Transportation Technical Services, Ohio Department of Transportation, Columbus; and Thoroughfare Planning Unit, North Carolina Department of Transportation, Raleigh. This research was sponsored by the Federal Highway Administration of the U.S. Department of Transportation. The contents reflect my views; I am responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the U.S. Department of Transportation.

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Stability Tests and Enhancements in Trip Distribution for Subarea and Corridor-Level Planning

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

This paper describes the investigation of three key issues in the stability of trip distribution modeling as a means toward development of a more robust model that would form the linchpin of a state-of-the-art subarea planning tool, the thoroughfare analysis process. The three issues addressed are (a) stability across trip purpose, (b) stability under subarea focusing, and (c) stability through time and changing development patterns. A set of base models is initially calibrated in much the same way as in conventional fixed-zone modeling. These models are then subjected to a series of stability tests and, where necessary, model enhancements are introduced for further testing. Model refinements are introduced to obtain greater stability with respect to trip purpose and subarea focusing.

This paper describes research into the stability of trip distribution modeling; its goal is to develop a robust model for highly detailed planning at the subarea or corridor level, for both short-range and long-range purposes. The objective is to extend the state of the art in trip distribution to form the pivotal component of the thoroughfare analysis process (TAP), a planning package that is supported by a multilayered data base and that possesses an automatic subarea focusing feature. The structure of the TAP and its application in diagnostic analysis and evaluation at the subarea level are documented by Howe, Ryden, and Penny (1).

Subarea focusing is the means by which the data base for an urban or regional study area is disaggregated to finer detail within an area of interest and aggregated externally to permit cost-effective analysis in greater detail within the area of interest. Such a capability permits a more rigorous, systems approach to subarea planning, e.g., planning the principal and minor arterial network-supporting freeways, diagnostic analysis of transportation systems at the community level, evaluation of community-level transportation system management (TSM) and capital projects, and more detailed long-range analysis of alternative capital investments for corridor improvements.

The stability of trip distribution under focusing was initially addressed by Nihan and Miller (2). The initial calibration of a trip-distribution model for the TAP package was described by Howe and Gur (3). Extending previous work, the research described in this paper examines the stability of the TAP gravity-form distribution model from the following perspectives:

1. Stability across trip purpose--The research described in this paper led to a modified gravity formulation to attain greater stability under multipurpose modeling, which is essential to treatment of separate trip types in diagnostic analysis and evaluation.
2. Stability under subarea focusing--This issue is critical to subarea systems modeling in general. In this case, research pointed to incorporation of additional model parameters to compensate for variation in zone size.
3. Stability over time and changing development--Research indicated a marked degree of stability over a 13-year period of substantial growth and shifts in socioeconomic activity. This finding is important to the use of systems modeling for planning medium- and long-range capital alternatives.

As a starting point, trip distribution models were calibrated on base-year (1964) data that represent a uniform zone structure for a two-county study region, much as one would develop models for conventional planning on a fixed-zone structure. These base models were then subjected to a series of stability tests that addressed the above issues, and model enhancements were made as needed to attain improved robustness.

MODEL FORMULATION AND BASE CALIBRATION

Model Formulation

The trip-distribution model discussed in this paper is ALDGRAV, a gravity-model formulation adapted from the Access and Land Development (ALD) model originally developed by Schneider (4-6) and further discussed by Kaplan (7). The model embodies the following basic assumptions:

1. Probability maximization is applicable to the distribution of trips.
2. For a given group of trip makers, the sensitivity to the disutility of travel is not a single value but ranges over a continuum.
3. The total disutility of travel incurred by the trips produced from a given zone must be finite.

The basic gravity model formulation may be expressed as

$$V_{ij} = V_i[G(F_{ij})A_j/\Sigma_r G(F_{ir})A_r] \quad (1)$$

where

V_{ij} = the number of trips produced by zone i and attracted to zone j;
V_i = the total number of trips produced by zone i;
$G(\cdot)$ = the travel (decay) function, representing the rate at which attractiveness declines with increasing travel disutility;
F_{ij} = the disutility of travel from zone i to zone j; and
A_j = the attractiveness (number of attractions) for zone j.

The travel disutility (F_{ij}) used in the model is a combination of three elements: $F_{ij} = F_{ij}{}^1 +$ FPENO + FPEND. $F_{ij}{}^1$ is a linear combination of travel time, travel distance, and tolls derived directly from minimum-impedance skim trees. FPENO and FPEND are fixed penalties assessed to each trip at its origin and destination. These penalties reflect the terminal impedances encountered in making a trip (e.g., parking cost, walk time).

For intrazonal travel, the minimum-impedance skim tree travel disutility ($F_{ij}{}^1$) is zero. The intrazonal disutility is estimated by using intrazonal travel cost per kilometer and the area of the zone.

In application, the model is doubly constrained; i.e., Equation 1 is iteratively adjusted to balance the trips received by each zone to the input number of attractions.

Specific gravity formulations are distinguished by different forms of the travel function $G(\cdot)$. Examples include the following:

1. The inverse power function, $G(F) = F^{-a}$;
2. The negative exponential function, $G(F) = \exp(-aF)$; and
3. The gamma density function, $G(F) = [F^{a-1} \exp(-F) \div \gamma(a)]$.

The travel function used in ALDGRAV is somewhat more complex than the above functions, but it can be related to the negative exponential function as follows: If the second basic assumption above is replaced by the simplified assumption of a single value (a) for traveler sensitivity, one derives the gravity model (Equation 1) by means of the negative exponential travel function. This model has been derived from entropy maximization principles by Wilson (8). The ALDGRAV formulation, however, is based on the theoretically more complete second basic assumption, which leads to integration over a range of sensitivity values and results in the gravity form that has the ALDGRAV travel function

$$G(F) = [K_2(2\sqrt{aF})/4aF] \quad (2)$$

where K_2 is the modified Bessel function of second kind and second order, and a is a value representing an average traveler sensitivity. Compared with the negative exponential function, the Bessel function has a faster decay rate for very small disutility values and more gradual decay over larger disutility values. Also, it can be shown that the expected distance remaining to be traveled, conditional on trip length $\geq$d, is the same for all d that has the negative exponential function but increases with d for the Bessel function.

Base Model Calibration

The ALDGRAV model was calibrated separately for each of four trip purposes: home-based work (HBW) trip, home-based nonwork (HNW) trip, non-home-based (NHB) trip, and truck and taxi (TNT) trips. The calibration dealt exclusively with vehicle (automobile-driver) trips rather than with person trips. The zone structure used in the base calibrations is comparable to that used in conventional fixed-zone modeling: 504 zones represent a study region of 6500 km^2 (2500 miles^2), with approximately 5 million total vehicle trips daily in 1964.

Origin-destination data from a 4 percent survey in 1964 were converted to a production-attraction format and summarized to obtain observed trip tables and trip ends. (For HBW and HNW trips, the production end is the home end; for NHB and TNT trips, the production end is the origin.) The observed trip ends were input to the calibrations in order to study trip distribution in isolation from possible trip-generation errors. For calculation of travel disutility, or impedance, a 1964 network was used to construct zonal-interchange matrices for travel time, distance, and direct cost (tolls). The disutility measure used in ALDGRAV comprises a weighted combination of time, distance, and cost, plus fixed penalties assessed at the production and attraction ends according to area type.

The region was stratified into four area types: (a) major central business district (CBD) (Dallas and Fort Worth), (b) CBD fringe and outlying CBD, (c) remaining urbanized area, and (d) rural. The parameters to be calibrated were (a) the multiplier constant a in Equation 2, (b) the fixed penalties FPENO (production-end) and FPEND (attraction-end) associated with each area type, and (c) the cost per kilometer (C/KM) used to calculate intrazonal impedance, which is also stratified by area type.

Calibration of ALDGRAV is accomplished in a structured cut-and-try fashion. The a parameter is first adjusted to obtain the correct overall average trip length. The fixed penalties can then be used to adjust trip length by area type. Finally, the C/KM parameters are adjusted to obtain the correct interzonal percentages by area type.

The calibration criteria, used in comparing estimated and observed trip tables, consisted of the following:

1. The average interzonal trip length and the percentage of trips that are interzonal, by area type;
2. Aggregation to 39 districts and summary;
3. Assignment of the district-level trip table to a spider network to examine screenlines; and
4. The standard deviation and coefficient of skew for the zonal trip-length frequency distributions.

The first criterion is geared to obtain the correct vehicle kilometers of travel (VKT) in traffic assignment, since

Table 1. Standard deviations and coefficients of skew.

Trip Type	SD (km)	Coefficient of Skew[a]	Trip Type	SD (km)	Coefficient of Skew[a]
HBW			NHB		
Observed	9.89	1.85	Observed	8.71	2.77
Estimated[b]	10.00	1.90	Estimated[b]	7.65	2.24
HNW			Estimated[c]	7.97	2.46
Observed	8.05	3.13	TNT		
Estimated[b]	6.55	2.07	Observed	9.71	2.09
Estimated[c]	7.69	2.55	Estimated[b]	9.47	2.05

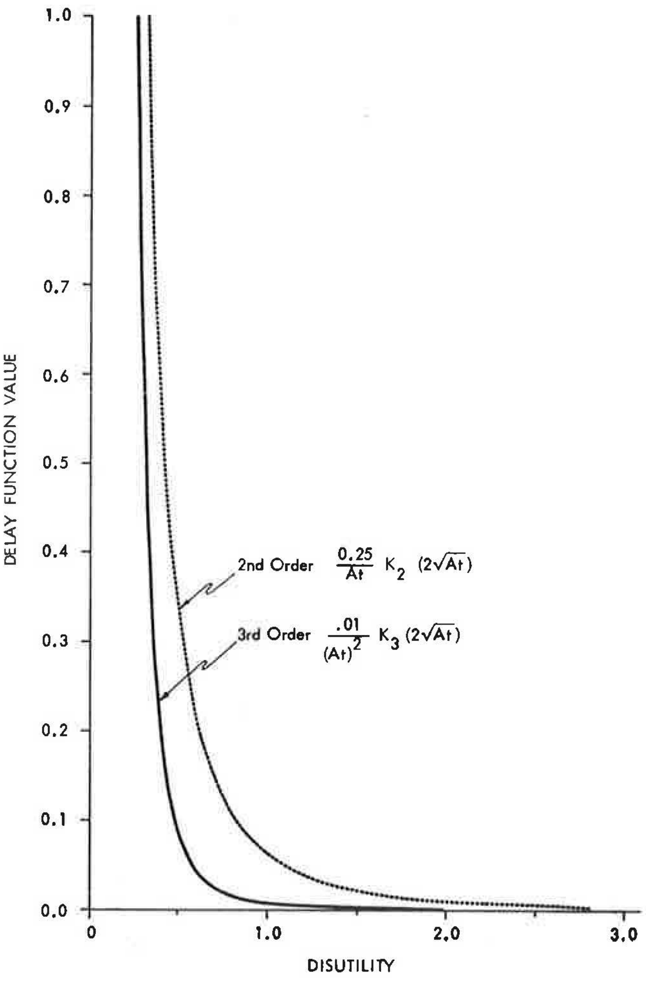
Note: 1 km = 0.62 mile.

[a] Coefficient of skew = $\sum_{i=1}^{n} (X_i - \bar{x})^3 / (n - 1) SD^3$.

[b] With second-order Bessel function.

[c] With third-order Bessel function.

Figure 1. Second-order and third-order Bessel functions.



$$\text{VKT} = \text{average interzonal length} \times \text{interzonal percentage} \times \text{number of trips} \quad (3)$$

As described in the next section, the fourth criterion was particularly helpful in determining the distinctive nature of HNW and NHB trips and in pointing the way to model enhancements to better handle these trip types.

STABILITY ACROSS TRIP TYPE

Refinements to Better Handle HNW and NHB Trips

The base calibration of ALDGRAV initially used the modified Bessel function of second order and second type (Equation 2) for all four trip types. The results for HBW and TNT were generally accurate with respect to interzonal percentage and length, as well as the district-level summaries. The HNW and NHB results, however, were inconsistent. For these trip types the interzonal percentage and length were correct, thus theoretically guaranteeing correct VKT, yet the district-level spider assignment gave estimated screenline volumes that were too high. In fact, the estimated volumes were too high in general on the spider network, indicating that the model was estimating too many interdistrict trips, despite its calibration to give the correct number of interzonal trips.

It appears that the HNW and NHB categories comprised fewer long (interdistrict) trips than could be estimated by the base model calibrated to the correct average length. The HNW category, for example, includes subtypes that are very short (e.g., local shopping trips) and very long (e.g., recreational trips). It was thus surmised that the observed trip length must have a more skewed distribution than that estimated by the base model. To test this hypothesis, the standard deviation and the coefficient of skew for the trip-length distribution were introduced as calibration criteria. Comparisons shown in Table 1 confirmed that, for HNW and NHB, the skew coefficients derived by the base model (second-order Bessel function) were too low.

On the basis of these observations, it was decided to modify the ALDGRAV program to permit selection of Bessel functions other than the second order for use as the travel function. For HNW and NHB trips in particular, the desirable features would be a steeper slope for small impedance values and a more gradual, nearly flat slope for larger impedance values. The heightened sensitivity to smaller impedances would promote more short trips, while the relative insensitivity to larger impedances would promote more long trips. As shown in Figure 1, the modified Bessel function of the third order and second type possessed the desired features. Different forms of the Bessel function and their usefulness in trip distribution are discussed in Kurth, Schneider, and Gur (9). The third-order function was introduced and tested as the travel function for HNW and NHB, with substantial improvements, particularly for HNW. The skew coefficients obtained by means of the third-order function are also shown in Table 1.

It should be noted that an alternative approach to handling skewed distributions is to adopt a long-short stratification or a more-detailed breakdown of trip purposes (e.g., treat shopping trips separately from social and recreational trips). In this case, the gains in accuracy must be weighed against the additional data requirements and costs in modeling and processing.

Results

The results of the base model calibration (after modification to use third-order HNW and NHB travel function) are shown in Table 2. The interzonal percentage and average length are shown, stratified by area type and by production versus attraction. In almost all cases, the estimated value is within 5 percent of the observed value, assuring highly accurate estimation of VKT (see Equation 3), assuming correct trip generation.

The model parameters determined by the calibration are shown in Table 3 to illustrate the substantial difference in parameters across trip purpose and across area type. It should be noted that thus far the fixed penalties FPENO and FPEND

Table 2. Vehicle trip-length distribution summary.

Category	HBW[a] Observed	HBW[a] Estimated	HNW[b] Observed	HNW[b] Estimated	NHB[b] Observed	NHB[b] Estimated	TNT[a] Observed	TNT[a] Estimated
All trips	701 522	701 521	1 734 359	1 734 363	900 514	900 523	489 077	489 077
Interzonal (%)	92.4	90.7	68.8	65.3	79.7	79.4	75.7	74.6
Avg interzonal length (km)	14.31	14.37	9.50	9.76	10.11	10.00	11.32	11.69
SD (km)	9.89	10.00	8.05	7.70	8.71	7.97	9.71	9.47
Coefficient of skew	1.85	1.90	3.13	2.55	2.77	2.46	2.09	2.05
Area 1								
Productions	1748	1748	3471	3471	76 582	76 582	32 031	32 031
Interzonal (%)	100.0	99.3	98.4	99.5	99.3	98.9	97.0	97.9
Avg interzonal length (km)	6.95	6.90	6.81	6.71	8.69	8.53	6.32	6.32
Attractions	101 559	101 664	77 159	77 247	67 907	70 111	31 999	33 889
Interzonal (%)	100.0	100.0	99.9	100.0	99.2	98.8	97.0	98.1
Avg interzonal length (km)	13.81	13.53	12.31	11.66	8.53	6.85	6.35	6.48
Area 2								
Productions	183 988	183 989	410 740	410 741	303 339	303 348	148 725	148 725
Interzonal (%)	93.1	92.8	71.4	68.3	81.4	81.3	76.7	76.5
Avg interzonal length (km)	10.98	10.90	7.81	7.73	8.79	8.79	8.89	9.19
Attractions	223 901	224 031	549 975	553 410	306 474	313 430	148 837	154 097
Interzonal (%)	94.4	94.1	78.7	76.5	81.6	81.9	76.7	77.3
Avg interzonal length (km)	13.02	13.61	8.29	8.71	8.65	8.87	9.03	9.85
Area 3								
Productions	468 737	468 737	1 207 388	1 207 391	491 580	491 580	268 865	268 865
Interzonal (%)	92.9	90.8	68.3	64.2	76.4	75.6	74.3	72.3
Avg interzonal length (km)	14.71	14.76	9.56	9.68	10.79	10.55	12.47	12.74
Attractions	349 964	349 675	1 021 882	1 024 082	496 400	493 429	268 498	266 290
Interzonal (%)	90.5	87.6	62.5	57.8	76.6	75.7	74.3	72.0
Avg interzonal length (km)	15.00	14.87	9.50	9.82	10.85	10.98	12.37	12.81
Area 4								
Productions	47 047	47 047	112 760	112 760	29 013	29 013	39 456	39 456
Interzonal (%)	83.8	81.2	63.9	64.1	66.5	71.4	63.6	64.8
Avg interzonal length (km)	24.56	25.77	15.89	18.77	19.45	19.85	19.50	21.44
Attractions	26 096	26 151	85 343	79 624	29 733	23 553	39 743	34 801
Interzonal (%)	70.8	66.1	52.3	49.2	67.3	64.8	63.9	60.1
Avg interzonal length (km)	19.74	19.60	16.48	16.39	19.53	18.92	19.40	20.26

Note: 1 km = 0.62 mile.

[a] Based on second-order Bessel function.

[b] Based on third-order Bessel function.

Table 3. Calibrated parameters.

Category	HBW[a]	HNW[b]	NHB[b]	TNT[a]
a (¢$^{-1}$)	0.0196	0.0080	0.0071	0.0161
FPENO (¢)				
Area 1	117	125	185	50
Area 2	73	26	60	30
Area 3	53	10	33	30
Area 4	15	0	0	0
FPEND (¢)				
Area 1	117	70	25	0
Area 2	73	0	0	0
Area 3	53	0	0	0
Area 4	15	0	0	0
C/KM (¢/km)				
Area 1	37.2	33.0	57.2	22.5
Area 2	13.1	57.2	49.8	23.1
Area 3	10.3	57.8	49.8	21.3
Area 4	15.5	46.7	46.1	29.3

Note: 1 km = 0.62 mile.

[a] Second-order Bessel function.

[b] Third-order Bessel function.

have been treated strictly as parameters; i.e., no attempt has been made to relate these to underlying real-world penalties, such as parking cost and terminal time. Possible relationships will be explored in future work as a means toward providing sensitivity to parking management, automobile-free zones, and other TSM policies that affect trip-end impedance.

STABILITY UNDER SUBAREA FOCUSING

Test Design

The models described in the previous section were calibrated on a zone structure appropriate for regionwide analysis, specifically 504 intermediate-sized regional analysis areas (RAAs). The issue addressed in this section is the stability of trip distribution under focusing of the zone structure for detailed planning within subareas.

As is shown in Figure 2, a subarea was selected and a focused zone structure delineated for its analysis. The subarea, comprising 299 fine-grained traffic survey zones (TSZs), is surrounded by a buffer of 154 intermediate-sized RAAs; the rest of the region is aggregated to 34 districts. For testing trip distribution in this subarea context, observed trip tables and trip ends were derived from 1964 data for the focused zone structure, and matrices for travel time, distance, and cost were similarly constructed.

The stability test consisted of applying the base models to the subarea and examining possible discrepancies arising from variation in zone size. Of primary concern were the interaction between the subarea and the rest of the region, and stability in the number of interzonal trips emanating from zones of varying size. For analytical purposes, trips were stratified into four classes: (a) subarea-subarea, (b) subarea-external (all zones outside the subarea are collectively denoted "external"), (c) external-subarea, and (d) external-external.

Comparison criteria for assessing the accuracy of the subarea-external interface included (a) number of trips falling in each class, (b) average trip length for each class, and (c) the contribution by each class to VKT within the subarea. (To measure subarea VKT, a special matrix was constructed by reskimming distance over subarea network links only. Multiplication of this matrix by a trip table yields subarea VKT on each interchange.) In addition, the interzonal percentages were examined for class 1 (small zones) and class 4 (dominated by the very large zones) trips.

Figure 2. Subarea definition.

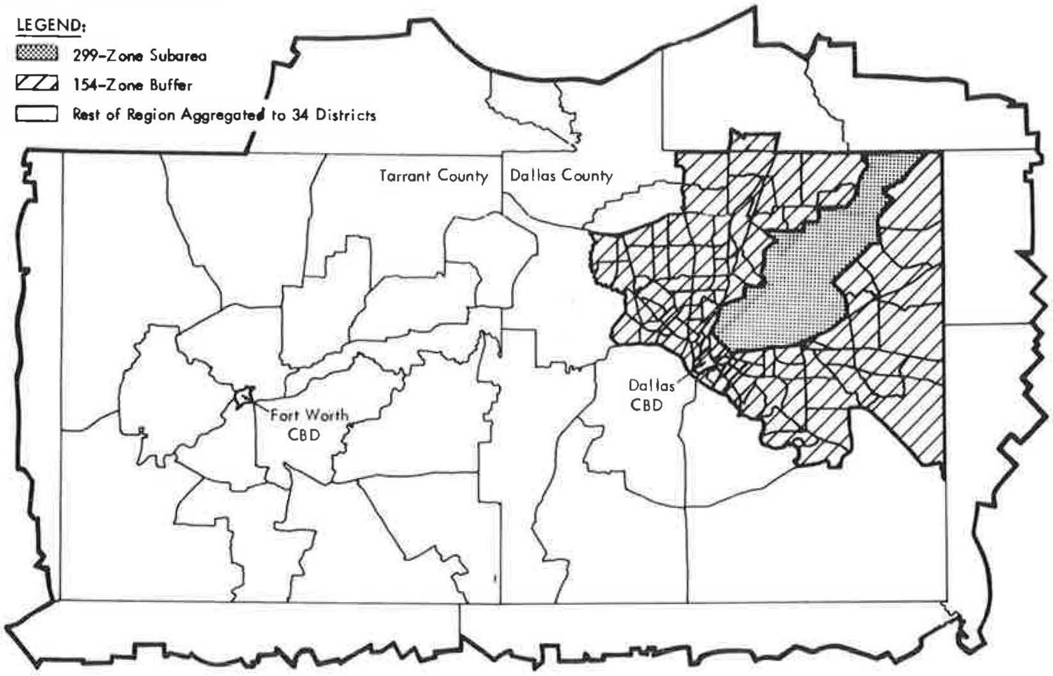


Table 4. Stability under subarea focusing for HBW and HNW trips.

	HBW Trips			HNW Trips		
Category	Observed	Base Model	Model with Zone-Size Parameters	Observed	Base Model	Model with Zone-Size Parameters
All trips	701 553	701 553	701 554	1 733 998	1 733 998	1 733 998
Interzonal (%)	78.1	68.1	76.5	49.3	61.9	50.9
Avg interzonal trip length (km)	17.82	17.23	18.11	12.82	15.45	13.35
Subarea VKT	810 552	798 906	803 192	1 049 858	966 989	984 073
Error (%)[a]		−1.4	−0.9		−7.9	−6.2
Subarea-subarea	34 665	33 682	34 075	166 616	175 817	173 059
Interzonal (%)	96.7	97.4	97.3	92.5	80.1	85.3
Avg interzonal trip length (km)	5.87	6.19	6.16	3.61	3.45	3.45
Subarea VKT	178 573	185 361	186 497	533 127	469 050	492 234
Error (%)[a]		+0.8	+0.9		−6.1	−3.8
Subarea-external	64 522	65 505	65 112	59 211	50 010	52 768
Avg interzonal trip length (km)	15.19	14.32	14.73	13.35	11.11	10.53
Subarea VKT	358 321	354 252	350 018	266 955	184 144	195 835
Error (%)		−0.5	−1.0		−7.9	−6.7
External-subarea	24 939	25 458	26 609	40 531	50 953	48 836
Avg interzonal trip length (km)	19.32	17.89	18.47	13.90	15.00	13.79
Subarea VKT	132 027	124 963	130 316	168 748	219 719	209 381
Error (%)[a]		−0.9	−0.2		+4.9	+3.5
External-external	577 427	576 908	575 578	1 467 640	1 457 218	1 459 335
Interzonal (%)	73.6	61.3	71.5	40.9	57.1	43.3
Avg interzonal trip length (km)	19.08	18.74	19.58	15.05	17.77	15.85
Subarea VKT	141 631	134 331	136 361	81 027	94 076	89 848
Error (%)[a]		−0.9	−0.6		+1.2	+0.8

Note: 1 km = 0.62 mile.

[a] Calculated as percentage of total observed subarea VKT.

Base-Run Results

A set of base runs was first made by applying the models from the regionwide calibration directly to the subarea. Base runs were made for HBW, HNW, and NHB trip purposes.

For HBW trips (see Table 4), base-run estimates for number of trips and for subarea VKT, by trip class, were quite accurate. The base-run average length is too short, however, for subarea-external and external-subarea trips. Further, the interzonal percentage for external zones is too low. It was hypothesized that both problems could be corrected by increasing the interzonal percentage for large zones, thus generating more travel from outlying districts and thereby reducing the excessive "pull" between the subarea and nearby external zones.

For HNW trips (see Table 4), the base run estimated too many subarea-subarea trips and too few subarea-external trips, while the subarea-subarea VKT was underestimated. These results are seemingly explained by the underestimated interzonal percentage for subarea zones. Also, there were too many external-subarea trips, a probable result of the excessive interzonal percentage for large zones. The proposed solution was to increase the

Table 5. Percentage change in intrazonal cost per kilometer stratified by zone size.

	Zone Size				
Trip Purpose	0-0.65 km^2	0.65-2.6 km^2	2.6-10.4 km^2	10.4-41.6 km^2	>41.6 km^2
HBW	-11	+4	+28	+48	+107
HNW	+40	+20	+16	-4	-27
NHB	+28	+19	+13	-10	-32

Notes: 1 km^2 = 0.38 mile^2.
The percentages of increase or decrease from the regionwide C/KM values are applied to each area type.

HNW interzonal percentage for small zones and to decrease it for large zones.

The NHB base-run results showed discrepancies similar to those for the HBW base run, although the NHB base run was more accurate overall. Similar adjustments to interzonal percentages were prescribed.

Model Refinements and Subsequent Results

In order to make the desired adjustments to the interzonal percentage by zone size, the intrazonal C/KM factor was stratified by zone size within area type. The C/KM factors directly affect the interzonal percentage by making intrazonal travel more or less attractive. An increase in C/KM results in an increased interzonal percentage and vice versa. It was hypothesized that travel speed of intrazonal trips and, thus, the C/KM vary with the zone size.

The parameter modifications are represented in Table 5. For HBW trips, the C/KM was increased for larger zones in order to increase the interzonal percentage for larger zones. For HNW and NHB trips, the C/KM for large zones was decreased in order to reduce the interzonal percentage for large zones, while the C/KM was increased to obtain higher interzonal percentages in the small zones.

Table 4 shows the results obtained by these refinements. Substantial improvements can be noted with respect to the discrepancies in the base-run estimates. For HBW trips, the estimated average lengths for subarea-external and external-subarea trips more closely approximate the observed values. For HNW trips, the breakdown of trips and subarea VKT, by trip class, are somewhat improved, although some discrepancies can still be discerned. Results for NHB trips were similar to those observed for HNW trips. For all three trip purposes, model refinements resulted directly in much-improved interzonal percentages, with concomitant improvements in most of the remaining values.

Interpretation and Implication of Refinements

The work described in this section suggests that (a) direct transfer of a conventionally calibrated gravity model to a focused zone structure may result in discrepancies because of variation in zone size and (b) refinements to permit explicit treatment of zone size in intrazonal calculations may lead to significant overall improvement in accuracy. To deal effectively with this problem, however, further experimentation with different subareas will be necessary for development of a generalized strategy for setting parameters by zone size. A number of factors specific to the subarea studied in this section may have affected the results: assumptions made in defining layers of zonal detail, layers of network detail, the construction of approach links and calculation of approach-link impedance, and possibly other factors pertaining to the type and location of the subarea within the study region.

Table 6. Temporal stability comparisons.

	1964		1977[a]	
Trip Type	Observed	Estimated	Observed	Estimated
HBW				
Total trips	701 522	701 521	1 139 920	1 119 436
Interzonal (%)	92.4	90.7	95.0	90.5
Avg interzonal length (km)	14.31	14.37	16.79	17.31
HNW				
Total trips	1 734 359	1 734 363	2 233 497	2 907 725
Interzonal (%)	68.8	65.3	75.0	73.4
Avg interzonal length (km)	9.50	9.76	11.35	11.89
NHB				
Total trips	900 514	900 523	1 581 566	1 588 449
Interzonal (%)	79.7	79.4	82.8	82.0
Avg interzonal length (km)	10.11	10.00	12.89	11.66

Note: 1 km = 0.62 mile.

[a] Differences between observed and estimated total trips for 1977 may be caused by inaccuracies either in the small-sample home-interview survey (observed) or in the 1964-based synthetic trip-generation rates (estimated). Actually, the corresponding totals are quite close except for the HNW category, where underreporting of trips in the home-interview data is suspected.

One approach to a generalized strategy would be to tie the parameter adjustments by zone size to measurable real-world phenomena. For example, the reduced large-zone C/KM values adopted for HNW and NHB trips could possibly be related to the fact that in large zones the intrazonal trips are longer and thus attain faster and more efficient speeds, in turn implying lower real-world costs per kilometer.

TESTS FOR TEMPORAL STABILITY

Test Design

For long-range analysis of capital alternatives, either at the regional or at the subarea level, it is essential that trip-distribution models possess stability through time and changing development patterns. The models described above were calibrated by using 1964 survey data. To test the models for temporal stability, it was decided to apply them in a recent (1977) base-year setting.

During the 13-year lapse between base years, the North Central Texas study region underwent substantial growth and shifts in socioeconomic development. Population grew by 41 percent, industrial employment by 33 percent, and service employment by 97 percent. Considerable urban sprawl occurred, and a number of suburban towns grew into medium-sized cities during this period. In preparation for the 1977 test runs, vehicle trip ends were derived from 1977 socioeconomic data by means of synthetic trip generation. A 1977 highway network was used to construct zonal-interchange matrices for travel time, distance, and cost. The zone structure selected for the test was the intermediate-level 504-RAA set typically used in regionwide analysis.

To provide a comparison with observed 1977 trip patterns, regionwide HBW, HNW, and NHB average trip lengths and interzonal percentages were derived from a small-sample home-interview survey (the Urban Area Citizens Survey) made in 1977 (10). The travel data, taken from 1158 households representative of the study region, included 10 500 trip records. The regionwide values were used as the primary criteria for comparison; more-detailed comparisons were not attempted because of the sparseness of the observed trip data for 1977 and because 1977 estimates for specific trip interchanges could be significantly affected by errors in the synthetic trip generation.

Results

The test results are shown in Table 6. The increase in total trips from 1964 to 1977 reflects, of course, the growth in development during this period. The substantial increases in the observed trip lengths, for all three trip purposes, reflect the increased dispersion of activity. Despite these changes, however, application of the 1964-based models to 1977 data closely approximates the observed regionwide trip lengths and interzonal percentages for 1977. It appears that there are no significant biases, except possibly for NHB average trip length, which is underestimated by 10 percent.

CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

From the stability tests described in this paper, the following conclusions are drawn:

1. Trip lengths for HNW and NHB trips appear to have more-skewed distributions than those for HBW and TNT trips, which may be a reflection of a short versus long dichotomy within the HNW and NHB categories.
2. Incorporation of a family of travel-function curves, e.g., the Bessel family, selected according to the underlying degree of skewness, appears to be a cost-effective approach to attaining stability across trip type.
3. To attain stability under subarea focusing, refinements to permit explicit treatment of zone-size variation are desirable, if not absolutely necessary.
4. It appears that a key determinant of stability under focusing is the calculation of intrazonal trips, and refinements to allow stratification by zone size appear to be a promising avenue to improved stability.
5. Limited testing indicates that the models described in this paper possess an encouraging degree of stability through time and development patterns.

At least two pressing needs for further research can be identified. The first concerns the fixed penalties, FPENO and FPEND, assessed at the production and attraction end, respectively. If these parameters can be successfully related to real-world trip-end impedances such as parking cost and walking distance, it will be possible to capture the sensitivity of trip distribution to such TSM policies as preferential parking, automobile-free zones, and parking cost strategies. Second, further experimentation with subarea focusing is required to derive generalized rules for handling variation in zone size. The discussion in the section on stability under subarea focusing suggests an approach to improved stability under focusing, but the parameter values derived there may be dependent on the specific problem studied, assumptions concerning approach-link impedances, etc. A generalized strategy for stratifying parameter values by zone size is needed, preferably a method that permits calculation from observable phenomena.

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New Techniques for Integrating Census Bureau Data and Software with the Urban Transportation Planning System

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A technology transfer project between the U.S. Bureau of the Census and the Urban Mass Transportation Administration has made Census Bureau software products and simplified Census Bureau data-access procedures available to the users of the Urban Transportation Planning System (UTPS). The Census Bureau software systems for geocoding and computer mapping, as well as utilities for zone definition and area boundary extraction, have been integrated into UTPS