CONTENTS

TRAVEL ESTIMATION TECHNIQUES FOR URBAN PLANNING

SUMMARY

This project was conducted in two phases. The first phase was to identify the critical travel estimation areas that would require updating or adding to the earlier *NCHRP Report 187.* The second phase was to collect the necessary data, update the travel estimation parameters and techniques, and prepare the revised report. During the first phase of this project a survey was conducted of the metropolitan planning organizations (MPOs) and state DOTs with the objective of identifying

- If and how *NCHRP Report 187* was used,
- What issues the transportation planners are facing that place added demands on the travel demand model, and
- Any travel surveys that the agency had conducted in recent years.

The survey found that the great majority of applications of the quick response techniques and parameters were for trip generation, either the site-specific vehicle rates or the general household-based trip production models. The mode choice procedures contained in *NCHRP Report 187* had never been used by almost 90 percent of the respondents and only 3 percent of the respondents are still using the model choice technique.

With the rapid growth in the capacity and deployment of microcomputers, the use of manual application techniques has been minimized. This report concentrates on travel parameters that can be applied in any of the available travel demand programs. The extensive, non-network-based, manual procedures (e.g., trip distribution and traffic assignment) contained in the earlier report are not included in this report. The travel parameters and techniques presented in this report follow the basic four-step process: trip generation, trip distribution, mode choice, and traffic assignment.

A chapter has been included that discusses the databases required to build a travel demand model. These include supply-side data (e.g., highway and transit networks) and demand-side data (e.g., zonal socioeconomic data on population and employment). A description of the data requirements is presented along with sources for building the database. Also in this chapter is a brief discussion of the use of geographic information systems (GIS) and the opportunities for using GIS in the building of the travel demand database and in model application. The survey of MPOs and state DOTs revealed that more than one-half of the agencies have GIS available.

procedure, the assumption is made that the traffic assignment is done by a travel demand package and that the default parameters required are the relationship of travel time to volume and capacity. Different functions are presented for different facility types, including freeways and multilane arterials. The corridor diversion and screenline smoothing techniques presented in *NCHRP Report 187* are presented in this report.

Capacity analysis is presented from two views—the analysis of intersection level of service and the development of link capacities that can be used as input to the building of the highway network in the modeling process. The revised 1985 *Highway Capacity Manual* was the source for the intersection procedures and the user is referred to that document as the primary source for applications.

A case study has been developed in order to illustrate the application of the parameters and techniques described in this report. The data included in this case study were provided by the State of North Carolina for the City of Asheville, North Carolina. The applications of the study parameters and techniques to this case study are presented at the conclusions of Chapters 1 through 9. This case study allows the user to follow the development and application of the travel forecasting model beginning with the data collection phase, where the highway networks and the socioeconomic data are presented. Subsequent chapters follow the model development through trip generation, where standardized trip generation rates are applied, and trip distribution, where standardized friction factors are applied. Ultimately, the final traffic assignment is presented, along with screenline comparisons of the existing traffic counts to the model results.

The final chapter of this report presents the case study in its entirety, from data collection through traffic assignment. As can be seen in this report, the results of this demonstration are quite reasonable when compared with the observed traffic volumes.

- Evaluation of the impacts of transportation investments on development levels (that is, the iterative relationship of land use patterns and transportation systems);
- Air quality analysis for both regional conformity analysis and localized non-attainment areas (such as intersections in non-attainment for CO concentrations); and
- Analysis of travel reduction programs, travel demand management (TDM) strategies, and Congestion Management System plans (as required by the Intermodal Surface Transportation Efficiency Act [ISTEA] of 1991).

These and other analyses require more detailed results than the 24-hour volume estimates for major facilities traditionally associated with travel-demand forecasting. Factors that must now be considered in the travel-demand forecasting process include time-of-day analysis, peak-period spreading, automobile-occupancy rates, and feedback mechanisms for congested speeds and land-use changes. Unfortunately, few areas have current, locally generated travel behavior data. For these reasons, the parameters in this report give added attention to trip generation rates, treatment of external travel, time-of-day parameters, and automobile-occupancy rates.

AREAS OF DEVELOPMENT

At least two recent, significant developments have affected the travel modeling approach and process. First is the use of geographic information systems (GIS) in the forecasting process. GIS allows the user to digest and display data relevant to the task at hand. Before the modeling process, GIS may be used to

- Map a study area network to determine the level of roadway detail needed for the model,
- Batch out the designated network in a format accepted by the model,
- Map demographic data at census block/tract level,
- Convert census blocks/tracts to traffic analysis zones (TAZs), and
- Export TAZ structure to form a demarcation file for use in the model.

Post-forecasting uses for a GIS include display of model outputs, such as link volumes, and display of trip ends by TAZ.

The other significant development has been the changing urban form. Suburban sprawl has changed the travel direction from simply suburb to central business district (CBD) travel to suburb to suburb as well. This change has manifested itself in increases in automobile ownership as well as vehicle miles traveled (VMT). Trip generation rates, however, have remained relatively stable. It is not necessarily the number of trips that have changed, but rather the way those trips are made.

THE FOUR-STEP TRAVEL-DEMAND FORECASTING PROCESS

Travel-demand forecasting is often referred to as the "four-step" process. The steps are: trip generation, trip distribution, mode choice, and assignment. These are the four major model components of the travel-demand forecasting process. Other submodels that compose the complete model set are illustrated in Figure 1.

The purpose of trip generation estimation (Chapter 3) is to determine the number of person or vehicle trips to and from activities in an analysis area. Trip generation is functionally related to the use of land, which is described in terms of the character, intensity, and location of activities. Specific factors that influence the number of trips in a region include automobile ownership, income, household size, density and type of development, availability of public transportation, and the quality of the transportation system. The best trip-generation techniques use disaggregate socioeconomic data, such as households classified by vehicle ownership, family size, or income group. This step produces estimates of the trip productions and trip attractions for each zone in the analysis area.

Trip distribution (Chapter 4) links the trip productions to the trip attractions for each pair of zones in the analysis area. The critical factor in trip distribution is the ease of travel between the two zones being analyzed. This is influenced by the distance between the zones and the efficiency of the transportation system linking them.

Mode-choice analysis (Chapter 6) is the third step in the traditional four-step travel-demand forecasting process. Mode-choice modeling splits the total zone-to-zone person trips resulting from the trip-distribution model into trips using each available mode between the zone pair. Mode-choice modeling is also used to evaluate improvements in bus systems and analyze high-occupancy vehicle (HOV) strategies.

Several simple submodels can be used to refine the estimates from the first three steps on the basis of analysis needs. Auto-occupancy estimates (Chapter 7) are used to convert person trips to vehicle trips. Time-of-day modeling (Chapter 8) produces hourly estimates of travel. External travel estimation (Chapter 5) captures those trips that originate or end outside the analysis area.

The last of the major steps in the traditional four-step process is traffic assignment, both for highways and transit (Chapter 9). The assignment of trips to the network is the final output of the modeling process and becomes the basis for validating the model set's ability to replicate observed travel in the base year as well as to evaluate transportation improvements in future years.

The simple four-step modeling process has undergone some refinements in an effort to create a process that more accurately reflects the interdependency of its components. Specifically, the introduction of feedback loops in the modeling zone travel times (often taken as uncongested or free-flow travel times in the initial estimation of the trip tables) and then iterate the revised travel times produced after the trip tables are assigned to the networks. This procedure is repeated until there are few or no observed changes in the resultant trip tables. At this point the tables are considered to be in equilibrium with the travel times. A possible deficiency in the process is the assumption that actual trip ends (trip generation) do not change as travel times change.

In a paper, prepared for the National Association of Regional Councils by Harvey and Deakin[1], the lack of iteration of various travel-demand model components is identified as the most significant weakness in the application of traditional travel-demand models. The primary purpose of the paper was to evaluate the effects of improved travel-demand models on the estimation of environmental impacts of transportation systems, particularly on air quality evaluation.

There are several opportunities for iterations within the traditional travel-demand forecasting process. These fall into two groups: those that are commonly done today and those that are desirable and subject to further research.

Common iteration procedures are as follows:

- Congested highway travel times and costs resulting from traffic assignment iterated back into the trip-distribution and mode-choice models,
- Transit times (where transit is on the highway network) and costs iterated back into the mode-choice model, and
- Transit times and costs iterated back to the trip-distribution model in the case where travel times are a composite of highway and transit interzonal times and costs (composite impedance).

Desirable iteration procedures are as follows:

- Highway and transit interzonal travel times and costs iterated back to the zonal socioeconomic data—residential and employment location models,
- Automobile occupancy iterated back into time of day, and
- Highway and transit interzonal travel times and costs iterated back to the automobile-ownership models used to predict trip-generation rates.

Travel time linked to trip-generation and automobile-ownership models is the least understood. Residential and employment location models have been the subject of considerable research; however, the political realities of establishing regional forecasts of population and employment make the use of a model subordinate to regionally adopted forecasts.

This discussion of the evolution of travel-demand forecasting is presented with the intention that the transportation planner using the parameters contained in this report has some appreciation of the dynamic nature of travel-demand forecasting and understands that the process is as much a craft as it is a science.

SUMMARY OF TECHNIQUES AND PARAMETERS

As noted earlier, the parameters and techniques in this manual are presented in chapters that follow the traditional four-step travel-demand forecasting process. Supporting techniques (e.g., the treatment of external travel, time-of-day characteristics, and automobile-occupancy rates) are presented in the order in which they would typically be addressed in the process. For each chapter, an example of the application of the parameters and techniques accompanies a discussion of the basis for development of the parameters.

Trip Generation

Trip generation parameters are presented in two formats. The first format presents the vehicle-trip generation rates that are commonly used for site-impact analysis and for estimation of vehicle-trips from special generators. The source of these rates is the Institute of Transportation Engineers (ITE) *Trip Generation* report, 5th Edition (1991). Only a subset of the trip generation rates contained in the ITE manual are extracted for this report. The user should refer to the complete and most current manual for more detailed categories of vehicle-trip generation rates. These rates also include information on trip rates during peak periods of both the generator and the background traffic.

The second set of trip generation parameters is presented in the format of cross-classification trip production and attraction rates typically used in travel-demand models. These rates are daily person trips. As with *NCHRP Report 187,* trip purpose parameters are presented. The standard trip purposes used in this manual are: Home-Based-Work (HBW), Home-Based Non-Work or Home-Based Other (HBO), and Non-Home-Based (NHB).

Included in the trip generation chapter are the submodel parameters of automobile ownership and household income distributions. In addition to the trip generation parameters, balancing regional productions and attractions is discussed.

Trip Distribution

The trip distribution parameters presented are consistent with the standard gravity model input requirements. The

[1]Barton-Aschman Associates, Inc., *Development and Calibration of Travel-Demand Models for the New Orleans Area,* prepared for the Regional Planning Commission, Jefferson, Orleans, St. Bernard, ad St. Bernard Parishes, Louisiana (1981).

table. Rather, a diversion function is developed, based on known volumes and operating speeds. This function is used to estimate shifts between facilities based on improvements to one facility.

Capacity Analysis

Correct designation of link capacity is critical to producing a model that accurately reflects real-world situations. A link capacity regulates the volume of travel that can be carried over that link. Thus, for measuring current congestion levels as well as those forecast, it is necessary to reflect accurate capacities in the network database. Default link capacities are presented, as is the planning procedure for intersection capacity analysis.

Development Density/Highway Spacing Relationships

The basic purpose of including this manual technique 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 within an area of land use, either in activities (people, households, jobs) or in acres by type of use, and given the presence of an existing highway system, future vehicle-trip ends are computed and adjusted for improved transit service. The average trip distance is then computed from counts or from trip-length frequency curves and adjusted for the future.

Average arterial volumes for a given spacing of freeways and arterials can be determined from the computation of vehicle miles of travel (VMT), and the level of service provided by each subarea can be computed. A comparison of the computed level of service with a desired level of service indicates a measure of highway needs for the study area. It is also possible to adjust land use inputs to revise the level of service or to compute the amount of additional land use that can be developed while still maintaining a given level of service.

Data Sources

Several sources of data were used to develop the trip generation, trip distribution, automobile occupancy, time of day, and other parameters in this volume. The primary data source was the 1990 *Nationwide Personal Transportation Survey* (NPTS). The NPTS is a periodic survey conducted to obtain travel behavior data from a large number of households (21,869). The project is sponsored by the U.S. Department of Transportation (US DOT), Federal Highway Administration (FHWA). More information on the NPTS can be found in US DOT report *FHWA-PL-92-007,* published December 1991.

The NPTS uses household interview techniques to collect data from each household over the telephone. The sample is drawn from listed and unlisted telephone numbers. Each sampled household is assigned a 24-hour travel day for which data on all travel by household members is collected. Each person older than 13 years is asked to report all trips taken during the designated travel day. The household members are interviewed within a 6-day period immediately following the travel day.

Data from travel surveys conducted in 11 cities around the country using home-interview techniques were also used. The trip rates derived from these surveys were used as a cross-check to the NPTS data. For more information on these data, see Appendix A.

CASE STUDY

A case study for the City of Asheville, North Carolina, has been developed in order to illustrate the application of the parameters and techniques described in this report. The application of the study parameters and techniques to this case study are presented throughout this report, at the conclusion of each chapter. This case study allows the user to follow the development and application of the travel forecasting model beginning with the data collection phase, where the highway networks and the socioeconomic data are presented. Subsequent chapters follow the model development through trip generation, where standardized trip generation rates are applied, and trip distribution, where standardized friction factors are applied. Ultimately, in Chapter 9, the final traffic assignment is presented, along with screenline comparisons of the existing traffic counts to the model results.

SUMMARY

Although the core of the modeling process has remained unchanged, many refinements to the process and technological advances have made the four-step traffic forecasting process a more intricate and comprehensive process. The computational power now available to virtually all planning departments is far superior to that in existence 20 years ago. The next chapter, Building a Transportation Database, describes some of the data sources available to the modeler and tells how to make use of them in modeling.

county files that make up a Metropolitan Statistical Area (MSA), or all files for a state.

If a highway network has not been prepared for a planning region, and an application software (GIS) is available, the basic data record (record type 1) of the Topologically Integrated Geographic Encoding and Referencing database (TIGER)/line can be used to create a roadway network. Each segment of the basic data record contains the geographic area code, latitude and longitude coordinates for all line segments, the name of the feature (such as highway name), and a class code (functional class). The geographic and cartographic data of a TIGER/line file can be combined with other statistical information (such as population, housing, or income) for planning purposes.

The census TIGER files are a comprehensive source of data. They can be used to produce area maps, such as census blocks or county boundaries, as well as a street system network. The TIGER files are available on CD-ROM from the Census Bureau, and most disks contain the data for two or three states, while some of the larger states are split onto two disks. The amount of detail available in these databases is more than is necessary to build the model network. Consequently, the user must take care to filter out unwanted detail, such as local streets. Even arterials and highways are described in significant detail in these databases. Great care was taken in their construction to create links that accurately reflect the true shape of the highway feature. The number of shape points used for this purpose, while useful in creating maps in GIS, is too much data for the models. Commercial digitized map files are also available from many vendors. The quality of census TIGER files may not be adequate for some study area's needs, and commercial vendors can be used as a source of digital maps.

With the use of GIS, many commercially produced networks are now available. Many of these are simply enhanced TIGER files, which save the user the time and effort of editing census TIGER files.

Scaled Maps

The base data to construct a computerized highway network file (location of links and nodes) can be digitized from scaled maps. That is, each facility selected for use in the network can be copied from the base map into digital form with an application software and a digitizer tablet. The digital input is scaled to either the latitude and longitude or a user-defined x, y coordinate system. There should be no dead-end links in the system. The links should be mapped with a node at every intersection and at each location where the number of lanes changes.

Figure 2 shows an example of a node and link plot with a zone centroid and connectors. Links connecting a centroid to the network (called centroid connectors) should be made roughly midlink, as shown. Care should be taken to suppress "backchannel" traffic on centroid links, although most modeling packages allow centroid control of this.

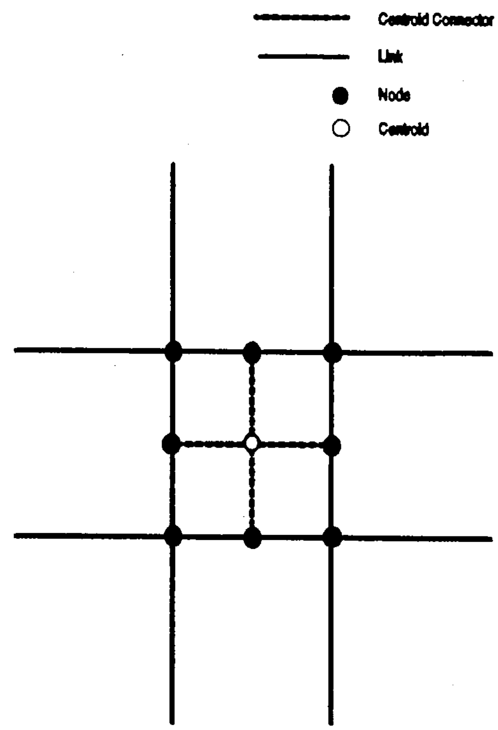

Figure 2. Example of network node and link plot with centroid connectors.

Network Coverage

The process used to select the links that will be included in the coded highway network requires the official functional classification of the roadways within the region, the average traffic volumes, street capacities, and a general knowledge of the area. Generally, all streets that carry a substantial volume of traffic should be included. The magnitude of volume considered to be substantial will vary by the population size of the area to be modeled, but it is reasonable to expect that all arterial streets and some collector streets will need to be represented. Local residential streets do not need to be included in the network, because they will be simulated using direct connections between traffic zone centroid nodes and the arterial street system via centroid connectors.

The kind of analysis for which the network will be used determines the level of detail required. For example, if a regional network is under analysis, all freeways and major arterials in the study area should be included as links. Additional links should be added when they: (1) create a contiguous network, connecting arterials and freeways together;

Area Type Considerations

Area type refers to a method of classifying small geographic areas by a rough measure of land use intensity, primarily based on population and employment density. A higher intensity of land use generally means more intersections, driveways, traffic signals, turning movements, and pedestrians, and, therefore, slower speeds.

Typically, roadway link speeds and capacities are adjusted slightly based on the area type where they are located. Many models use approximately five area type codes representing: CBD, CBD fringe (or outlying business district), urban, suburban, and rural.

Roadway link records include an area type field that computer software can use, in conjunction with facility type information and the number of lanes, to determine appropriate link capacities and speeds.

Final Network Database

This section describes procedures for establishing the network database. Among the attributes that should be included for each link are

- "A" and "B" node numbers and their associated x, y coordinates;
- Links defined by "A" and "B" nodes;
- Link length;
- Functional classification, including the divided or undivided status of the link's cross-section;
- Number of lanes;
- Controlled or uncontrolled access;
- One-way versus two-way status;
- Area type;
- Speed; and
- Capacity.

In addition, the coding of the traffic analysis zone in which each link is located on the link record facilitates the identification of area type for the link and is useful in producing assignment summaries. Base-year ground counts also may be coded for automatic screenline analysis.

Transit Networks

The transit network is developed after the highway network. Essentially, a route name is designated and the node-to-node path that makes up the transit line is coded. Additional information about the transit line includes

- Headway (typically, three different headways can be coded: AM, Midday, and PM),
- Route name/number, and
- An average speed, although this can be derived from the assignment process and fed back into the transit model.

In addition to the routes, the transit network will need to include walk links if they are not adequately covered by the centroid connectors. If park-and-ride lots are used, highway links are used to connect the zones to the park-and-ride lots.

SOCIOECONOMIC DATA

Socioeconomic data used in the planning process include household and employment data. Socioeconomic and land-use data are compiled and coded to units of geography to give the transportation planner an understanding of the way land is used in each section of the planning area. Most urban areas already have developed TAZs and collected land-use and socioeconomic base data within the zone geography. Where this is not the case or where the level of detail, comparability with census tract or block boundaries, or a specific project requires it, zones will need to be developed or modified.

Structure of the TAZs

Zones are geographic areas dividing the planning region into relatively similar areas of land use and land activity. Zones represent the origins and destinations of travel activity within the region. As it is not computationally feasible to represent every household, place of employment, shopping center, and other activity as a separate origin and destination, these entities are first aggregated into zones and then further simplified into a single node called a centroid.

A centroid is a point that represents all travel origins and destinations in a zone. Zone centroids can be placed in the center of activity of the zone, using land use maps, aerial photographs, and local knowledge. Unique special generators, especially when surrounded by a very different land use (such as a college campus in a predominantly residential area) should be isolated as separate zones. The center of activity is not necessarily the geographic center—it is the midpoint of activity. Often judgment is more useful than measurement technique in determining where the zone centroid should be located.

Each centroid, or loading point, must be connected to the highway and transit systems. Typically in the highway network, these centroids are connected to the highway system at several points to represent the many paths over which each of the discrete origins and destinations within a zone accesses the highway system. Multiple connections tend to smooth the traffic on the adjacent links—if only one connection is given, the point at which the centroid connects to the street system will show abrupt changes in traffic volume at that point. Special generators should have the actual load points coded, areas. When compared with the aerial photographs, each land use can be associated with a particular land use type (e.g., retail and industrial) for each building.

6. *Telephone Directory*—The telephone directory is a rich database that lists residential units and businesses by street address for any planning area; however, the rate of unlisted residential numbers is rising and may influence the use of telephone directories.
7. *Polk Directory*—The Polk Directory is a comprehensive list of household and employment data sorted by name and address. For households, such information as occupation and employer can be ascertained. For business establishments, type of business—including associations, libraries, and organizations that may not be on the tax file—can be determined.

Data Source Deficiencies

1. *Population.* The only data source acceptable to initially establish a residential database is the U.S. census. All of the other data sources identified above do not provide comparable population statistics by specific area (i.e., block level).
2. *Employment.* Each of the above data sources has some deficiency in accurately specifying employment for small geographic areas. The census provides total labor force by TAZ; however, this represents only employment location of residents and not total employment. The employment commission data provide accurate employment for each business but only partially list street addresses (with the remaining having P.O. box listings). Commercial listings have all employers by street address. Although these listings are extensive, the accuracy is controlled internally and often cannot be considered comprehensive (because of the lack of information regarding collection methodology), but it offers a check for other data sources. The aerial photography assists only in determining potential nonresidential areas. The land-use data obtained from aerial photography provide a geographic location of businesses but do not provide employment numbers. A similar condition exists with the telephone directory. The directory covers most businesses and provides addresses for most of them. Several multi-use areas, such as shopping centers, do not provide numbered street addresses.

In summary, none of the data sources offers a complete inventory of employment by geographic location.

Employment data are the most difficult data component to collect. The census data show labor force statistics by industry group but do not compile this by employer and specific geographic area (i.e., block). Therefore, the methodology for developing the employment database should be based on the most efficient and accurate method by which employment can be collected and organized into the database file.

Control Totals for the Database

The control totals for the database should be determined before the compilation of the data. The source of the control totals for population should be the U.S. census.

IMPACT AND USES OF GIS ON DATABASES

Geographic information systems are designed to capture, store, retrieve, analyze, and display data files referenced to detailed geographic location; for example, latitude and longitude, state plane coordinates, census tract or block, or a locally developed geographic scheme. GIS software enables the planner to process geographic-based information from a multitude of sources. For instance, the tax assessor's office collects and maintains a wealth of information organized by tax parcel and indexed by a complicated map reference system. Likewise, public utilities, school districts, police, and fire departments all collect information on the populations they serve and often have their own system of geographic reference. State departments of transportation have data on traffic accident locations, pavement condition, bridge locations, signs, and rights-of-way.

A GIS organizes and provides access to these data, allowing the user to overlay and analyze it using a common frame of reference (either address- or block-specific), and display it in an easily understood format. This allows otherwise unavailable or cumbersome data to be used in transportation planning. Increasingly, the major differences between traditional planning and GIS are becoming blurred.

Three typical applications of GIS in transportation planning are geocoding, processing socioeconomic data, and cartography.

Geocoding

One of the reasons that the compilation of transportation information is so expensive is that data gathered from surveys on trip origins and destinations must be related to specific physical location. This process, commonly referred to as geocoding, is usually a tedious and time-consuming manual process. Many GIS applications include a geocoding capability that automates this process, allowing a street address, place name, or intersection to be geographically referenced to latitude and longitude, census tract, or TAZ. Good geocoding software includes the ability to handle misspelled names; ambiguities caused by similar names given to avenues, streets, and boulevards; and incomplete addresses.

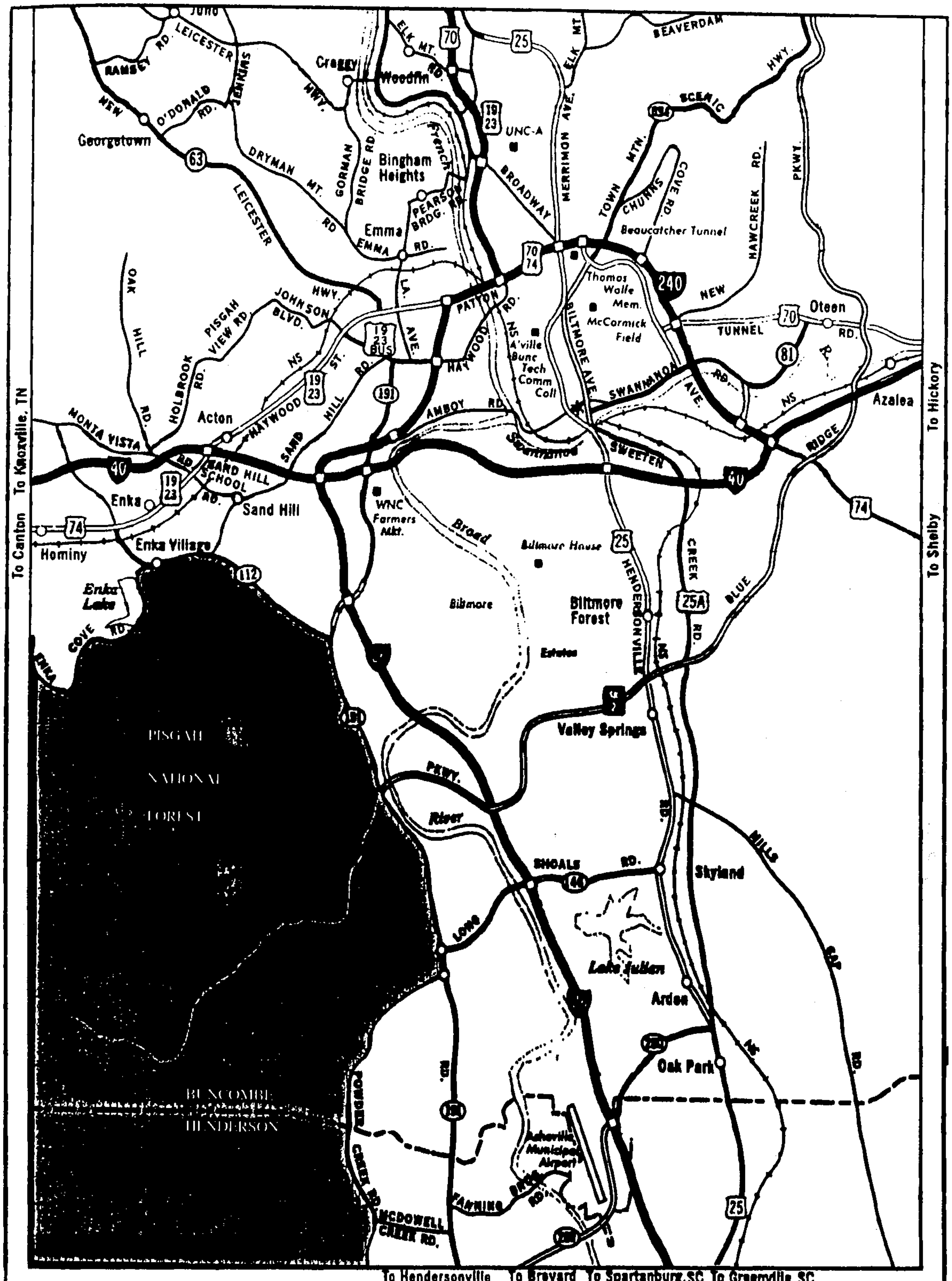

Figure 3. Asheville, North Carolina, highway map (courtesy of North Carolina Department of Transportation).

TABLE 2 External stations

Station No.	Description	1989 ADT	Classification
108	Route 251	1,800	Minor
109	Routes 19 & 23 Bypass	27,700	Principal
110	Routes 19 & 23 Business	7,000	Minor
111	BRP (N)	2,850	Minor
112	Snope Creek Road	2,000	Minor
113	Route 70	16,100	Principal
114	I-40 (E)	24,700	Interstate
115	Route 74	11,000	Minor
116	Route 25	12,450	Minor
117	I-26	33,100	Interstate
118	Routes 191 & 280	7,400	Minor
119	BRP (S)	970	Minor
120	Route 151	1,550	Minor
121	I-40 (W)	27,500	Interstate
122	Leicester Highway	14,000	Principal
123	Bear Creek Road	3,940	Minor

SUMMARY

The range of electronic data now available to the modeler is substantial. These data are most useful in the creation of the socioeconomic inputs to the model as well as the development of the model network itself. This allows finer detail and greater accuracy than was available even a few years ago. While these advances are on the whole good for the modeler, one must be careful not to be overwhelmed by the amount of data available and to use only what is truly necessary to create the desired output.

With the use of GIS, many commercially produced networks are now available. Many of these are simply enhanced TIGER files.

The next chapter, Trip Generation, begins the four-step modeling process with a discussion of data needs and the process used to create a basic trip table that will be used as an input to the model.

TABLE 3 Site-specific vehicle trip generation rates

Land Use	Daily Vehicle-Trip Rate	per	Percent of Total Daily Vehicle Trips A.M. Peak	P.M. Peak	ITE Code
Residential					
Single-Family	9.55	DU	8.0%	10.7%	210
Apartment	6.47	DU	8.6	10.7	220
Condo/Townhouse	5.86	DU	7.5	9.2	230
Mobile Home Park	4.81	Occupied DU	8.9	12.1	240
Planned Unit Development	7.44	DU	7.8	9.7	270
Retail[1]					
Shopping Center					
Under 100,000 sq. ft.	70.7	1,000 sq. ft. GFA	2.3%	9.2%	820
100,000 to 1,000,000 sq. ft.	38.7	1,000 sq. ft. GFA	2.1	9.5	820
500,000 to 1,000,000 sq. ft.	32.1	1,000 sq. ft. GFA	2.0	9.3	820
More than 1,000,000 sq. ft.	28.6	1,000 sq. ft. GFA	1.8	9.1	820
Office					
General[2]	11.85	1,000 sq. ft. GFA	13.8%	13.1%	710
Medical	34.17	1,000 sq. ft. GFA	10.0	13.0	720
Office Park	11.42	1,000 sq. ft. GFA	16.1	13.2	750
Research and Development Center	7.70	1,000 sq. ft. GFA	16.0	13.9	760
Business Park	14.37	1,000 sq. ft. GFA	11.3	10.3	770
Restaurant[3]					
Quality Restaurant	96.51	1,000 sq. ft. GFA	6.6%	10.1%	831
High Turnover (Sit Down)	205.36	1,000 sq. ft. GFA	8.7	15.5	832
Fast Food without Drive-Through	786.22	1,000 sq. ft. GFA	9.7	13.7	833
Fast Food with Drive-Through	632.12	1,000 sq. ft. GFA	9.5	7.3	834
Bank					
Walk-In	140.61	1,000 sq. ft. GFA	13.7%	0.4%	911
Drive-Through	265.21	1,000 sq. ft. GFA	13.3	19.3	912
Hotel/Motel					
Hotel	8.7	Occ. Room	7.5%	8.7%	310
Motel	10.9	Occ. Room	6.7	7.0	320
Parks and Recreation					
Marina	2.96	Berth	5.7%	7.1%	420
Golf Course	37.59	Hole	8.6	8.9	430
City Park	2.23	Acre	NA	NA	411
County Park	2.99	Acre	NA	NA	412
State Park	0.50	Acre	NA	NA	413
Hospital					
General	11.77	Bed	10.0%	11.6%	610
Nursing Home	2.6	Occupied Bed	7.7	10.0	620
Clinic (one data point)	23.79	1,000 sq. ft. GFA	NA	NA	630

(continued on next page)

TABLE 4 Percent of households by autos owned and income

	Autos Owned			
Income	0	1	2	3+
Urbanized Area Size = 50,000 - 199,999				
Low*	17	55	23	5
Medium	3	31	48	18
High	0	12	52	36
Weighted Average	8	32	40	20
Urbanized Area Size = 200,000 - 499,999				
Low	17	51	24	8
Medium	2	32	53	13
High	0	13	53	34
Weighted Average	7	32	42	19
Urbanized Area Size = 500,000 - 999,999				
Low	21	55	20	4
Medium	3	39	44	14
High	1	10	59	30
Weighted Average	7	33	42	18
Urbanized Area Size = 1,000,000 +				
Low	19	52	22	7
Medium	2	40	42	16
High	1	10	55	34
Weighted Average	7	31	41	21

* In actual 1990 dollars: Low = less than $20,000, Medium = $20,000 to 39,999, and High = $40,000 and up.

ings about variations in trip rates across urban area sizes and characteristics. The NPTS data provided the only consistent source of travel data throughout all ranges of urban area size and location; however, the NPTS rates were low compared with the rates collected by local areas. The lower rates can be attributed to the collection methodology of the NPTS. For generation data, the NPTS rates were factored in a normative distribution to match more closely the rates determined by the urban areas used as source data. A comparison of the actual rates is shown in Appendix Table A-2.

A major finding after reviewing the home-interview data and the NPTS data was that the difference between trip generation rates across urban areas of different sizes was not large, particularly when compared with the difference presented in *NCHRP Report 187*. The findings of the study resulted in trip generation rates closely grouped around an average of 9.0 daily person trips per household. A summary of the comparison of the average trip production rates contained in this report and those contained in *NCHRP Report 187* is presented below.

The impact of the revised trip rates should be reviewed by those who developed models using the earlier *NCHRP Report 187* rates. In many cases, it was acknowledged that the rates for small urban areas were high and the actual applied rates were adjusted downward. If the complete model set was calibrated and validated to match observed traffic count data, then any adjustments to the model should be reviewed in light of the revised rates.