Use of Traffic Forecasting Models in the Development of Traffic Management Plans for Construction of the Central Artery/Tunnel Project

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The Central Artery/Tunnel (CA/T) Project is a $6 billion federal highway project to be constructed in downtown Boston and adjacent areas. The major components are a Third Harbor Tunnel (I-90) linking downtown Boston and Logan Airport, and a new underground 8- to 10-lane Interstate highway (I-93) in downtown Boston to replace the existing 6-lane elevated highway. The construction will affect traffic operations in one of the densest urban environments in the United States. The purpose of this paper is to describe the transportation planning approach to manage traffic during this construction. The focus of this paper is on the extraordinary extent to which the CA/T project team is attempting to predict and mitigate the impacts of construction on traffic congestion and air quality. This effort has already resulted in major changes in construction staging and traffic management plans. The first section of the paper describes the CA/T Project and the accompanying traffic management issues that have been raised. The second section describes the process for developing traffic management plans, with particular attention on the interaction between traffic forecasting, traffic engineering, and the design of construction stages. The third section presents a case study of how the traffic forecasting process contributed to a change in the traffic management plan. The fourth section describes the application of traffic forecasting to air quality analysis, and the fifth section describes the approach to analyzing the role of public transportation as a traffic management mitigation measure.

The Central Artery/Tunnel (CA/T) Project is a $6 billion FHWA project to be constructed in downtown Boston and adjacent areas. Most of the project is eligible for federal Interstate funding. The project will be constructed entirely within the cities of Boston and Cambridge.

The project is under the direction of the Massachusetts Highway Department (MHD) with support from its management consultant, Bechtel/Parsons Brinckerhoff (B/PB). Traffic forecasts were developed by Cambridge Systematics, Inc., a subconsultant on the B/PB team. Regional input to the traffic forecasting process was provided by the Massachusetts Central Transportation Planning Staff (CTPS).

As shown in Figure 1, the project includes the following elements:

- An 8- to 10-lane underground highway (I-93) and 6-lane surface arterial to replace the existing Central Artery, a 6-lane elevated highway in downtown Boston;
- A four-lane Third Harbor Tunnel (I-90), doubling the cross-harbor capacity of the two existing harbor tunnels between downtown Boston and Logan International Airport;
- A four- to six-lane Seaport Access Highway (I-90) connecting the Third Harbor Tunnel to the regional highway system and to an interchange in the seaport and development area of South Boston;
- Three major new highway interchanges at the southwest, north, and east approaches to the city; and
- The South Boston Bypass Road, providing a truck route from the south to the South Boston seaport and industrial areas and to the Third Harbor Tunnel.

Construction is under way on the Third Harbor Tunnel and its approach roads, the first phase of the South Boston Bypass Road, and the early phases of downtown construction. An early opening of the Third Harbor Tunnel for commercial vehicles [trucks and high-occupancy vehicles (HOVs)] is scheduled for 1995. Full opening of the Third Harbor Tunnel is scheduled for 1998, and project completion is planned for 2001.

The Third Harbor Tunnel and related roadways are being constructed within Boston Harbor or on adjacent industrial land in South Boston and airport property in East Boston. Although major engineering, environmental, and planning issues are associated with this construction, it will result in little change in existing traffic operations. Construction of the Central Artery, however, must be undertaken in the heart of downtown Boston—one of the oldest and most densely developed urban areas in the United States. Although the existing elevated highway may be kept in operation, changes will be made in existing surface street operations and ramp connections to and from the highway.

The following are the four major phases of Central Artery construction:

- Relocation of utility lines in the path of the future tunnel boxes;
- Construction of slurry walls and installation of surface decking;
- Tunnel construction beneath decking; and
- Restoration of a permanent surface roadway system.

Planning and engineering are nearly complete for the first phase of this construction, with engineering approaching 100

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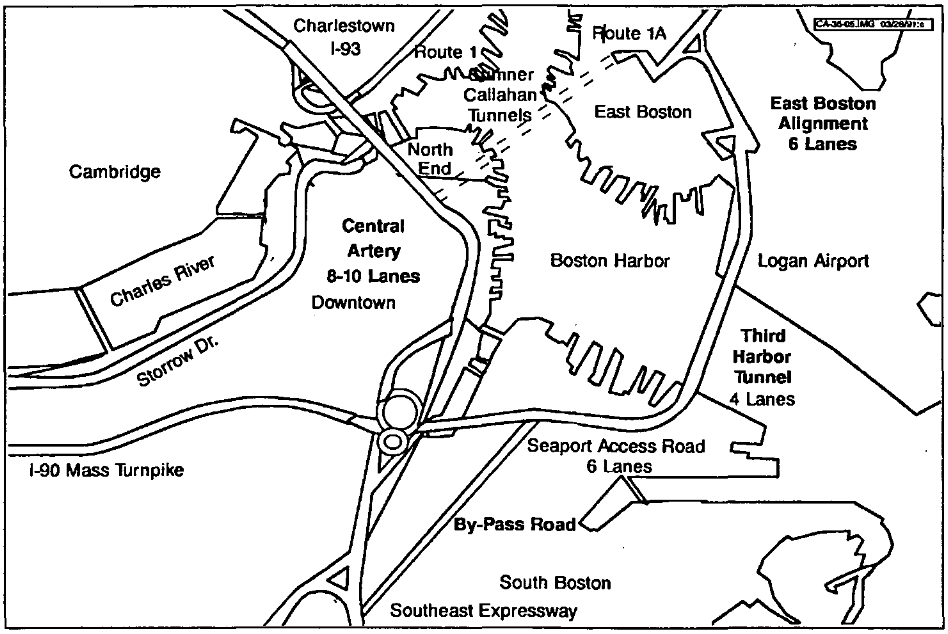

FIGURE 1 Proposed action for CA/T Project.

percent final design for parts of the remaining phases. This paper describes the steps being taken to manage traffic primarily during the first phase of downtown construction—utility relocation—although subsequent mainline tunnel construction is also discussed. Figure 2 shows some of the major impacts to existing traffic patterns that will result from the downtown utility relocation construction. These impacts are summarized as follows:

- Relocation of a major on-ramp to the Central Artery northbound (the Northern Avenue on-ramp). This ramp has a p.m. peak hour volume of 1,200 vehicles.

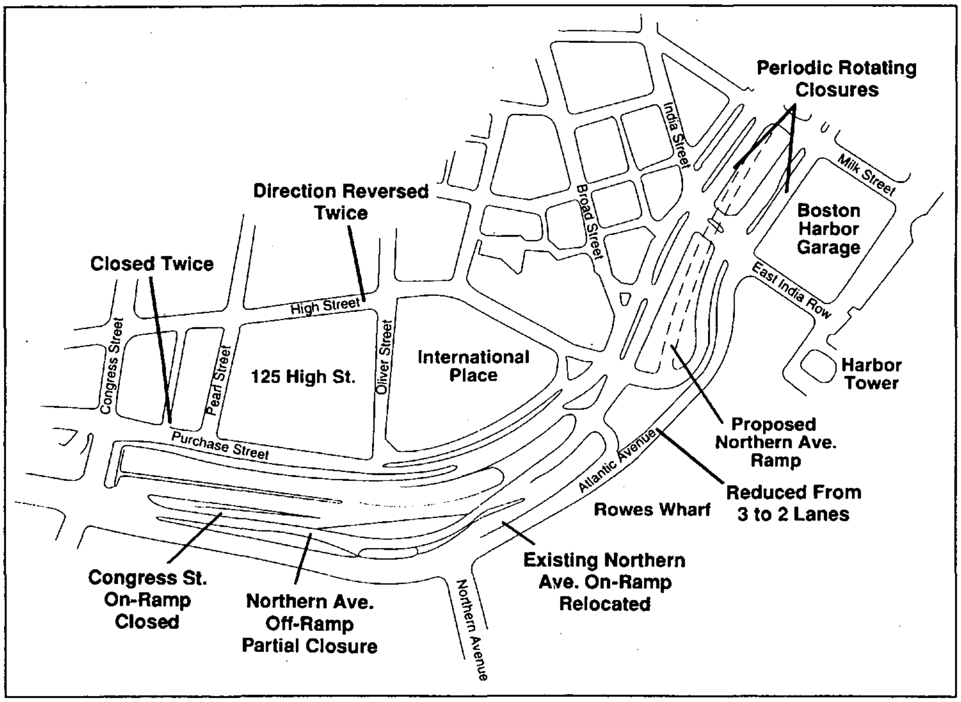

FIGURE 2 Selected major traffic impacts in the financial district.

- Elimination of a major branch of a northbound off-ramp (the Northern Avenue off-ramp). This ramp has a total p.m. peak hour volume of 2,000 vehicles, with 1,500 using the eliminated branch.
- Reconfiguration of the surface street pattern along the downtown waterfront. Today, there are two parallel two-way roadways (Atlantic Avenue and the Surface Artery) with a combined capacity of 10 lanes on average plus parking lanes. The revised condition will create a single one-way pair with a combined capacity of six to eight lanes and no parking.
- Relocations and capacity reductions on several major arterial routes carrying regional traffic flows into the city from the north and south.
- Closure of a major southbound surface arterial in the financial district with traffic diverted to an underused parallel roadway in combination with peak period parking restrictions.

DEVELOPMENT OF TRAFFIC MANAGEMENT PLANS

It is likely that no highway project in the United States has been subjected to as extensive an analysis of traffic operations during construction as has the CA/T Project. This process began during the preparation of the Supplemental Final Environmental Impact Statement (SFEIS), which received federal approval in 1991. The SFEIS described a proposed construction sequence based on 25 percent preliminary design plans. All traffic detours required to implement this construction sequence were described in detail and subjected to manual traffic reassignments using existing volumes.

In addition, the environmental reviewing agencies [U.S. Environmental Protection Agency (EPA) and Massachusetts Department of Environmental Protection (DEP)] also required that a sample quantitative analysis of traffic operations during a construction "snapshot" be incorporated in the final document. The primary motivation for this requirement was concern about the potential air quality impacts of extensive construction-related traffic detours in the downtown area. Boston has for many years been in nonattainment status with federal Ambient Air Quality Standards (AAQS) for carbon monoxide (CO).

An analysis was completed for a period designated as "1994," during which time the mainline Central Artery tunnels would be under construction downtown before the planned early opening of the Third Harbor Tunnel. This scenario is believed to represent one of the likely worst cases for traffic management. Results of this analysis indicated that there would be major volume increases at three intersections as a result of the proposed closure of the Northern Avenue off-ramp from I-93 northbound and its replacement with a ramp several blocks to the south that is currently closed. The ramp to be closed carries a volume of 2,000 vehicles in both the a.m. and p.m. peak hours. The surface intersections near the reopened ramp could not handle the increased volume. As a result, these intersections would exceed the 8-hr concentration for CO.

Although project managers stressed that this was a preliminary finding based on 25 percent design, it served to heighten the concern of the oversight agencies that the project could not be constructed without significantly worsening traffic congestion, resulting in air quality degradation. In order to alleviate these concerns, MHD and FHWA entered into a Memorandum of Understanding (MOU) with the oversight agencies. This MOU provided for an ongoing analysis of the traffic and air quality implications of the construction staging plans. The agreement is administered by the interagency Construction Air Quality (CAQ) Committee, which meets quarterly.

In order to implement the MOU, the traffic forecasting capability of the project had to be expanded. In support of the SFEIS, forecasting models had been developed for the project's base year (1987), opening year (1998), and design year (2010). The construction year forecast for 1994 included in the SFEIS had been developed by simply assuming that traffic volumes would fall roughly halfway between those of the base year and opening year. Project design year traffic forecasts were based on parcel-by-parcel assumptions about growth in land use within the study area. The study area included all of Boston east of Massachusetts Avenue and small portions of several adjoining municipalities. Trip assignments were made to a detailed roadway network developed specifically for the project study area. A personal computer-based Tranplan network was used. Input from the larger regional network was provided to the project by CTPS.

The process used to develop the opening and design year forecasts for the SFEIS was replicated for the construction period. Three models were developed:

- 1992—Early utility relocation downtown,
- 1994—Mainline tunnel construction downtown before the Phase I opening of the Third Harbor Tunnel, and
- 1996—Mainline tunnel construction downtown after the Phase I opening of the Third Harbor Tunnel.

These models were initially based on the preliminary design plans for construction staging and traffic detours as presented in the SFEIS, with the intention of updating them as final design plans became available. An extensive data base management system, as shown in the sample in Figure 3, is used to administer the large number of link changes required for each model scenario.

Given the scale of the CA/T Project, final design is being awarded to more than 22 individual section design contractors (SDCs). Each SDC is responsible for the development and analysis of construction staging and traffic detour plans within

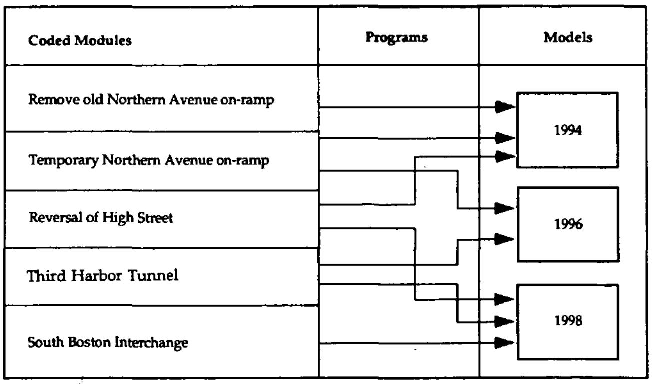

FIGURE 3 Data base management of construction scenarios.

its design area. The management consultant retained responsibility for ensuring consistency and continuity across section boundary lines. On the traffic side, this was accomplished through the use of the construction phase traffic forecasting models.

The process works as shown in Figure 4. When an SDC begins work, the management consultant provides it with the traffic forecasts for each construction scenario based on the preliminary design plans. As the SDC proceeds toward 75 percent final design, a series of working sessions are held with a management consultant team consisting of design engineers, construction planners, traffic engineers and planners, community liaisons, and environmental permitters. Major traffic staging concepts that differ from the preliminary design plans are tested via the forecasting models; the resulting volume estimates are used by the SDC's traffic engineers to analyze operating conditions. The traffic management plans for specific sections may be analyzed in the context of other construction activity performed simultaneously. At 75 percent design, the SDC's plans are submitted to MHD and the Boston Transportation Department (BTD) for review. After resolution of comments the plans are reviewed by community groups, major abutters, and other public agencies. Changes are then incorporated into the 100 percent design plans, which serve as the basis for the plans, specifications, and estimates (PS&E) that define the bid package for the construction contractors.

At the 75 percent design stage, the management consultant revises the traffic forecasting model to reflect the changes from preliminary design recommended by the SDCs. The downtown area was divided into three separate utility design contracts. Each SDC was responsible for analyzing traffic impacts within its design area. By creating a forecasting model based on the three SDC design plans, the management consultant was able to comprehensively examine traffic operations throughout downtown, assuming that all of the utility relocation work occurred simultaneously (a worst case assumption). The resulting traffic forecasts then served as the basis for an analysis of CO concentrations as per the air quality MOU. A similar process is now under way for the analysis of mainline construction. The intersections analyzed as part of this process and the three utility contracts are shown in Figure 5. Only the intersection at State Street and Atlantic Avenue (#6) showed a significant degradation in level of service (LOS)—from C to E. This is a major intersection that regulates the movement of surface traffic. The degradation was caused by the reduction in lane capacity on the surface arterial system and the proposed elimination of the Northern Avenue on-ramp to the Central Artery northbound (see Figure 2). The issues raised by the proposed elimination of this ramp are used as a case study of how the traffic forecasting process resulted in the modification of the proposed traffic management plan.

CASE STUDY: NORTHERN AVENUE ON-RAMP

The elimination of the Northern Avenue on-ramp was a controversial element in the traffic management plan for downtown utility relocation, although it had been included in the preliminary design plan as presented in the SFEIS. The ramp is in the path of the new utility corridor and future slurry wall of the tunnel box. In addition, it juts out into the adjacent surface street (Atlantic Avenue), making it impossible to maintain sufficient surface capacity while performing the required construction.

Opposition to the ramp removal was expressed by BTD, interests along adjacent surface streets in the downtown area, and trucking interests associated with the seafood industry in nearby South Boston. Because this part of the utility relocation work was located within the boundary of the former tidelands of the Commonwealth of Massachusetts, a waterways license was required under Chapter 91 of the Massachusetts General Laws. Chapter 91 imposes stringent public-purpose requirements on nonwater-dependent activities on the former tidelands and gives special standing to such water-dependent users as seafood wholesalers.

The SDC traffic management plan provided for three alternate routes to replace the ramp. Traffic could detour back to an on-ramp one block to the south at Congress Street via two routes. The combined volume of the two existing on-ramps at Northern Avenue and Congress Street is approximately 2,000 vehicles in the p.m. peak hour. By making minor improvements to the Congress Street ramp so that it would have increased storage capacity, it could theoretically accommodate this volume. In addition, the SDC assumed that some

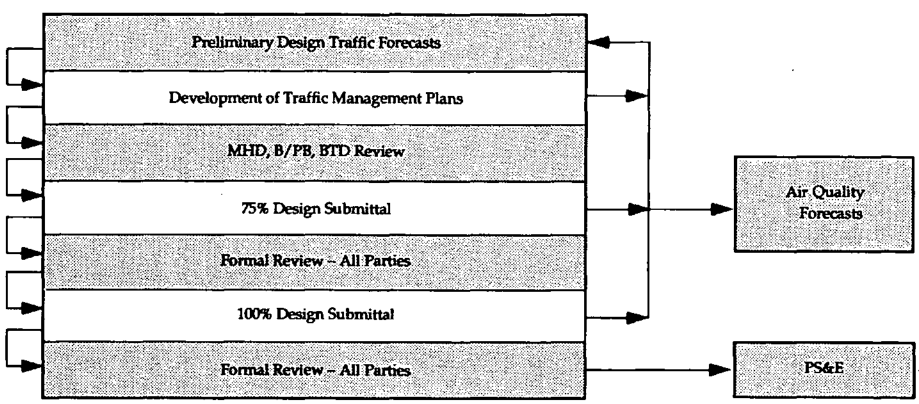

FIGURE 4 Development of traffic management plans.

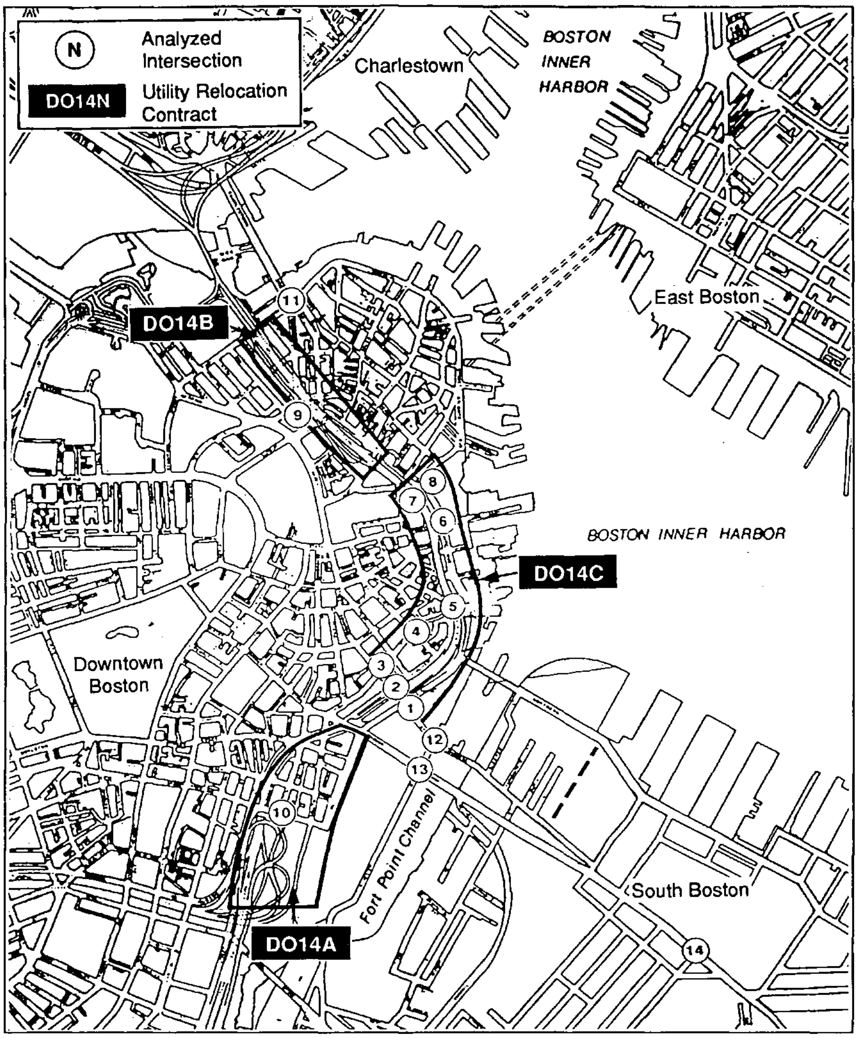

FIGURE 5 Downtown utility relocation contracts and analyzed intersections.

trips would proceed north on surface streets instead of accessing the Central Artery in this area.

In developing this plan, the SDC manually assigned approximately 140 peak hour trips to one of the detour routes. This assumption was not tested in the traffic forecasting model. When the model was later updated on the basis of the 75 percent design plans, it assigned no trips to this route. This was intuitively correct because it is unlikely that Boston drivers would travel south within the downtown area to access the congested northbound Central Artery instead of seeking alternate surface routes to the north. As a result of this experience, the process of model testing SDC assumptions before 75 percent design was initiated.

BTD proposed that the ramp be replaced approximately one block to the north, as shown in Figure 2. The new ramp could be constructed off-road in a median area and was out of the way of the planned utility relocations. At the same time, the SDC designing the mainline tunnel section in this area rejected the preliminary design plan calling for the elimination of the Northern Avenue off-ramp. This was the element that had been tested during the SFEIS and was found to cause traffic and air quality problems. Instead, the SDC proposed that the off-ramp be reconstructed in the space occupied by the Congress Street on-ramp and that the on-ramp be eliminated. The location of the future slurry wall precluded maintaining both ramps. Eliminating the Congress Street on-ramp required, however, that a Northern Avenue on-ramp move be maintained.

As a result of the convergence of these two events—opposition to the removal of the Northern Avenue on-ramp and the desire to retain the Northern Avenue off-ramp—MHD agreed to pursue the replacement on-ramp. As with most policy choices on the project, this decision produced its own negative reactions. It was opposed by residents of Harbor Towers, an upscale, 2,000-resident condominium complex partially fronting on the proposed new ramp. Also, the final designer objected to the design of the ramp because its interface with the Central Artery could not be made to conform to AASHTO standards. Because the Central Artery predates AASHTO standards, no ramp on the road conforms to them. FHWA was willing to grant a design waiver as a temporary construction measure. Although many temporary ramps will be constructed as part of the CA/T project, this is the only case in which a new mainline interface was required because the location of the ramp was changed.

The traffic forecasting model was modified to test the results of adding the replacement ramp. The project team developed the capability to use the geographic information system software ArcInfo in conjunction with Tranplan to more graphically display the results of a particular assignment. This was a useful tool in both evaluating the intuitive correctness of an assignment and displaying the results in a manner that the public could understand.

Inclusion of a replacement on-ramp caused volume along Atlantic Avenue to decrease by around 200 vehicles in the p.m. peak hour because drivers chose to access the Central Artery via the relocated ramp. This would result in an improvement in traffic operations to LOS D at the critical intersection #6 (State Street and Atlantic Avenue). Although this still represents a degradation from the existing LOS C due to reduction in arterial capacity, it is significantly better than the previously forecast LOS E.

AIR QUALITY ANALYSIS

In addition to traffic operations, CO concentrations were also forecast throughout the downtown construction area for the traffic management plans with and without the replacement on-ramp. ArcInfo was also used to display these findings. Under both the build and no-build conditions, four intersections were predicted to exceed the AAQS for CO of 9 ppm for 8 hr. However, due to changes in traffic flow, the location of several of the intersections in exceedance was predicted to change.

Two intersections affected negatively were State and Atlantic (#6) and Congress and Atlantic (#1). Both were affected by the removal of the Northern Avenue on-ramp—State and Atlantic by the increase in northbound volume on Atlantic Avenue, and Congress and Atlantic by the diversion of trips to the Congress Street on-ramp. The addition of the replacement on-ramp would slightly reduce ambient CO levels at both intersections in comparison to the build scenario without the on-ramp, although they would remain above 9 ppm.

Actual CO concentrations were monitored at the State and Atlantic intersection (and one other) before the start of construction to establish baseline conditions. This was a joint program implemented by the project team and EPA and DEP. Monitored concentrations were less than half the level of that predicted by the no-build models, with values in the range of 4 to 5 ppm instead of more than 9 ppm. This tended to confirm that the modeling process (on both the traffic and air quality sides) indeed simulated worst case scenarios.

Although the modeling process provided a certain amount of comfort to the process participants that real conditions were apt to be better than forecast conditions, there was also some concern about the apparent inaccuracy of the process. The primary factors causing this disparity were the regional recessionary conditions that had depressed projected increases in traffic volume and the requirement to base CO forecasts on worst case meteorological conditions. In particular, the use of cold and calm winter days to forecast CO concentrations in Boston is somewhat unrealistic because of the rarity of sustained calm wind conditions, particularly in cold weather.

However, these findings were generally acceptable to the CAQ Committee, which agreed that the project should proceed with the proposed traffic management plan.

ANALYSIS OF TRANSIT MITIGATION PROGRAMS

A major theme throughout the planning effort for the CA/T Project was that public transportation should continue to play a major role in regional transportation. This applied to the project construction period, when public transit would be expected to attract additional riders from the highway system, and after completion of the project to prevent the new highway system from being overwhelmed by new trip attractions.

The Massachusetts Bay Transportation Authority (MBTA) operates or contracts for the operation of bus, rail, and water transportation services in Boston and surrounding communities. MBTA has aggressively upgraded and expanded services during the past 2 decades and continues to do so. These projects have been justified on their own merits but have also been cited in the planning documents of the CA/T Project for their potential benefits in reducing highway tripmaking during and after CA/T construction.

MHD officials wanted to more directly demonstrate a link between transit projects and the mitigation of potential traffic congestion caused by CA/T construction. It contracted with MBTA to conduct this analysis with technical direction provided by the CA/T project. This study is being conducted by the firms of Vanasse Hangen Brustlin and Multisystems, with support from CTPS.

In Phase I of the study, a list of some 60 possible transit mitigation measures was developed. These measures were qualitatively evaluated on the basis of six criteria; about 20 measures were eliminated through an interagency review process. The remaining measures were then packaged into six alternative concepts. The evaluation criteria were as follows:

- Compatibility with existing and planned services,
- Environmental impact,
- Feasibility of implementation in the short term,
- Subsidy required,
- Impact on traffic operations, and
- Cost-effectiveness (subsidy versus impact).

The evaluation packages are as follows:

- Demand management with limited service expansion,
- Improved express bus service (with and without HOV facilities),
- Improved downtown bus operations,
- Fringe park-and-ride facilities,
- Rail and water transportation improvements, and
- Hybrid—the best elements from each category.

These measures are primarily short-term operational actions that MBTA did not plan to implement on its own within the time frame necessary to mitigate CA/T construction impacts. Because the traffic analysis for the 1992–1993 utility relocation work did not demonstrate a need for major transit mitigation actions, the focus of the study was on the early stages of mainline tunnel construction in the downtown area, scheduled for 1994.

Using the 1994 preliminary design traffic forecasts, the consultants identified potential traffic problem areas and mitigation actions that could divert automobile trips to transit. A process was established to quantitatively analyze the most promising measures. CTPS, using its regional modeling capability, is analyzing the potential ridership attractiveness of each package of transit alternatives. The results of this analysis will be used by the CA/T traffic forecasting group to reduce the number of automobile trips in the CA/T study area consistent with the ridership forecast for each set of alternatives. Traffic operations at key intersections will then be compared; the standard construction scenario with no transit mitigation will be compared with construction with each of the possible transit mitigation scenarios.

The objective of this analysis is to quantitatively determine the most effective transit mitigation strategies and the extent to which these strategies will be useful in reducing traffic congestion.

CONCLUSION

The CA/T Project has extensively applied traffic forecasting capability to the development of traffic management plans for project construction. The level of analysis undertaken for the construction period is probably unprecedented in projects of this type and is more typical of the level of analysis applied to final build conditions in most projects. This iterative process of design and traffic analysis has led to a number of significant changes in construction staging and traffic management strategies. The final test of the effectiveness of this approach will become apparent during the coming decade of CA/T construction.

ACKNOWLEDGMENTS

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