Manual Techniques and Transferable Parameters for Urban Transportation Planning

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This paper summarizes research conducted under the National Cooperative Highway Research Program to identify contemporary transportation policy issues and to evaluate current travel estimation models and procedures in terms of their abilities to respond to such issues. A set of manual techniques and transferable parameters corresponding to the commonly used four-step transportation planning process is described. Brief descriptions are provided for trip generation, trip distribution, mode choice, traffic assignment, time-of-day characteristics, car occupancy factors, capacity analysis, and land development and highway spacing relationships. The travel estimation material developed has been organized in the form of a user's guide, which also includes applications to three scenarios of realistic situations. The manual methods are more advantageous than the computer methods in that transferable parameters allow for quick response in terms of the time required to collect and process local information.

Much of the emphasis of past urban transportation planning has been put on the development of long-range transportation plans such as the Chicago Area Transportation Study (CATS) of the late 1950s and early 1960s (1). The complex travel-estimating procedures in use then (and now) were designed primarily to evaluate regional transportation systems, in particular highway systems, and to ultimately provide design volumes.

Most initial studies or major updates proceed on a 2- to 3-year time schedule; much of this time is taken up by very costly data collection, data processing, and model calibration. These long-range data-intensive planning processes have often been criticized; their relevance has been questioned; and recommendations have been made for alternative approaches to planning (2, 3).

Recently, however, issues such as energy considerations and the promotion of public transportation modes have taken a much larger role in the planning process. Also, ever-increasing input to the planning process from citizens and elected officials, preparation of environmental impact statements, corridor hearings, and consideration of low-capital and no-build options all demand that the planning process be able to provide analytical support to decision makers in a very short time frame.

Concurrently, emphasis is beginning to shift away from long-range planning to relatively shorter time horizons. Recent papers by Heanue (4) and Manheim (5) have highlighted such a shift in planning strategies.

In light of these trends, it is quite evident that existing planning procedures often fail to permit an analytical response to the various policy issues within the desired time and cost constraints. What is needed are simplified planning methodologies that are easy to understand, relatively inexpensive to apply, and, above all, responsive to the policy issues of the day. It is quite possible to simplify the conventional planning procedures so that more resources can be devoted to other areas of concern (6). Typical improvements on these very involved planning techniques might

1. Avoid dependence on computerized models and instead use manual estimation techniques;
2. Reduce data-collection efforts by utilizing readily available data, transferable parameters, or synthetic models;
3. Analyze regional plans at the district rather than the zone level and focus planning efforts on corridor and subareas; and
4. Estimate travel for only one purpose, and then expand these trips to obtain total travel.

Much work has already been done along these lines. A fair degree of success has been attained, for both highway and transit analysis (7, 8, 9, 10, 11, 12). If such modifications can be applied to the existing planning structures, it would be possible to achieve quicker response capabilities for the travel estimation techniques. This in turn would enable simplified but rapid evaluation of transportation policy alternatives.

On this basis, the National Cooperative Highway Research Program (NCHRP) contracted with the COMSIS Corporation and the Metropolitan Washington Council of Governments to undertake a research and development study to develop manual techniques and transferable parameters for quick response to urban policy issues. The research approach is summarized below.

RESEARCH APPROACH

The study was conducted in two separately funded phases. Specific objectives, tasks, and results for each phase were as follows.

Phase 1

The phase 1 research effort involved completion of the following objectives:

1. Objective 1-A: Identification and categorization of contemporary urban policy issues for which travel estimates are required.
2. Objective 1-B: Evaluation of current and emerging travel estimation models and procedures with respect to their ability to satisfy the requirements of policy issues.
3. Objective 1-C: Preparation, on the basis of objectives A and B, of a fully supported set of recommendations for the subsequent phase of the project.

The research approach and results of the phase 1 study have been fully documented (13).

Phase 2

The results of phase 2 are the focus of this paper. The phase 2 research effort required the following objectives:

1. Objective 2-A: Development of a user's guide to describe transferable parameters and their use with manual and computer techniques for providing quick response travel estimation.

2. Objective 2-B: Identification of areas of potential high payoff for development efforts beyond the scope of the current study.

Details of the phase 2 study are contained in the user's guide (14).

MANUAL TECHNIQUES AND TRANSFERABLE PARAMETERS DEVELOPED

A set of manual, noncomputerized techniques was developed as a main feature of the phase 2 research project. This set of techniques parallels the classical four-step transportation planning elements of trip generation, trip distribution, mode choice, and trip assignment. The corresponding elements are very similar to procedures used by most transportation planners. However, several shortcuts were made to these elements. To cite a few, model calibration has been eliminated through the use of selected parameters produced from past research studies (e.g., trip rates and friction factors). In some instances, various input data have been minimized by providing estimates from simple nomographs such as zone-to-zone travel times. Overall, the level of applicational effort has been minimized through the provision of step-by-step instructions and simplified work sheets for calculations.

In addition to the four-step components, transferable parameters were provided for the analysis of automobile occupancy, the determination of directional distribution of traffic by time of day, the analysis of highway volume and capacity, and the estimation of facility spacing requirements for alternative land development densities.

General Capabilities of the Manual Techniques

It is intended that a transportation planner or analyst with a 2- to 3-year experience level can apply the techniques contained in the user's guide. The user can follow these procedures without referring to other sources and with nothing more sophisticated than a hand-held electronic calculator. It is also possible to train a technician to use portions or all of the methods. Ideally, the procedures are most suitable for small-scale transportation projects or localized land-use impacts. Specific projects might include the evaluation of system needs within a single corridor, the assessment of impacts of a transit route extension, or the analysis of increased frequency of transit service. Also, the manual techniques have been designed to adequately address the traffic impacts of a proposed major development on the surrounding street system.

The techniques are also capable of allowing a transportation analysis at the regional level. If a regional analysis is contemplated, it is recommended that the number of analysis areas (zones) be limited to allow application within a reasonable time frame.

The manual methods have proved manageable in application, and it has been found possible to produce reasonable results quite rapidly for many applications (14). For example, the transit demand potential on a single route was estimated in a few hours; spacing requirements based on alternate land development policies were determined within two to three person-days. Further, the transportation impacts of a major residential site were calculated within a week, and a proposed improvement in a corridor was evaluated in about the same time.

In order to fully realize the potential of the manual techniques, it is necessary that the user-planner modify conventional ideas about the planning processes. First, it must be understood that since the manual methods provided are quick and simple, clerical and technical help can be substituted for the computer and computer specialist. Therefore, manual analysis can be very cost-effective. Also, it is anticipated that in most practical cases, through application of the methods, the user would acquire a deeper understanding of the circumstances surrounding the problems than if all comparable work were done by computer. Consequently, his or her ability to clearly present the process and results to clients, elected officials, and the public would be enhanced. Finally, the manual approach stresses simplicity rather than precision in its application and output, thus enabling a larger degree of flexibility and versatility than the computerized planning process does. It must be pointed out, however, that the manual methods are not offered as a replacement for the computer models but rather as an extension of existing analysis techniques.

Use of Transferable Parameters

Recent transportation research has revealed that certain parameters, factors, and relationships from one study area can quite satisfactorily suffice when transferred to another area having similar characteristics (8, 10, 15, 16). In the NCHRP project study, therefore, every effort was made to capitalize on these conclusions. A large array of transportation data was compiled for use as "default" values. Where more pertinent local information is not available, or where collection of new data is not warranted, these transferable values can be useful in manual and computer applications. This material, which has been supplied in the user's guide, is in the form of tables, charts, nomographs, and formulas. In the development of such manually applicable information, data consistency was maintained throughout. That is, wherever possible and appropriate, the parameters have been grouped together and reported for the four urban population groups—50 000 to 100 000 people, 100 000 to 250 000 people, 250 000 to 750 000 people, and 750 000 to 2 000 000 people—and the three trip purposes—home-based work (HBW) trip, home-based nonwork (HBNW) trip, and non-home-based (NHB) trip.

MANUAL TECHNIQUES AND TRANSFERABLE PARAMETERS

As mentioned above, the manual techniques and transferable parameters developed have been documented in the user's guide (14). The following sections highlight the capabilities of the major travel estimation components of the transportation planning process contained in the user's guide.

Trip Generation

Numerous reference sources (15, 16, 17, 18, 19, 20) were used to develop the trip-generation characteristics provided in the user's guide. The information retrieved from this review was compiled into tables and graphs representing (a) average vehicle trip rates and other trip characteristics of generators, (b) detailed trip-generation characteristics by household income (Table 1), and (c) generalized trip-generation parameters for trip productions and attractions.

By knowing the percentage of households by income group or auto ownership per household (for an analysis zone), it is possible to arrive at the estimate of

Table 1. Trip-generation characteristics for an urban population of 100 000-250 000.

Income, 1970 ($000s)	Average Autos Per Household	Average Daily Person Trips Per Household	Households Owning No. of Autos (%) 0	1	2	3+	Average Daily Person Trips Per Household by No. of Autos 0	1	2	3+	Average Daily Person Trips by Purpose[a] (%) HBW	HBNW	NHB
0-3	0.49	4.0	57	37	6	0	1.0	7.5	10.5	13.8	20	63	17
3-4	0.72	6.8	36	56	8	0	1.7	9.2	13.3	16.4	22	60	18
4-5	0.81	8.4	29	61	10	0	2.5	10.2	14.5	17.6	22	58	20
5-6	0.94	10.2	21	65	13	1	3.5	11.4	14.5	19.0	22	58	20
6-7	1.01	11.7	17	66	16	1	4.5	12.5	15.6	20.5	20	58	22
7-8	1.14	13.6	12	65	21	2	5.4	13.8	17.0	22.2	20	57	23
8-9	1.25	15.3	9	61	28	2	5.8	15.0	17.5	23.0	20	57	23
9-10	1.34	16.2	6	58	33	3	6.3	15.8	18.0	23.5	19	57	24
10-12.5	1.50	17.3	4	50	40	6	6.8	16.0	19.0	24.5	19	57	24
12.5-15	1.65	18.7	2	40	51	7	7.0	16.0	20.4	25.0	19	56	25
15-20	1.85	19.6	2	28	57	13	7.2	15.0	21.0	25.5	18	56	26
20-25	2.01	20.4	1	20	61	18	7.5	15.0	21.0	25.5	18	55	27
25+	2.07	20.6	1	19	59	21	7.5	15.0	21.0	25.2	18	55	27
Weighted average	1.55	14.5	14	48	33	6	5.4	13.7	18.4	22.4	20	57	23

[a]Source is Baerwald (41).

the average daily person-trips by purpose for that zone by using Table 1, for the 100 000-250 000 urban population group.

Trip Distribution

Various trip-distribution methods were investigated for transformation to manual application (21, 22, 23). Since the gravity model (GM) has been the most widely used technique, the model was structured to operate in a manual environment. The conversion required a streamlining of its mode of operation—for instance, calibration of the model friction factors for the four urban population groups and the three trip purposes was totally eliminated by using other information (24). Also, the socioeconomic (K) factors in the computer GM formulation were discarded altogether, since these cannot be handled efficiently manually. One major assumption was that the interzonal travel-time matrix, which has to be developed for input to the GM, is triangular; that is, the travel time from zone i to zone j is the same as that from j to i.

Input data to the GM consist of the balanced productions and attractions by zone, the interzonal travel times obtained from the travel-time matrix, and the corresponding friction factors. In order to perform the GM calculations efficiently, a simplified work sheet was designed. To assess the time requirements for conducting trip distribution at the regional level, the manual GM was tested at a 34 × 34-district "real" example for Atlanta, Georgia. The entire trip distribution process (i.e., developing the interdistrict and intradistrict travel times and the corresponding friction factors, and undergoing two iterations) required approximately 26 person-hours to complete using an electronic desk calculator with memory.

The manual GM was also applied in a 19 × 19-district, three-purpose "site development impact scenario" for Boise, Idaho, and an 18 × 18-zone, two-purpose "corridor analysis scenario" for Columbus, Ohio. The Boise scenario required 14 person-hours for the HBW trip distribution, and a total of 19 person-hours for the HBNW and NHB distribution. The Columbus HBW trip distribution was completed in approximately 20 person-hours.

An empirical relationship was formulated between the time required to carry out manual trip distribution versus the number of analysis areas. This was done to allow the user-planner to estimate the applicational time requirements.

Manual trip distribution probably constitutes the most time-consuming element of the manual procedures provided in the user's guide. But, overall, manual trip distribution was found to be quite manageable and accurate and compares reasonably well with computerized applications. Manual trip distribution is recommended for up to 50 analysis areas.

Other important and useful material developed and provided in the user's guide for the trip distribution phase included nomographs for the development of zone-to-zone travel-time and friction-factor matrixes for the four population groups (Figure 1), gravity model travel-time exponents for three urban population groups and five trip purposes, a method for distributing trips around a site by reversing productions and attractions, the use of accessibility indexes (once computed from a manual GM application) for quick determination of interzonal trip interchanges, and trip-distribution patterns for selected generator sites.

The use of the travel-time and friction-factor nomographs warrants some discussion. Essentially, in-vehicle travel times can be derived by first measuring the zone centroid-to-centroid airline distance on a map, then estimating the proportion of travel on arterials or freeways, next determining the distances traveled in each subregion (CBD or central city or suburbs), and last entering nomographs such as the one illustrated in Figure 1. Appropriate nomographs must be selected according to whether the travel is totally within a subregion or across two or three subregions. The nomographs also provide the origin-destination (O-D) terminal times, which, when added to the in-vehicle travel time, result in the total O-D travel time. The user can then read the corresponding friction factors for each of the three trip purposes (HBW, HBNW, NHB).

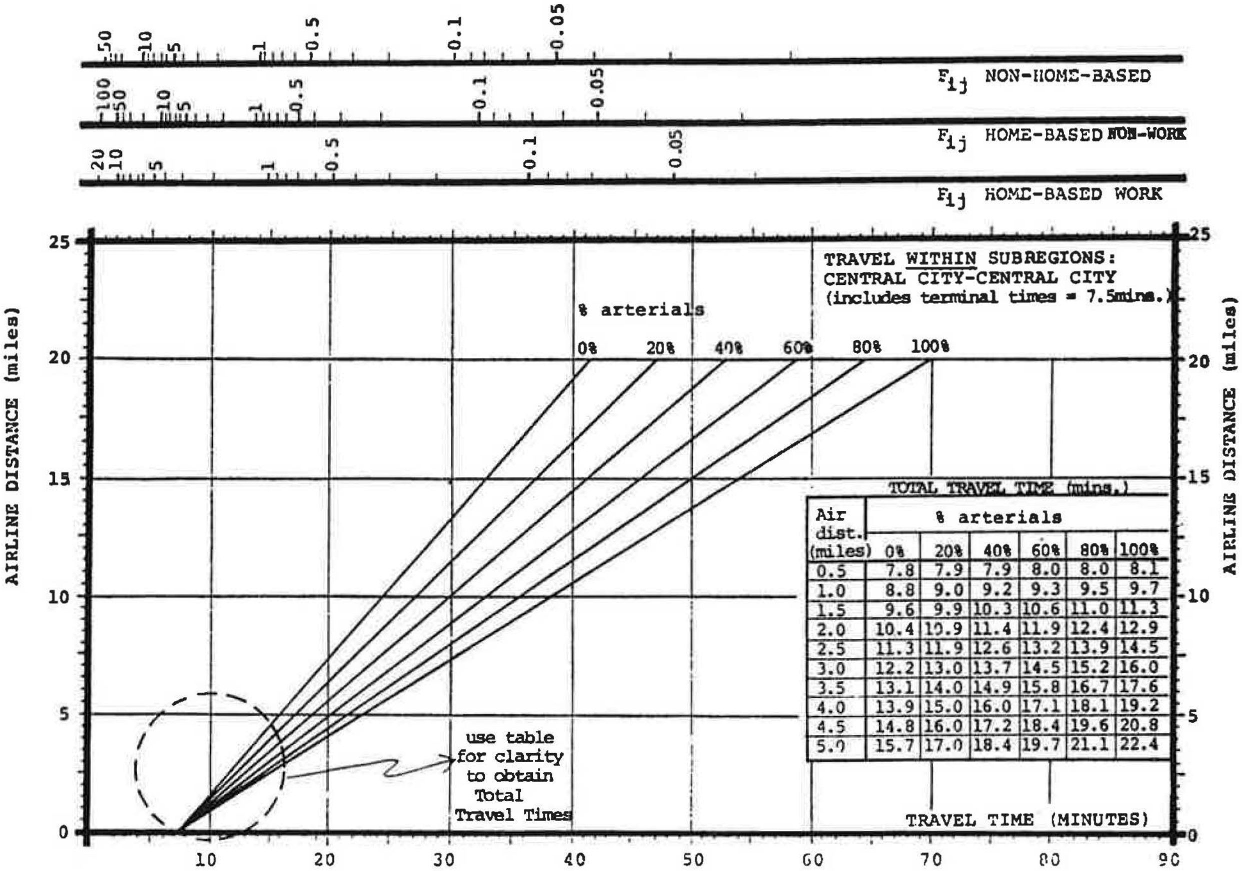
In summary, these nomographs constitute a set of practical tools for determining the travel-time and friction-factor matrix. The user's guide provides instructions for the planner to allow construction of these nomographs to suit particular local conditions, if so desired.

Mode Choice

A thorough literature review (25, 26, 27) was undertaken to identify mode-choice models having potential for manual conversion. Ultimately, the Urban Mass Transportation Administration default model contained in the program UMODEL (14) was selected for transformation to the manual format. The default model is a simultaneous logit model for trip distribution and modal split.

The transformation described in the user's guide and by Carter (28) converts the logit model into a very sim-

Figure 1. Airline distance versus travel time versus distribution factors by trip purpose for an urban population of 100 000-250 000.



Air dist. (miles)	% arterials 0%	20%	40%	60%	80%	100%
0.5	7.8	7.9	7.9	8.0	8.0	8.1
1.0	8.8	9.0	9.2	9.3	9.5	9.7
1.5	9.6	9.9	10.3	10.6	11.0	11.3
2.0	10.4	10.9	11.4	11.9	12.4	12.9
2.5	11.3	11.9	12.6	13.2	13.9	14.5
3.0	12.2	13.0	13.7	14.5	15.2	16.0
3.5	13.1	14.0	14.9	15.8	16.7	17.6
4.0	13.9	15.0	16.0	17.1	18.1	19.2
4.5	14.8	16.0	17.2	18.4	19.6	20.8
5.0	15.7	17.0	18.4	19.7	21.1	22.4

ple modal choice formula given by

$$MS_{t(ij)} = [I_a^b/(I_a^b + I_t^b)]\,100 \qquad (1)$$

where

$MS_{t(ij)}$ = market share percentage on transit for any ij zone pair,
I_a = auto impedance for the ij zone pair,
I_t = transit impedance for the ij zone pair, and
b = exponent of time (similar to gravity model travel-time exponents).

The user's guide provides a nomograph based on Equation 1 for each of the three trip purposes (see Figure 2 for HBW trips). Once the auto and transit impedances have been calculated for any ij pair, the nomograph can be entered to arrive at the market share percentage of transit. The user has an option of using localized values of b for the specific urban area under study. The auto and transit impedances are computed by using special nomographs drawn from procedures used elsewhere (12). Basic input information such as highway and transit airline distances and auto-operating and parking speeds is necessary for the application of these graphs.

Some other practical tools supplied in the user's guide for mode-choice analysis include a nomograph for converting highway airline distances to average operating speed, simplified worksheets for calculating auto and transit trips, and simple rules of thumb for quick estimates of transit demand.

The mode-choice technique was tested using travel data from Washington, D.C., and Atlanta, Georgia. Good results were obtained and have been documented (28). The overall success of the manual mode-choice procedure prompted San Diego to incorporate the technique for nonwork travel analysis in a current transportation study. Also, Atlanta has replaced its previous mode split models with a computerized procedure using this technique.

Auto Occupancy

Two major data sources utilized for auto occupancy factors and relationships are found elsewhere (28, 29). In addition, numerous urban transportation studies were reviewed. A series of tables delineating the variations in average daily auto occupancy rates with respect to other exogenous factors was developed. Typical tables included in the user's guide deal with auto occupancy rates by each of the four urbanized area population groups and by trip purpose (Table 2), auto occupancy rates by income level of trip maker and parking cost at trip destination, auto occupancy rates by urban population and land use at destination, auto occupancy adjustment factors by time of day, and auto occupancy adjustment factors by trip length.

The user's guide also presents several illustrative examples to accustom the user to the application of the tables.

Time-of-Day Distribution

The majority of the manual techniques and parameters contained in the user's guide are based on average daily travel conditions. For an analysis of particular highway facilities, transit routes, and other related work, peak-period or specified hour demand estimation is often necessary. The time-of-day analysis information provided permits various types of conversion.

The material, in the form of tables, explicitly recognizes the characteristics of travel by time of day according to location within the study area (CBD, central city, or suburb) and to orientation of the facility in relation to the core area (radial or cross-town). Facilities considered are freeways and expressways, arterials, and collectors. Much of the material developed here has been obtained from another study (30).

For example, the following relationships and procedures have been incorporated in the user's guide: hourly distribution (a) of internal driver travel by each of the four urban population groups and by trip purpose, (b) of internal driver and total vehicle travel by urban population, and (c) of total travel on various highway facilities by urbanized area population; and conversion factors (a) for critical time periods of internal person travel by urban population (see Table 3) and (b) for critical time periods of transit patronage.

These factors might prove particularly handy for traffic impact analyses, trip-purpose mix studies, and, in view of the critical role of transportation system management (TSM) requirements, for such a management study.

Figure 2. Mode-choice nomograph.

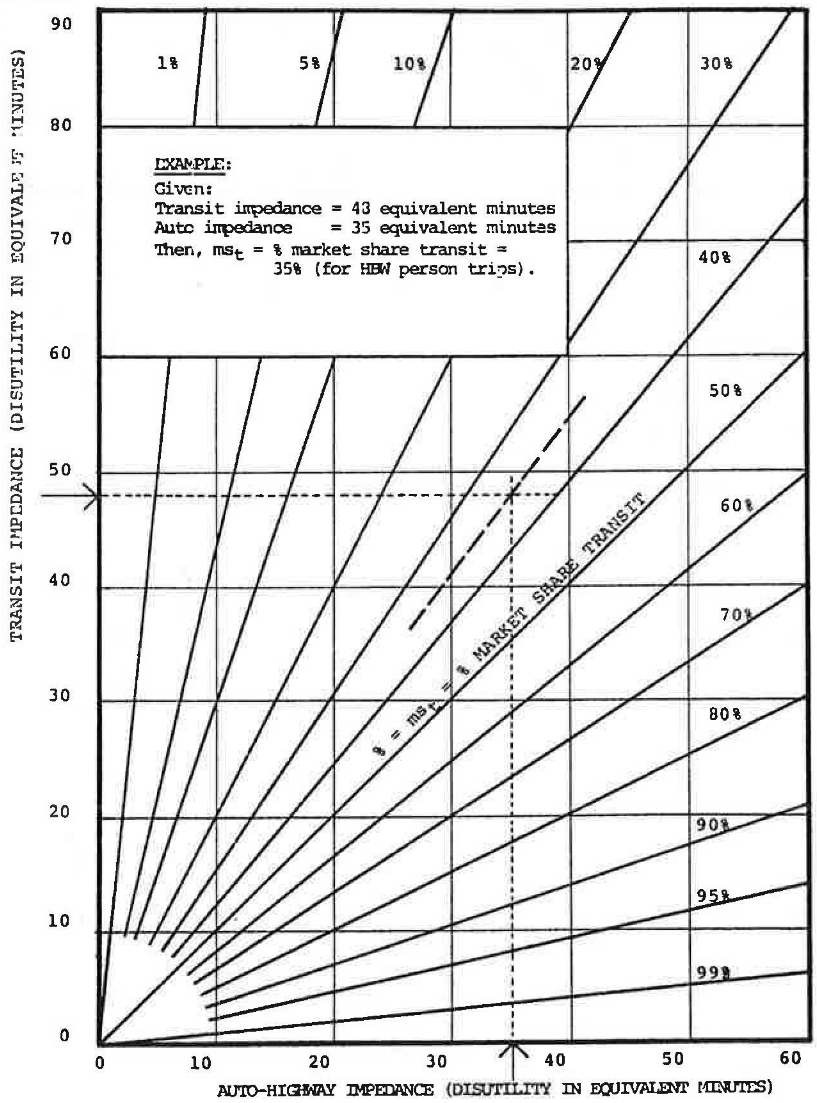


Table 2. Average daily auto occupancy rates by urban area and trip purpose (42).

Urban Population	Trip Purpose: HBW	HB Shopping	HB Social-Recreational	HB Other	HBNW[a]	NHB	All Purposes[b]
50 000-100 000	1.38	1.57	2.31	1.52	1.82	1.43	1.50
100 000-250 000	1.37	1.57	2.31	1.52	1.81	1.43	1.50
250 000-750 000	1.35	1.57	2.30	1.52	1.77	1.43	1.50
750 000-2 000 000	1.33	1.58	2.29	1.51	1.74	1.43	1.51

[a]Weighted average of auto occupancy rates for HB Shop, HB Social-Recreational, and HB Other trip purposes.
[b]Weighted average of auto occupancy rates for all trip purposes.

Table 3. Conversion factors for critical periods of internal auto travel for urban population of 100 000-250 000.

Travel Type	Total	Total Work[a]	Combined Peak Period	Peak-Hour Total	Combined Peak-Period Work	Morning Peak-Period Work	Evening Peak-Period Work	Peak-Hour Work
	Travel Hours							
Total		0.200	0.322	0.099	0.116	0.062	0.053	0.039
Total work	5.000		1.610	0.495	0.579	0.312	0.267	0.195
Combined peak-period total	3.106	0.621		0.307	0.360	0.194	0.166	0.121
Peak-hour total	10.101	2.020	3.253		1.170	0.630	0.539	0.394
Combined peak-period work	8.621	1.727	2.781	0.855		0.539	0.461	0.337
Morning peak-period work	16.026	3.205	5.160	1.587	1.856		0.856	0.625
Evening peak-period work	18.727	3.745	6.029	1.854	2.169	1.169		0.730
Peak-hour work	25.641	5.128	8.256	2.538	2.969	1.600	1.369	

[a]Work refers to HBW trips. Total is (HBW + HBNW + NHB) trips. See text for definitions of travel for the various time periods.

Trip Assignment

After a comprehensive literature review on existing trip assignment methodologies, three manual assignment techniques were selected for inclusion in the user's guide. The first is the traditional all-or-nothing assignment process (7, 31, 32). Major modifications of this commonly used method included the assumption that minimum time paths can be selected by judgment; then, a procedure for smoothing assigned volumes between a set of parallel facilities (33) was provided. Finally, simplified work sheets were designed to systematically keep track of the resulting trip volumes.

The second method was generally guided by a report by Gruen Associates (34). This method enables the estimation of traffic generation and attenuation and the corresponding highway facility requirements such as number of lanes and spacing. Improvements on this method permit the use of more specific estimates of generated trips, for example, by employing Table 1, by using a more responsive decay function, and by providing directional sensitivity.

The third procedure is based upon the multiroute probabilistic process developed by Dial (35). The manual formulation presented in the user's guide provides a means of determining the probable shifts (divisions) in volumes between competing facilities in a corridor.

Examples of some of the products resulting from these three techniques include simplified assignment work sheets, a series of charts for estimating street requirements based on land use, and a graph for determining traffic shifts between facilities in a corridor.

Capacity Analysis

Capacity analysis addresses the question of how much system is required to satisfy the estimated travel demand or how much traffic the existing street system can accommodate before intolerable congestion develops. Two types of techniques are included in the user's guide for analyzing capacity. First, a corridor analysis procedure is described to investigate volume-to-capacity (V/C) conditions within a highway corridor and to profile these relationships along a corridor route and, second, an intersection analysis procedure to evaluate vehicle movements through intersections (36).

The corridor approach draws upon and extends existing procedures for analysis at screenlines and cutlines. The approach is to analyze V/C conditions in an aggregate sense at key points along a corridor.

The intersection analysis method utilizes turning and through lane movements to determine the critical volume of an intersection. It is presumed that such an intersection capacity analysis would be used if a user were investigating the impacts of a site on local street conditions. The technique requires trip assignment, including the tabulation of turning movements at an intersection.

Using capacity information (37), several manually applicable tables and nomographs were constructed for use in the V/C analysis. Examples of some are generalized capacity measures for freeways, expressways and arterials and capacity nomographs for one- or two-way streets, with or without parking.

Land Development Density and Highway Spacing Analysis

The basic purpose of the land-use and highway spacing relationships described in the user's guide is to permit the rapid development of a "first-cut" estimate of future highway needs based on a desired level of highway service. Given a distribution of land use in a study area, either in terms of activities (people, households, jobs) or subarea by type of use, and given the presence of an existing highway system, future vehicle trip ends are computed and then adjusted for improved transit service. Next, the average trip distance is computed from counts or from curves provided and adjusted for the future.

Average arterial volumes, by subarea, for a given spacing of freeways and arterials can then be determined from the computation of vehicle-kilometers of travel and the level of service provided. A comparison of the level of service with a desired level gives a measure of highway needs for the study area. A description of the method in flowchart form is shown in Figure 3.

Some of the analytic techniques in the form of graphs and charts, based on other sources (38, 39, 40), include a graph for least-cost volumes for various facilities, graphs for determining freeway and arterial spacing based on the magnitude of travel, and information on level-of-service volumes for various facilities.

SCENARIO APPLICATION OF THE MANUAL ESTIMATION TECHNIQUES

To ascertain the capabilities of the manual methodologies and transferable parameters described in the user's guide, extensive applications were made to three differ-

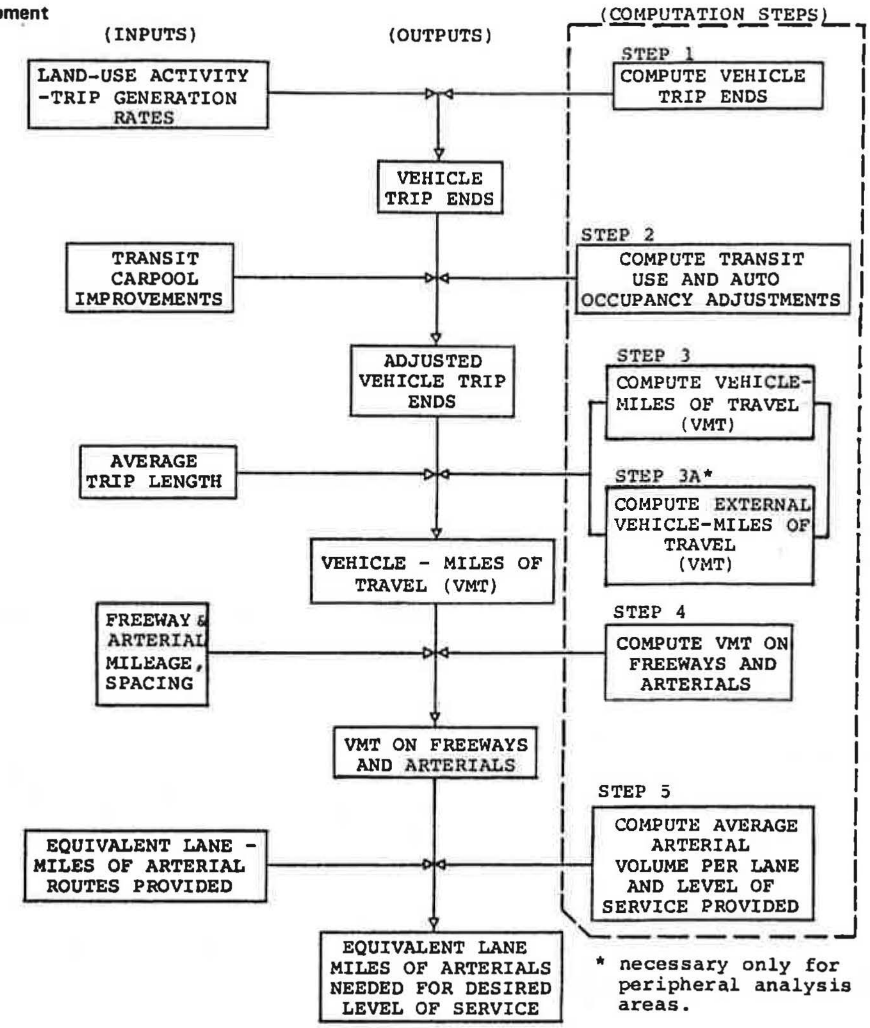


Figure 3. Diagram of development density and highway-spacing methodology.

ent types of transportation scenarios. Each of these scenarios was based on authentic field conditions and data input obtained from the three study areas: Boise, Idaho; Columbus, Ohio; and Fairfax County, Virginia. The choice of these study areas was dictated by and based on their population variations (small, medium, and large, respectively) and their geographical distribution.

The Boise scenario was based on the investigation, for the year 2000, of traffic impacts on the surrounding highway system of a proposed residential development and a large shopping center. Almost all of the manual techniques contained in the user's guide were put to use to quantify these effects. All three trip purposes were analyzed, the analysis itself yielding satisfactory results. The entire investigation—trip generation through trip assignment and capacity analysis—required a total of 60 person-hours. It was estimated that if only HBW trips were developed and then expanded to total trips (using factors such as those contained in Table 3), the work effort would have been reduced to about 40 person-hours.

The object of the Columbus scenario was to determine, for the year 2000, the impacts of a proposed corridor development located on the outskirts of the region and the current growth. Again, most of the manual estimation techniques described above were used for the corridor impact analysis. The scenario was conducted in about 66 person-hours and produced output that was in reasonable agreement with local forecasts.

The Fairfax County scenario determined the base year and future year (1985) levels of service provided by the current and planned transportation systems in the county. The manual techniques described in the user's guide were used to estimate present and future travel, to allocate this travel by subarea to freeway and arterial facilities, and then to compute the resulting levels of service. The scenario required approximately 22 person-hours and produced acceptable results.

CONCLUSIONS

This paper has presented a brief summary of the research effort undertaken to identify contemporary urban policy issues, to evaluate currently available methods and procedures, and to develop manual travel estimation techniques and transferable parameters. On the basis of the test applications, it is believed that these manual methods are applicable to many transportation planning problems. Further, the manual methods will result in time and cost savings for various applications when compared to computer-oriented solutions.

Since the final report (14) was only recently distributed, the manual techniques have not yet undergone widespread testing and application. We hope this will occur as the techniques are put to use. Plans are under way to develop instructional material for use in training sessions. These sessions, similar in nature to the

Highway Capacity Manual workshops, will be conducted to assist state and local planners in the application of the numerous techniques contained in the user's guide. The Transportation Center of the University of Tennessee will assist COMSIS in the implementation of this phase.

For the manual procedures to achieve full potential and acceptance, additional experimentation is needed. It would also be worthwhile to extend the analytic and estimation features of the techniques summarized in this paper, and to conduct further research to develop other noncomputerized transportation planning techniques for which a need exists. Such techniques could prove useful in responding to the ever-changing issues of the day in shorter time frames.

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REFERENCES

1. Chicago Area Transportation Study. Chicago, IL, 3 Vols., 1959-1960.
2. G. V. Wickstrom. Are Large-Scale Home-Interview Origin-Destination Surveys Still Desirable? Paper presented at the 50th Annual Meeting of the TRB, Jan. 1971.
3. H. S. Levinson. Simplifying the Comprehensive Transportation Planning Process—Prospects and Perspectives. Paper presented at the 51st Annual Meeting of the TRB, Jan. 1972.
4. K. E. Heanue. Changing Emphasis in Urban Transportation Planning. Paper presented at the 56th Annual Meeting of the TRB, Jan. 1977.
5. M. L. Manheim. The Emerging Planning Process: Neither Long-Range Nor Short-Range, but Adaptive and (Hopefully) Decisive. Paper presented at the 56th Annual Meeting of the TRB, Jan. 1977.
6. A. B. Sosslau and G. V. Wickstrom. Quick Response to Urban Transportation Issues. Paper presented at the ASCE Annual Convention, New Orleans, Apr. 1975.
7. DeLeuw Cather Canada Ltd. A New Procedure for Urban Transportation Planning. Paper prepared for the Canada Department of Highways, Toronto, Sept. 1969.
8. H. M. Hajj. Synthesis of Vehicle Trip Patterns in Small Urban Areas. HRB, Highway Research Record 369, 1971, pp. 181-198.
9. T. Hillegass, C. Fleet, and K. E. Heanue. A Proposal for a Simplified Urban Transportation Modeling Process. U.S. Department of Transportation, Federal Highway Administration, 1973.
10. S. Khasnabis and M. R. Poole. Synthesizing Travel Patterns for a Small Urban Area. Traffic Engineering, Vol. 45, No. 8, Aug. 1975.
11. K. W. Heathington. Simplified Procedures for Preliminary Evaluation of Public Transportation Alternatives. Paper presented at the 56th Annual Meeting of the TRB, Jan. 1977.
12. DeLeuw, Cather and Company. Transit Corridor Analysis—A Manual Sketch Planning Technique. Prepared for U.S. Department of Transportation, Urban Mass Transportation Administration, May 1976.
13. COMSIS Corporation. Travel Estimation Procedures for Quick Response to Urban Policy Issues. Final Rept., prepared for NCHRP, June 1977.
14. COMSIS Corporation. Quick-Response Urban Travel Estimation Manual Techniques and Transferable Parameters: A User's Guide. Prepared for NCHRP, Nov. 1977.
15. L. E. Keefer. Urban Travel Patterns for Airports, Shopping Centers, and Industrial Plants. NCHRP, Rept. 24, 1966.
16. L. E. Keefer and D. K. Witheford. Urban Travel Patterns for Hospitals, Universities, Office Buildings, and Capitols. NCHRP, Rept. 62, 1969.
17. Comparison of Virginia Urban Trip Generation Studies With Similar Investigations Conducted by the States of Maryland and California. Virginia Department of Highways, Metropolitan Transportation Planning Division, Richmond, VA, July 1972.
18. Trip Generation—An Informational Report. ITE, Committee 6A6, Arlington, VA, 1976.
19. Trip Generation by Land Use, Part I: A Summary of Studies Conducted. Maricopa Association of Governments, Transportation and Planning Office, Phoenix, AZ, Apr. 1974.
20. COMSIS Corporation. Trip Generation Analysis. Prepared for U.S. Department of Transportation, Federal Highway Administration, Aug. 1975.
21. T. J. Fratar. Vehicular Trip Distribution by Successive Approximations. Traffic Quarterly, Jan. 1954.
22. M. Schneider. Panel Discussion on Inter-Area Travel Formulae. HRB, Bulletin 253, June 1960.
23. Calibrating and Testing a Gravity Model for Any Size Urban Area. U.S. Department of Commerce, Bureau of Public Roads, Oct. 1965.
24. Urban Trip Distribution Friction Factors. U.S. Department of Transportation, Federal Highway Administration, 1974.
25. M. J. Fertal and others. Modal Split—Documentation of Nine Methods for Estimating Transit Usage. U.S. Department of Commerce, Bureau of Public Roads, Dec. 1966.
26. R. H. Pratt. A Utilitarian Theory of Travel Mode Choice. HRB, Highway Research Record 322, 1970, pp. 40-53.
27. P. R. Rassam, R. H. Ellis, and J. C. Bennett. The n-Dimensional Logit Model: Development and Application. HRB, Highway Research Record 369, 1971, pp. 135-147.
28. M. M. Carter. Development of a Simple Logit Choice Model. Paper presented at the 56th Annual Meeting of the TRB, Jan. 1977.
29. Estimating Auto Occupancy: A Review of Methodology. U.S. Department of Transportation, Federal Highway Administration, no date.
30. Peat, Marwick, Mitchell and Company. An Analysis of Urban Area Travel by Time of Day. Pre-

pared for U.S. Department of Transportation, Federal Highway Administration, Jan. 1972.
31. COMSIS Corporation. Traffic Assignment. U.S. Department of Transportation, Federal Highway Administration, Aug. 1973.
32. R. J. Paquette, N. Ashford, and P. H. Wright. Transportation Engineering: Planning and Design. Ronald Press, New York, 1972.
33. R. H. Pratt and Associates. A Method for Distributing Traffic Volumes Across Cutlines. Kensington, MD, 1976.
34. Gruen Associates. Land Use and Arterial Spacing in Suburban Areas. Prepared for U.S. Department of Transportation, Federal Highway Administration, May 1977.
35. R. B. Dial. A Probabilistic Multipath Traffic Assignment Model Which Obviates Path Enumeration. Prepared for U.S. Department of Transportation, Federal Highway Administration, May 1970.
36. H. McInerney and S. Peterson. Intersection Capacity Measurement Through Critical Movement Summations: A Planning Tool. Traffic Engineering, Vol. 41, No. 1, Jan. 1971.
37. Highway Capacity Manual. HRB, Special Rept. 87, 1965.
38. R. Creighton and others. Estimating Efficient Spacing for Arterials and Expressways. HRB, Bulletin 253, 1960.
39. A. Haikalis and H. Joseph. Economic Evaluation of Traffic Networks. HRB, Bulletin 306, 1961.
40. System Considerations for Urban Freeways. ITE, Washington, D.C., Informational Rept., Oct. 1967.
41. J. E. Baerwald, ed. Transportation and Traffic Engineering Handbook. Prentice-Hall, Englewood Cliffs, NJ, 1976.
42. Nationwide Personal Transportation Study. U.S. Department of Transportation, Federal Highway Administration, Repts. 1 and 8, Apr. 1972.

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Tabulating Demand Elasticities for Urban Travel Forecasting

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This paper presents a compendium of demand elasticities in a tabulated form in order to facilitate urban travel forecasting. A number of elasticity estimates have been reported for a variety of cities over the past decade, but the scenarios or base conditions differ from one site to another. In order to systematically tabulate these disparate estimates, demand elasticities were pooled into four cells according to urban size (large versus medium) and urban structure (core-concentrated versus multinucleated). Such a classification has been verified to stratify cities into groups sharing common socioeconomic and travel patterns. Demand elasticities can be divided into two categories: empirical elasticities and calibrated elasticities. The former were measured in the field before and after notable incidents such as a fare increase in the transit system, while the latter were derived from demand models. The elasticities can be further identified as either aggregate or disaggregate depending on whether they are calculated from areawide or subarea data. All these result in a collection of elasticities that have rather different values. This paper tries to explain some of these differences to gain insights into the general characteristics of elasticities for urban areas of different sizes and structures. The elasticity tabulation and the general properties of the elasticities provide both practitioners and researchers with factual information for estimating urban travel demand simply and systematically.

Demand elasticities are often used in conjunction with urban travel forecasting. They have been applied frequently, however, under circumstances that are inconsistent with the assumptions under which they were derived. The purpose of this paper is to resolve some of these inconsistencies and to provide some guidelines—including a systematic tabulation of the available elasticities—for their consistent application in demand estimation.

There are three areas where inconsistencies may be introduced. First, elasticities are often applied in a scenario very different from the base conditions from which they were empirically developed. For example, a fare elasticity of -0.13 measured during the New York subway fare increase of January 1970 refers specifically to the base conditions that existed at that time, including the patronage and fare level. To apply the elasticity indiscriminately for other fare and patronage levels is a futile exercise at best. Unfortunately we found many cases where elasticities are cited out of context and, hence, erroneous inferences are drawn.

Demand elasticities found in a large metropolis such as New York City provide little information on other cities either smaller or of similar size, since they may have drastically different urban structures. Very limited research has been performed in relating elasticities to cities classified according to size and other urban characteristics. Until a better understanding of such a relationship is gained, our knowledge about elasticities in specific sites cannot help us in demand forecasting in other cities.

The measurement of elasticities was performed by using methods ranging from areawide empirical tabulations to disaggregate demand modeling. These various levels of aggregation can often lead to very different estimates of demand elasticities for the same study area. A case study in Chicago, for example, shows that the difference between areawide and household elasticities can be as high as 40 percent, depending on the homogeneity of travel behavior among households in the area (1, Appendix 8). Citing an elasticity without specifying the level of aggregation can therefore result in estimates significantly out of kilter with reality. All these conditions point to the fact that guidelines for applying demand elasticities need to be found. The way the elasticities