files are structured hierarchically. The zonal hierarchy ranges from 40 jurisdictions at the coarsest level to 5000 traffic analysis zones at the finest level. The hierarchical structuring of the highway network data is analogous to that for zones--level 1 links provide connectivity for jurisdictions, the addition of the level 2 network provides connectivity for the second coarsest zone level, and so on. The structuring of the transit line data base is somewhat simpler and serves mainly to identify those lines likely to be accessed by automobile.

Subarea focusing is then performed to extract subfiles tailored specifically to the analysis. Full detail is preserved within the area of interest, and progressively less detail is given away from the area of interest. Approach links are automatically constructed after zonal and network subfiles have been extracted from the master file.

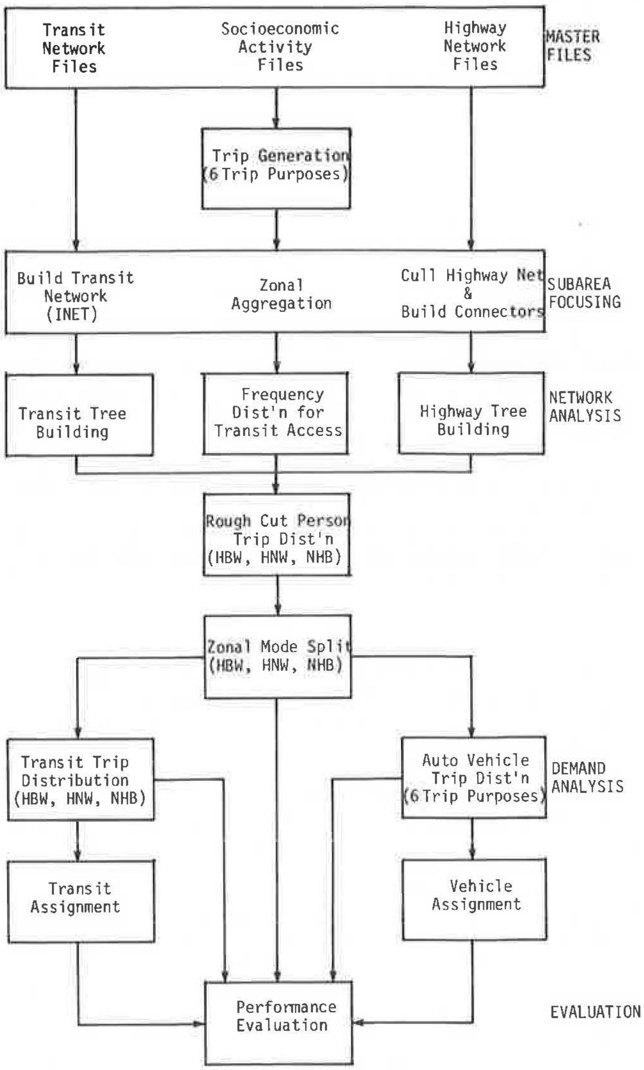
The network analysis phase follows, in which the following functions are performed:

1. Highway and transit network tree building and skimming,
2. Preparation of stripped (line-haul) transit skim trees, and
3. Calculation of zonal frequency distributions for transit access-egress impedances.

Certain criteria are used in the creation of the stripped skim trees to remove network impedances that are expected to have large intrazonal variation (e.g., access-egress by walk or by short feeder-bus legs). The intrazonal variability is explicitly dealt with later, by Monte Carlo sampling from the access-egress frequency distributions.

In the demand analysis phase, MTAP departs from the conventional modeling sequence in that mode split precedes trip distribution and is performed at the zonal (trip end) rather than the zone-pair (trip-interchange) level. The mode split thus provides trip ends stratified by mode. Automobile vehicle trips and transit person trips are subsequently distributed separately, each based on their respective networks. Finally, vehicle and transit trip tables are assigned to their respective net-

Figure 1. MTAP design.



works and evaluation of the results takes place.

Principles

MTAP aids in the analysis of problems when estimates of highway link volumes and transit line boardings are needed for evaluation. Mode-specific assignments and, hence, mode-specific trip tables are necessary to address such problems. Further, MTAP is designed for detailed but cost-effective analyses at the subregional or corridor level. Thus, the challenge has been to find a model structure for producing mode-specific trip tables that is robust enough to withstand drastic variation in zone structure without necessitating extensive calibration or adjustment for each subarea. Finally, a time element was introduced by the need to meet the schedule for upcoming alternatives analyses. Thus proven methodologies were used as much as possible.

The conventional modeling sequence (i.e., multimodal person trip distribution followed by interchange-level mode split) was considered with skepticism. Aggregate models for multimodal trip distribution abound but are more complex than mode-specific distribution (e.g., accounting for transit captivity effects, or measuring multimodal impedances) and, in light of our experience with automobile vehicle trip distribution under focusing (4), did not appear promising for short-term implementation. Disaggregate models for destination choice would, in theory, be more promising under variable zone structures, but experience with such models in producing trip tables suitable for accurate assignment remains somewhat limited.

On the other hand, disaggregate sampling for mode split seemed suitable for use either at the trip-end or trip-interchange level. Disaggregate mode-choice models, applied in a disaggregate sampling and weighting framework, permit accurate treatment of intrazonal variability in socioeconomic characteristics and access-egress impedances and immediately resolve problems incurred in the application of disaggregate models at aggregate levels (6). Performance of mode split at the trip-end level permits the sampling of intrazonal variability more cost effectively than would be possible at the trip-interchange level and also places less demand for accuracy on the mode split and the preceding calculation of person trip weights.

With these considerations in mind, we opted for trip-end mode split followed by separate trip distributions for automobile vehicles and transit persons. Separate distribution of transit person trips allows the unique characteristics of transit to be addressed free from the overwhelming effects of automobile travel. We also capitalized on proven methodologies for mode split and automobile vehicle distribution, and the distribution of transit person trips remained a relatively low-risk research and development project. A relatively simple model for multimodal person trip distribution was devised for constructing matrices of person trip weights.

Mode Split

The inputs required by the mode split program include the highway and transit network skim trees and, for each zone, frequency distributions for transit access-egress impedances and trip-maker (socioeconomic) characteristics. To describe transit access-egress for each zone, the primary frequency distribution required is that for travel distance. Other terminal impedance variables (e.g., travel time and travel cost) are calculated as functions of distance. Ultimately, as many as four competing transit access-egress submodes are represented for each zone, depending on mode availability: walk, feeder-bus, park-and-ride, and kiss-and-ride. For representation of trip-maker characteristics, a multivariate frequency distribution for income, household size, and automobile ownership is derived for each zone from input zonal averages by a process similar to marginal weighting (7). The theory and process by which the access-egress impedances and the trip-maker characteristics are represented are somewhat involved and a complete description lies beyond the scope of this paper. The procedures are well-defined and quite efficient, however, and have been successfully applied in mode split models for the Chicago Area Transportation Study (8) and the Northeast Ohio Areawide Coordinating Agency.

An additional input required by the mode split program is a matrix of person trip weights. The weighting matrix is derived by a preliminary distribution of person trips, based on a relatively crude multimodal impedance formulation that is sensitive to both highway and transit level of service. For a given origin zone, individual trips are sampled and weighted in proportion to the weighting matrix vector that corresponds to this zone. Since this matrix is used solely as a destination weighting matrix, the demand for accuracy is far less than is required in a trip interchange mode split model. The weighting matrix can only affect the final, mode-specific tables through the trip-end mode splits. The latter are not affected significantly by inaccuracies in the matrix of person trip weights as long as the multimodal trip table is relatively correct [for example, in the distribution of origins for trips to the central business district (CBD) and in the proportion of central city versus suburban destinations for trips that originate in various parts of the region].

For a given origin zone, the mode split program ultimately derives aggregate mode splits as follows. First, potential destinations from this zone are sampled in proportion to the corresponding weighting matrix vector. A sample of 50-200 individual trips results, along with the weighting factors necessary to expand the sampled trips to the total trips for the zone. For each individual trip, highway impedances and transit line-haul impedances are immediately available from the skim trees. Transit access and egress travel distances are sampled from the frequency distributions for the origin and destination zone. Other impedance values for the available transit access-egress modes are then calculated as functions of access-egress distance. Trip-maker (socioeconomic) characteristics are also determined by sampling from zonal frequency distributions. When all necessary values are thus determined, disaggregate choice probabilities are calculated for each individual trip by using a nested multinomial logit model. Finally, the sample results are weighted and summed to obtain the aggregate (zonal) mode splits.

For each zone, the following mode splits are obtained for trip productions: (a) automobile versus transit and (b) transit access mode (walk versus feeder bus versus park-and-ride versus kiss-and-ride). For input to transit trip distribution, the transit trip productions are also broken down by class:

1. Trips to the CBD,
2. Corridor trips (non-CBD trips that do not include transfers), and
3. Other trips (non-CBD trips that include one or more transfers).

The classification is obtained by a straightforward tabulation during the sampling and weighting of individual trips: Each trip is classified based on type of destination (CBD versus non-CBD) and number of transfers. The mode splits calculated for trip attractions for each zone are somewhat simpler: (a) automobile versus transit and (b) transit egress mode (walk versus feeder bus). The trip attraction mode splits are obtained by accumulation of destination-end effects during origin-zone processing. The user also has the option of processing each zone as a destination, analogous to the processing of origins; but, simple accumulation is obviously cheaper and has proven effective.

TRANSIT TRIP DISTRIBUTION

Theory

The classification of transit trips was deemed to be an important prerequisite for enhanced simulation of transit travel patterns because of the dual nature of transit travel. Transit patrons include transit captives and noncaptives (those who are free to choose between automobile and transit). If we assume that noncaptives choose the best mode available, then transit trips by noncaptives are likely to be concentrated where transit service is competitive with automobiles. Transit captives, on the other hand, are limited in the selection of their destinations to areas that are served by transit. Transit trips by captives are largely dictated by activity pattern rather than by choice of mode, hence are likely to be less concentrated than trips by noncaptives.

The classification of trip productions performed in mode split accounts for captivity effects without the difficult task of definition, measurement, and prediction of captivity. The three transit trip classes are defined below, in order of decreasing transit travel intensity, transit level of service, and, most likely, percentage of transit patrons who are noncaptive.

The CBD trip class includes all trips for which the attraction end lies in the CBD. Since the CBD trip class generally receives the most-intensive transit service, this class would be expected to have the highest proportion of noncaptives.

Among transit trips that are not attracted to the CBD, those made without transfer generally enjoy better service than those that incur transfers. Thus, the corridor trip class is defined to include non-CBD trips that do not include transfer, although not all such trips lie within clearly delineated radial corridors. Only line-haul transfers are used to identify corridor trips. For example, a non-CBD trip that uses short feeder access to priority service would be considered corridor unless a subsequent transfer to a different line-haul mode was made. For this class, the proportion of noncaptives is perhaps less than that for CBD trips but is expected to be greater than for trip interchanges with transfers.

The other trip class includes all non-CBD trips that incur one or more (line-haul) transfers. The proportion of noncaptives is expected to be the smallest for this class.

In the modeling process, the class distinction permits control over the range of attractions from which a given transit patron may select a destination. CBD patrons are forced to find an attraction in the CBD, corridor patrons must choose from a relatively tight range of non-CBD attractions, and all remaining attractions are available to other patrons. If a zone has high automobile ownership, hence fewer transit captives, then in mode split, transit will capture a significant share only when transit is competitive with the automobile. The CBD and corridor classes will tend to dominate among the transit trips produced by such a zone. Later, when transit trips from this zone are distributed, a large percentage will be restricted to CBD or corridor interchanges where transit service is competitive. Conversely, for a zone that has low automobile ownership (more captives), the portion of other trips will be larger and a generally broader range of attractions will be available.

Design

In MTAP, transit person trips are distributed by the program TTDGRAV, a gravity-model formulation adapted from the access and land development model originally developed by Schneider (9). The basic gravity formulation may be expressed as

$$T_{ij} = P_i [G(F_{ij})A_j / \sum_r G(F_{ir})A_r] \quad (1)$$

where

T_{ij} = number of trips produced by zone i and attracted to zone j;
P_i = total number of trips produced by zone i;

G(F) = travel (decay) function, which represents the decline in attractiveness as a function of increasing travel impedance;
F_{ij} = impedance of travel from zone i to zone j;
A_j = attractiveness (number of trip attractions) for zone j; and
r = one through total number of zones.

In the TTDGRAV model, the basic formulation is extended to handle simultaneous distribution of distinct trip classes,

$$T_{ij} = P_i^{c_{ij}} [G(F_{ij})A_j / \sum_{r \epsilon c_{ij}} G(F_{ir})A_r \quad (2)$$

where

c_{ij} = class of the ijth interchange,
$P_i^{c_{ij}}$ = number of trip productions of class c from zone i, and
A_j = number of trips attracted by zone j (all classes).

As in typical gravity applications, the model is applied iteratively to balance trips received to trip attractions (i.e., $\sum_i T_{ij} = A_j$ for each zone j).

The specific inputs required by TTDGRAV are the following:

1. Transit trip productions and attractions, with productions stratified by trip class;
2. Stripped transit skim trees; and
3. Standard (UTPS) transit skim trees.

The trip ends, stratified as indicated, are provided by the mode split program. The stripped skim trees provide the number of line-haul transfers used in the classification of trip interchanges and a priority mode indicator that is used to identify nontransit interchanges. The UTPS skim trees provide total weighted impedance, which is the basic zonal separation measure used in transit distribution. The total impedance measure is a weighted sum of access times, run times, wait times, and transfer times.

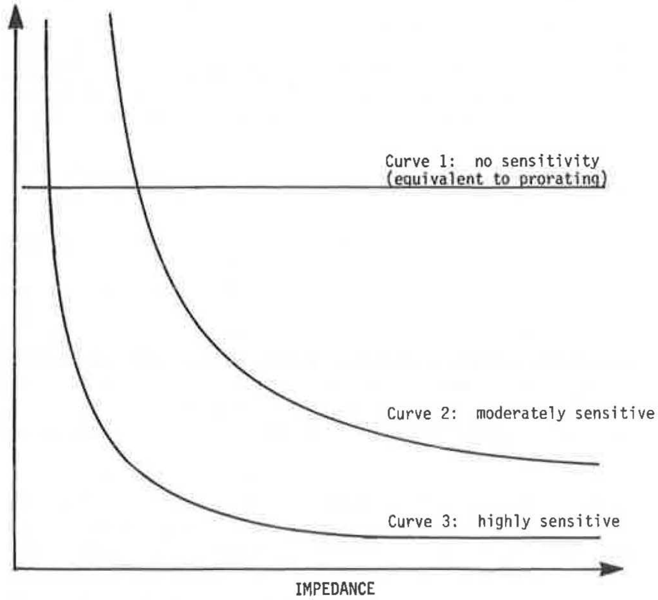
TTDGRAV CALIBRATION AND SENSITIVITY ANALYSIS

The calibration of TTDGRAV was carried out within the context of a major transit investment alternatives analysis for the North Central Expressway corridor in Dallas, Texas. The subarea focusing methodology was used for a highly detailed presentation of this corridor within the NCTCOG study region.

Extensive on-board survey data (10,11) provided an exceptionally rich data base for observed travel patterns on the Dallas Transit System (DTS). Approximately 30 000 boardings were surveyed and weighted to represent approximately 87 000 total trips and 110 000 total boardings, including transfers. From these data, observed transit trip ends and trip tables [home-based work (HBW), home-based nonwork (HNW), and nonhome based (NHB)] were constructed for calibration of distribution of transit trips. For the sake of brevity, only results for HBW will be discussed in detail.

To assess goodness of fit, the 504 zones were aggregated to 61 districts and 10 superdistricts. The districts and superdistricts conformed to logical boundaries in the region (e.g., major thoroughfares and the CBD). In addition, districts and superdistricts were also focused on the corridor to reduce the possibilities of improving fit simply

Figure 2. Alternative decay functions.



through aggregation. The calibration procedures and criteria were structured as follows:

1. Comparison of observed versus estimated trip tables: R^2 calculated for district-level interchanges, average trip length by trip class within superdistrict, percentage of trips received by trip class for each superdistrict, and possible trends or biases in average trip lengths for individual zones; and
2. Comparison of ULOAD assignments of observed versus estimated trip tables: percentage root mean squared error (RMSE) of boardings by line and maximum loading points and load volumes on individual lines.

The parameters to be calibrated included those that define the shape of the decay function [G(F) in Equation 1]. The decay function is a concave, monotonically decreasing function that reflects traveler sensitivity to impedance in selecting among potential destinations. Examples are shown in Figure 2. The steeper the curve, the greater the (simulated) sensitivity.

Other parameters to be considered and calibrated, if necessary, were two types of fixed penalty (i.e., surcharges) added to the basic zonal separation measure in certain instances. The two penalty types are (a) a transfer penalty, possibly stratified by trip class, and (b) production-end and attraction-end penalties for certain groupings of zones. The penalties permit adjustment to account for phenomena not otherwise represented in the basic impedance measure.

Decay Function Options

The spatial allocation of trip attractions around the production end of a single trip production is referred to here as the opportunity surface. The opportunity surface governs the probabilities for selecting among competing trip attractions and consequently affects average trip length and other characteristics of trip distribution from the given production zone. If travel impedance did not have a deterrent effect, then all attractions in the opportunity surface would have the same probability of

Table 1. Opportunity surface analysis for HBW trips.

	CBD			Other			Corridor		
Zone	Avg Trip Length	Avg Opportunity Length	Ratio	Avg Trip Length	Avg Opportunity Length	Ratio	Avg Trip Length	Avg Opportunity Length	Ratio
18	57.1	57.8	0.99	120.6	115.5	1.04	74.8	85.3	0.88
77	53.5	54.8	0.98	100.8	109.5	0.92	74.4	93.8	0.79
90	76.1	75.9	1.00	120.0	133.0	0.90	71.4	80.0	0.89
132	122.8	122.7	1.00	163.1	177.4	0.92	117.5	112.1	1.05
223	79.6	78.2	1.02	127.3	129.6	0.98	80.9	73.0	1.11
228	61.6	61.3	1.00	124.0	133.7	0.93	92.1	101.7	0.91
246	57.8	57.2	1.01	142.0	126.2	1.13	82.0	101.7	0.81
294	58.8	56.0	1.05	107.4	111.4	0.96	68.1	87.0	0.78
335		20.6		84.7	73.9	1.15	78.7	69.9	1.13
374	75.8	79.9	0.95	120.6	134.7	0.90	77.6	98.7	0.79
421	97.6	98.5	0.99	166.9	168.7	0.99	139.8	142.7	0.98
433	74.7	75.5	0.99	121.3	131.2	0.92	78.8	76.3	1.03
473	87.4	87.5	1.00	142.8	141.0	1.01	84.1	85.0	0.99

Note: Length is total weighted transit impedance in minutes.

serving as destinations (i.e., the average trip length would be equal to the average distance of opportunities from the production end). The amount by which the average opportunity distance exceeds average trip length indicates the extent of traveler sensitivity to impedance.

Table 1 lists the average HBW trip impedance, the average HBW opportunity impedance, and the ratio of trip impedance to opportunity impedance for a small sample of zones. The zones were selected judgmentally to represent different parts of the study region and also to ensure at least five trips in each trip class. The impedance ratio is relatively high in all trip classes and ranges from 0.79 to greater than 1.0. This phenomenon marks a clear distinction of transit travel from highway or person travel. The sensitivity to impedance is much less than observed elsewhere (2) for automobile vehicle trips.

For the CBD trip class, the ratios in Table 1 are all close to 1.0, which indicates virtually no sensitivity to impedance. Simple prorating is thus considered for distribution of CBD trips, separate from the decay function for corridor and other trip classes. In the other trip class, the ratios range from 0.89 to 1.0, which indicates a small degree of sensitivity and suggests use of a very shallow travel function. The corridor trips display more sensitivity to impedance; this does not necessarily imply that distinct decay-function parameters are required, however. Corridor trips are generally shorter than other trips, and the slope of a typical decay function (Figure 2) decreases with increasing impedance, which means that the portion of the travel function applicable to corridor trips will generally be steeper than that for other trips.

Sensitivity Analysis

The sensitivity issues to be explored include the following:

1. Sensitivity to parameters that govern the steepness of the decay function,
2. Selection of travel functions for different trip classes, and
3. Sensitivity to fixed penalties.

For the initial attempt to simulate HBW transit trip patterns, it was decided to use a relatively shallow decay curve for all three trip classes. No fixed penalties were applied in this base run. The goodness of fit attained by this initial run is evidenced by an R^2 of 0.98 on all nonzero district interchanges. In the superdistrict summary of trips and trip lengths, by class, nearly all items were accurate to 5 percent or better. The following discrepancies, however, were noted:

1. Trips from the CBD were too short;
2. Average length for corridor trips was understated by 3 percent, and
3. Average trip length was consistently short for zones served by the main crosstown route.

Interestingly, problems seem to occur where the distinction between corridor and other trips is unclear (trips from the CBD, trips served by the crosstown).

To assess sensitivity to the shape of the decay curve, two additional test runs were made in which decay-curve steepness was first increased and then decreased. The goodness of fit was excellent in all cases and there was surprisingly little difference in the test results despite order-of-magnitude variation in decay function parameters. These results suggest that much of the robustness of the model is attributable to the trip classification scheme.

Next, simple prorating (constant decay function) was considered for the CBD trip class. The base run parameters slightly underestimated average impedance for the CBD class, and prorating overestimated the average impedance. Some sensitivity to impedance, however slight, appears to be required in the travel function. To correct for underestimation of average impedance by the base run parameters, a transfer penalty is imposed on the CBD class.

Remaining discrepancies noted in the base run were addressed by introduction of additional fixed penalties. A transfer penalty was imposed on the corridor trip class, which reduced the error in the (underestimated) average impedance by 46 percent. A production-end penalty was assessed for trips produced by the CBD, which reduced the underestimation of average impedance by 64 percent. To increase trip lengths on the crosstown service, error was reduced by 76 percent via imposition of a production-end penalty on zones thus served.

Final Calibration Results

The final comparison of observed versus estimated trip tables is shown in Table 2. The overall R^2 exceeded 0.98 for nonzero interchanges.. The superdistrict comparisons show better than 10 percent accuracy for nearly all entries. Average trip length for total trips by class is estimated within 2 percent accuracy in all cases. The final results generally show a high degree of accuracy in replicating

Table 2. Observed versus estimated trip lengths.

	CBD				Other				Corridor				Total			
	Trips		Avg Length		Trips		Avg Length		Trips		Avg Length		Trips		Avg Length	
Super-district	Sent	Received	Sent	Received	Sent	Received	Sent	Received	Sent	Received	Sent	Received	Sent	Received	Sent	Received
Observed HBW Trips																
1	25	34 662	31.6	73.3	52	0	93.8	0.0	857	0	78.3	0.0	934	34 662	78.0	73.3
2	2 455	0	55.2	0.0	603	1 357	112.1	112.0	235	506	76.9	86.8	3 293	1 863	67.1	105.1
3	1 834	0	74.2	0.0	317	1 827	125.4	129.9	185	240	84.5	79.9	2 336	2 067	82.0	124.1
4	1 142	0	74.7	0.0	52	430	140.8	147.5	48	64	100.0	110.1	1 242	474	78.5	142.7
5	3 366	0	84.7	0.0	1 443	4 275	138.5	124.7	750	1174	105.1	105.8	5 559	5 449	101.4	120.6
6	4 229	0	71.4	0.0	3 166	1 187	120.2	114.0	442	784	78.2	75.5	7 837	1 971	91.5	98.7
7	6 515	0	66.9	0.0	1 664	2 320	116.5	116.2	509	741	84.7	86.4	8 688	3 061	77.4	109.0
8	3 889	0	84.4	0.0	213	334	144.7	165.0	246	71	119.9	96.8	4 348	405	89.3	153.1
9	5 993	0	78.8	0.0	1 580	868	124.3	120.6	547	484	98.4	83.9	8 120	1 352	81.8	107.4
10	5 214	0	69.3	0.0	4 240	732	122.8	124.7	834	589	80.1	80.1	10 288	1 321	92.2	104.8
Total	34 662	34 662	73.3	73.3	13 330	13 330	123.2	123.2	4653	4653	88.6	88.6	52 645	52 645	87.3	87.3
Estimated HBW Trips																
1	25	34 662	30.6[a]	73.3	52	0	89.0[b]	0.0	867	0	75.6	0.0	944	34 662	75.3	73.3
2	2 455	0	56.2	0.0	603	1 412	110.6	111.1	235	464[b]	80.4	83.2	3 293	1 876	67.9	104.2
3	1 834	0	74.4	0.0	317	1 798	128.4	131.0	185	283[a]	84.2	83.0	2 336	2 081	82.5	124.4
4	1 142	0	74.4	0.0	52	438	135.0	150.0	48	54[b]	108.1[b]	105.0	1 242	492	78.2	145.5
5	3 366	0	84.6	0.0	1 443	4 053[b]	139.0	124.6	750	1321[a]	101.8	102.2	5 559	5 374	101.1	119.1
6	4 229	0	71.0	0.0	3 166	1 221	118.9	115.2	442	766	79.9	75.5	7 837	1 987	90.8	99.9
7	6 515	0	66.9	0.0	1 664	2 300	117.4	116.8	509	790[b]	88.7[b]	84.5	8 688	3 090	77.9	108.5
8	3 889	0	84.8	0.0	213	370[a]	151.7	164.5	246	74	121.2	112.0[a]	4 348	444[b]	90.1	155.8
9	5 993	0	78.6	0.0	1 581	920[b]	127.3	121.4	547	411[a]	102.5	90.5[b]	8 121	1 331	89.7[b]	111.9
10	5 214	0	68.9	0.0	4 240	819[b]	122.1	119.2	834	500[a]	76.8	78.3	10 288	1 319	91.4	103.7
Total	34 662	34 662	73.3	73.3	13 331	13 331	123.2	123.2	4663	4663	88.3	88.3	52 656	52 656	87.3	87.3

Note: Length is total weighted transit impedance in minutes.
[a]Error more than 10 percent. [b]Error more than 5 percent but less than 10 percent.

Table 3. Assignment of observed and estimated trip tables.

		HBW			
Sector	No. of Routes	Observed	Estimated	Percentage Difference	Percentage RMSE
Southwest[a]	7	22 072	22 088	0.7	0.7
Southeast[a]	7	9 978	10 014	0.4	1.7
Northeast[a]	4	9 485	9 517	0.3	1.3
North Central-East[b,c]	6	6 123	6 171	0.8	1.8
North Central-West[b,c]	7	6 619	6 719	1.5	2.7
Northwest[a]	6	11 972	11 929	-0.4	1.6
Crosstown[c]	2	956	913	-4.5	9.6
Total	39	67 205	67 351	0.2	1.4

[a]Unit of comparison = cluster of Dallas Transit System (DTS) routes.
[b]Within North Central Expressway corridor.
[c]Unit of comparison = individual DTS routes.

observed travel patterns.

In an additional calibration test, observed and estimated trip tables were assigned to the transit network by the UTPS transit assignment program ULOAD. Results were compared to examine the propagation of transit trip table errors through assignment. Summary results are shown in Table 3. Estimated boardings were compared with observed boardings (actually, boardings that resulted from assignment of the observed trip table) for each route. The comparison shown in Table 3 generally indicates that the effect of errors in trip table assignment is minimal. The overall RMSE is remarkably low--1.4 percent.

In more detailed examination of the assignment results (not shown), the maximal load point and the maximal load were compared for each route. In nearly all cases, the maximal load point was the same in both the estimated and observed assignments, and the maximal load was estimated within 5 percent accuracy. Thus, even at a highly disaggregate level, evaluation of the accuracy of TTDGRAV, in terms of the effect on assignment results, seems quite favorable.

CONCLUSIONS

In response to a growing need for detailed planning of multimodal transportation facilities at the subregional level, NCTCOG has undertaken the development of a multimodal subarea focusing methodology, MTAP. For greater stability under focusing and validity in simulating travel patterns for distinct segments of the travel market, MTAP employs disaggregate mode choice estimation in conjunction with mode-specific trip distributions.

The separate distribution of transit person trips, with explicit treatment of distinct transit trip classes, affords several advantages. First, travel patterns of transit users are clearly distinct from those of automobile users: The spatial allocation of opportunities is dictated by the presence of transit service; further, observed sensitivity of transit travelers to impedance is markedly less than for automobile users. Second, additional distinctions may be drawn between captive and noncaptive users of transit, since the latter group is more likely to use transit in CBD and intracorridor interchanges where transit is more competitive with the automobile. The MTAP classification scheme permits the capturing of differences in travel patterns.

Specific conclusions from the calibration of the transit trip distribution model include the following:

1. The model replicates observed travel patterns with a high degree of accuracy;
2. Model performance is relatively insensitive to decay-function parameters, which suggests that much of the apparent robustness is attributable to the classification scheme;
3. Despite observed differences between trip classes, use of a common travel function together with the fixed penalties for selected categories appears feasible;
4. More precise evaluation of transit-oriented policies is possible with such a model.

The success in formulating a reliable transit trip distribution model validates a major MTAP design decision for attaining robustness under subarea focusing: It is worthwhile to forgo the estimation of interchange specific mode splits and to concentrate on improved estimation of transit trip ends. With the improved estimation of trip ends, the transit trip distribution model can provide excellent trip tables for analysis purposes.

The results in this paper indicate that a workable travel demand model structure can be obtained by integrating the strengths of disaggregate (primarily mode split) and aggregate (e.g., trip distribution) models. For modeling within a subarea focusing framework, in particular, this approach shows much promise for obtaining credible results for practical applications.

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