MBTA Bus Route 66
Arterial Improvement Study

A report produced by the Central Transportation Planning Staff for the Massachusetts Bay Transportation Authority and the Massachusetts Highway Department

MBTA Bus Route 66 Arterial Improvement Study

Author
Lourenço Dantas
with
Amanda Amory
Jim Gallagher

Contributing Analysts
Stephen M. Falbel
Mark Scannell
Coleman McDonagh

Cover Design
Jane M. Gillis

Photography
Amanda Amory

The preparation of this document was supported by the Massachusetts Highway Department and Federal Highway Administration through MassHighway Agreements PL/SPR 98085, PL 99055, FTA §5303 #8169001, and Special Projects 97196.

Central Transportation Planning Staff
Directed by the Boston Metropolitan Planning Organization. The MPO is composed of state and regional agencies and authorities, and local governments.

December 2001

Table of Contents

Introduction

BACKGROUND AND REPORT ORGANIZATION

The 1997 documentation of the Congestion Management System (CMS) performance monitoring and reporting[1] identified the MBTA Bus Route 66 as one of the routes most in need of improvements. Transit service evaluations conducted for the MBTA also recognized that Route 66 needed corrective action: both crowding and schedule adherence performance measures for this route were measured as poor. The CMS report recognized that one of the causes of the poor route performance was low levels of service for traffic flow on key arterials used by the bus route. Thus, the CMS report recommended conducting a study of the transit/arterial corridor.

The study consisted of developing an understanding of the existing conditions, both physical and operational, and analyzing alternative improvement measures. The following chapter of this report summarizes the existing conditions, including recent measures of route performance and of arterial street and intersection level-of-service. The subsequent chapter presents an overview of the recommendations of the study; for context, the report briefly reviews some of the analyses upon which the recommendations are based. The report concludes with a summary of the issues and recommendations, followed by some thoughts on implementation. The appendices include materials (such as technical memoranda) produced over the course of the study that document in more detail both the existing conditions in the study corridor and the study's analyses.

DESCRIPTION OF THE BUS ROUTE, STUDY CORRIDOR, AND ISSUES

Bus Route 66 travels on a series of major and minor arterials between Dudley Station at Dudley Square in the Roxbury neighborhood of Boston and Harvard Station at Harvard Square in Cambridge, via Brookline and the Allston-Brighton neighborhood of Boston. Being a circumferential route, this bus service crosses several other transit routes (bus and rail), providing multiple transfer opportunities. A map of the study corridor is presented in Figure 1. For a detailed description of Route 66, please refer to Appendix A pages 1 through 3. Included in the description are the hours of operation, frequency of service, and rider characteristics.

The bus encounters a series of impedances along its route. Route 66 is intersected by a number of major traffic routes that have heavier and priority movements. Forty of the intersections that the route traverses are controlled by a traffic signal. Lane obstructions resulting from commercial truck activity and improperly parked vehicles, are typically present along the route. Pedestrian conflicts are also common. All these characteristics contribute to numerous delays in the bus service, resulting in poor schedule adherence and, consequently, crowding.

---

[1] Central Transportation Planning Staff, for the Boston Metropolitan Planning Organization, *Mobility in the Boston Region—The Congestion Management System Annual Report for 1997: Existing Conditions and Next Steps*, February 1998.

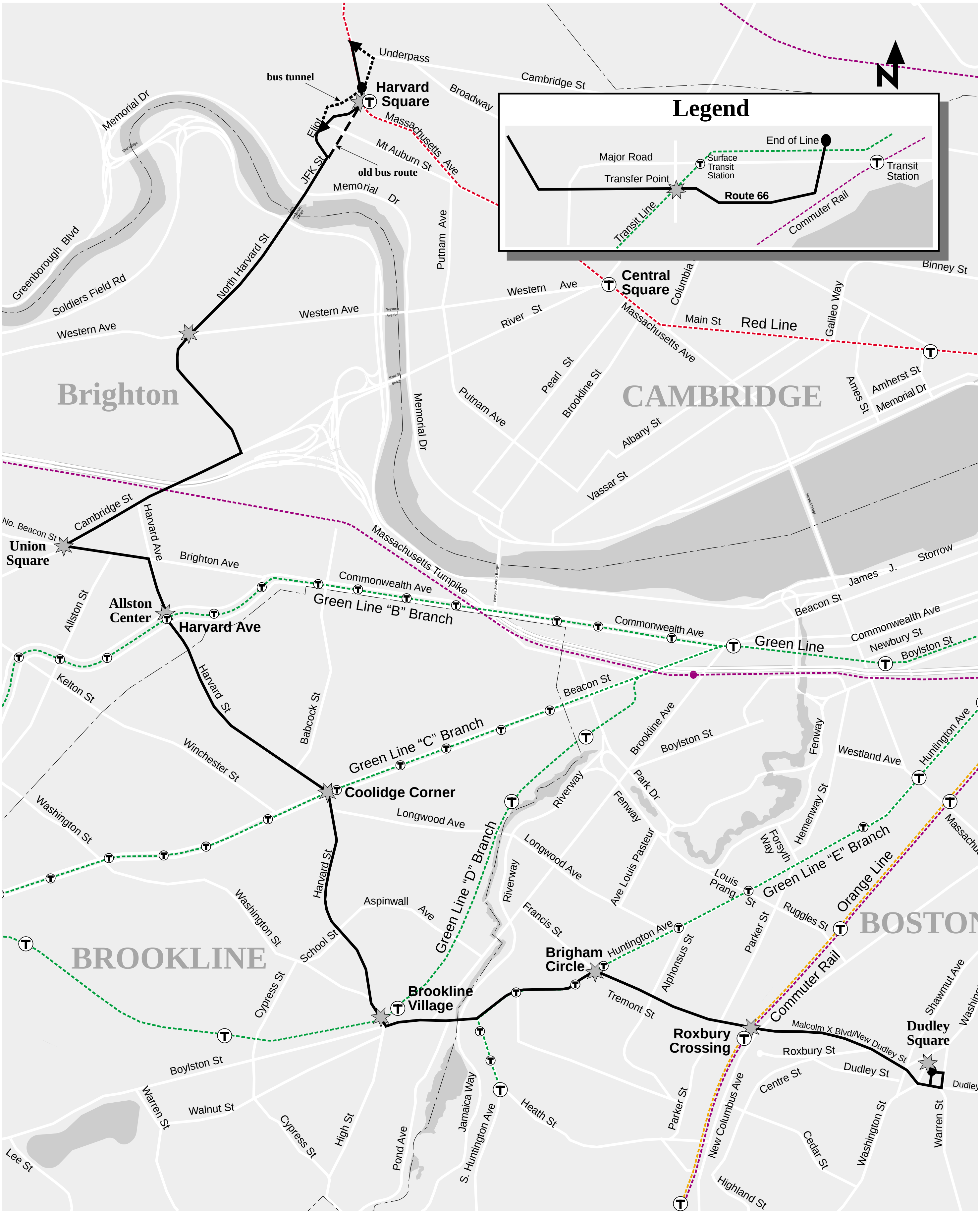
Averaging over 11,000 passengers per weekday, Route 66 is one of the most utilized bus routes in the MBTA system. The peak passenger volume occurs in the morning peak period on trips that depart from Dudley Station. Fifty percent of these northbound trips typically exceed the MBTA's passenger loading standard of 140 percent of seated capacity, based on past ridecheck surveys. In some cases, passengers were observed to remain standing for the length of the route due to the unavailability of seats. Southbound trips (departing from Harvard Station) in the morning were observed to lie within the loading standard. Evening trips in both directions, although crowded, also were observed to be within the standard.

Poor schedule adherence performance of the bus route, not the frequency of service (headways are as low as 9 to 10 minutes during the peak periods), is often the cause of crowded conditions. Observations of on-time performance indicate that most of the Route 66 bus trips do not arrive on time, despite on-time departures.[2] During the morning peak hours, over 70 percent of the trips failed to arrive on time. In the evening, 83 percent of the trips did not arrive on time. Even during the midday, 71 percent of the trips were observed to be off schedule.

The objective of this study is to identify the factors contributing to the undesirable performance characteristics of Bus Route 66 and to recommend potential improvement measures.

[2] *On-time* is defined in the MBTA's service planning assessment as: departing on the scheduled time or within 5 minutes past the scheduled time (no early departures), and arriving at the scheduled time or within 5 minutes past the scheduled time (no early arrivals).

Figure 1
Study Corridor
MBTA Bus Route 66 Arterial Improvement Study



Existing Conditions and Performance

This section presents the observations from the data collection efforts for the various performance measures. Both the bus service and the conditions along the arterial corridor were investigated.

BUS SERVICE

Two sets of ridecheck data and a set of timecheck data provided the foundation for the bus service analysis. The ridecheck data provided both schedule adherence and ridership load information. The route was observed as part of the Comprehensive Ridecheck Program in the spring of 1996 (Round I) and the winter of 1997 (Round II). The timecheck data provided information on schedule adherence and bunching conditions. The surveys were conducted on three days in April 1998 during the morning peak travel period (7:00 a.m. to 9:00 a.m.), the midday period (11:30 a.m. to 1:30 p.m.), and the evening peak period (4:00 p.m. to 6:00 p.m.). Departure and arrival time data were collected at the two endpoints (Harvard Square and Dudley Square) and at three intermediate points of the route (Brookline Village, Coolidge Corner, and Commonwealth Avenue).[3]

Appendix A provides a detailed description of the Bus Route 66 service operations, including ridership characteristics and schedule adherence. The following is a summary.

Schedule Adherence

Schedules for bus routes are set to reflect the running times under the conditions prevalent in the route's corridor. Hence, to a certain extent, schedule adherence is a function of how the schedule is defined for a particular route. Yet, a number of factors—particularly traffic-related—contribute to a bus's running time. For instance, traffic signal delay, parking conditions, and pedestrian activity all contribute to bus schedule adherence problems.

Schedule adherence information was gathered and documented as part of the study effort. The performance breakdown is presented in the "Schedule Adherence" section of Appendix A for weekday service (both peak and non-peak periods), Saturday service, and Sunday service. Observers found that the time the buses take to complete their trips is highly variable.

Bus Route 66 operates with peak period headways of 9 to 10 minutes and midday headways of 15 minutes. Scheduled trip cycles[4] range from 88 to 110 minutes, and average 100 minutes. The bus schedule design includes 12 to 16 minutes of layover time at the end of a one-way trip. "Inbound" trips are those departing Harvard Square; "outbound" those departing Dudley Square.

---

[3] Since the data collection effort, the outbound path of Route 66 in the Harvard Square area has been changed from following JFK Street to Massachusetts Avenue through the square. Outbound buses now enter the bus tunnel via Bennett Alley. The effect of this change is assumed to have a negligible effect on the analysis and recommendations.

[4] A one-way trip consists of both *running time* and *layover time* and constitutes half of a *trip cycle*. The layover time is the period between the time a bus arrives at its destination and the time it is scheduled to depart for the return trip. Essentially, the layover time regulates the bus schedule; it provides time to absorb delays experienced on the prior trip, thus preventing a late departure of the next trip.

Quite often, all of a trip cycle's scheduled layover time is used to absorb delays encountered by the bus, or the amount of delay exceeds the scheduled layover time. On the other hand, sometimes trip cycles have as much as half an hour of layover time when less impedance than usual is encountered. At present, substantial layover time is necessary due to the variability of the running times.

The variability of the running times for the bus within various time periods is investigated in detail in Appendix A. In the morning peak period, for instance, some one-way trips were observed to run as much as 14 minutes early and up to 13 minutes late. On average, though, inbound buses arrived 5 minutes later than scheduled (running times: about 14 percent longer), while outbound buses arrived 7 minutes later than scheduled (about 21 percent longer). The midday service performed better: the inbound service ran only slightly longer than scheduled, on average; the outbound service ran about 4 minutes late on average (about 11 percent longer). Inbound running times in the evening peak period varied between 31 and 57 minutes, averaging 6.5 minutes longer than scheduled (about 16 percent longer). Outbound evening peak trips were observed to vary between 30 and 65 minutes and averaged 8 minutes longer than the scheduled time (about 14 percent longer). The examination of Saturday and Sunday service is also detailed in Appendix A.

Appendix B shows the further investigation of existing bus performance conditions that can affect the variability of the running times, such as bus stop activity and delays experienced at intersections.

Ridership and Passenger Loading

Passenger loading (also referred to as passenger crowding) is another measure investigated as part of the study. The MBTA service policy includes standards for passenger loads, in order to maintain acceptable levels of service.[5] Based on ridechecks, Route 66 boardings and passenger loads are high in all the time periods on all days of the week. At several times in each service day, individual trips carry heavy passenger loads in which many passengers are forced to stand. Though the average load for the peak periods generally does not exceed the service policy standard, numerous individual trips within each peak period do experience crowded conditions. The "Loading" section in Appendix A further discusses the violations of passenger loading standards.

The segments of the route that typically carry the greatest passenger loads are shown in Table 1 below.

[5] The passenger load is calculated as the total ridership for the time period divided by the number of bus seats provided during the time period. The maximum passenger load standard for morning and evening peaks is 140 percent of seated capacity. On an individual trip this load standard translates to 40 seated passengers plus 16 passengers that would need to stand at the peak load point. The maximum load standard for midday trips is 100 percent of seated capacity. In this case, an individual trip would have a maximum of 40 passengers on board, with no one forced to stand.

Table 1. Bus Route 66 Segments with the Heaviest Observed Passenger Loads

Peak Hour	*Inbound*	*Outbound*
AM Peak Hour	From Union Square to Brookline Village	From Coolidge Corner to Soldiers Field Road and, occasionally, the entire route.
Midday Peak Hour	From Coolidge Corner to Roxbury Crossing	From Brigham Circle to Union Square
PM Peak Hour	From Harvard Square to Coolidge Corner	From Brigham Circle to Union Square

Appendix B contains further detailed information on passenger loading profiles. Included in this documentation is the ratio of passengers on board to number of seats on the bus following each bus stop. Across all time periods of the day, the peak load segment is between Brookline Village and Commonwealth Avenue. Furthermore, the crowding patterns show that a significant percentage of riders use the bus to travel from Brookline neighborhoods to Harvard Square in the morning peak, and return in the evening peak. Also, several crowded trip segments correspond to the portion of the route that experience the greatest travel delays, between Coolidge Corner and Harvard Square.

Bus Stop Placement

Bus stop placement is a key element affecting the efficiency of transit operations. The locations of bus stops influence the distribution of passenger volume and boarding and alighting activity. The frequency of bus stops also affects the delay faced by passengers. Investigating the bus stop spacing and passenger activity helps to point out improvements that can streamline the bus service.

The six-mile-long Bus Route 66 has 46 outbound and 47 inbound bus stops, varying in placement on the near side and far side of intersections throughout the route. The average bus stop spacing for the route is about 7 stops per mile or nearly 2 stops per quarter-mile—a generous spacing for a bus transit service. Roughly 60 percent of the route miles and 65 percent of the bus stops are in the two Boston neighborhoods, with an average of 8.3 stops per mile. The remainder of the route averages 6.7 stops per mile.

Boarding and alighting counts at the various stops indicate the most and least utilized ones. The greatest concentrations of boarding and alighting activity are at the termini and at the places where the route intersects the Orange Line and the Green Lines. In Roxbury and Brighton, where the bus stop density is higher than in Brookline, passenger use per stop is lower. Appendix B, part C, provides the counts of boarding and alightings by bus stop.

Passenger Delay

Passenger-hours of delay is essentially a measure of the passenger discomfort related to traffic congestion encountered by the bus during its run. In technical terms, this measure is the count of passengers on board a bus at an approach to a signalized intersection multiplied by the average seconds of traffic signal delay at the intersection approach.[6] This statistic places delay in terms of the number of persons affected, as opposed to simply vehicles. Passenger-hours of delay, a function of both passenger loads and signal delays, can serve as a baseline for measuring improvements in both passenger comfort and schedule adherence.

In this study, congested intersections identified via traffic operations analyses (described in the following section), were further analyzed for passenger-hours of delay experienced on Route 66. (Figure 2, which is provided at the end of this chapter, presents the congested intersections.)

For the inbound service, from Harvard Station to Dudley Station, the evening peak hour experiences the worst levels of passenger-hours of delay: almost twice the amount experienced in the morning peak hour. The intersections that have over three hours of passenger-hours of delay in any peak period are listed below, in order from north to south:[7]

- John F. Kennedy Street at Memorial Drive (intersection #52)
- North Harvard Street at Soldiers Field Road (#51)
- North Harvard Street at Western Avenue (#50)
- Cambridge Street at Harvard Avenue (#43)
- Harvard Street at Verndale Street (#37)
- Harvard Street at Aspinwall Avenue and School Street (#21)
- Washington Street at Boylston Street (#17)
- Huntington Avenue at Tremont Street (#10)
- Tremont Street at Parker Street (#6)

In the outbound direction of service, from Dudley Station to Harvard Station, all three peak hours experience high delays, but none as high as those experienced by the evening inbound service. Most notably, the intersection of Harvard Street with Aspinwall and School Streets stands out as the intersection with the highest levels of delay. Intersections with high (over three hours) outbound passenger-hours of delay are listed below:

- North Harvard Street at Soldiers Field Road (#51)
- North Harvard Street at Western Avenue (#50)
- North Harvard Street at Cambridge Street (#45)
- Harvard Avenue at Commonwealth Avenue (#38)
- Harvard Street at Stedman Street (#32)
- Harvard Street at Aspinwall Avenue and School Street (#21)
- Huntington Avenue at S. Huntington Avenue (#13)
- Tremont Street at Huntington Avenue (#10)
- Tremont Street at St. Alphonsus Street (#8)
- Tremont Street at Parker Street (#6)

[6] Delay is also experienced due to impedances other than intersections. However, the delay caused by slowdowns and stops at intersections is the only measurable delay. Hence, passenger-hours of delay only refers to the delay experienced by the bus at an intersection approach.
[7] The intersection numbers, which are used throughout the report, derive from a consecutive numbering of all of the intersections of the route, from south to north.

Detailed information on these observations can be found in Appendix B. Figures 5 and 6 of Appendix B illustrate the traffic signal–related passenger-hours of delay during each peak period for the inbound and outbound runs. Some of the intersections that experience high passenger-hours of delay at certain times of the day do operate at "acceptable" levels of service for vehicle delay. Such a characteristic is due to the high volume of passengers on certain buses coupled with moderate levels of service.

Appendix B also contains two tables (Tables 6 and 7) that list the inbound and outbound peak hour passengers on board at key intersections (those analyzed with Highway Capacity Software), the average delay faced by vehicles in the lane group the buses use, and the passenger-hours of delay for buses at the intersections.

ROADWAY CONDITIONS

Field Observations

A field reconnaissance of the route traversed by Bus 66 was conducted in order to understand, firsthand, the conditions of the corridor and identify potential problem characteristics and behavior. Overall, the reconnaissance provided observations that the entire corridor is significantly congested. In some cases, the congestion stems from heavy traffic volumes; in other situations, the signal timings and phase plans are not well adjusted to the traffic volumes by approach. Based on the observations, most of the signalized intersections seem to operate at a poor level of service at some point during the day. Failures at downstream signals often compound the problems at nearby upstream signals. In addition, throughout the bus route, parked cars are prevalent on both sides of the street, and parking even occurs in bus stop areas. Signing on several segments of the route are cluttered, potentially confusing drivers about parking restrictions. In these areas, double-parking in the travel lanes was observed to be a recurring problem. CTPS identified two commercial loading zones along the route, neither of which was located where the double-parking occurs.

A full description of the route reconnaissance is provided in Appendix C. Both quantified and subjective observations are included. The type of characteristics covered are: traffic volumes and congestion levels, traffic signal operation, intersection operation, parking, pedestrian and traffic safety, land use/activity, street design/geometrics, and street signs/striping. The observations are listed in geographic sequence by segment and intersection.

Roadway and Intersection Performance Analyses

As part of investigating the potential causes of schedule adherence problems of the Route 66 bus service, the performance characteristics of vehicular traffic along the route's arterials were studied. CTPS conducted two analyses of delay conditions: one used GPS-equipped vehicles to estimate travel time through the corridor (and to map the delay locations), the other used turning movement and signal timing data to estimate signalized intersection level-of-service based on the guidelines of the Highway Capacity Manual. Based on these two analyses a total of 26 intersections were identified as operating under congested conditions. These are illustrated in Figure 2, which is provided at the end of this chapter.

Travel Time Runs

A sample of travel speed and segment delay measurements was collected via travel time runs. Based on the average travel speeds, the route was found to generally operate at arterial level of service (LOS) D throughout the day. The worst recorded levels-of-service occurred in the midday and evening peak periods, during which some segments operated under LOS F conditions. Figures 2 through 4 in Appendix D illustrate the measured speeds/LOS on the Bus Route 66 segments. Segment delay was used to identify "priority" intersections for a subsequent intersection LOS analysis (which is described below). These are listed in Tables 7 and 8 in Appendix D.

Intersection Performance Analysis

Following the identification of critical arterial segments and intersections on the route used by Bus Route 66 (based on the field reconnaissance, the travel time runs, and the passenger-hours of delay analysis), an intersection performance analysis was conducted. The analysis consisted of calculating the level of service for signalized intersections, as well as conducting a capacity analysis, for the weekday morning, midday, and evening peak periods. In addition, the impacts of traffic queues are also described and summarized. Refer to Appendix E for the complete analysis.

Based on the analysis of intersection LOS, the following intersections were selected for improvement recommendations:[8]

- John F. Kennedy Street at Memorial Drive (intersection #52)
- North Harvard Street at Soldiers Field Road (#51)
- North Harvard Street at Western Avenue (#50)
- North Harvard Street at Cambridge Street (#45)
- Cambridge Street at Harvard Avenue (#43)
- Cambridge Street at Brighton Avenue (#42)
- Brighton Avenue at Harvard Avenue (#39)
- Harvard Avenue at Commonwealth Avenue (#38)
- Harvard Street at Beacon Street (#30)
- Harvard Street at School Street and Aspinwall Avenue (#21)
- Harvard Street at Washington Street (#19)
- Washington Street at Boylston Street (#17)
- Huntington Avenue at Tremont Street (#10)
- Tremont Street and New Dudley St. (now Malcolm X Blvd.) at Columbus Ave. (#5)
- Dudley Street at Warren Street (#1)

[8] The Harvard Street Rehabilitation/Improvements Project in the Town of Brookline implemented improvements to several intersections along Harvard Street between Beacon Street and Commonwealth Avenue. Completed during the course of this study, in 1998, this project included new signals at Verndale Street, Fuller Street, and Stedman/Williams Street. Hence, the study does not provide recommendations for those intersections.

Traffic Signal Control Systems

Information was collected on the traffic signal controls at the intersections along Bus Route 66 for use in identifying problems and possible improvements. Boston and Cambridge have centralized traffic signal control systems; Brookline has interconnected signals/closed-loop systems. These are illustrated and described in Appendix F, Section B.

Parking

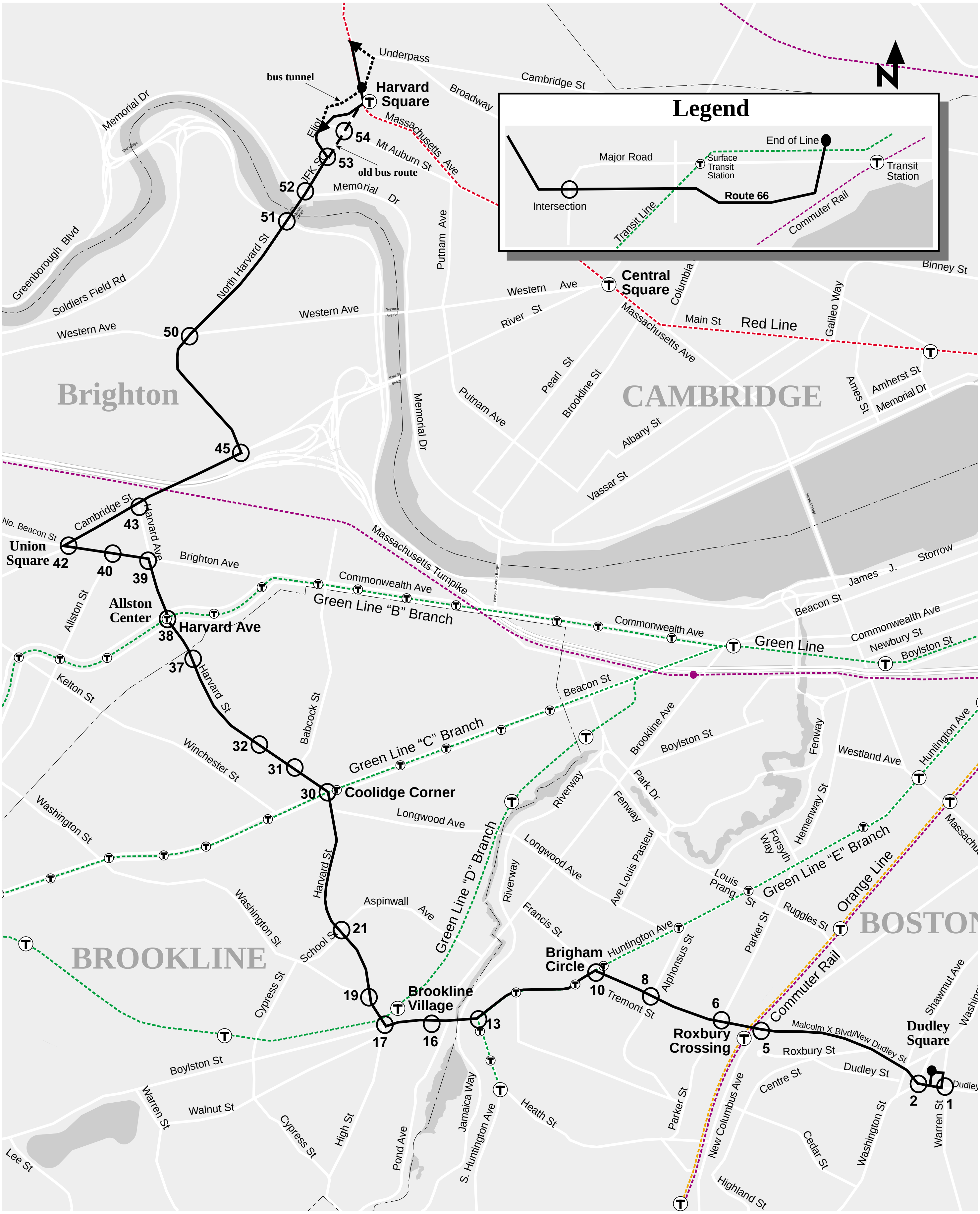
A major problem along the corridor is parking-related congestion. Throughout most of the route, parked cars are found on both sides of the street. Since many segments of the corridor provide access to local businesses, on-street parking is commonly provided. However, cars do not simply park in designated areas: many vehicles are found double-parked. Since Route 66 is in a commercial corridor and the supply of parking spaces is limited, truck drivers often double-park to load and unload vehicles. This behavior causes traffic to queue up, creating delays for the general traffic and failures in on-time performance for the bus.

Parking within intersection approaches and in bus stops are two other forms of illegal parking along the route that causes delay. Such parking behavior creates delays for turning vehicles and obstructs the movement of buses through intersections. In addition, when vehicles occupy bus stops, rider access to buses becomes difficult and unsafe. Furthermore, in situations where only one lane of traffic is available, buses that must stop outside of designated bus stop spaces cause delays to general traffic.

Poor pavement marking and signs also appear to contribute to motorist confusion regarding parking restrictions. This creates unnecessary traffic delays as drivers slow down and/or make additional vehicle movements.

The route reconnaissance described in Appendix C provides an inventory of the parking availability, restrictions, and signs/striping. Appendix F provides further detail of the parking situation encountered at specific locations along Bus Route 66, and discusses preliminary alternatives for improvement. Recommended actions are described in the following section.

Figure 2
Congested Intersections
MBTA Bus Route 66 Arterial Improvement Study



Recommended Improvement Strategies

This study's recommendations for improving Bus Route 66 service fall into three general categories: bus service, roadway/intersection, and parking. Recommended modifications and enhancements include bus schedule changes, bus stop relocation and consolidation, Intelligent Transportation System (ITS) applications, traffic signal timing, roadway geometrics, on-street parking restrictions, and commercial-vehicle loading restrictions. The last section of this chapter discusses the responsibilities for the implementation of improvements.

BUS SERVICE

In addition to parking and signalized intersection improvements, modifications to various aspects of the bus transit service itself are recommended. Described below, they include:

- changing the printed bus schedule, in order to reflect longer running times, due to the conditions along the corridor;
- increasing the frequency of service during particular periods,
- modifying bus stop locations, via elimination, consolidation, and relocation; and
- implementing adaptive traffic signal controls for bus priority.

An interim product of this study was a technical memorandum (see Appendix A) that included proposed recommendations for specific changes in Route 66 running times and headways. In the period of time between the transmittal of that memo and the release of the present, final report on this study, the MBTA has adopted a number of the recommendations made by CTPS in the memo.[9] The recommendations that outlined below are the outstanding recommendations from the memo.

Bus Operations

This study recommends adjustments to the scheduled running times for several time periods to improve schedule adherence. The adjustments are described below. (Time periods apply to weekday service, unless noted otherwise.)

---

[9] Service changes since September 1998:

- *Weekdays.* One bus has been added to both the morning and evening peak periods, as well as to the early afternoon. The running times, however, have remained the same. These additional vehicle assignments have slightly improved the scheduled headways.
- *Saturdays.* Running time and cycle time have been increased. Two additional buses have been added to the route; the headways have remained the same.
- *Sundays.* Beginning with the Summer 2001 schedule change, the Sunday running times and cycle times between 11 a.m. and 4 p.m. were increased. One additional bus was added to the route and headways remained the same.
- *Midpoint*. For the purposes of internal timetables (used by the bus operators, not the general public), the route has been divided into two segments. The intent is to support schedule adherence to midpoint departure times at Union Square, in the Allston neighborhood. The printed schedule reflects this, showing a departure time for buses at Union Square, as opposed to an estimated midpoint arrival time as provided by previous printed schedules. This change was implemented in the fall of 2000.

- *Early MORNING Service (beginning of service – 6:59 a.m.).* In the outbound direction, the scheduled running time is inadequate for all trips starting later than 6:00 a.m. It is recommended that four minutes be added for trips between 6:10 a.m. and 6:50 a.m. to raise the scheduled outbound running time from 26 to 30 minutes. Such a change would require alterations to the schedule, due to the relatively tight cycle lengths. No schedule changes are recommended for the inbound service.
- *Peak MORNING Service (7:00 a.m. – 8:59 a.m.).* In spite of the variation in morning peak running times, resetting the schedule to 42 minutes for both the outbound and inbound directions is recommended. This would provide a more reasonable average running time than the current scheduled times of 37 minutes for the inbound service and 35 minutes for the outbound service.
- *Early MIDDAY Service (9:00 a.m. – 11:29 a.m.).* Most observed outbound running times were longer than the scheduled times: six minutes longer, on average, in 1996. and three minutes longer in 1997. Based on the observations, the scheduled running time for this period should be increased from 36 minutes to 39 minutes. No schedule changes are recommended for the inbound service.
- *Peak MIDDAY Service (11:30 a.m. – 1:29 p.m.).* For outbound trips, it is recommended to increase the running time from 36 minutes to 39 minutes. This would reduce the number of late trips by seven and increase the number of early trips by seven (five of these would still be early by only one or two minutes). The scheduled inbound running time should remain the same. An additional vehicle should be brought into service, reducing headways to 14 minutes from 15 minutes and increasing the cycle time from 90 minutes to 98 minutes.
- *Late MIDDAY Service (1:30 p.m. – 3:59 p.m.).* In this period, the average running time for inbound trips was 47 minutes in both 1996 and 1997, six minutes longer than the scheduled running time. Enough inbound trips took more than 45 minutes to warrant extending the scheduled running time by at least four minutes to 41 minutes. No schedule changes are recommended for the outbound service.
- *Peak EVENING Service (4:00 p.m. – 5:59 p.m.).* Of the 38 inbound observations, 34 had observed running times greater than the scheduled 41 minutes and 25 of those had running times greater than the allowed 46 minutes. In the outbound direction, 27 of 36 observations had trip times greater than the scheduled 42 minutes and 19 of those had trip times greater than the allowed 47 minutes. The scheduled inbound running time should be increased from 41 to 47 minutes and the outbound running time should be increased from 42 to 48 minutes.
- *EVENING Service (6:00 p.m. – 8:59 p.m.).* In the inbound direction, the average running time observed in 1997 was 43 minutes, seven minutes longer than the 36-minute scheduled time; four trips took at least 50 minutes to complete their run. Although much variation occurred in the observed running times, and several trips in the 1996 ridechecks ran more quickly, extending the scheduled inbound running time to 40 minutes is recommended. Both sets of ridechecks suggest an extension of scheduled outbound running time from 35 minutes to 39 minutes.
- *NIGHT Service (9:00 p.m. – end of service).* The scheduled inbound and outbound running times should remain the same.
- *SATURDAY Service.* The main recommendation is to add a vehicle to the midday service, in response to the observed difficulties in meeting the schedule, and overall crowded conditions. This will permit headways to be reduced from 15 minutes to 14 minutes and

increase the cycle time from 90 minutes to 98 minutes. Adjustments to the scheduled running times for all periods of the day are also recommended, as shown in Appendix A, Table 8.

- *SUNDAY Service.* Adjustments to the scheduled running times are also recommended, as shown in Appendix A, Table 9.
- *Overall.* Enforcement of schedule adherence needs to occur, especially at the recently established midpoint at Union Square.

Bus Stop Consolidation/Relocation/Elimination

As noted earlier, the frequency of bus stops on Route 66 is high, particularly in the Boston neighborhoods. The basic improvement strategies related to bus stops include: consolidation, relocation, and elimination of stops. The individual recommendations are based on the assessment of boardings and alightings at stops and on the arterial improvements that address traffic and parking issues. In general, closely-spaced stops with light activity should be considered for consolidation with other stops.

By adjusting bus stop placement, schedule adherence can be improved while maintaining good access to the bus service. Moreover, relocating stops that are very close to intersections where the bus must turn left would improve the traffic weave the buses must make to accomplish the turn. Another benefit of eliminating bus stops is the creation of space that can be used to establish commercial loading zones, especially in high-activity areas.

The recommended bus stop location strategies are:

Inbound

- *North Harvard Street at Western Avenue.* Relocate the stop further north. This would allow for the creation of a second lane for right turns at the intersection.
- *Cambridge Street.* Either the Royal or Franklin Street stop between N. Harvard Street and the Mass Pike overpass can be eliminated via consolidation. Another stop between the Mass Pike overpass and Union Square can be eliminated by consolidating two stops.
- *Harvard Street at Longwood Avenue.* Replace two parking spaces with a new stop just south of Longwood Avenue on the southbound side of Harvard Street. This would greatly facilitate the southbound left-turning movements as well as the through movements on Harvard Street at Longwood Avenue.
- *Harvard Street at Aspinwall Avenue.* North of the intersection, near Vernon Street, relocate the southbound bus stop further north, closer to the entrance to the Stop-and-Shop establishment. On southbound Harvard Street, move the bus stop to the far side of the intersection.
- *Huntington Avenue, west of Wait Street.* This low-activity bus stop can be eliminated.
- *Tremont Street.* One stop can be eliminated via consolidation between Huntington Avenue and Columbus Avenue.
- *New Dudley Street (Malcolm X Boulevard).* One stop can be eliminated in this segment between Columbus Avenue and Washington Street via consolidation, while keeping the Madison Park High School stop.

Outbound

- *New Dudley Street (Malcolm X Boulevard).* Between Washington Street and Columbus Avenue one or two stops can be eliminated via consolidation, although the Madison Park High School stop should be kept.
- *Tremont Street*. One stop can be eliminated via consolidation between Columbus Avenue and Huntington Avenue.
- *Tremont Street at Huntington Avenue.* Relocate the northbound stop on Tremont to a position south of Worthington Street. This change would allow more travel room and the creation of a commercial loading zone.
- *Harvard Street at Aspinwall Avenue*. Relocate the northbound stop to the near side of Aspinwall Avenue by relocating or eliminating two or three parking spaces.
- *Harvard Street at Beacon Street*. Combine this bus stop with the stop north of the intersection between Beacon Street and Babcock Street. On the approach to Beacon Street, relocate both the bus stop and the Elderbus stop between Beacon Street and Longwood Avenue to the near side of Longwood Avenue. This should help the traffic flow at both the intersection with Longwood Avenue and with Beacon Street.
- *Harvard Avenue at Brighton Avenue.* Relocate the outbound bus stop on Harvard Avenue northbound farther south of Brighton Avenue. This would provide the buses with more room to merge to the left before making the left turn onto Brighton Avenue.
- *Cambridge Street at North Harvard Street*. Relocate the northbound stop away from the intersection. This would provide room for the bus to merge across three lanes of traffic for the left turn onto North Harvard Street. Alternatively, instead of simply relocating the stop, consolidate this stop with the one at Linden Street.
- *North Harvard Street*. One stop can be eliminated along the segment between Cambridge Street and Western Avenue. Another one can be eliminated along the segment between Western Avenue and the Larz Anderson Bridge.

Adaptive Traffic Signal Control for Transit

Another strategy to consider is the use of adaptive signal control (also known as signal preemption or traffic signal priority). Bus vehicles equipped with automated vehicle-locator (AVL) devices could communicate with traffic signals along the route in order to obtain favorable green time. Transit services in other cities have implemented this Intelligent Transportation System technology with notable success, obtaining improved schedule adherence, enhanced bus transfer coordination, and increased accuracy in schedule adherence monitoring and reporting, among other benefits.

A two-step approach to implementation should be considered for this corridor. The first step would entail permitting a few signals to extend green time for only those buses that are running behind schedule, when the transit vehicles need the travel time benefit. Buses that are running on time or ahead of schedule would be subject to the normal operating conditions. The second step, if the first implementation step works appropriately, would have the purpose of improving the overall running time of the Route 66 buses in general. In this step, on a trial basis, traffic signal priority would be given to all Route 66 buses and at most of the traffic signals in the corridor.

The use of adaptive traffic signal control may not be feasible at intersections with critical arterials. In many instances, the bus travels on the minor approach, crossing major transit corridors and high-volume roadways. Extending green times for the minor approaches could cause excessive delays for the major, more heavily-traveled approaches. Plus, many of the traffic signals along the corridor are part of coordinated signal systems. In these cases, changing the timing for one signal would mean that changes would need to be made to the other signals in the system. This could create added delay.

Isolated traffic signals (those not connected with other signals) are the strongest candidates in this corridor to accommodate signal preemption for transit. In the segments of the route in which the bus travels on the major approaches, some traffic signals that are part of a coordinated system could also be appropriately equipped. In any case, caution would need to be exercised to avoid adverse effects on cross street traffic.

An examination of the potential use of adaptive traffic signal control in the corridor should be conducted. A thorough analysis is called for, as traffic coordination through the area is complex. In addition, the implementation of ITS technologies in both transit vehicles and traffic control equipment would be involved due to the dual jurisdiction of transit authority and signal operator. The MBTA is the agency that is most appropriate to lead this effort. This ITS application should be considered as a possible accompaniment to the MBTA's adoption of AVL technologies.[10]

Appendix H provides a more complete description of adaptive traffic signal controls for transit.

INTERSECTIONS

Recommendations for improving the route's intersections are presented below, proceeding in the inbound direction along Bus Route 66, from Cambridge to Boston. (The intersections are shown in Figure 2. The intersection numbers (in parentheses) derive from a consecutive numbering of all the intersections on the route, starting at Dudley Square.) The recommended intersection improvements focus on signal timing changes, signal coordination, lane restriping, and changes in parking practices.

In general, any signalized intersection that has a leading-green phase, a green arrow should be included in the appropriate signal heads to make it clear to drivers when they have a protected left turn.

[10] The MBTA has plans to test AVL deployment on a select number of routes. The CT (crosstown) bus routes have been identified as candidate routes for AVL, and the Silver Line Bus Rapid Transit system is being designed to use AVL technology. Thus, these corridors are also potential routes for the testing of adaptive traffic signal controls.

Regarding pedestrian crossings, any recommendation is based on a set of principles that address the tradeoffs between vehicle delay and pedestrian mobility.[11] The recommendations discuss at which locations the removal of exclusive pedestrian phases is necessary to improve the LOS and which locations concurrent phasing or actuation seem to be most appropriate.

Intersection improvement recommendations are not presented for the congested intersections along Harvard Street between Beacon Street (Coolidge Corner) and the northern Brookline-Boston townline, since these intersections have recently undergone improvements.

Recommendations

John F. Kennedy Street at Memorial Drive (#52)

The existing vehicle volumes are not high enough to warrant turning one of the two existing lanes on each approach into an exclusive left- or right-turn lane. Retiming the signal to optimize operations at a 100-second cycle length would still result in LOS F for the morning and evening peak periods and LOS D for the midday peak (even with the recent removal of left turns from Memorial Drive at this intersection[12]). Nevertheless, signal retiming would still greatly improve the vehicle flow. A pedestrian phase of 20 seconds is built into every cycle, so there is no need for pedestrian actuation to accommodate the high pedestrian volumes. There would probably be further improvement at this intersection if there were signal coordination with the North Harvard Street at Soldiers Field Road intersection, but that was not evaluated. Aside from that, any additional improvement at this location would require either the elimination of left turns from JFK / North Harvard Street or a major redesign of the intersection.

---

[11] For many of the congested intersections along this route, it is impossible to change the allocation of green time in order to achieve an acceptable level of service (LOS) D or better while maintaining a full pedestrian phase that becomes actuated more than a few times during the peak hours. To obtain LOS D for vehicles, all pedestrian movements must be concurrent. However, concurrent pedestrian movements present some safety concerns, especially for children and the elderly. Since we did not collect pedestrian counts at any of these intersections, we cannot know precisely how heavily they are used. However, based on the average signal timings found in the field observations, pedestrians use the actuation buttons during at least one in ten cycles during the peak hours.

In the tradeoff between pedestrian safety and vehicle delay, the following three general principles are applied:

1. Concurrent pedestrian phases are appropriate at commercial intersections, particularly near non-essential commercial establishments. (An example of such locations are in the commercial area of bars and restaurants—places not often frequented by children and the elderly—that surround the Harvard Avenue at Cambridge Street and Harvard Avenue at Brighton Avenue intersections.)
2. Pedestrian actuation is more appropriate for intersections in residential neighborhoods or near a school.
3. When an intersection warrants pedestrian actuation, it should be limited to the “most hazardous” crossing. “Most hazardous” refers to the widest street or the streets with the most traffic turning onto them during the concurrent phase.

[12] The Metropolitan District Commission (MDC) recently prohibited left turns from Memorial Drive onto JFK / North Harvard Street from 7:00 to 9:00 a.m. and from 4:00 to 7:00 p.m.

Recommendations

1. A pretimed cycle length of 100 seconds should be set for this intersection and for the intersection of North Harvard Street at Soldiers Field Road (# 51), and the two signals should be coordinated along JFK/North Harvard Street.
2. In almost every cycle, some drivers ignore the left turn prohibition from Memorial Drive onto JFK/North Harvard Street. Since prohibiting these left turns greatly improves operations at this intersection, better enforcement of this prohibition is necessary.

North Harvard Street at Soldiers Field Road (#51)

Currently, this intersection, as well as most of its approaches, operates at unacceptable level of service during all three peak periods. Changing the lane configuration and traffic signal phase design, as described below, including the retiming of the signal to a 100-second cycle length, would allow the intersection to operate at an acceptable LOS during all three peak hours.

The left-most North Harvard Street southbound lane is a de facto left-turn lane, and striping it to reflect that use would improve operations. A sign would also be needed on the southbound approach to describe the lane designation. In addition, the area where parking is prohibited during peak periods at the North Harvard Street northbound approach should be striped to indicate that it can be used as a right-turn lane during those times.

Recommendations

1. Currently, the Soldiers Field Road ramps are semi-actuated, with a cycle length of 90 to 150 seconds. A cycle length of 100 seconds, coordinated with the JFK/ Memorial Drive intersection, would improve operations at both intersections.
2. Restripe the de facto left-turn lane on North Harvard Street southbound and add a left-turn arrow for the green southbound phase. Stripe a right-turn lane on North Harvard Street northbound in the extended no-parking zone.

North Harvard Street at Western Avenue (#50)

All approaches currently operate at LOS F in all three peak periods, and a signal retiming cannot significantly improve the intersection's operation. Prohibiting parking (currently allowed) on all four approaches and restriping each approach to two lanes would allow all approaches to operate at LOS D or better in all three peak periods. If removing parking on all approaches is not feasible, removing parking on only the North Harvard Street approaches used by the Route 66 bus, both northbound and southbound, would result in LOS E or better for North Harvard Street in the morning and midday peak periods, although all approaches would remain at LOS F for the evening peak period. Converting the pedestrian-only phase to concurrent pedestrian movement would allow North Harvard Street to operate at LOS D in the evening peak.

Recommendations

1. Eliminate parking along North Harvard Street southbound near the intersection (about five or six spaces), at least during peak periods, and restripe North Harvard Street for two shared lanes in both directions.

2. Move the bus stop location on North Harvard Street southbound further from the intersection, to allow use of the right lane.
3. Eliminate pedestrian actuation and restrict pedestrian crossings to concurrent phases, since little pedestrian activity was observed in this area.

North Harvard Street at Cambridge Street (#45)

Cambridge Street eastbound left turns fail during all three peak periods, and problems with southbound left turns from North Harvard Street were also observed. Eliminating the leading-green phase on Cambridge Street eastbound and allocating more green time to the North Harvard Street and Cambridge Street exclusive-left phases would allow all movements to operate at LOS D or better.

Recommendations

1. Eliminate the leading-green phase for eastbound Cambridge Street.
2. Allocate more green time to the North Harvard Street and Cambridge Street exclusive left-turn phases.
3. Relocate the bus stop on eastbound Cambridge Street further back from the intersection, or combine it with the stop at Linden Street, to facilitate the merging of buses into the left-turn lane to North Harvard Street.

Cambridge Street at Harvard Avenue (#43)

Left turns from Cambridge Street westbound and right turns from Harvard Avenue northbound fail in all three peak periods, and other movements fail on occasion. Removing the pedestrian phase and allocating more green time to the Cambridge Street westbound leading-green phase would allow all movements to operate at LOS E or better during all three peak periods; however, this would create an unsafe crossing for pedestrians due to the heavy left-turning movement.

Improvements at this intersection would require that changes be made to accommodate traffic at Brighton Avenue / Harvard Avenue as well. One of the biggest problems on Harvard Avenue southbound is the lengthy queue extending from Brighton Avenue, and any increase in throughput here will only increase that queue.

Recommendations

1. Allocate more green time to the westbound Cambridge Street leading-green phase (left-turn arrow).
2. Remove three to four on-street parking spaces on Harvard Avenue northbound to allow unobstructed right turns (from Harvard Avenue) during the Cambridge Street westbound leading-green phase and provide a right-turn arrow for that phase.

Cambridge Street at Brighton Avenue and North Beacon Street (Union Square) (#42)

Left turns from Cambridge Street northbound to North Beacon Street westbound are prohibited, but more than 30 of these left turns were counted during each peak hour. Analysis showed no LOS problems for any peak period.

Traffic queues from the signal on North Beacon Street at Everett Street frequently back up into this intersection. The Everett Street intersection is currently in the Brighton Avenue local coordination network. The problem is that this network has a different coordination strategy from the Cambridge Street network.

Recommendations

1. Provide clearer signs for (and enforce) the left-turn prohibition.
2. On the westbound side of North Beacon Street, either provide yellow curb markings that prohibit parking, thus removing a few parking spaces, or enforce the current prohibition during evening peak hours. This should allow better merging of traffic.[13]
3. Since snow and ice can obscure curb markings, install a sign stating "No Parking Any Time" (MUTCD sign number R7-1). Provide enforcement of the no-parking restriction.[10]
4. A coordination network integrating all the intersections in this area should be created.

Brighton Avenue at Harvard Avenue (#39)

Changing to a concurrent pedestrian phase with a leading left-turn phase on Brighton Avenue and more green time on Harvard Avenue would produce LOS D or better for the morning peak period, but Harvard Avenue southbound would still fail in the evening peak. Adding a leading-green phase with a left-turn arrow for Harvard Avenue southbound would enable all movements to operate at LOS D or better in both the morning and evening. Currently, drivers on Harvard Avenue making left turns, both northbound and southbound, are trying to occupy the same space, and they need to be separated. Queues from this intersection currently extend along Harvard Avenue to Cambridge Street.

Recommendations

1. Eliminate the exclusive pedestrian phase and the actuation buttons. This commercial area is an appropriate location for concurrent phasing.
2. Restripe Harvard Avenue to provide left-turn storage bays of 100 feet in both the northbound and southbound approaches. This will require four on-street parking spaces to be removed on each approach. Also, the bus stop on northbound Harvard Avenue would have to be moved further south to allow the Route 66 bus to get in the left lane.[10]

---

[13] The *Route 20 Transportation Planning Study* [Asante, S. *Route 20 Transportation Planning Study*. Central Transportation Planning Staff, May 1998] also recommends this improvement.

3. Add a leading-green phase with a left-turn arrow for Harvard Avenue southbound, within the existing 110-second cycle (in order to maintain coordination along Brighton Avenue).[10]
4. Signal coordination in this area is along North Beacon and Cambridge Streets. Coordination along Harvard Avenue might be more effective, and should be studied.

Harvard Avenue at Commonwealth Avenue (#38)

A major redesign of the intersection has recently been completed. The design includes relocation of the MBTA tracks to the center of Commonwealth Avenue and other changes that should improve operations. Under these circumstances, the recommendations focus on signing and striping to improve the traffic flow at this intersection.

Recommendations

1. All right turns from Commonwealth Avenue to Harvard Avenue should be made from the frontage roads rather than from Commonwealth Avenue itself. This would require that signs be located at least one intersection “upstream” on both Commonwealth Avenue and the frontage roads, alerting drivers to this requirement.
2. Left turns from the frontage roads are prohibited, but the only signs are at the intersections. Again, signs with the proper directions should be added at least one intersection upstream.
3. On Harvard Avenue, both northbound and southbound, conflicts between left-turning and through vehicles take place at numerous points within the intersection. Striping the paths for the left and through vehicles should greatly reduce the number of conflict points.
4. Signs for the businesses and addresses along each section of the frontage road, again upstream from where the frontage roads need to be entered, would help reduce confusion and the excessive number of U-turns that occur in this area.

Harvard Street at School Street and Aspinwall Avenue (#21)

Removing the southbound leading-green phase and adding a third southbound lane (right turn only) would improve the evening peak LOS to D or E. However, the traffic operations during the morning peak still fail, because of the high volume of southbound and eastbound turning traffic. Eliminating the pedestrian phase and actuation buttons in order to improve intersection LOS is not desirable, since the vicinity consists of residences and schools.

Recommendations

1. On southbound Harvard Street, move the bus stop to the far side and reconfigure this approach to three lanes.
2. North of the intersection, near Vernon Street, relocate the southbound bus stop further north, closer to the entrance to the Stop-and-Shop establishment. (Author’s note: Brookline has recently moved the bus stop north to #148 Harvard St.)
3. Allocate more green time to the southbound Harvard Street leading-green phase.

Harvard Street at Washington Street, Kent Street, and Davis Avenue (#19) (Brookline Village)

In both the morning and evening peak periods, Washington Street southbound and Harvard Street southbound operate at LOS F. During the midday peak, Harvard Street southbound experiences traffic problems, but a simple retiming would probably solve this.

To achieve LOS E or better during the evening peak would require removing some on-street parking so that either the Washington Street or Harvard Street southbound approaches could operate as two lanes near the intersection. Washington Street southbound, however, only operates as one lane heading away from this intersection.

No counts were done for Kent Street. Observation suggests that too much green time is allocated for the number of vehicles using Kent Street. Since the Davis Avenue right turn can also take place during the Kent Street phase, no problems are encountered during the morning peak (when analyzed as an isolated intersection).

Furthermore, the Washington Street southbound green phase is currently coordinated with the southbound green phase at the next intersection, Washington Street at Boylston Street. As a result, the Harvard Street southbound traffic frequently backs up. Since Harvard Street southbound carries heavier volumes than Washington Street, this coordination should be changed to favor Harvard Street southbound.

Recommendations

1. Kent Street and Davis Avenue should have vehicle actuation, with the maximum green time set at no more than 10 seconds for Kent Street and 5 seconds for Davis Avenue.
2. Coordinate the Harvard Street southbound phase with the Washington Street southbound phase at the Washington Street-Boylston Street intersection. This might require some adjustment of the signal further upstream at Washington Street and School Street.

(Author's note: The Town of Brookline recently indicated that the Washington Street corridor is scheduled to be improved with the installation of a closed-loop system. Please refer to Appendix J for written comments received during the review of the draft report.)

Washington Street at Boylston Street and High Street (#17)

Southbound Washington Street left turns fail in all three peak periods. Running a three-phase semi-actuated operation (for the Boylston Street, Washington Street, and High Street approaches) improves the intersection to LOS C while preserving the cycle length to allow coordination.

Recommendations

1. Run the signal as a three-phase, semi-actuated operation.

Huntington Avenue at Tremont Street and Francis Street (#10)

In terms of signal timing, the only way to reduce traffic delays encountered by the bus is to allocate a few more seconds of green from Huntington Avenue to the Francis Street-Tremont Street phase.

Recommendations

1. Re-time the signal to provide more green time to the Tremont Street-Francis Street phase.
2. Address the frequent double-parking at this location.

Tremont Street at New Dudley Street (Malcolm X Boulevard) and Columbus Avenue (#5)

Northbound Columbus Avenue left turns operate at LOS E or F during the morning and evening peak hours; eastbound Tremont Street and westbound New Dudley Street operate at LOS E during the evening peak. Signal retiming for the morning or evening peak traffic does not improve level of service, according to the analysis. Pedestrian congestion in the area is very pronounced at the end of the school day.

Recommendations

1. Extend the signal coordination along Tremont Street to include all the intersections between Roxbury Crossing and Brigham Circle.
2. Improve safety by deploying police and/or school crossing guards at the end of the school day to minimize pedestrian-vehicle conflicts.

Dudley Street at Warren Street (#1)

While LOS calculations show some problems, they are based on legal lane use. Currently, frequent double parking blocks many of the legal lanes. Parking enforcement is a problem, but the frequent double-parking indicates that demand exceeds supply in the area. Lack of adequate parking and poor striping of the existing lanes are responsible for many of the problems in Dudley Square.

The high demand for on-street parking at Dudley Square indicates a need for public off-street parking. Enhanced enforcement of parking restrictions is not enough. Once the parking situation improves, other traffic-related problems can be appropriately analyzed and mitigated.

Recommendations

1. Locate a site for an off-street parking garage and begin construction as soon as possible.
2. On the pavement at the Dudley Street westbound approach to Washington Street paint channelization arrows and stripes to provide three lanes: a left-turn lane, a shared left- and through-lane, and a through-lane.
3. Restripe the Dudley Street eastbound approach to Warren Street to reduce the number of lanes from three to two, eliminating the right-most through lane adjacent to the free-right-turn lane. (The eliminated lane appears to be unused; if this lane

were used, queues in it would block the eastbound right turns onto Warren Street.) Extend the existing pedestrian island into the space created by elimination of the lane.

4. Limit pedestrian crossings at the Dudley Street eastbound right-turn lane to occur only during the pedestrian-actuation phase, and allow these right turns from Dudley Street during all other phases.
5. Stripe and channelize Warren Street to create a left-turn and a through lane at the intersection with Dudley Street. Restripe the single Dudley Street westbound lane as two shared lanes for through and turning movements.

PARKING

As discussed in the preceeding section, traffic flow along the corridor is observed to be affected by parking conditions. The detailed description of the conditions at specific locations are given in Appendix F.

This study recommends both a long-term analysis of parking demand and alternatives as well as a short-term set of local improvements. These are listed below:

1. For long-term relief of parking-related delays, the recommendation is to **conduct a parking demand study** in order to assess the suitability of creating off-street parking facilities. Such a study would provide insight into the nature of the parking demand. The parking study should also conduct a turnover rate analysis to help quantify the volume. The Dudley Square area of Roxbury stands out as one location for the study of off-street parking.
2. In the short term, this study recommends the types of parking-related measures listed below, in order to help limit parking activity that interferes with traffic flow throughout the corridor.
    - **Increase enforcement of parking regulations** along the entire route. In particular, as much as possible:
        - Bus stops should be kept clear of parked cars.
        - Double-parking should not be allowed.
        - Loading/unloading should not be permitted outside designated areas.
    - **Clearly mark reserved areas for commercial vehicles** in which loading and unloading may be done without blocking traffic. Critical business areas include Tremont Street in Roxbury and Harvard Avenue in Brighton. Also, local governments may want to consider expanding the available space for loading zones.
    - **Better designate parking spaces** with pavement striping, parking meters, and well-defined parking restrictions. Opportunities to use curb extensions, such as neckdowns, for designating on-street parking areas should be explored.
    - At several locations, **add parking meters to the existing parking spaces**. These mechanisms help to reduce confusion regarding on-street parking restrictions. Plus, money collected from parking meters could generate revenue for the acquisition of property or construction costs to build off-street parking facilities.

- **Remove parking for a short distance at intersection approaches**. This will free up roadway space so that a short lane or "pocket" may be created for turning vehicles. This strategy also improves the visibility of and for pedestrians wishing to cross the street at such points.

Specific Recommendations

The recommendations are addressed to the City of Boston, the Town of Brookline, and the City of Cambridge, which are the agencies responsible for implementation. An adequate public participation process should be conducted if local governments consider the removal of on-street parking spaces along the corridor. Local residents and merchants should be given the opportunity to express their thoughts and concerns regarding such measures.

Suggested improvement strategies, as detailed in Appendix F, are the following:

John F. Kennedy Street, Cambridge

- Identify appropriate locations for commercial loading reservations.
- Enforce parking restrictions to eliminate double parking

North Harvard Street at Western Avenue, Brighton

- Enforce parking restrictions.
- Look for an appropriate place to site an off-street parking facility.

Cambridge Street, Brighton

- Paint curbside parking spaces to delineate them from travel lanes, curb cuts, and bus stops.
- Define the parking limits (location and time periods).
- Add parking meters to the parking spaces.
- Paint bus stop bays at the bus stops to delineate them from parking spaces and curb cuts.

Union Square, Brighton

- Enforce parking restrictions.
- Look for an appropriate location to site an off-street parking facility.
- Eliminate parking spaces on North Beacon Street that are too close to the intersection.

Harvard Avenue between Cambridge Street and Commonwealth Avenue, Brighton

- Paint parking spaces and install parking meters.
- Identify appropriate locations for commercial loading zones, and paint the appropriate parking restrictions for trucks at the curbsides.
- Identify appropriate locations to site off-street parking facilities to address the high parking demand on Harvard Avenue.
- Paint bus reservations at the bus stops.
- Enforce parking restrictions.

Harvard Street at Beacon Street (Coolidge Corner), Brookline

- Remove two spaces of legal parking on the southbound side of Harvard Street.

Tremont Street and Huntington Avenue, Roxbury

- Stripe the parking lanes with parking spaces and install meters. This should discourage drivers from attempting to fit too many cars in a given segment. Set a lower limit to the number of cars permitted to park on the street.
- Forbid on-street parking at locations where the lane geometry is too narrow to safely accommodate parking, such as the curbside fronting the Calumet Market.
- Consolidate some bus stops on both sides of Tremont Street between Roxbury Crossing and Huntington Avenue in order to free up curb space for on-street parking and reduce the conflict between bus and traffic maneuvers.
- Mark the pavement at bus stops with large lettering and bus-length bays to clearly distinguish the bus stops from parking spaces.
- Reserve a portion of the curb on both sides of Tremont Street for commercial loading zones. These should be staggered, instead of being directly across from one another. Set time limits on commercial parking activity.
- Search for an appropriate location to site an off-street parking facility.

New Dudley Street between Tremont Street and Shawmut Avenue, Roxbury

- Stripe the eastbound side of New Dudley Street to clearly differentiate the parking area from the right-turn-only lane.
- Enforce the parking restrictions on New Dudley Street.
- Provide for parking lanes in each direction when repairing and/or restriping the street.
- Reduce the number of bus stops to two in each direction in order to reduce the conflicting demand for curbside space among buses and cars.
- Mark bus loading zones on the pavement with painted bus bays for the full length of the bus reservation.

Dudley Street at Shawmut Avenue and Washington Street, Roxbury

- Enforce the “No Stopping” and other parking restrictions in this area.
- Remove the inconsistent parking signs.

Warren and Dudley Street

- Install parking meters and stripe the parking spaces on Warren Street approaching Dudley Street and north of the intersection.
- Install parking meters on Dudley Street westbound and west of the intersection.
- Eliminate the parking spaces in front of A Nubian Notion to facilitate traffic flow.

Dudley Square

- Search for an appropriate location to site an off-street parking facility. Given the prevalence of on-street parking and the disregard for parking restrictions indicates a demand for a parking facility in the area.

IMPLEMENTATION

Implementation of many of these recommendations depends on community approval. For example, parking elimination, bus stop relocation, and concurrent pedestrian signal phases may be controversial strategies and may possibly not be practical in certain areas. Public outreach efforts should be undertaken before implementation of these types of improvements.

In the case of improvements to the bus service, the responsibility for implementation belongs to the MBTA, with support from the local governments. The implementation of adaptive traffic signal controls would require careful three-way coordination between: the local governments and MassHighway, who own and control the traffic signals, and the MBTA, operator of the buses. Bus stop signing and relocation and some pavement striping also require careful communication between the municipalities and the transit authority. The responsibility for implementing arterial improvements (parking and intersection recommendations), lies with either the City of Boston, the Town of Brookline, MassHighway, or the Metropolitan District Commission, depending on the location. (Appendix I provides notes from discussions with the implementing agencies that were made during the course of the study.)

Each of the various recommendations can be implemented according to plans determined by the implementing agencies. Except for the adaptive traffic signal controls, the implementation of one recommendation does not depend on the implementation of another. In other words, projects can proceed when the implementing agencies are ready.

Summary of Issues and Recommendations

The six-mile-long Bus Route 66, which provides crosstown service between Dudley Square and Harvard Square, is among the busiest routes in the MBTA bus system, with an average weekday ridership of between 11,000 and 12,000 passengers. The bus travels along a densely developed urban corridor through numerous intersections, most of them signalized. Low speeds between intersections and delays at signalized intersections are typical during the peak hours of travel, morning, midday, and evening. As a result, this bus route has schedule adherence deficiencies, which in turn appear to cause a number of trips violating the MBTA's passenger loading standard. The purpose of this study has been to identify congestion problems along the corridor and develop traffic- and bus-operations strategies to mitigate these problems. If implemented, this study's recommendations, which are summarized below, would collectively have a positive impact both on the operation of Bus Route 66 and on general mobility and safety along the corridor.

First, the bus operations were examined. The study found that even though the buses normally depart on time, they are often late arriving at destinations. For instance, fifty percent of the outbound trips in the morning peak period exceed the loading standard, carrying heavy passenger loads for most of the route. Individual bus trips that ran very late were found to be quite crowded, as they tend to pick up passengers who would otherwise have taken the following bus. This study's recommendations related to bus operations may be summarized as follows:

- Adjust the scheduled running times, to better reflect actual travel times.
- Increase the level of service for weekday middays and Saturdays.
- Relocate, consolidate, or eliminate bus stops.

Once other recommendations have been implemented—and have resulted in changes to mobility in the corridor—another look at scheduled and actual running times will be necessary.

In addition, the study recommends investigating the use of adaptive traffic signal controls. The use of traffic signal priority for transit has yielded beneficial results in bus operations in other metropolitan areas. This corridor, if deemed a viable candidate, may also benefit from the use of ITS technology. The tests already planned by the MBTA of AVL deployment on selected bus routes will provide invaluable insight into the practicality of incorporating this promising technology in its transit operations.

The study found that traffic flow along the corridor is impeded by parking conditions—the greatest single factor adversely affecting the bus service. Hence, the study makes several general recommendations on parking management:

- Apply more strict enforcement of existing parking regulations, including the no-parking restriction at bus stops.
- Clearly mark loading and unloading spaces for commercial vehicles.
- Improve definition of legal parking with pavement striping, curb extensions, parking meters, and parking-restriction signs. Consider limiting on-street parking to fewer vehicles.
- Remove parking areas at intersection approaches to facilitate turning movements.

- Contract parking studies in Roxbury to identify needs and recommend, if appropriate, off-street parking. The parking demand in Brighton should also be studied.

Location-specific recommendations related to parking have been detailed in this report.

Another element of the corridor that was explored is the effect of signalized intersection delay on the bus service. The operations of 31 signalized intersections were analyzed using data collected from each of three time periods: the morning, midday, and evening peak hours. Many of these intersections demonstrate failing levels of service for at least one approach in at least one of the periods. Delays and queues are worst during the evening peak hour. This study's recommendations for intersection improvements fall in the following categories:

- Shorter cycle lengths
- Modified signal timings and / or phases
- Elimination of exclusive pedestrian phases
- Signal coordination
- Lane reallocation to traffic movements
- Parking elimination near intersections
- Bus stop relocation

The application of the appropriate types of intersection / signal improvements has been detailed in the report. In general, the recommended strategies, if implemented, would not be expected to dramatically improve the operation of the intersections, but rather should improve their levels of service to marginally acceptable ones.

Appendices

[A .pdf version of the appendices is not available.]

APPENDIX A: ROUTE 66 ANALYSIS AND PROPOSED CHANGES (TECHNICAL MEMORANDUM)

APPENDIX B: BUS OPERATIONS—ANALYSIS OF EXISTING CONDITIONS

APPENDIX C: FIELD OBSERVATIONS OF THE CORRIDOR

APPENDIX D: TRAVEL TIME DATA COLLECTION (TECHNICAL MEMORANDUM)

APPENDIX E: TRAFFIC OPERATIONS ANALYSIS

APPENDIX F: STRATEGIES TO ALLEVIATE PARKING-RELATED CONGESTION (TECHNICAL MEMORANDUM)

APPENDIX G: BUS ROUTE 66 SCHEDULES

APPENDIX H: OVERVIEW OF ADAPTIVE TRAFFIC SIGNAL CONTROL FOR TRANSIT

APPENDIX I: AGENCY COORDINATION (TECHNICAL MEMORANDUM)

APPENDIX J: WRITTEN RESPONSES TO THE DRAFT REPORT