

## **The New Hampshire Statewide Travel Model System**

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### **INTRODUCTION**

The New Hampshire Department of Transportation (NHDOT) began an important statewide study to carry the Department's transportation planning into the 21st century. The overall goal of the Statewide Planning Study is to "provide recommendations for developing a coordinated transportation system that will facilitate the movement of persons and goods in a safe, cost effective, efficient, and environmentally conscious manner." Recommendations from this study were to be directed to all transportation modes in the State of New Hampshire, including highways, public transportation, and freight movement. The study began in the year 1994 and is in its final stages now. The Department and its consultant team, with a multi-dimensional public participation program incorporated the concerns and ideas of the citizens of New Hampshire into the planning process.

NHDOT's consultant team was led by Cambridge Systematics, Inc., and included Holden Engineering & Surveying, Inc. and Wallace, Floyd, Associates, Inc. The study was closely coordinated with the Regional Planning Commissions, who were represented on the Advisory Committee and participated in the data collection and analysis.

This study reflected the emerging direction of transportation planning. It also reflected the Department's desire to lead in this direction, as NHDOT strives to meet the goals of transportation-related legislation, such as the Federal Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, and the Clean Air Act Amendments of 1990. Among other things these laws call for increasing the availability of transportation options to reduce the reliance on single-occupant vehicles, and for greater public participation in transportation planning and decision making.

The Department recognized that the success of the Statewide Planning Study, and the ability to meet the goals of the legislation, depended on public involvement and commitment to the transportation planning and decision-making process. NHDOT also recognized that better study decisions can be made through an open public participatory process. With this in mind, a comprehensive public participation program was developed to accompany the Statewide Planning Study. Elements include: a Legislative Advisory Committee, Technical Steering Committee, periodic newsletters, public workshops, and a Travel Demand Management brochure and video.

Other study objectives included: developing methodologies to assess the impacts of transportation projects; coordinating local and regional travel demand planning and management; helping to implement recommendations of the Department's Transportation in the 21st Century January 1993 report; and demonstrating on specific corridors (I-93 and Route 16) the analytical tools developed through this study.

The New Hampshire Statewide Travel Demand Model System (NHSTMS) was developed as part of this study. The model will help predict travel behavior (i.e., how people travel- by car, bus, etc.) and travel demand (i.e., how many people want to travel on a certain road or by a certain mode). The model is

based on statewide data collected on highway, bus, rail and airport systems; and land use, social and economic characteristics. Household travel, roadside motorist, and transit rider surveys were conducted as part of the data collection effort. The Department and its consultants plan to use the model to identify potential new or improved transportation services and strategies, designed to improve overall transportation services, reduce congestion and improve air quality.

The remainder of this paper describes the NHSTMS and how it works. The next section describes the objectives of the model system. This is followed by a summary of the model structure. Section four discusses the data requirements of the NHSTMS. Section five describes the zone system and networks in the NHSTMS. Section six provides a detailed discussion of the trip table creation, mode choice, and assignment processes, and Section seven describes the database and GIS features of the model system.

## **OBJECTIVES OF THE STATEWIDE MODEL SYSTEM**

The Statewide Model System was developed to address the needs of the Department in the following areas:

### *Project/subarea analysis*

The model will be used as a tool to analyze the impacts of major highway projects such as new corridors, widening of existing alignments etc.

### *Project alternative analysis*

The model has the capability to look at impacts of policy decisions such as increases in tolls, transit fare increase etc.

### *Air Quality analysis*

The model is designed to generate, for peak and off-peak periods of a summer average weekday, VMT estimates which can be used as input to air quality analyses.

### *Inputs to regional models*

The statewide model is expected to provide the external cordon line volumes for other regional models (such as the models developed by the Metropolitan Planning Commission).

### *Management Systems*

The model will serve as a tool to develop Congestion Management, Public Transportation, and Intermodal Management system.

### *Statewide Planning Study analysis*

The model will be used to identify potential new or improved transportation services (such as bus, rail) and strategies, designed to improve overall transportation services and reduce reliance on single occupant vehicles, reduce congestion, and improve air quality.

## **MODEL STRUCTURE**

## Description of Model Structure

The NHSTMS is a tour-based model system consisting of many submodels, or components. The model system structure<sup>1</sup> is illustrated in Figure 1. The model system is intended to model travel by auto and transit modes for peak and off-peak periods of a summer weekday.<sup>a</sup> The base year of the model is 1990 with analysis capabilities for all forecast years ranging from 1997 to 2020 although years beyond 2020 could be analyzed using extrapolation of socioeconomic forecasts.

The NHSTMS is implemented as a series of multinomial logit models estimated using data primarily from a household travel and activity survey conducted for the Statewide Planning Study. This survey is similar to many recent efforts in U.S. metropolitan areas. Because of the low incidence of transit trips in New Hampshire, the estimation of the mode choice models required additional data. This information comes from a stated preference survey that was conducted for a subset of households from the original activity-travel survey and onboard surveys of transit riders.

The model system components are summarized in Table 1. All of the model components listed in this table are multinomial logit models except the time of day model, which consists of sets of factors for each trip purpose which convert daily trips to a.m. peak, midday, p.m. peak, and off-peak trips. The multinomial logit model is a means of determining the probabilities for a set of discrete choice alternatives given a set of individual and alternative specific attributes. For example, the choice of mode given the characteristics of individuals (e.g., income, auto ownership) and of auto and transit use (travel times, costs, etc.) could be modeled using a logit model.

Because existing modeling software is geared toward four-step trip-based models, components 1 through 6 in Table 1 are implemented using programs written specifically for the NHSTMS. The outputs of the secondary destination choice model are converted to traditional origin-destination trip tables, and the EMME/2 software<sup>2</sup> is used to apply the mode choice and time of day models. Auto vehicle trips are assigned to the highway network using traditional equilibrium assignment methods, and transit trips are also assigned using standard methods. The model outputs are therefore similar to those for a traditional four-step trip-based process.

The basic modeling process in the NHSTMS can be summarized as follows:

1. Develop the necessary data (networks and socioeconomic data);
2. Prepare and run the trip table creation process :
  1. Vehicle availability (auto ownership) modeling;
  - b. Tour generation;
  3. Primary destination choice;
  - d. Auto/non-auto tour modeling;
  5. Tour type; and

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<sup>a</sup>Summer is defined roughly as the period from June through September. This definition is intended to include not only the large number of recreational trips, but also school trips.

- f. Secondary destination choice.
3. Constraint of home-based work attractions
4. Mode choice
5. Transit assignment
6. Time of day
7. Truck trip modeling
8. Constraint of external station trips
9. Highway assignment

The assumptions associated with the NHSTMS are summarized in Table 2. Details of individual model components are provided on the remaining sections of this report.

## **TOUR BASED MODELING APPROACH**

With few exceptions, urban area and statewide travel model systems in the United States use the traditional four-step modeling process. The inability of the four-step process to perform certain necessary transportation analyses and recent advances in both research and computing capability has prompted a reexamination of the four-step modeling paradigm. One of the most significant problems with the four-step process is the treatment of individual trips as independent decisions where the effects of other activity decisions are not considered (even the mode choice for a preceding trip to the origin). During the development of the plan for the NHSTMS, New Hampshire officials expressed concern about modeling trip chaining behavior.

To address this concern, a *tour-based*, or trip chaining, modeling approach was developed as an alternative to the four-step process. Tour-based models have already been implemented in urban areas both in the United States and other countries and do not require data beyond what is needed to develop a four-step travel model system.<sup>3</sup> Although tour-based model systems are relatively new to the U.S., models have been around in some European countries, such as Sweden and the Netherlands, for several years. Prior to the development of the NHSTMS, a tour-based model system was implemented in the Boise, Idaho urban area. This means that as of 1998, the NHSTMS is one of only two tour-based model systems being used in the U.S. (Portland, Oregon, is currently implementing a new activity/tour-based model system.)

Another innovative approach used in the NHSTMS is the use of *sample enumeration* to create data inputs for the trip table creation submodels. Unlike the common practice of using zonal averages for variables such as household size, the NHSTMS computes the number of households in each zone which fall into categories specified by the cross-classification of household size, number of workers, income level, and dwelling type. The models are then applied separately to the households in each stratum in each zone. In the recent past, sample enumeration could not be considered in the context of large regional or statewide model systems because of the computational cost. However, modern microcomputers can perform this analysis in a reasonable amount of time.

The major advantage of the sample enumeration approach is that aggregation error resulting from the use of zonal averages is greatly reduced. For example, say that transit use in a particular area is predominantly among low-income households. If a model using zonal averages were used, transit use

would occur mainly in zones with low average incomes; however, there may be no such zones. The sample enumeration method would show transit use among low-income households (with access to transit) in any zone in which they exist.

## **DATA USED IN MODEL DEVELOPMENT**

A variety of data sources were used in the development of the NHSTMS. These include the following:

- Surveys:
  - Household activity and travel;
  - Transit onboard;
  - Vehicle intercept; and
  - Stated preference.
- Highway Network Data:
  - NHDOT GDS-based highway inventory;
  - U.S. Census TIGER files;
  - Field collection of highway data; and
  - Other data provided by NHDOT (e.g., speed limits).
- Transit Operation Data:
  - Schedules; and
  - Fare structures.
- Socioeconomic Data:
  - U.S. Census (households by municipality, tract, and block group by income level, number of persons, number of workers, and number of vehicles available);
  - New Hampshire Department of Employment Security figures on employment by category for each municipality;
  - U.S. Census Public Use Microdata Sample (PUMS) for New Hampshire;
  - Dun & Bradstreet employment database for New Hampshire; and
  - New Hampshire Office of Planning Population and household forecasts by community, and employment forecasts by county.
- Geographic Boundary Information:
  - U.S. Census TIGER files.

These data sources are described below.

### **Survey Data**

#### *New Hampshire Activities and Travel Survey*

The primary data source for the estimation of the travel behavior models was the New Hampshire Activities and Travel Survey, which was conducted for the statewide planning study by the firm of

Market Opinion Research. A total of 2,844 households in New Hampshire provided data on the activities and travel undertaken by household members over a 24-hour period. Households were recruited for the survey by phone, were sent a diary form for travel and activity data, and were called back to retrieve the diary data. The survey was conducted between August 1994 and June 1995.

For the model estimation process, a total of four files were created from the survey data:

*Household*– For each household, the number of persons, number of workers, number of children, number of vehicles, location (address and various categorizations such as regional planning area, urban/rural, etc.), number of tours by purpose.

*Person*– For each person, the age, sex, driver’s license status, worker/student status. There were over 7,000 persons in the survey.

*Tour*– For each tour beginning and ending at home made by each person, the location and purpose of the primary destination, number and location of stops, time tour began and ended, whether an auto was brought on the tour. Level of service information between the home and the primary destination for highway and transit, including in-vehicle and out-of-vehicle time and cost was obtained from the highway and transit networks and attached to each record. There were about 10,000 tours in the survey.

*Trip*– For each trip (tour segment), the origin and destination of the trip, mode(s) used, time trip began and ended, trip purpose. Level of service information between the home and the primary destination for highway and transit, including in-vehicle and out-of-vehicle time and cost was obtained from the highway and transit networks and attached to each record.

#### *Transit On Board Surveys*

A series of transit on board surveys was conducted in summer/fall 1994 to supplement the household survey data on transit trips. Surveys were conducted of riders of bus service from New Hampshire on C&J, Concord Trailways, Coach, and Vermont Transit. Riders were handed survey forms on the buses or at the stops which were mailed back for tabulation. This provided a trip file similar to the household survey trip file. This file was used to supplement the trip file from the household survey, which, not surprisingly, had relatively few transit trips.

Data were also obtained from a 1994 survey of riders on the Massachusetts Bay Transportation Authority (MBTA) commuter rail service. A total of 210 of the records from this survey represented trips by New Hampshire residents boarding on the Fitchburg, Lowell, Haverhill, and Ipswich lines. These records were important because there were only a handful of actual commuter rail riders in the household survey. They were added to the trip file from the transit onboard survey.

#### *Vehicle Intercept Surveys*

A series of vehicle intercept surveys was conducted in summer 1994 by Holden Engineering to obtain data on external trips. In this context, external trips refer to trips made by New Hampshire residents to locations outside the state and trips made by non-New Hampshire residents to or through New

Hampshire. Drivers were surveyed at 24 locations at or near major New Hampshire border crossings using one of three methods:

- Drivers were stopped and asked the questions at the survey sites. Responses were tabulated on hand held computers.
- Drivers were handed survey forms and asked to mail them back.
- License plates were recorded and matched against records from motor vehicle departments in New Hampshire and Massachusetts (this procedure was used only at sites on the Massachusetts border).

This survey provided a trip file similar to the household survey trip file. This file was used to model trips by non-New Hampshire residents.

#### *Stated Preference Surveys*

A stated preference survey is conducted to obtain information about behavior which is rare or nonexistent and therefore cannot be easily obtained from travel behavior surveys. A stated preference survey was conducted by Market Opinion Research on a subset of the respondents to the Activities and Travel Survey. Respondents were asked to make hypothetical choices given the availability of new transit service, increased auto costs, or other potential changes to the transportation system. This resulted in another supplemental trip file which contained a richer sampling of transit choices.

#### **Highway Network Data**

The main source for information about the highway system in New Hampshire was the database maintained by NHDOT using the Graphics Design System (GDS). The GDS database contained information on all roads in New Hampshire, including the following characteristics that were important for the development of the NHSTMS highway network:

- Physical locations of roads, intersections, and interchanges;
- Roadway types;
- Segment lengths;
- Number of lanes; and
- Surface type (paved/unpaved).

For roadways in the NHSTMS network located outside New Hampshire, the TIGER files available from the U.S. Census Bureau were used. These files provided the necessary geographic information to determine the physical locations of roads, intersections, and interchanges.

The GDS and TIGER databases did not provide all information necessary for model development. It was necessary to supplement this information with field data checks. The major data item lacking from

these sources was speed data. For New Hampshire roadways, speed limit data were obtained directly from NHDOT.

## **Transit Operation Data**

The NHSTMS has a transit network which is used for developing travel time and cost information for the mode choice and transit assignment processes. This network focuses on longer intercity routes such as the intercity service provided by C&J, Concord Trailways, Coach, and Vermont Transit, and commuter rail service provided by the MBTA. The following data on these transit services were required for model development and/or application:

- Fare structures;
- Headways/frequencies;
- Travel times; and
- Ridership

This information was obtained directly from transit operators or from published information (e.g., schedules).

## **Socioeconomic Data**

The NHSTMS requires a significant amount of socioeconomic data for both model development and model application. Tables 3 and 4 summarize the data requirements for model development and model application respectively.

### *Base Year Socioeconomic Data*

The base year of the NHSTMS was chosen to be 1990 to coincide with the most recent U.S. Census. Zone boundaries were chosen to be consistent with census geography, and so it was a relatively simple task to estimate the population and number of households by type (see Table 3) for each zone. This process was facilitated by the use of the TIGER files since the zone boundary layer of the NHSTMS GIS could be overlaid with the census data in the TIGER files. The population and household estimates for each zone were reviewed by the appropriate regional planning commission and NHDOT before they were finalized.

Employment estimates by employment type for each zone for 1990 were developed from estimates for each municipality obtained from the New Hampshire Department of Employment Security. For cities and towns which consist of more than one zone, the Dun & Bradstreet data file was used to allocate the employment among the various zones comprising the municipalities. The regional planning commissions reviewed these figures and provided revisions. These revisions were numerous due to the relatively imprecise nature of the original estimates, particularly in communities where allocation of Department of Employment Security figures was required.

### *Socioeconomic Forecasts*

There are two “base” forecast years for the NHSTMS: 2005 and 2020. Zonal forecasts of the model variables shown in Table 4 were made for these two years. Forecasts for any intermediate year are made



by straight line interpolation between 1990 and 2005, or 2005 and 2020.

The New Hampshire Office of Planning has developed population and household forecasts at the municipality level. For the many New Hampshire communities which correspond to exactly one NHSTMS zone, the Office of Planning forecasts are therefore the zonal forecasts. For communities which consist of more than one NHSTMS zone, the forecast for the city or town was maintained, and the growth in population or households from 1990 allocated to zones proportionally based on the 1990 population/number of households. The resulting initial forecast estimates were reviewed by NHDOT and the regional planning commissions, who provided valuable insight into the expected locations of future development. This resulted in more reasonable allocations of growth within a community in many cases.

Employment forecasts were available only at the county level. It was therefore necessary to allocate the expected growth among all zones within each county among all zones in the county. The review by NHDOT and the regional planning commissions was even more critical since the allocations were made over much larger areas (counties rather than cities and towns).

It should be noted that although socioeconomic forecasts have been provided (or can be interpolated) for all forecast years through 2020, alternate growth forecasts for a particular alternative can also be analyzed by replacing the standard forecasts for the affected zones with the desired replacements.

#### *Disaggregate Household Forecasts*

As discussed earlier, the NHSTMS model system is applied using sample enumeration. This means that rather than using zonal averages for each model variable, the model is applied to each individual household based on its characteristics. Actually, since households are defined in terms of a four-dimensional cross-classification, the models are applied to each category of households within a zone, and the resulting tours and trips multiplied by the number of households falling into each category.

For the base year, the census data provide most of the necessary categorization of households for each zone. For forecast years, the household forecasts provide one-dimensional classifications of households by each category (income level, number of persons, number of workers, and single family vs. multi-family). The full cross-classification of the household forecasts is achieved through the use of iterative proportional fitting (IPF). In this process, which is equivalent to the Fratar process used in other components of the model system, the base year classification is adjusted iteratively until the marginal totals match the targets. The IPF process is implemented using Excel spreadsheet macros.

#### **Geographic Boundary Information**

Because the final model system was to reside in a geographic information system (GIS), it was necessary to obtain detailed information on geographic boundaries which could be used for zone boundary definition. The major source for this information was the TIGER file, which contained boundary information on all census geography, including municipal, tract, and block group boundaries.

## **ZONES AND NETWORKS**

### **Traffic Analysis Zones**

The NHSTMS uses the traditional approach of aggregating trip end locations to traffic analysis zones. It is reasonable to use a relatively small number of zones since the statewide model system does not focus on short local trips.

The model area is the area which includes the origins and destinations of most trips which are made wholly or partially in New Hampshire. This area includes the entire state of New Hampshire and locations in neighboring states which represent destinations for significant numbers of New Hampshire residents, or whose residents make significant numbers of trips to New Hampshire. The areas outside New Hampshire which are included in the model area are described below.

In general, internal zones were defined to be consistent with municipal boundaries, census tracts and/or block groups, and zone boundaries for the models maintained by Regional Planning Commissions (RPCs) in New Hampshire. Each city and town is represented by 1 to 21 zones.

Because of the large number of trips between New Hampshire and the Boston area, it was necessary to include in the NHSTMS external zones in Massachusetts extending south to Boston. This also allowed the inclusion in the transit network of nearly all intercity bus routes which serve New Hampshire.

External stations were used to represent the “other ends” for trips to and from the internal and external zones which lay outside the model area. External stations also represented the origins and destinations of through trips (trips which used roadways in the NHSTMS network but had neither an origin nor a destination in the model area).

### **Transportation Networks**

The transportation networks are the basis for all modeling analyses. The networks represent the specific highway and transit route assumptions for the scenario being analyzed and are used for estimation of level of service variables (travel times and costs) and for highway and transit assignments.

The highway and transit networks consist of a series of links, representing roadway and rail line segments, and nodes, representing the points where links intersect. Links connecting the zone centroids to the network are also included in the networks.

The transit routes which are identified as part of the NHSTMS are the major intercity or long-distance routes in the model area. The NHSTMS transit modeling capabilities focus on these longer distance transit routes because local transit cannot be adequately modeled by the relatively coarse zone structure of the statewide model system and because there is relatively little local transit travel to model in New Hampshire. Local transit is more appropriately handled in urban area model systems.

## **TRIP TABLE CREATION, MODE CHOICE, AND ASSIGNMENT**

This section describes the process used to create person trip tables by trip purpose and mode in the NHSTMS and to assign vehicle and transit person trips. These processes use zonal data— such as socioeconomic data— and highway and transit network data to estimate the tour making patterns in New Hampshire and, from that, the number of trips by purpose between each pair of zones. These person trip tables are used as inputs into the mode choice and time of day models.

The required inputs for the trip table creation process are the zonal socioeconomic data, the number of households in each zone in each category of the four-dimensional classification (household size, number of workers, income level, and dwelling type), and the travel impedances by highway and transit. Table 5 displays the required impedance components.

The trip table creation process creates as outputs 12 trip tables containing person trips. These trip tables are used as inputs into the mode choice and subsequent submodels. These are listed below:

Trips made by New Hampshire residents:

- Home-based work trips in auto tours;
- Home-based work trips in non-auto tours;
- Home-based school trips in auto tours;
- Home-based school trips in non-auto tours;
- Home-based other trips in auto tours;
- Home-based other trips in non-auto tours;
- Non-home based trips in auto tours;
- Non-home-based trips in non-auto tours; and
- Work subtour trips in auto tours

Trips made by non-New Hampshire residents:

- Home-based work trips;
- Home-based school trips; and
- Home-based other trips.

### **Vehicle Availability**

The vehicle availability submodel essentially adds a fifth dimension—the number of autos per household—to the four dimensional categorization of households. Like the vehicle availability models which are part of many urban area model systems, this submodel is a multinomial logit model which is based on household characteristics such as income, household size, number of workers, as well as

locational characteristics of the household. This submodel was estimated using the PUMS dataset for New Hampshire.

## **Tour Generation**

Tour generation models constitute the second step in the trip table creation process. The tour generation model relates the number of tours generated by a household to that household's socioeconomic and geographic characteristics. These models, one for each tour purpose, are somewhat analogous to the first step of the traditional four step modeling process, trip generation. Tour generation models were developed for the following tour purposes: Work, School, Other, Shopping, Recreation, and Chauffeuring.

For trip generation, the norm in trip-based models involves the development of production and attraction models linking the total zonal trips or trips per household to the household and zonal socioeconomic characteristics. Tour generation models look at travel as "tours" that combine a number of linked trips. For example, a person traveling from home to work may actually stop on the way to drop off someone and/or do personal errands.

In the NHSTMS, a tour is thus defined as a sequence of trips/activities that start at home and end at home. The analysis of trip chaining divides trip generation into two parts: estimation of the number of tours, and prediction of the tour type, that is the number and purposes of stops in each tour. Assume a single person household making one tour a day, starting at home, going to work, and then shopping before ending the day at home. The first part of the trip generation involves predicting that the household makes one tour, and the next step involves predicting that the tour has two intermediate stops, one at work and the other for shopping, in that order. The modeling of intermediate stops is discussed later.

## **Destination Choice**

Destination choice models predict the probability of choice of all likely destination zones for a tour. All zones in the study area make up the choice alternatives. The destination choice model system includes primary destination choice, described here, and secondary destination choice submodels, described later.

The primary destination choice models were developed using data from the household Activities and Travel survey, which provides information on travel patterns of households within the state of New Hampshire. Due to the non-availability of similar data for households outside New Hampshire, models developed for internal zones are appropriately applied for travel from external zones.

The zone of primary activity on a tour is termed as the primary destination. The purpose of the primary activity/trip on a tour is the purpose of the tour itself. For example, in a work tour, the highest decision in the hierarchy of destination choices is the work destination. Based on the primary destination, the other stops along the tour are determined. Primary destination choice models were developed for the following tour purposes: Work, School, Other, Shopping, Recreation, and Chauffeuring. All submodels are developed as multinomial logit models in which the traveler chooses a zone among all potential

choices in the model area as the actual destination.

### **Mode Choice - Stage 1**

Since the stated preference and onboard surveys had to be trip-based, a two-stage mode choice model is used. First, the tours are classified as “auto,” in which the traveler brings an auto from the home, or “non-auto.” Then, a trip-based model is used for each type of tour. For each type of tour, constraints govern the choice set of modes. Trips on auto tours must ensure that the automobile is available for each trip on the tour; the mode for each trip must be “drive alone,” “two-person carpool,” or “three or more person carpool” unless the origin is revisited in the tour (i.e., a subtour exists). Trips on non-auto tours do not have the auto driver modes available but do have transit and non-motorized modes available.

Besides the effect on trip level mode choice, there is also reason to believe that a personal vehicle provides for an increased flexibility in movement and could result in different travel behavior than when a vehicle is not available. This aspect of auto tours is dealt with in greater detail in the tour type models.

The level of transit usage on a tour is also largely dependent upon whether auto is the primary mode or not.

The choice of whether to bring an auto on a tour depends upon its availability for usage and the ease of travel to the primary destination by transit as compared to auto. For this reason, these models cannot be applied until after the primary destination models. Also, because of the fact that the availability of an auto influences the travel pattern, these models should immediately follow the application of the primary destination models. Accessibility of the primary destination from home is measured by a composite variable that combines the level of service of auto and transit.

### **Tour Type**

Tour type models determine the number of stops on a tour and whether a tour has a subtour associated with it. Based on observations made from the household activity survey data used for model estimation, and due to the complexity associated with determining destinations in tours with multiple stops, the maximum number of stops on a tour is limited to three (primary, secondary, and tertiary destinations), excluding the subtour stops. Subtours or midday tours, modeled only for work tours, are made during the day and have the beginning and ending as the work location.

One of the most important factors in determining the tour type is the availability of a vehicle on a tour. The ease of travel and the flexibility associated with the availability of an auto (hereafter referred to as auto tours) prompts an increase in the amount of travel. Therefore, auto tours exhibit a different travel pattern from non-auto tours and hence should be treated separately. Since the non-availability of an auto inhibits free movement, it could be safely assumed that travelers not using auto for their primary activity know a priori that their primary destination is the only stop on the tour. Therefore, non-auto tours are restricted to be one-stop tours without any midday tours from work. Separate tour type models are developed for each of the six purposes.

### **Secondary Destination Choice**

Secondary destination choice models, including tertiary and subtour destination choice models, predict the starting and ending locations of study area trips. In simple terms, these models help determine the locations of the second, third, and midday stops for tours respectively. The secondary destination choice models are developed using data from the household Activities and Travel survey, which provides information on travel patterns of households within the state of New Hampshire.

The outputs of the secondary destination choice models are traditional person trip tables. At this point, it is possible to perform the remaining functions of the NHSTMS using the matrix manipulation and assignment capabilities of EMME/2.

## **Mode Choice - Stage 2**

The second stage mode choice models are applied to the daily person trip tables which are outputs of the trip table development process. The mode choice models are multinomial logit models applied using EMME/2 macros. Models were estimated for eight tour type/trip purpose combinations as described below. The models were estimated from a combined data set containing data from household activity/travel, transit onboard, and stated preference surveys.

The main data set used for model estimation is a combination of:

- The trip file from the household Activities and Travel Survey;
- The trip file from the stated preference survey;
- The trip file from the transit onboard survey; and
- The records for New Hampshire residents from the MBTA survey of commuter rail riders.

Vehicle trip tables are required as inputs to the highway assignment process so that volumes can be estimated on highways. Vehicle trip tables consist of the following components:

- Auto trips;
- Auto access to transit trips; and
- Truck trips.

Auto person trip tables are the outputs of the mode choice modeling process. For each trip purpose, person trip tables are output for auto with one, two, or three or more occupants. For one and two person autos, the conversion from person to vehicle trips is straightforward. The single occupant vehicle and person trip tables are the same. The two-person auto trip tables are divided by two to obtain vehicle trips. For the three or more person trips, vehicle occupancy averages were determined from the household survey data by trip purpose.

## **Time of Day**

The NHSTMS assigns vehicle trips for four time periods, which comprise an average summer weekday.

These periods are defined as follows:

**AM Peak**– 6:00 a.m. to 9:00 a.m.;

**Midday**– 9:00 a.m. to 3:00 p.m.;

**PM Peak**– 3:00 p.m. to 6:00 p.m.; and

**Off-Peak** – 6:00 p.m. to 6:00 a.m.

The trip tables that are outputs of the trip table development and mode choice process represent average daily travel. The daily trip tables by purpose are divided into trip tables for each time period by purpose through a set of factors. These factors were developed from the household survey data and adjusted to reflect traffic counts by time of day.

### **Truck Trips**

Truck trips are estimated separately from the tour-based modeling process. Truck travel is estimated using the following process:

1. For internal (New Hampshire) zones, daily truck trip ends are estimated based on employment by category and households, based on information from the FHWA *Quick Response Freight Manual*<sup>4</sup>
2. For external zones and stations, daily truck trip ends are estimated as five percent of the total estimated vehicle trips.
3. Trip distribution is performed using a gravity model. The friction factors are given by a formula based on the Quick Response Freight Manual. For external stations, as recommended in the Quick Response Freight Manual, distance is added to represent the distance traveled outside the model area.
4. Time of day factors, based on the Quick Response Freight Manual, are applied to the daily truck trip table resulting from step 3.
5. The resulting truck trip tables for each period are added to the vehicle trip tables which are the outputs of the time of day submodel.

### **Transit Assignment**

In the transit assignment process, the daily bus and rail trips are loaded onto the transit network. This process consists of the determination of transit paths between origins and destinations and the assignment of the trips from the mode choice model onto these routes. It should be noted that this process differs from the transit assignment process in a typical urban area model since the transit trips being modeled are longer intercity trips rather than short local trips. The major differences for the statewide transit assignment process are as follow:

- Distances are long, usually at least 10 miles and often much more, between stations. This means that the exact paths routes take between stations are unimportant as long as the travel times between the stations are accurate. It also means that buses may often achieve speeds as high as auto speeds over long sections of routes.

- Fares are nearly always distance-based although fare structures vary significantly throughout the model area.
- Auto access portions of park-and-ride or trips may be fairly long.

In the transit network development process, the network is defined in terms of both the links available to bus, rail, and access modes (auto, walk, and subway) and the specific routes operated in the model area. The first step in transit assignment is to determine the paths – the ordered sets of links along the network – over which the routes operate.

The next step is to determine the paths connecting the stops. This is done, using EMME/2 and custom programs written for this process, by determining the shortest paths between stops in a manner similar to that used during network skims. The result is a set of paths which include all nodes and links between the origins and destinations.

The transit assignment process is simply an all-or-nothing assignment procedure using the paths developed from the skeletal route files. However, it should be noted that only the portions of trips that are actually on board transit vehicles are assigned. The auto access portion of trips are separated from the transit trip tables using matrix convolution capabilities of using EMME/2 and custom programs written for this process. The auto access trips are then added to the auto vehicle trip tables prior to auto assignment.

### **Highway Assignment**

The highway assignment process consists of assigning the vehicle trip table for each of the four time periods (a.m., p.m., midday, and off-peak) to its respective highway network. The vehicle trip tables consist of:

- Auto trips by New Hampshire residents;
- Auto trips in New Hampshire by residents of other states;
- Truck trips which travel within, to, from, or through New Hampshire; and
- The auto access portions of transit trips.

The four trip tables are assigned to the networks using traditional equilibrium assignment techniques within EMME/2. Because of the relatively uncongested nature of the majority of the highway network in New Hampshire, the base year assignments converge in two to three iterations.

### **DATABASE/GIS APPROACH**

One of the unique aspects of the NHSTMS is that all network link and node data are stored in a series of databases. This is done to facilitate management of model data for various scenarios and data display using the GIS capabilities which are part of the NHSTMS.

All link and node records which are part of any scenario run using the NHSTMS are stored in a “master database.” This database contains coordinates for all nodes as well as the relevant information for each



link, including length, link type codes, number of lanes, counted volume data, and speed. For each scenario, a separate database indicates which nodes and links from the master database are to be used. The user accesses and edits the databases through a Windows menu system, which also enables the user to create and manage scenarios, perform screenline analysis, and generate network data input files in EMME/2 format.

The use of a database manager to store network data allows easy transition of the model input and output data to a GIS. The GIS programs which are part of the NHSTMS, programmed in Arc/Info, allows a number of user capabilities including querying, color and bandwidth coding, and comparison of scenarios.

## CONCLUSION

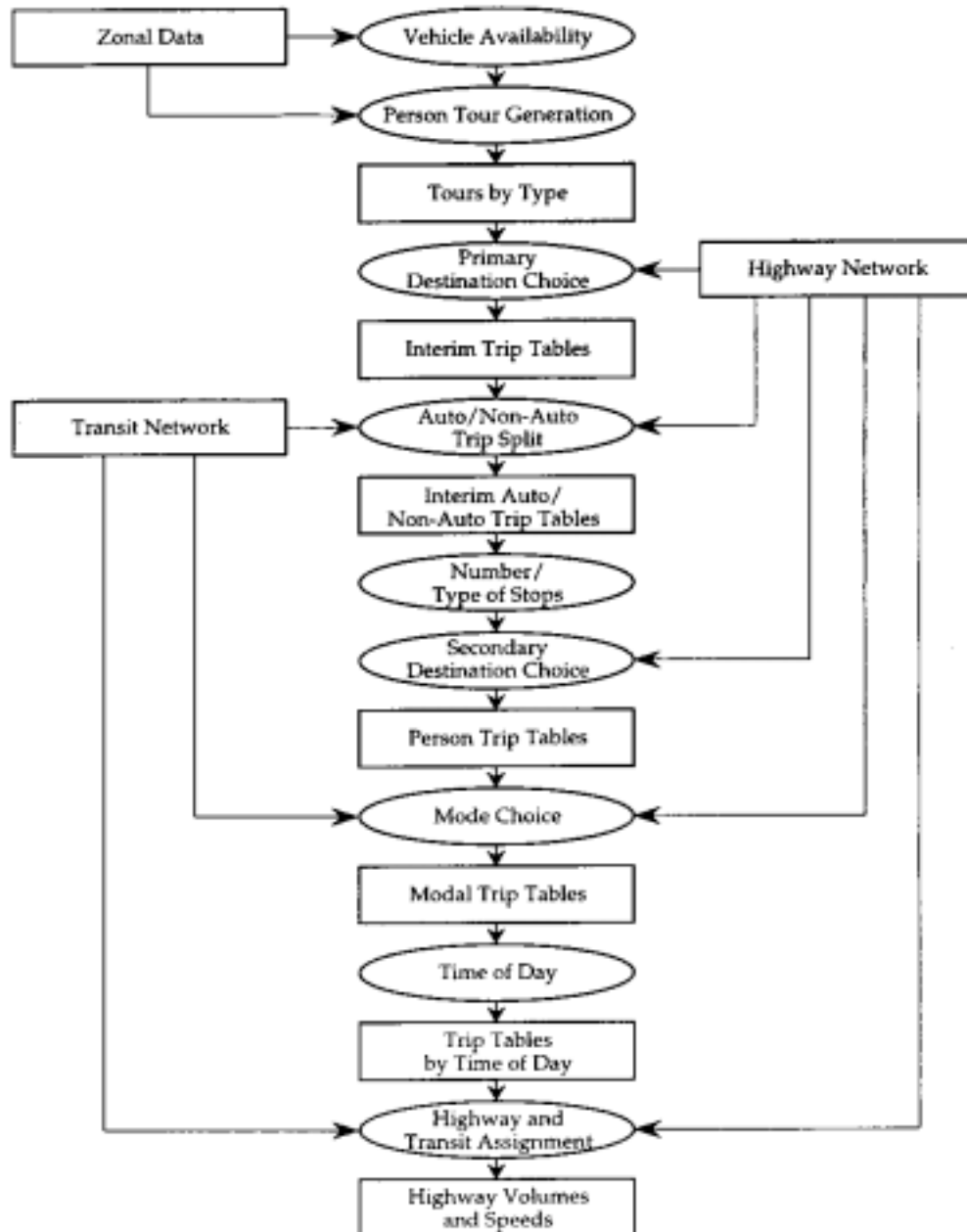
The NHSTMS is expected to be an important and flexible analysis tool in New Hampshire for years to come. It has many unique features including database/GIS capabilities, a tour-based model structure, and an underlying set of disaggregated estimated models. It is a state-of-the-art tool that will provide planners in New Hampshire the capability to perform a wide variety of analyses.

## REFERENCES

1. Cambridge Systematics, Inc. *New Hampshire Statewide Travel Model System: Model Documentation Report*, 1998.
2. INTRO Consultants. *EMME/2 User's Manual, Version 7.0*, 1995.
3. Rossi, Thomas F. and Yoram Shiftan. *Tour Based Travel Demand Modeling in the U.S.* Paper presented at the 8<sup>th</sup> IFAC/IFIP/IFORS Symposium on Transportation Systems '97, Chania, Greece, June 1998.
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Figure 1 Tour-Based Travel Model System



**TABLE 1 New Hampshire Statewide Travel Model System Components**

<b>Component</b>	<b>Basis</b>
1. Vehicle availability (auto ownership)	Household
2. Tour generation (number of tours by purpose)	Household
3. Primary destination choice of tour	Tour
4. Tour level mode choice (auto vs. non-auto tour)	Tour
5. Tour type (number and type of stops)	Tour
6. Secondary destination choice	Trip
7. Trip level mode choice	Trip
8. Time of day	Trip

**TABLE 2  
New Hampshire Statewide Travel Model System Assumptions**

<b>Model Feature</b>	<b>Assumption</b>	<b>Data Source</b>
Base Year	1990	Households: U.S. Census Employment: NH Department of Employment Security
Forecast Years	Capable of analyzing any year through 2020, perhaps beyond if willing to extrapolate socioeconomic data. Socioeconomic forecasts exist for 2005 and 2020, other years available via interpolation	State Planning Office municipal/ county totals, disaggregated to zones and reviewed by RPCs
Base Modeling Period	Summer weekday	N/A
Times of Day	Three-hour a.m. and p.m. peak periods, midday and nighttime periods. Daily travel estimates can be reported.	Factors derived from survey data
Unit of Travel	Person-tours through trip distribution, person trips for mode choice and time of day	Household travel, stated preference, vehicle intercept (external), and transit onboard surveys
Zone System	Consistent with: existing RPC model zone boundaries, municipal boundaries, census geography	Census boundaries, RPC models

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**TABLE 2****New Hampshire Statewide Travel Model System Assumptions**

Transportation Network	Multimodal – highway, bus, rail	NHDOT GDS, transit route information from operators and schedules
Tour Purposes	Work, school, shop, recreational, other, pick-up/drop-off	Household travel survey
Trip Purposes(mode choice/time of day)	Home-based work, home-based school, home-based other, non-home-based for each tour type (auto/non-auto), also subtrips	Household travel, stated preference, and transit onboard surveys
Modes Included	Vary by purpose, but generally include: SOV, HOV2, HOV3+, bus, rail, non-motorized	Household travel, stated preference, and transit onboard surveys

**Table 3 Socioeconomic Data Requirements for Model Development****All data items required at zone level****Employment by type**

Number of households by:

Vehicle availability level

Income level

Number of persons

Number of workers

Single family vs. multi-family dwelling

Land area

**Total population**

Whether zone has a:

Airport

Beach

College

Park

Other recreational area

**Table 4 Socioeconomic Data Requirements for Model Application****All data items required at zone level****Employment by type**

Number of households cross-classified in four dimensions:

Income level

Number of persons

Number of workers

Single family vs. multi-family dwelling

Land area

**Total population**

Whether zone has a:

Airport

Beach

College

Park

Other recreational area

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**Table 5 Impedance Measures Required  
by the Trip Table Creation Process**

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Auto distance

Auto costs

Rail out-of-vehicle time

Rail fares (work)

Rail in-vehicle time

Rail fares (non-work)

Bus out-of-vehicle time

Bus fares (work)

Bus in-vehicle time

Bus fares (non-work)

Auto travel times

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