Appendix 1

Traffic Model Development

TRAFFIC MODEL DEVELOPMENT

INTRODUCTION

CTPS developed a traffic model to simulate current and future traffic conditions in the study area. Travel demand forecasting is a method of simulating existing conditions and estimating future demand on a transportation system. The underlying concept of travel demand forecasting is the relationship between land use, socioeconomic trends and travel demand. A model consists of a network and an associated zone structure contained within a study area. The network is a representation of the transportation system under study. The zones are representations of the socioeconomic and land-use conditions within them. The internal zones are connected to the network by zone connectors. External zones represent the interface between the study area and the outside world, and are connected to the network at external stations. External zones are aggregate representations of the socioeconomic and land-use conditions and roadway system in the area subtended by the respective external stations and are located where major roadways cross the boundary that defines the study area.

The Highway Emulator (THE), a microcomputer-based software package, was used to forecast future highway travel demand in the Route 2 study area. This modeling software was developed by Edward Bromage when employed at CTPS. (Complete documentation of THE is available at CTPS.)

The preliminary steps in producing travel demand forecasts are the establishment of a network and a zone structure. Once base-year, base-case conditions have been established, the expected future-year network, socioeconomic conditions, and land-use conditions are coded into the model.

The actual travel demand forecasting process is traditionally divided into four steps. A brief description of data preparation and the methods used in the travel modeling process for this study follow.

1.0 BASE-YEAR MODEL DEVELOPMENT

The purpose of a base-year model is to simulate current conditions--traffic volumes, turning movements, origin-destination patterns--and to serve as a basis for predicting future travel conditions in the study area. The initial base-year model for Route 2 was calibrated to 1992 traffic conditions, but then it was updated to 1995 to comply with the base-year requirement for the Crosby's Corner grade separation draft environmental impact report (DEIR).

1.1 Project Area and Highway Network

The project area covers the towns of Acton, Bedford, Concord, Lexington, and Lincoln and a small portion of western Burlington. A map highlighting the extent of the area modeled is presented in

Figure 1-1. The size of the area is sufficiently large to simulate current traffic conditions as well as to serve as the basis for determining the effects of various long-term design alternatives at intersections along Route 2.

The study area roadway network is also presented in Figure 1-1. All of the numbered roadways as well as the unnumbered ones shown here are included in the model. Also included in the model are length, speed and capacity for each roadway link in the network.

1.2 Traffic Analysis Zones

The zones into which, for modeling purposes, the study area was divided are called traffic analysis zones. There are two types of zones--external and internal. THE assumes the internal zones of the modeled area are in a closed system. No trips may enter or leave the system except at specific points. These points are those locations where a road crosses a cordon line drawn around the internal zones. This cordon line was drawn far enough from the center of the modeled area that no traffic would divert from this crossing point because of network changes . Each road included in the highway network that crosses the cordon line becomes an external zone. There are 52 external zones in the model.

The boundaries of the internal zones were established after the external zones were defined. The model attempts to simulate the activities of areas where trip-making characteristics are similar. For example, high-income households make more auto trips than low-income households, and retail sales centers attract more auto trips than manufacturing centers. Therefore, areas with similar land uses were consolidated into 91 internal zones. The internal zone structure is presented in Figure 1-2.

1.3 Traffic Volumes

CTPS gathered a variety of traffic count data to establish existing conditions on the study area's roadway network and to calibrate the traffic model. As was previously mentioned, the model is an updated version of a 1992 model. A count program specifically designed for the original model was conducted in June 1990. This program included directional automatic traffic recorder (ATR) counts at 15 locations. These counts typically covered a 48-hour period. Manual turning movement counts were performed at 15 intersections and covered the peak periods of 7-10 AM and 3-6 PM.

Additional traffic count data were obtained from ATR and manual intersection turning movement counts performed for MHD's Route 128 Study in May and June 1990. Actual field count sheets as well as computer spreadsheet files were made available for use in this study. Traffic count data obtained for the 1989 Hanscom Air Force Base Study were also used. Other traffic data were obtained from the MHD statewide traffic counting program. Where necessary, counts were factored to 1990 levels and all were normalized to reflect 1990 average annual weekday traffic (AAWDT) operating conditions.

The process of collecting and adjusting intersection and mainline traffic counts resulted in the development of the 1990 base year mainline and turning movement volumes used in the model calibration process. In order to accurately model 1992 base year conditions, an assessment was done of traffic volume trends between 1990 and 1992. Several counts were taken and compared with the 1990 counts. Traffic count volumes were adjusted where necessary.

In order to adapt the model for the Crosby Corner EIR, which required a 1995 base year, CTPS compared the 1992 turning movement counts collected at Crosby's Corner to counts collected manually by Louis Berger and Associates in April 1995 as part of the vehicle occupancy study for the DEIR. ATR counts were also performed by MHD in April 1995. No seasonal adjustments were made when comparing 1995 counts, with 1992 counts as the seasonal variation of traffic for October and April is very similar.

The 1992-1995 traffic volume percent change in either direction along Route 2 was on the order of -5% to 4%. The peak hour movements, eastbound in the AM and westbound in the PM changed by 0% and 1%, respectively. Based on the results of this analysis, it was decided to use the 1992 calibrated model for Route 2 as the 1995 calibrated model for the Crosby Corner DEIR and to also use 1995 as the base year for analysis in the Route 2 Long-Range Feasibility Study.

1.4 Socioeconomic Data

It was necessary to estimate the number of households, average household income and retail and non-retail employment for each zone in order to generate trips and distribute them on the highway network. Among the sources used to estimate the base year data were the 1990 U.S. Census population, household and income data, Massachusetts Department of Employment and Training (DET) employment data, employment data from the CTPS regional model, information from various town planners, and field reconnaissance.

Geographic correspondence between the zones and Census tracts and/or block groups was determined. This correspondence was used to distribute Census data to the TAZs. New housing developments that occurred between 1990 and 1995 were identified and added to the appropriate zones.

DET publishes town-level employment data. CTPS's employment data by employment type classification was used to split the DET data between retail and non-retail employment. Total retail and non-retail employment were then distributed to census tracts and their "zone group equivalents" based on geocoded CTPS employment data. The "zone group equivalents" were distributed to zones based on previous Route 2 zone-level data. The location, size and type of each new commercial development that occurred between 1990 and 1995 were identified. The ITE Trip Generation Manual's average land use densities were used to estimate the number of employees per development based on size and type of development. The number of new employees were then added to the appropriate zones.

1.5 Trip Generation

The first step of the four-step modeling process is to estimate the number of trips that each zone generates. THE uses trip generation rates established in NCHRP Report #187[1] (referred to as the QRS manual). The QRS manual estimates trip productions and attractions on the basis of zonal household data and zonal retail and non-retail employment. The QRS manual refines its trip generation estimates through the use of scaling factors based on urban area population. These factors can be used to translate total productions and attractions into auto driver trips and to distribute 24-hour trip generation estimates to specific time periods.

Mode split is usually the third step of the modeling process, but it may be done within either the trip generation or trip distribution step. It consists of categorizing trips according to their mode (highway, transit, bus, taxi, etc.). In THE, auto driver trips are extracted from total trips during trip generation.

1.6 Trip Distribution

This step of the modeling process distributes the generated trips between the model's zones. Traditionally, trips are distributed through the application of an algorithm known as the gravity model. The gravity model distributes trips between zones according to the size (in terms of population and employment) of the zones and the distance between them. Application of the gravity model algorithm produces a trip table which is a matrix of the trip exchanges between all the model's zones.

1.7 Traffic Assignment/Model Calibration

THE will calibrate an existing origin/destination table (derived from the two preceding steps) to observed traffic counts. The calibration algorithms employed by THE are based on a maximum entropy algorithm developed and refined by H.J. Van Zuylen and Professor L.G. Willumsen of the University of Leeds.[2] The calibration process is iterative in nature. A trip table is calibrated until the difference between an assignment from it and observed traffic counts is within an acceptable range of error. Error is calculated in terms of percent root mean square error (% RMSE). A % RMSE of less than 10% is generally acceptable; less than 5% is considered very good.

THE uses either a conventional capacity-restrained or an equilibrium algorithm to assign a trip table to a network. It is capable of single iteration assignments (all-or-nothing) and multiple iteration assignments.

In a multiple iteration assignment, each iteration is weighted equally in calculating the final assignment. THE employs Moore's algorithm to determine the shortest path between zone pairs.

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[1]National Cooperative Highway Research Program Report #187: *Quick-Response Travel Estimation Techniques and Transferable Parameters User's Guide*, Transportation Research Board, Washington, D.C. (1978).
[2]Henk J. Van Zuylen and Luis G. Willumsen, "The Most Likely Trip Matrix Estimated from Traffic Counts," *Transportation Research*, Volume 14B, pp 281-293.

In the capacity restrained assignment, the BPR (Bureau of Public Roads) curve is used to account for capacity effects on network links. This curve determines the increases in a link's travel time due to an increase in the link's volume-to-capacity ratio. Travel time is developed incrementally by combining the current iteration's travel time with the previous iteration's travel time in a 1:3 ratio.

In this study, the AM peak hour base year trip table was calibrated to 2.6% RMSE. The PM peak hour trip table was calibrated to 4.1% RMSE. AM and PM peak hour calibrated volumes for 1995 are presented in Figures 1-3 and 1-4.

2.0 FUTURE CONDITIONS

2.1 No-Build Network Development

The future Route 2 no-build network is essentially identical to the base case network except that it includes the grade separation at Crosby's Corner. At the time the model was developed, there were no additional major infrastructure changes planned for the study area. Transportation systems management projects, such as plans to update and/or coordinate intersection traffic signals, are taken into account in the of level-of-service analysis. Specifically, the effect of the recently upgraded traffic signal at Route 2 and Walden Street (Route 126) is reflected in the No-Build level of service calculations.

2.2 Socioeconomic Forecasts

Future socioeconomic conditions were defined for 2000[3] and 2020. For modeling purposes, it is necessary to forecast the number of households and the retail and non-retail employment in each TAZ. These forecasts were derived from a variety of data sources. Metropolitan Area Planning Council (MAPC) 2000 and 2020 town-level population and employment forecasts were used as control totals.

Future-year household forecasts were developed using detailed information received from each town about proposed new development. Information on housing development proposals with completion dates between 1995 and 2000 were obtained from MAPC and from local planners. The developments were located in the appropriate zones and added to the base-year households in those zones. The average household size for a given community was estimated by applying an expected rate of change to base-year household size. This predicted average household size and the forecasted population at the town level were used to estimate the total future-year households in a community. If the number of households obtained from adding proposed developments to the base was less than the number obtained by using forecasted household size and population, the zonal distribution of households was adjusted proportionally to reflect the latter. Forecasts for 2020 were distributed using the same procedure.

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[3]Originally, the CTPS model forecasts were for 1998 and 2020, because the model was developed for a different application. In order to upgrade the 1998 AM and PM peak hour trip tables to 2000 for the Crosby Corner EIR, CTPS requested information about residential and commercial development growth between 1998 and 2000 from the town planners of Acton, Bedford, Burlington, Concord, Lexington and Lincoln.

The process for forecasting 2000 employment was similar to the one described above. The location, size and type of new retail and non-retail development were obtained from MAPC, from conversations with and information received from town planners, and through examination of environmental notification forms. The ITE Trip Generation Manual's average land use densities were used to estimate the number of employees per development based on size and type of development. A vacancy rate was included for developments that were vacant or that are scheduled to be completed in or near 2000. The numbers of new employees by traffic zone were summed to the town level and compared with MAPC's town total. In instances where there was not a favorable comparison, the proportion of the town total employment in each zone was determined, and then the remainder of the MAPC town total was distributed to the zones based on that proportion.

With one exception, the above procedure was used for the 2020 employment forecasts. The redevelopment of Fort Devens, which is expected to be completed by 2015, is forecasted to generate an additional 250 vehicle trips during the AM and PM peak hours. Therefore, 250 vehicles were added to Route 2 in the off-peak direction of the AM and PM peak hours.

Growth in external zones was handled in a different manner. With the exception of major highways (Routes 2, 3 and 128), the area of influence of each external zone was determined. Projected population and employment growth in the area of influence (which could include many communities) was used to forecast increases in productions and attractions for each external zone. Annual increases in productions and attractions of 3%, 2% and 1.5%, respectively, were assumed for Routes 3, 2, and 128.

2.3 Vehicle Trip Table Development

Future-year trip tables have to reflect the modifications that were made to the base-year trip tables in order to simulate the observed turning movement counts as well as to incorporate temporal changes in the volume and distribution of trips. This was achieved by first deriving a future-year origin/destination table through trip generation and distribution. The resulting table was then adjusted by a matrix of factors that was created by dividing the base-year calibrated trip table by the base-year origin/destination table (seed table). This procedure was followed for both 2000 and 2020 trip table development.

2.4 No-Build Traffic Assignment

Traffic assignment is the process by which the trips from an origin to a destination are assigned to the various routes (paths) between them. A multiple iteration capacity-restrained assignment which considers the effect of congestion on the choice of travel route was used for this purpose. The result of the traffic assignment step was the AM and PM peak hour road segment and turning movement volumes for the years 2000 and 2020. These assignments are also called the 2000 and 2020 No-Build Alternatives.

2.5 Year-2020 Traffic Operations: Traffic Volumes and Traffic Patterns

As the Route 2 study is about testing long-range alternatives, it was proposed to the CAC that CTPS staff evaluate No-Build and Build traffic conditions for the year 2020 only.

Figures 2-1 and 2-2 present No-Build 2020 AM and PM peak hour mainline volumes in the modeled area. Substantial increases in volumes are forecasted for the AM off-peak direction (westbound) on Route 2. These increases range from a low of approximately 22% north of Main Street in Acton to a high of about 50% east of Page Road. Increases in the peak direction are much lower, ranging from 6% east of Sudbury Road to 14% east of School Street. This type of change means that traffic will be less peaked directionally in the 2020 AM peak hour. Overall, AM peak hour traffic increases around 8 or 9% over the 25-year period.

As in the AM, increases in PM peak hour traffic volumes are higher in the off-peak direction (eastbound) than in the peak direction. Increases in eastbound volumes range from a low of 30% east of Bedford Road to a high of 45% east of School Street. Westbound increases range from a low of 6% (east of Page Road, west of Crosby's Corner and east of Sudbury Road) to a high of 26% (east of School Street and north of Main Street). Growth in the off-peak direction is higher because that direction is currently less congested allowing room for additional growth. Some of the additional traffic that would have been attracted to Route 2 in the peak direction diverts to less congested competitive routes. Overall, PM peak hour traffic increases by approximately 5 to 7%.