# Callahan Tunnel Capacity Management

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ABSTRACT

The Callahan Tunnel capacity management actions that were implemented beginning May 1983 in conjunction with one-way inbound toll collection are described. Traffic operations and capacities for both "before" and "after" conditions are analyzed. The analyses of existing Callahan peak-hour traffic volumes, flows through the parallel Sumner Tunnel, and volumes in the four New York City tunnels provided a basis for estimating tunnel and tunnel-system capacity. The analyses suggested a tunnel capacity of 1,600 to 1,650 vehicles per lane per hour compared with average peak-hour system volumes of 1,450 vehicles per lane. Channelization of the tunnel approach, elimination of outbound toll collection, and realignment of the tunnel exit lanes were estimated to increase system throughput by about 350 to 400 vehicles per hour--up to 200 vehicles per lane. "After" studies conducted during June 1983 indicated that flow rates of more than 1,600 vehicles per lane were achieved. The plan is significant in another respect--speed of implementation. Improvement concepts were formulated during March and April 1983, and their implementation began during May of that year.

The opening of the Sumner Tunnel in 1934 as a two-lane, two-way facility created the first significant and direct automobile link between East Boston and North Shore communities and the city of Boston and communities lying to the south of the Charles River and Boston Harbor. Traffic demands steadily increased, reflecting the accessibility created by the tunnel, growth in North Shore communities, and growth of the Logan Airport complex. To meet this demand, harbor crossing capacity was increased in 1962 by building the parallel two-lane Callahan Tunnel. At that time, the Sumner Tunnel was converted to one-way westbound flow from East Boston to the Boston central business district (CBD).

## BACKGROUND

Peak-hour traffic across the harbor continued to increase to the point where demand exceeded capacity because of toll collection, tunnel geometry, and the configuration and traffic control of access roads. This resulted in a lengthened peak period, increased congestion on streets adjacent to the tunnel approaches, and increased cross-harbor travel times. Resulting impacts were different geographically. Sumner Tunnel impacts were primarily felt on the East Boston side, including impacts on movement from Logan Airport to the Boston CBD and other areas south and west of Boston Harbor. Callahan Tunnel impacts were predominantly in the Boston CBD on surface streets and the Central Artery, often significantly affecting nontunnel traffic flows on these facilities. In addition, the Callahan Tunnel limited the reliability and quality of vehicle access to the Logan Airport complex.

Various agencies had long recognized that, without improvements in cross-harbor capacity, congestion problems would become increasingly severe. In response to these concerns, several studies were made of ways to increase cross-harbor capacity ranging from long-term major capital actions (third harbor crossing) to low-cost, short-term transportation systems management (TSM) approaches. The management action that received the greatest attention was to collect tolls only in the inbound direction (Sumner Tunnel) in coordination with similar one-way inbound toll operations on the Tobin Bridge (Mystic River Bridge). Underlying objectives were to (a) increase tunnel throughput, (b) reduce the amount and duration of queueing at the tunnel approach, and (c) reduce the tunnel journey time.

A report prepared by the Central Transportation Planning Staff in 1980 identified those factors that inhibit maximum flow potential and that should be alleviated through the one-way toll operation and TSM actions. A subsequent Massachusetts Port Authority staff report on Callahan Tunnel operations (March 1982) estimated that as much as a 14 percent increase in peak-hour throughput traffic volume is possible with elimination of toll collection, removal of the Callahan Tunnel toll booths, and traffic management improvements on the tunnel approach and within the tunnel.

## SCOPE AND APPROACH

The Callahan Tunnel capacity management actions that were implemented beginning in May 1983, in conjunction with one-way inbound toll collections, are described. The preimplementation conditions (March, April 1983) are reviewed; the likely effects of improved traffic operations are analyzed; and before and after traffic operations are compared. More complete discussions of the feasibility and follow-up analyses are presented elsewhere (1,2).

Data obtained from the Massachusetts Turnpike Authority (MTA), Massachusetts Port Authority, and other public agencies were supplemented by videotape monitoring of peak-hour traffic on the tunnel approach and the toll plaza.

The analyses considered the Callahan Tunnel system as containing three interrelated operating sections: the approach area to the west portal, the tunnel itself, and the toll area from the east portal through the toll booth. The aim was to determine the maximum capacity for each of the three sections, identify the points of minimum capacity, and suggest corrective actions to increase system throughput.

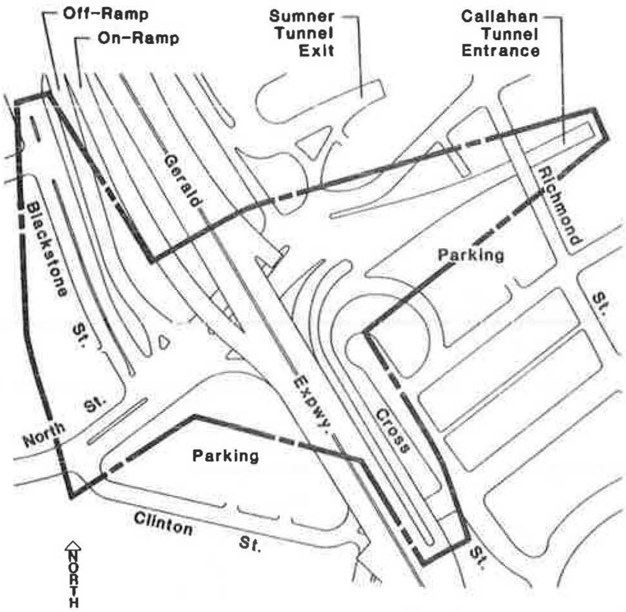


FIGURE 1 Study area boundaries–Callahan Tunnel approach area in downtown Boston.

INITIAL PHYSICAL AND TRAFFIC CONDITIONS

Physical and traffic characteristics of the Callahan Tunnel and its environs before implementation in May 1983 are discussed in the following subsections.

## Physical and Geometric Features

The Callahan Tunnel contains two lanes 10 ft 6 in. wide, with a 1-ft lateral clearance. There are three vertical sections: west portal to end of descent, end of descent to beginning of ascent, and beginning of ascent (3.25 percent, 2,300-ft upgrade) to east portal.

The approach area in downtown Boston is shown in Figure 1. It extends from the intersection of Blackstone Street and North Street to the west to the tunnel portal and includes the Central Artery northbound off-ramp, the Surface Artery northbound lanes, and the North Street lanes that feed the tunnel. Before implementation, eight lanes of traffic merged into the two tunnel lanes as follows:

- Northbound Artery off-ramp--24 ft operating as two traffic lanes,
- Northbound Surface Artery--one 17-ft roadway operating as two traffic lanes, and
- North Street--a 43-ft roadway operating as three or four 10- or 11-ft lanes (including tunnel-bound traffic from North Street, Blackstone Street, and the Southbound Central Artery off-ramp).

The tunnel portal walls and the Central Artery defined the limits of the physical area within which actions could be developed. The preimplementation physical and operational features and constraints within the approach area are shown in Figure 2.

The east tunnel portal and its environs, as of March-April 1983, are shown in Figure 3. The toll plaza contained seven booths, five manual and two automatic, before toll collection was discontinued. Design of the plaza area was constrained by the presence of seven Sumner Tunnel westbound toll booths to the north and the portal walls to the south.

The distance from the East Boston portal of the Callahan Tunnel to the center of the toll plaza, measured along the right edge of the pavement, was approximately 710 ft. This section of the alignment consisted of a curve 337.43 ft long having a radius of 2,000 ft and a curve 183.73 ft long with a radius of 330 ft connected by a 9-ft tangent section. Less than 200 ft beyond the toll booths, Route 1A, a three-lane roadway, continues north with a branch to the airport. South of and adjacent to these two roadways are Havre Street and Porter Street, two local one-way streets that were relocated and, in part, removed to accommodate the toll plaza.

Traffic traveling through the Callahan Tunnel would continue through the toll plaza and onto Route 1A or turn sharply to the right and onto Porter Street. Havre Street traffic could turn right onto Porter Street or continue onto 1A. Havre Street is the only access to Route 1A for the surrounding area. The intersection between the tunnel traffic turning onto Porter Street and the Havre Street traffic turning onto Route 1A was controlled by a stop sign on Havre Street.

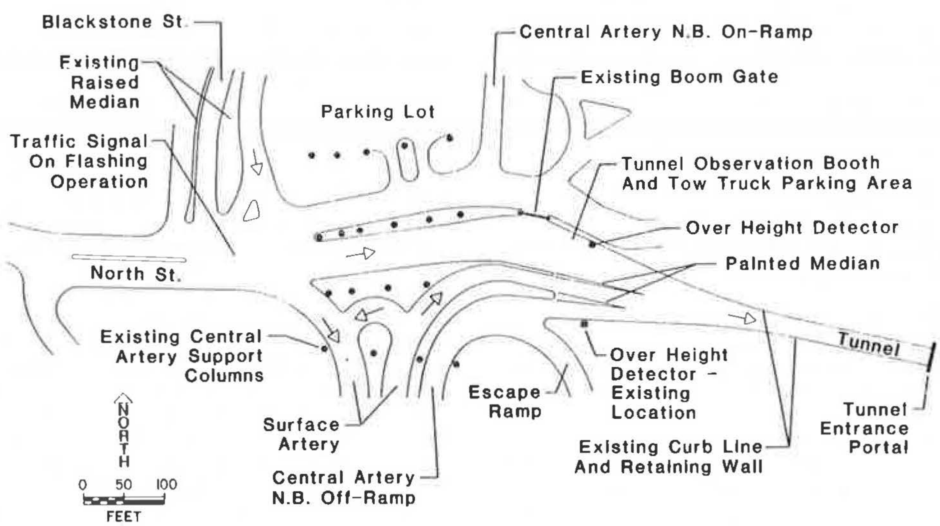


FIGURE 2 Approach area conditions, April 1983.

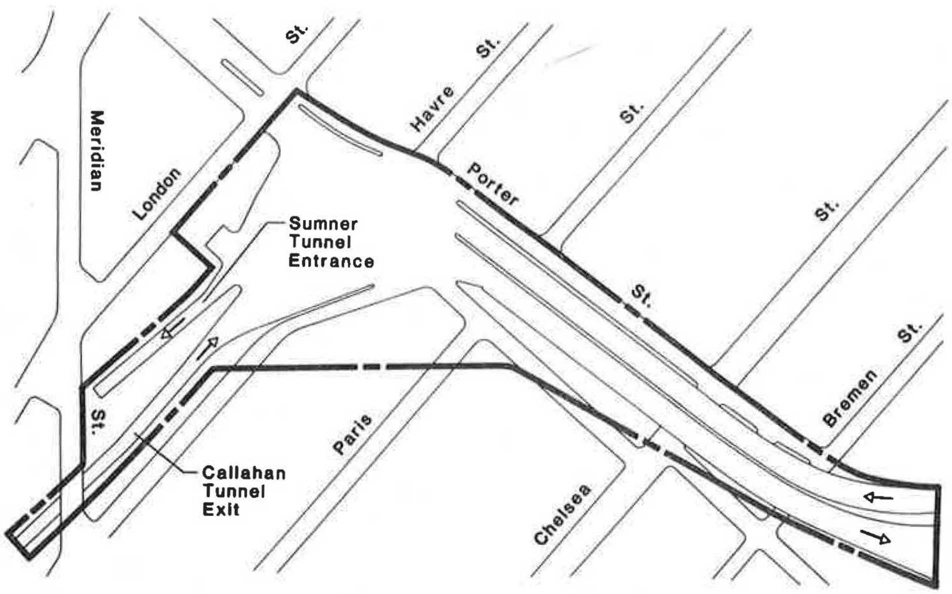


**FIGURE 3 Study area boundaries—Callahan tunnel toll plaza area in East Boston.**

"Before" Traffic Volumes

Table 1 gives average day and afternoon peak-hour volumes for the Callahan Tunnel taken from 1982 Massachusetts Turnpike Authority hourly counts. These "before" counts show an average daily traffic volume of 38,667 and an average afternoon peak-hour volume of 2,805 vehicles. Annual average daily traffic was 38,049 in 1982. Trucks and buses averaged 2.4 percent of the total peak-hour flow.

Table 2 gives peak-hour volume characteristics for October 1982 taken from toll station counts provided by the Massachusetts Turnpike Authority. The average volume was 2,794 vehicles, or 1,347 per lane if traffic were equally distributed; peak-hour tunnel traffic exceeded 3,000 vehicles for less than 10 percent of the time.

**TABLE 1 Average Daily and Peak-Hour Tunnel Volumes, Callahan Tunnel, 1982**

| Day | Date | 24-Hr Volume | Peak-Hour Volume (4:00 p.m.-5:00 p.m.) |
|---|---|---|---|
| Monday | 9/13/82 | 39,353 | 2,797 |
| Tuesday | 9/14/82 | 40,782 | 2,886 |
| Monday | 9/20/82 | 38,935 | 2,662 |
| Tuesday | 9/21/82 | 36,958 | 2,845 |
| Wednesday | 9/22/82 | 38,281 | 2,769[a] |
| Monday | 9/27/82 | 37,329 | 2,723 |
| Tuesday | 9/28/82 | 38,155 | 2,871 |
| Wednesday | 9/29/82 | 39,540 | 2,927 |
| Average (8 days) | | 38,667 | 2,805 |
| 1982 Annual average daily traffic | | 38,049 | |

[a]3:00 p.m. to 4:00 p.m.

**TABLE 2 Analysis of Callahan Tunnel Peak-Hour Volumes, October 1982**

| | Total Vehicles | Vehicles per Lane |
|---|---|---|
| Maximum | 3,059 | 1,530 |
| 90 percent | 2,993 | 1,497 |
| 85 percent | 2,975 | 1,488 |
| 75 percent | 2,937 | 1,468 |
| 50 percent | 2,850 | 1,425 |
| Average volume | 2,794 | 1,397 |
| Standard deviation | 213 | 107 |

Table 3 gives April 1983 4:45 p.m. to 5:45 p.m. peak-hour volumes, based on field surveys and volume analysis, entering the tunnel by direction of approach. Volumes approximated 3,000 vehicles per hour (vph) of which about 2 percent were trucks or buses. Flows were slightly higher than those indicated by the Turnpike Authority data, which were recorded on an hourly basis.

**TABLE 3 Distribution of Callahan Tunnel Approach Volumes, March 1983 (4:45 p.m. to 5:45 p.m. peak hour)**

| Source | Volume | Percentage of Total Traffic |
|---|---|---|
| From the south | 1,849 | 60.9 |
| Central Artery | 998 | 32.9 |
| Surface Artery | 851 | 28.0 |
| From North Street | 1,185 | 39.1 |
| North St. (eastbound) | 218 | 7.2 |
| Blackstone St. (southbound) | 352 | 11.6 |
| Central Artery (southbound) | 615 | 20.3 |
| Total | 3,034 | 100 |

The tunnel approach volumes were found to be unevenly distributed between the approaches from the south (Artery northbound off-ramp and Surface Artery) and the approaches from the north and west (Artery southbound off-ramp, Blackstone Street, and North Street). Approximately 61 percent of the traffic came from the four northbound lanes and 39 percent from the three or four North Street lanes. (North Street operated as three lanes for most of the 3:00 p.m. to 6:00 p.m. time period when data were collected, but the videotapes recorded the emergence and disappearance of a fourth lane throughout the peak hour in response to congestion in the other three lanes.)

TUNNEL CAPACITY ANALYSIS

The capacity of a tunnel system is determined by the capacities provided at the tunnel approach (entrance), within the tunnel itself (the upgrade), or at the tunnel exit (toll plaza for the Callahan Tunnel) (see Figure 4). The goal is to equalize the capacity of these three points to maximize tunnel throughput and to avoid creating "shock waves."

If the volume entering the tunnel and reaching the foot of the upgrade exceeds the capacity of the system, shock waves can develop that, in turn, reduce the capacity of the system. These waves also can be triggered by inadequate capacity at the exit point. Actions at the approach area and exit portal, then, must be developed to ensure stable traffic flows at the optimum density, speed, and speed variance that are necessary to achieve the maximum throughput capacity that can be developed for the tunnel section (Figure 5).

The capacity analysis first examined the capacity of the tunnel itself, then the exit portal and toll plaza, and finally the approach area to determine the capacity of each section and the effects of each section on tunnel-system capacity. The analysis was based on a review and analysis of previous reports, MTA toll station records, and tunnel experience in the New York metropolitan area. The analysis reflects the results of field reconnaissance investigations, videotape studies, and meetings with Port Authority of New York and New Jersey personnel.

Tunnel Sections

Freeway and tunnel flows in other cities provided a basis for assessing the capacity of Callahan Tunnel:

- Peak-hour direction volumes on 23 urban freeways in larger U.S. cities ranged from 1,400 to 2,000 vehicles per lane per hour. The average was 1,730, and standard deviation was about 190.
- Reported tunnel volumes in the New York metropolitan area averaged 1,270 vehicles per hour. These flows reflect the metering effects of the street systems and toll plazas as well as the vehicle mix. Trucks, for example, comprised about 25 to 30 percent of the peak-hour peak-direction flow in the Holland Tunnel where the 90 percentile volume averaged 1,300 vehicles per hour per lane.
- The New York City Department of Transportation estimated that maximum potential tunnel-system capacity was 1,300 to 1,415 passenger vehicles per lane per hour. The Port Authority of New York and New Jersey's Tunnels and Bridges Department considers 1,350 to 1,400 passenger car units per hour a realistic maximum potential capacity; it estimates the theoretical (but unreachable) capacity based on

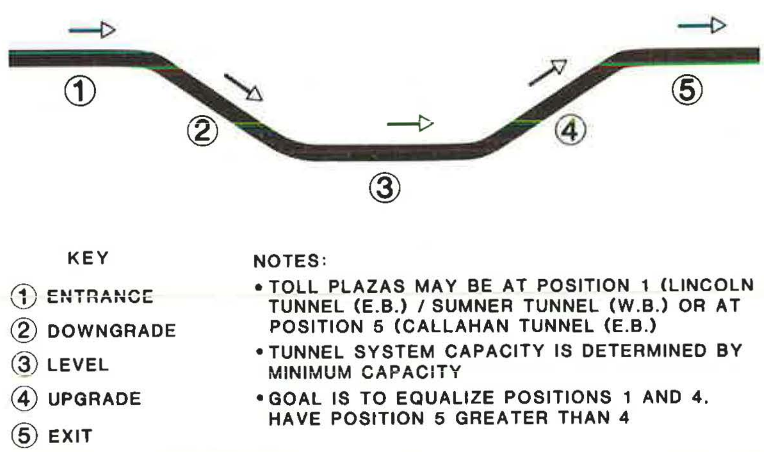


FIGURE 4 Components of tunnel capacity.

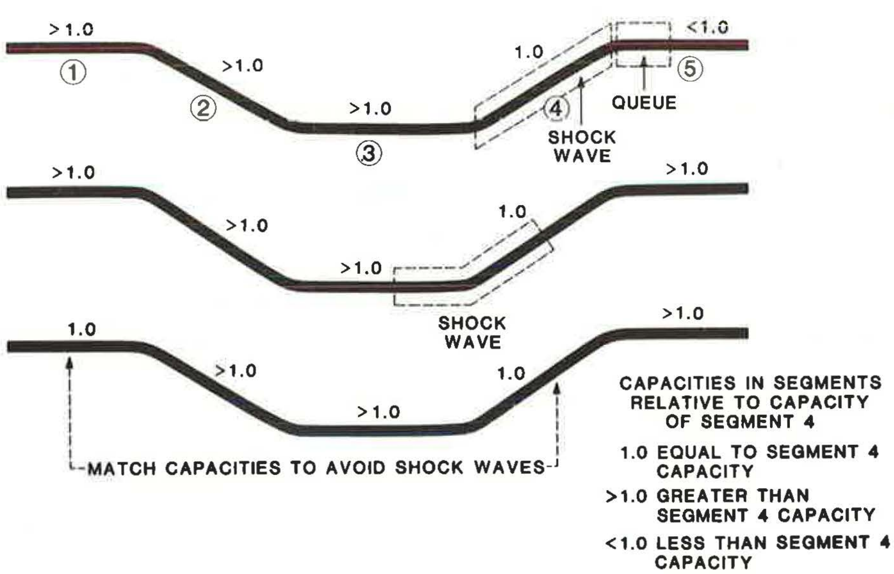


FIGURE 5 Matching section capacities to avoid shock waves.

TABLE 4 Comparative Tunnel Capacity Estimates (vehicles/lane/hour)

| | Tunnel Only | System | |
|---|---|---|---|
| | | In | Out |
| New York City | | | |
| Brooklyn-Battery | | 1,390[a] | 1,310[a] |
| Queens Midtown | | 1,390[a] | 1,415[a] |
| Lincoln | | 1,320[a] | 1,350[a] |
| Holland | | 1,300[a] | 1,415[a] |
| New York Port Authority | | | |
| Theoretical maximum (effects of lane width and clearance) | 1660[a] | | |
| Practical | | 1,350-1,400[a] | |
| Boston | | | |
| Callahan | | | |
| Observed | | 1,400-1,500 | |
| Transportation Systems Center (1970) | 1,550 | 1,520 | |
| Interim Materials on Highway Capacity (TRB Circ. 212) | 1,435-1,485 | | |
| Sumner | | 1,600 | |
| Suggested value for Callahan (April 1983) | 1,550-1,650 | 1,450-1,500 | |

[a]Passenger car equivalents.

lane widths and lateral clearances at 1,660 vehicles per hour.

• A 1970 study conducted by the Transportation Systems Center estimated a minimum capacity of 1,550 vehicles per lane at the beginning of the upgrade in the Callahan Tunnel.

A summary of the various capacity estimates is given in Table 4. On the basis of these estimates the capacity of the Callahan Tunnel before improvements was estimated at 1,600 to 1,650 vehicles per lane per hour. This compares with maximum peak-hour system volumes of 1,450 to 1,500 vehicles per lane per hour. The differences between tunnel capacity and actual system volume resulted from the turbulence and constraints at entry and exit points. The tunnel entrance and exit, not the tunnel itself, limited the capacity of the system.

## Approach Area

The tunnel approach area was characterized by nearly equal flows merging with each other. There were, however, backups on various approaches, suggesting that the approach road system and weaving areas limited system capacity. Accordingly, weaving vehicles were tracked by videotape to determine their effects on approach traffic flow.

A summary of weaving volumes is shown in Figure 6. There were four key findings:

• The two Central Artery lanes and the southerly Surface Artery lane contributed 96 percent of the traffic in the south tunnel lane, with only 4 percent coming from the other four or five lanes. Similarly, the North Street lanes plus the northerly Surface Artery lane contributed 95 percent of the traffic in the north tunnel lane, with only 5 percent coming from the remaining three lanes.

• Weaving traffic thus constituted 4.5 percent of total approach traffic.

• The highest weaving volumes came from the two Surface Artery lanes (11.3 percent of Surface Artery total). However, equal Surface Artery lane volumes fed each tunnel lane. The Surface Artery lanes, which offer the most choice between tunnel lanes, served as a "load balancer" for the system.

• There was practically no weaving from either of the two outer lanes.

The number of weaves was translated into approach area capacity reductions by assigning seconds of delay for each lane crossed by a weaving vehicle and

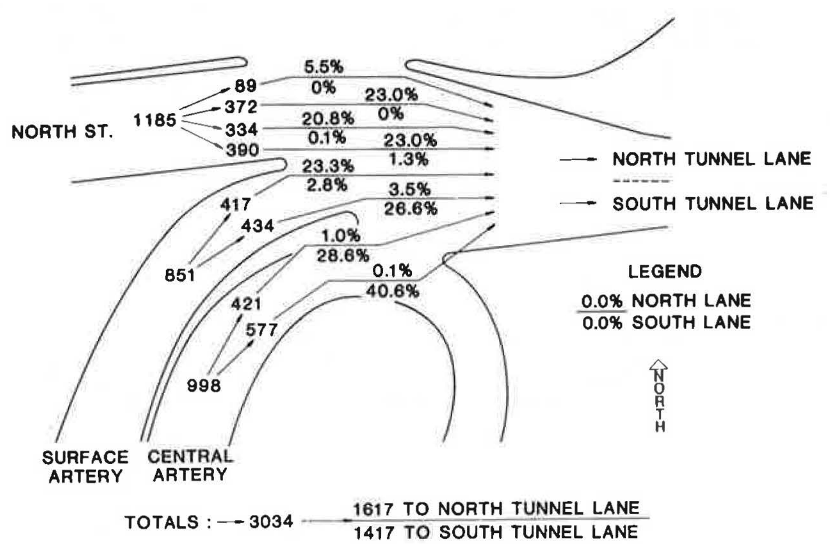


FIGURE 6 Summary of approach area weaving analysis.

translating the total delay into a capacity loss. The delay values were based on actual delays measured from the videotapes. Delays usually resulted from weaving vehicles waiting for gaps during which to enter the next lane. Delays were particularly noticeable for trucks and buses, which required a longer gap. The resulting average delays for each weaving vehicle are given in Table 5.

The capacity loss in vehicles per hour was estimated from the following formula:

$$Cr = D \times F = WTF$$

**TABLE 5 Calculation of Approach Area Weaving Delay by Lane**

| | Cars Weaving from Lane (south to north) | No. of Lanes[a] Crossed | Total Delay (sec) |
|---|---|---|---|
| Central Artery | A | 3 | 25 |
| | B | 2 | 15 |
| Surface Artery | C | 1 | 5 |
| | D | 1 | 5 |
| North Street | E | 2 | 15 |
| | F | 3 | 25 |
| | G | 4 | 30 |
| | H | 5 | 35 |

[a]Includes lane entered.

where

D = total seconds of lane delay = W x T;
F = flow rate, expressed in vehicles per lane per second;
Cr = capacity reduction in vehicles per hour; and
T = seconds of delay per weave.

Table 6 gives seconds of delay converted into capacity losses in vehicles for four flow rates ranging from 2,900 to 3,350 vehicles per hour, or 0.11 to 0.133 vehicle per lane per second. The reduction in capacity caused by weaving delays ranged from 120 to 150 vehicles per hour depending on the flow rates through the tunnel.

In a merging situation, traffic volume in a lane next to a wall must be greater than volumes merging in an adjacent lane. Otherwise, the lane along the wall is "pinned" against the wall with a total loss in capacity. Analysis of the approach area videotapes showed that the north lane of traffic entering the tunnel presented a flow problem that related to a "weak wall." Figure 6 shows that the southernmost approach lane carried the highest volume into the tunnel--577 peak-hour vehicles. This steady stream of traffic fed almost completely into the south tunnel lane and contributed 41 percent of the volume of the south lane. To the north, however, the northerly North Street lane carried 372 vehicles, and this flow was disturbed by the intermittent formation of the eighth lane to the north. Because these flows were both lower and perturbed in nature, vehicles proceeding to the north tended to be pinned against the portal wall as vehicles from the other lanes merged toward the tunnel. Each pinned vehicle would create delays as it negotiated its way back into the stream from a dead stop. Although the effects on capacity of the weak wall were not quantified, strengthening the flow in the northerly lane would minimize stops and improve the flow rate.

## Toll Plaza Operations

Turbulence in the toll plaza environs, and imbalanced use of both toll plazas and tunnel lanes, resulted in a capacity loss of about 250 vehicles per hour at the tunnel exit. This estimate was based on a detailed analysis of videotapes that provided traffic flows through each of the service toll booths at 5-min intervals.

The counts were then factored to hourly volumes to establish maximum flow rates (i.e., toll booth capacity). Toll Booth 11, which handled the highest volumes, achieved a maximum hourly service rate of 552 vehicles and an average rate of 511. If all seven toll booths had been used evenly, their total capacity would have approximated 3,580 vehicles; this is nearly 300 vehicles per hour more than the capacity of the tunnel itself.

However, both the videotape analysis and counts taken at the exit portal and at the toll booths revealed an uneven use of the seven toll booths (Figure 7, based on videotape counts by SG Associates, Inc., May 8, 1983, and Table 7):

- First, although lane usage entering the tunnel was almost exactly equal, at the exit portal 54 percent of the traffic used the north lane and 46 percent used the south lane, indicating that crossovers to the left were occurring within the tunnel in response to the trapping effect of the right-lane queues.
- Maximum peak-hour flow rate for Booth 1, based on 5-min volumes, was 348, as opposed to 516 for Booth 13 and 540 for Booth 11.
- Actual peak volumes for the two right booths were 974 as opposed to 726 in the two left lanes.
- Total volume increased in the 5:00 p.m. to 6:00 p.m. hour by 190 over the 4:00 p.m. to 5:00 p.m. hour. Of this increase, 133 vehicles, or 70 percent, used the left three booths, increasing booth volume in Booths 1, 3, and 5 by 12 percent as

**TABLE 6 Hourly Approach Area Capacity Loss Resulting from Weaving Vehicles Under Slow-Speed and Forced-Flow Conditions**

| | Lane | No. of Vehicles Weaving | Delay per Weave (sec) | Total Lane Delay (sec) | Capacity Loss in Vehicles at Flow Rate: 410 (.11 veh/sec) | 430 (.12 veh/sec) | 470 (.13 veh/sec) | 480 (.133 veh/sec) |
|---|---|---|---|---|---|---|---|---|
| Central Artery | A | 2 | 25 | 50 | 6 | 6 | 7 | 7 |
| | B | 16 | 15 | 240 | 26 | 29 | 31 | 32 |
| Surface Artery | C | 57 | 5 | 285 | 31 | 34 | 37 | 38 |
| | D | 40 | 5 | 200 | 22 | 24 | 26 | 27 |
| North Street | E | 18 | 15 | 270 | 30 | 32 | 35 | 36 |
| | F | 2 | 25 | 50 | 6 | 6 | 7 | 7 |
| | G | 0 | – | – | – | – | – | – |
| | H | 0 | – | – | – | – | – | – |
| Total | | | | 1,075 | 121 | 131 | 143 | 147 |

Note: Dashes = not applicable because the number of weaving vehicles was zero.

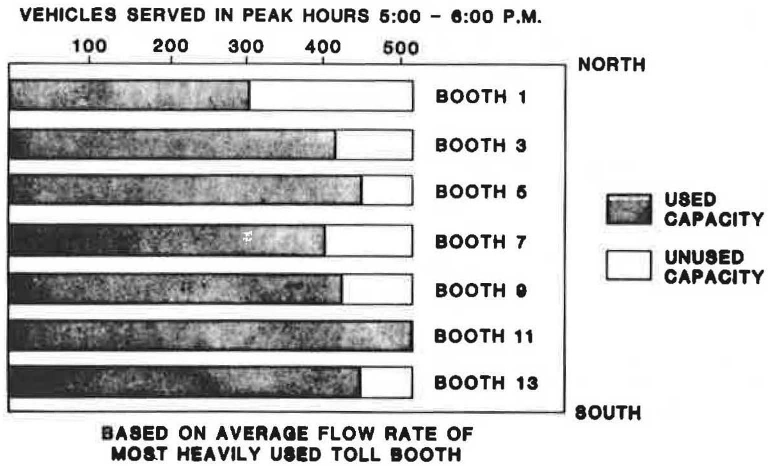


FIGURE 7 Unused toll booth capacity under booth usage patterns of April 1983.

TABLE 7 Toll Booth Usage from Videotape Record 4:00 p.m. to 5:00 p.m. and 5:00 p.m. to 6:00 p.m., April 1983

| | | 4:00 p.m.-5:00 p.m. | | 5:00 p.m.-6:00 p.m. | |
|---|---|---|---|---|---|
| | Booth | No. | Percentage | No. | Percentage |
| North | 1 | 283 | 9.9 | 308 | 10.0 |
| | 3 | 378 | 13.1 | 422 | 13.8 |
| | 5 | 412 | 14.3 | 476 | 15.5 |
| Subtotal (1, 3, 5) | | 1,073 | 37.3 | 1,206 | 39.3 |
| South | 7 | 382 | 13.2 | 406 | 13.2 |
| | 9 | 444 | 15.4 | 455 | 14.9 |
| | 11 | 499 | 17.4 | 511 | 16.7 |
| | 13 | 478 | 16.7 | 488 | 15.9 |
| Subtotal (9, 11, 13) | | 1,421 | 49.5 | 1,454 | 47.5 |
| Total | | 2,876 | | 3,066 | |

opposed to a 6 percent rise in Booth 7 and only a 2 percent rise in Booths 9, 11, and 13. The larger increase in Booths 1, 3, and 5 clearly illustrates the potential capacity gain of more evenly distributed booth usage.

The imbalanced toll booth use caused queues at the three south booths to extend farther and farther back during the peak hours. "Escape" to the left was prohibited. This caused both tunnel lanes, but especially the south lane, to slow down in the tunnel upgrade section. The slowdown in the south lane encouraged crossovers to the north lane within the tunnel--an illegal movement. Further, the tendency toward the right booth and the "trapping" effect reduced the throughput potential of the south tunnel lane.

The result of this queueing on tunnel-system capacity is apparent from the differences in lane volumes at the tunnel exit portal. Between 4:00 p.m. and 5:00 p.m. the north tunnel lane carried 1,526 vehicles, as opposed to 1,252 in the south lane. The difference between the two lane volumes represented the loss in capacity to the geometry of the toll plaza and driver behavior--about 235 to 275 vehicles per hour.

It was this phenomenon, not the toll booths per se, that limited tunnel capacity. The toll booths themselves could handle more than 3,500 cars in the peak hour, or 1,750 per lane; yet the uneven distribution of booth usage, the resultant queueing, and the trapping of vehicles in the south lane reduced capacity by approximately 250 vehicles in the peak hour.

Summary

Adding the capacity reductions caused by conflicts at the entrance and exit portals gave an approximation of the throughput that could be attained if these problems were eliminated:

| | |
|---|---|
| Toll plaza geometry and driver behavior | 250 vehicles/hour |
| Approach area weaving | 120-150 vehicles/hour |
| Total capacity reduction | 370-400 vehicles/hour |

When this capacity reduction is added to the March-April 1983 p.m. peak-hour volumes of 2,800 to 3,000 vehicles, a volume of 3,170 to 3,400 vehicles per hour results. This improved volume represents the tunnel-system flows that could be achieved on a sustained basis if improvement actions were implemented--a 13 percent improvement over existing peak-hour conditions. It compares with the estimated in-tunnel capacity of 3,200 to 3,300 vehicles per hour. The estimated capacity gain would be more evident in the south tunnel lane and less pronounced in the north lane, which was effectively at capacity.

## REVISED CONDITIONS

The operations and capacity analysis of existing conditions provided the basis for traffic management actions after May 1983. The various improvements to the tunnel entry and exit points were designed to (a) maximize Callahan Tunnel throughput and (b) improve cross-harbor travel times. Accordingly, the following specific design principles were keyed to each of those sections of the tunnel road system:

1. Approach area
   • Weaving in the approach area should be reduced or eliminated, leading to a capacity increase of 405 percent;
   • The tunnel approach area should be kept filled with traffic to ensure maximum flow into the tunnel, yet queues should not extend to the local streets or main-line expressway (Figure 8);
   • Approach flows should be balanced to achieve equal (maximum) volume in each tunnel lane and hence maximum total tunnel volume;
   • Trucks and buses should be allowed to use either tunnel lane (necessary to eliminate weaving in the approach area);
   • Earlier warning for oversize vehicles should be provided to facilitate escape before entry into the approach area;
   • The weak wall of traffic in the north lane should be strengthened to ensure two strong flows on the outside; and
   • Conflicts at the North and Blackstone intersection should be reduced to allow a more regular flow of traffic from North Street and the southbound artery ramp into the tunnel.
2. Tunnel area
   • Speed reductions on the upgrade within the tunnel should be minimized; and

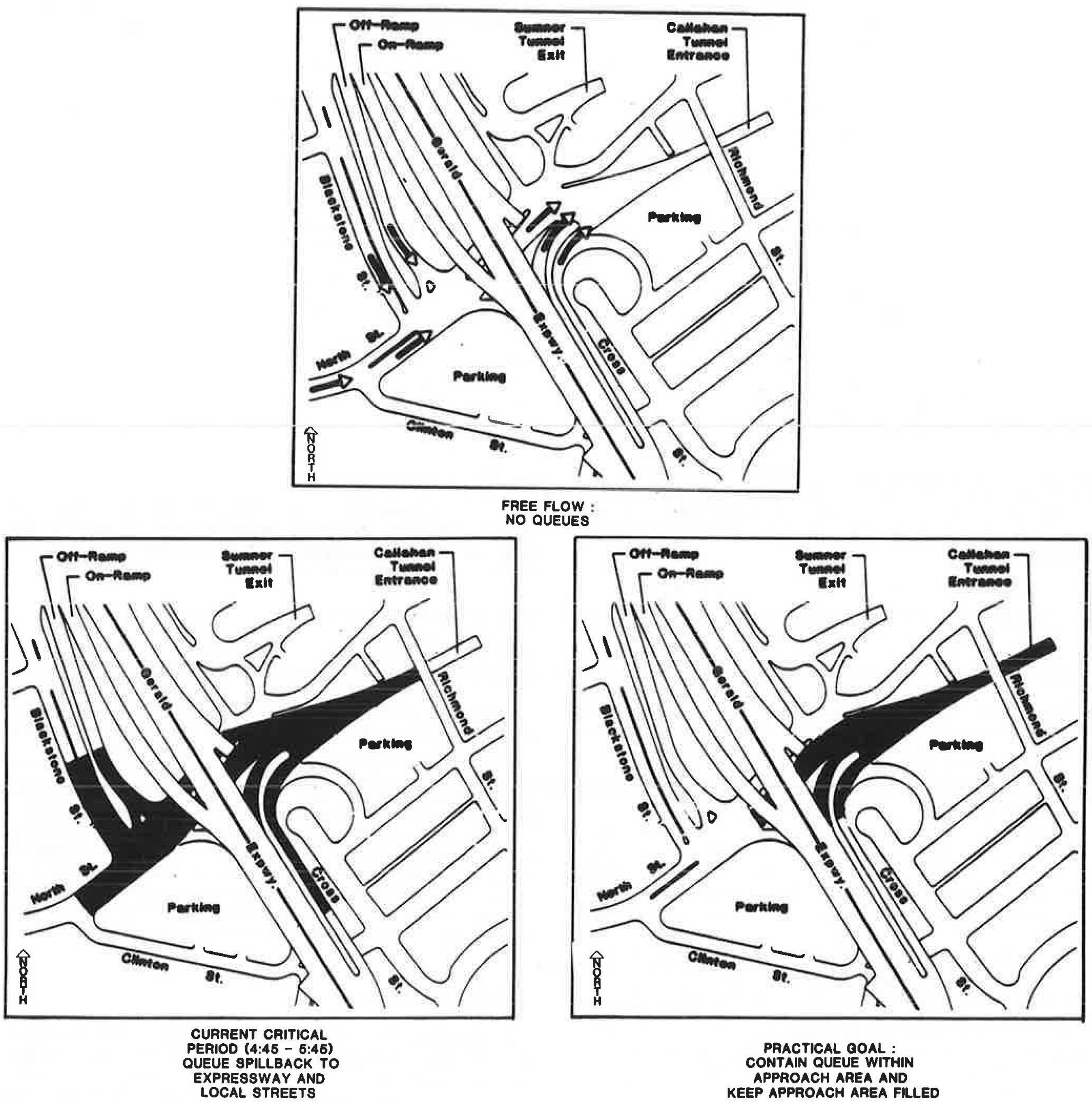


**FIGURE 8** Goal of approach area TSM actions.

- Speed variations throughout the tunnel should be minimized; maximum volume throughput is achieved at an optimum speed with minimal speed variation.

3. Exit portal and toll booth area
   - The capacity restraint resulting from uneven use of the toll booths should be eliminated through channelization in the exit area or by elimination of toll collection, or both;
   - As vehicles exit the toll booth area, conflicts between those headed for local streets and those headed for McLellan Highway should be reduced;
   - Adequate maneuvering room must be provided for tow trucks; and
   - Adequate provision must be made for emergency vehicles in case of an airport-related or other disaster.

On the basis of these guidelines, various improvement options were developed and reviewed by participating public agencies. This led to three basic actions that were implemented beginning May 2, 1983:

- One-way toll collection inbound on the Sumner Tunnel and elimination of outbound toll payment on the Callahan Tunnel;
- Realignment of the tunnel exit road, made possible by eliminating the toll booths and collection (Figure 9); and
- Channelization of the tunnel approach roads, first by barrels and then by permanent construction to better funnel flow and reduce weaving movements (Figure 10).

RESULTS

Traffic volumes and patterns on the approach to the tunnel were obtained from videotape analysis for conditions "after" the one-way toll collection and temporary approach channelization were placed in effect. Table 8, based on field and videotape counts done by SG Associates in 1983, and Figure 11 present comparisons of the before and after patterns:

- The p.m. peak-hour traffic volumes for the after conditions totaled 3,238 vehicles compared with 3,034 before the improvements were made. This

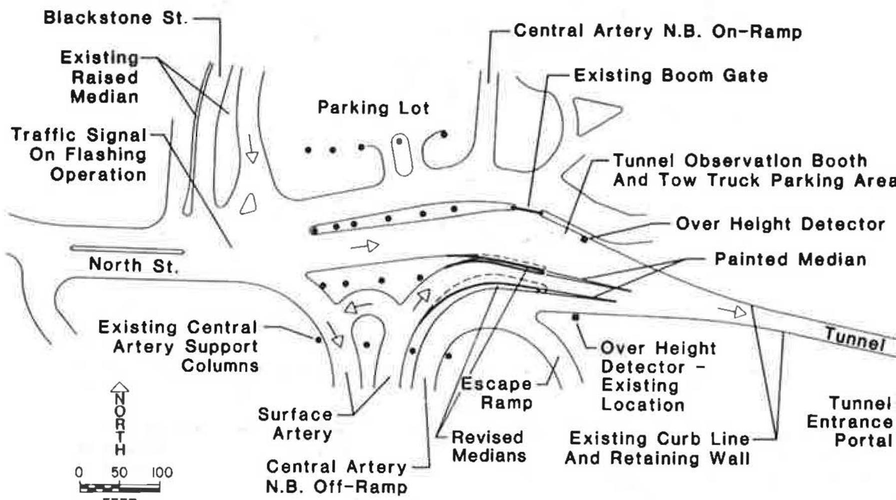


FIGURE 9 Alignment plan for Callahan and Sumner tunnels—exit road.

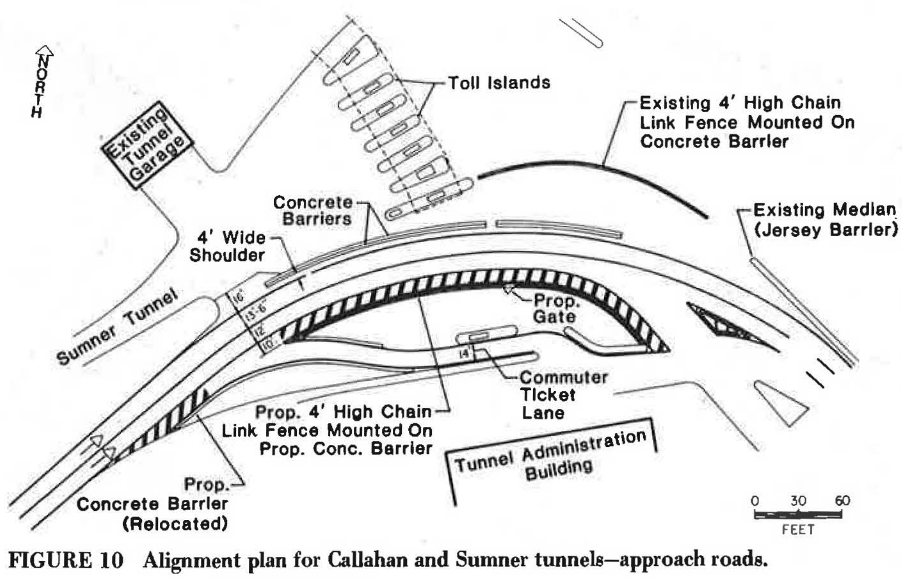


FIGURE 10 Alignment plan for Callahan and Sumner tunnels—approach roads.

**TABLE 8 Summary Distribution of Callahan Tunnel Approach Volumes Before and After One-Way Toll Experiment and Approach Area Channelization**

| | 4:45 p.m.-5:45 p.m. Preexperiment Peak Hour (3/4/83) | | 5:00 p.m.-6:00 p.m. Postexperiment Peak Hour (6/10/83) | | Difference | |
|---|---|---|---|---|---|---|
| Source | Volume | Percentage of Total Traffic | Volume | Percentage of Total Traffic | Volume | Percentage |
| Central Artery | 998 | 32.9 | 1,021 | 31.6 | 23 | 2.3 |
| Surface Artery | 851 | 28.0 | 888 | 27.4 | 37 | 4.3 |
| Subtotal from the south | 1,849 | 60.9 | 1,909 | 59.0 | 61 | 3.3 |
| From North Street | 1,185 | 39.1 | 1,329 | 41.0 | 144 | 12.2 |
| Total | 3,034 | 100 | 3,238 | 100 | 204 | 6.7 |

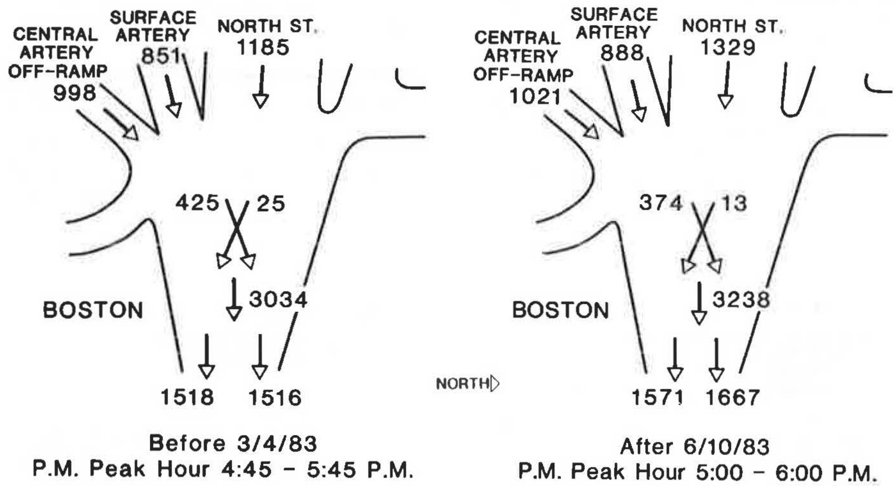


FIGURE 11 Callahan Tunnel traffic volumes.

suggests a volume increase of 200 vehicles. The after peak volume falls within the 3,200 to 3,300 capacity range anticipated for the tunnel system.

- The crossover or weaving volumes dropped from 450 to 387 vehicles, even though there was no change in the approach distributions; they remained 60 percent south and 40 percent north.
- Volumes recorded at the tunnel exit in East Boston increased from 3,120 to 3,280 vehicles.

Thus, the operational changes appear to have improved Callahan Tunnel performance. In addition to the capacity gains, there was a reduction of delays and turbulence at both the entry and the exit, and average speeds through the tunnel improved.

The improved speeds have resulted in fewer breakdowns (due to stoppages) and lower utility costs for tunnel fans (due to the "piston effect" of moving traffic and reduced CO emissions).

## SUMMARY AND INTERPRETATION

The analyses of existing tunnel-system volumes and operations suggested a tunnel capacity of 1,600 to 1,650 vehicles per lane per hour compared with existing peak-hour system volumes of 1,450 per lane. The tunnel capacities exceed those obtained by traditional capacity procedures--1,435 to 1,485 vehicles per lane per hour.

Channelization of the tunnel approach, elimination of outbound toll collection, and realignment of the tunnel exit lanes were estimated to increase system throughput to about 1,650 vehicles per lane. Sample "after" studies indicate that this flow rate is actually achieved with reduced delay throughout the tunnel system.

Perhaps even more significant was the rapid implementation of improvements--too often lacking in management actions. Proposed concepts were developed in March and April 1983 and implemented during May 1983 by the various state agencies.

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