This document fulfills the requirements of Task 5 in the study scope of work. It combines revised versions of the Task 1 and Task 2 reports with previously unreleased Task 3 and Task 4 reports. Task 1 includes an assessment of existing conditions in the Western Avenue corridor between 59th Street and 87th Street. Task 2 includes a technology review of transit signal priority (TSP) applications in the Chicago region and elsewhere. The Task 3 includes development of a concept design for TSP treatment in the study corridor, a preliminary system architecture and logical architecture based on the National ITS Architecture, traffic simulation modeling of TSP in the study corridor, and high-level functional requirements. Task 4 includes an operational test plan, cost estimates, and an outline for a draft intergovernmental agreement to support implementation and testing.
WESTERN AVENUE
TRANSIT SIGNAL PRIORITY
FEASIBILITY STUDY

Project Summary Report

Executive Summary

The Regional Transportation Authority (RTA) is leading the development of a Regional Transit Signal Priority Integration Plan for the Chicago area. The goal of the plan is to guide the development of signal priority systems for improved bus service and to compliment the region’s ongoing efforts to reduce travel times and increase operating efficiency on roadways.

In partnership with RTA, the Chicago Transit Authority (CTA), and Pace Suburban Bus Service (Pace), the City of Chicago Department of Transportation (CDOT) has initiated a project involving a feasibility study, preliminary design, and operational test plan for installation of transit signal priority (TSP) treatment along Western Avenue within the Chicago city limits between 59th Street and 87th Street. The study, being completed for the City by Wilbur Smith Associates (WSA), includes investigation of current operations by both the CTA and Pace along Western Avenue, with a focus on the CTA X49 express bus route. Results of similar studies, including the work by Pace and the Illinois Department of Transportation (IDOT) on the Cermak Road Bus Signal Priority demonstration project, are being reviewed.

This project includes an overview of previous TSP-related work in the Chicago region and elsewhere, an inventory of existing traffic, transit and geometric conditions in the study corridor, an assessment of technology alternatives for providing conditional priority to transit vehicles, a microsimulation traffic operations analysis, a concept design and preliminary system architecture for the pilot project, high-level functional requirements, an operational test plan, preliminary cost estimates, and an outline for a draft intergovernmental agreement to support implementation and testing.

The Technology Review recommended that infrared or optical detection be considered as the bus-to-roadside controller technology for the Western Avenue pilot project. This technology has proven interoperability with a variety of bus Automatic Vehicle Location (AVL) systems and traffic signal controllers, and thus represents a solution that could offer region-wide applicability. Optical signal priority systems have been implemented by more than 90 suburbs for emergency vehicle preemption.

The microsimulation traffic operations analysis found that TSP would produce transit travel time savings for the X49 service of up to 15%. These results are similar to real-world project experience on the Pace/IDOT Cermak Road TSP Demonstration and recent implementations elsewhere, which demonstrated time savings of approximately 10% of total travel time. The time buses spend stopped in traffic was reduced by 35% or more by TSP treatment.
On an intersection by intersection basis, the analysis also revealed that travel time savings were achieved in a majority of the study corridor without substantial adverse impacts on cross-street traffic. However, at 79th Street and 87th Street, high cross-street traffic volumes precluded TSP treatment. In addition, TSP treatment was not justified at 62nd Street because priority requests were found to be rare at this location due to low cross-street traffic volumes and the fact that Western Avenue already receives at least 70% of the green time. Based on this analysis, it was recommended that the TSP project include the 10 signalized intersections along Western Avenue at 59th, 61st, 63rd, 65th, 67th, 69th, 71st, 74th, 77th, and 83rd Streets. Because only a single intersection would be tested and the resulting time savings would likely be small or immeasurable, there was no need to equip Pace buses on Route 349 with TSP-related equipment for the pilot project.

Because far-side bus stop locations provide the traffic signal control system with greatest flexibility to serve priority requests, it is recommended that existing near-side bus stops for the X49 service at three intersections be relocated. This approach is consistent with the CTA TSP demonstration on Martin Luther King Jr. Drive and has been tested and proven on a number of transit signal priority and bus rapid transit systems, including the Los Angeles MetroRapid system. This provides an opportunity to improve passenger convenience for the X49 service with upgraded passenger shelters, countdown displays to give passengers advance warning of approaching buses, ADA accessibility features, and new signage. The design of these improvements is considered outside the scope of this study.

A concept design and preliminary system architecture was developed for a TSP system at 10 intersections between 59th Street and 83rd Street and on 25 buses designated by the CTA for X49 service in the corridor. The concept design includes interfaces with existing systems, including CDOT’s system of Peek LMD40 traffic signal controllers and CTA’s Bus Service Management System (BSMS). New components to be added include planned enhancements to the CTA BSMS software to support schedule adherence monitoring, modifications as required to on-board BSMS system settings to request TSP treatment when certain schedule adherence conditions are met, optical emitters on each bus, optical detectors mounted on the signal mast arm or other suitable location at each intersection, phase selector cards installed in auxiliary traffic signal cabinets at each intersection, and intersection-specific “pre-emption plans” for each traffic signal controller.

The preliminary system architecture is based on the National ITS Architecture and is summarized in Figure 0.1.
Preliminary cost estimates were prepared for the installation of hardware and some software associated with the pilot project. Software development costs include the preparation of traffic signal preemption plans at each intersection, but no allowance has been included for CTA’s efforts associated with the interface between the BSMS and the Optical Emitter and development of the schedule-location database needed to support on-board schedule adherence computations by the BSMS Mobile Data Terminal. The preliminary installation cost estimate is approximately $84,000 for the 10 intersections and 25 buses.

An operational test plan was also developed to guide the City in evaluating the performance of the TSP system and its effects on traffic flow. Three alternatives were prepared. A low-cost alternative makes use of data collected at the beginning of the study to support the microsimulation traffic operations analysis and supplements it with similar data collected after installation to support travel time studies for traffic and transit. A higher-cost alternative collects more detailed traffic counts and queuing information before and after installation to support traffic delay studies at key intersections along the TSP corridor. Costs estimates for these studies range from $8,700 to $30,600.
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<td>AADT</td>
<td>Annual Average Daily Traffic</td>
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<tr>
<td>AASHTO</td>
<td>American Assoc. of State Highway Transp. Officials</td>
</tr>
<tr>
<td>ADA</td>
<td>Americans with Disabilities Act</td>
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<tr>
<td>ADT</td>
<td>Average Daily Traffic</td>
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<tr>
<td>APC</td>
<td>Automatic Passenger Counter</td>
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<td>AVL</td>
<td>Automatic Vehicle Location</td>
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<td>AWG</td>
<td>American Wire Gauge</td>
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<td>BOE</td>
<td>CDOT Bureau of Electricity</td>
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<tr>
<td>BSMS</td>
<td>CTA Bus Service Management System</td>
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<tr>
<td>CAD</td>
<td>Computer Aided Dispatch</td>
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<tr>
<td>CATS</td>
<td>Chicago Area Transportation Study</td>
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<td>CDOT</td>
<td>City of Chicago Department of Transportation</td>
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<tr>
<td>CD-ROM</td>
<td>Compact Disc - Read-Only Memory</td>
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<td>CTA</td>
<td>Chicago Transit Authority</td>
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<tr>
<td>DSR</td>
<td>Dedicated Short-Range Communications</td>
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<tr>
<td>FS</td>
<td>Far-Side bus stop</td>
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<tr>
<td>GIS</td>
<td>Geographic Information System</td>
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<tr>
<td>GPS</td>
<td>Global Positioning System</td>
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<td>IBS</td>
<td>Pace Intelligent Bus System</td>
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<td>IDOT</td>
<td>Illinois Department of Transportation</td>
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<td>IDOT-DPT</td>
<td>IDOT Division of Public Transportation</td>
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<tr>
<td>IR</td>
<td>Infrared</td>
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<tr>
<td>ITS</td>
<td>Intelligent Transportation Systems</td>
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<td>NEMA</td>
<td>National Electrical Manufacturers’ Association</td>
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<td>NS</td>
<td>Near-Side bus stop</td>
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<td>NTCIP</td>
<td>National Communications for ITS Protocol</td>
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<tr>
<td>RF</td>
<td>Radio Frequency</td>
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<td>Read-Only Memory</td>
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<td>RS</td>
<td>Roadway Subsystem</td>
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<td>RTA</td>
<td>Regional Transportation Authority</td>
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<td>Roadway Traffic Monitoring System</td>
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<tr>
<td>SRA</td>
<td>Strategic Regional Arterial</td>
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<tr>
<td>TCIP</td>
<td>Transit Communications Interface Protocol</td>
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<tr>
<td>TCS</td>
<td>Traffic Control System</td>
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<tr>
<td>TMC</td>
<td>Traffic Management Center</td>
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<tr>
<td>TMS</td>
<td>Traffic Management Subsystem</td>
</tr>
<tr>
<td>TrMS</td>
<td>Transit Management Subsystem</td>
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<tr>
<td>TSP</td>
<td>Transit Signal Priority</td>
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<tr>
<td>VAP</td>
<td>Vehicle Actuated Program</td>
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<td>VISSIM</td>
<td>Verkehr in Stadt Simulation</td>
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<tr>
<td>VS</td>
<td>Vehicle Subsystem</td>
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<td>WSA</td>
<td>Wilbur Smith Associates</td>
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1. Introduction

The Regional Transportation Authority (RTA) is leading the development of a Regional Transit Signal Priority Integration Plan for the Chicago area. The goal of the plan is to guide the development of signal priority systems for improved bus service and to compliment the region’s ongoing efforts to reduce travel times and increase operating efficiency on roadways. In addition, the plan seeks to prove that a saving in the cost for installation and maintenance is realized when integrated signal priority systems are used.

In partnership with RTA, the Chicago Transit Authority (CTA), and Pace Suburban Bus Service (Pace), the City of Chicago Department of Transportation (CDOT) has initiated a project involving a feasibility study, preliminary design, and operational test plan for installation of transit signal priority (TSP) treatment along Western Avenue within the Chicago city limits between 59th Street and 87th Street. The study, being completed for the City by Wilbur Smith Associates (WSA), includes investigation of current operations by both the CTA and Pace along Western Avenue, with a focus on the CTA X49 express bus route. Results of similar studies, including the work by Pace and the Illinois Department of Transportation (IDOT) on the Cermak Road Bus Signal Priority demonstration project, are being reviewed.

This report presents the results of this feasibility study, including an overview of previous TSP-related work in the Chicago region and elsewhere, an inventory of existing traffic, transit and geometric conditions in the study corridor, an assessment of technology alternatives for providing conditional priority to transit vehicles, a concept design and preliminary system architecture for the pilot project, high-level functional requirements, an operational test plan, preliminary cost estimates, and an outline for a draft intergovernmental agreement to support implementation and testing.

Figure 1.1 on the following page shows the location of the project in the City of Chicago.
Figure 1.1: Project Location
2. Transit Signal Priority in the Region

The Regional Transportation Authority (RTA) is leading the development of a Regional Transit Signal Priority Integration Plan for the Chicago area. The goal of the plan is to guide the development of TSP systems for improved bus service and to compliment the region’s ongoing efforts to reduce travel times and increase operating efficiency on roadways. In addition, the plan seeks to demonstrate that a saving in the cost for installation and maintenance can be realized when integrated signal priority systems are used.

The RTA has completed Phase I of its feasibility study of TSP. This includes development of a GIS-based traffic signal inventory in conjunction with the Chicago Area Transportation Study (CATS) and the Illinois Department of Transportation (IDOT) and a location study to determine corridors for simulation. RTA is especially interested in determining the overall regional effects of signal priority, not just corridor effects. Seventeen corridors have been identified nearly 70 bus routes for microsimulation modeling in Phase II.

The RTA initiative exists within a context of TSP demonstration projects and related work over the last ten years. A summary of the major efforts for giving priority to transit vehicles at signalized intersections in Northeastern Illinois follows.

2.1. Cermak Road Test and Deployment

In June 1997, the IDOT Division of Public Transportation, in collaboration with Pace and the CTA, implemented a TSP demonstration in a 2.5 mile corridor of Cermak Road located in the Chicago suburbs of Cicero, Berwyn, and North Riverside, Illinois. The corridor was selected because of traffic congestion caused by a high volume of vehicles and numerous signalized intersections that contributed to schedule reliability problems on three routes namely 25, 304 and 322. Briefly, the Pace and CTA buses on Routes 25, 304 and 322 are equipped with a constantly activated transmitter mounted on the underside of the chassis. As buses approach traffic signals in the corridor of Cermak Road, loop detectors buried in the pavement approximately 6 bus lengths from the intersection detect signals emitted by the transmitters. The loop is connected via communication cable in a conduit system to a detector amplifier that is able to detect the call from the transmitter and send a request to the signal controller for earlier green or to extend the green phase. As buses pass the intersection, the signal timing resumes its normal cycle. Initial results consider the demonstration successful at reducing transit travel times without substantially increasing delay on cross streets. As the first TSP demonstration in the region, IDOT-DPT is conducting a follow-up study of the project. Results are not expected until after this study is completed.

2.2. CTA King Drive Traffic Signal Priority Demonstration

The CTA, as part of its Bus Service Management System (BSMS) deployment project, is testing TSP at five intersections along Martin Luther King Jr. Drive between 43rd and 51st Streets (or alternatively between 51st and 63rd Streets) in Chicago. BSMS-equipped buses will send signals using short-range wireless radio (1000-foot range) to traffic signal controllers when the on-board computer determines that the bus is behind schedule and at a certain distance from the
intersection. The GPS-based automatic vehicle location (AVL) system will send signals requesting priority when it determines that the bus is 100 meters upstream of the intersection and will send a check-out signal when it is 25 meters downstream of the intersection. The system will be used on far-side stops only. The traffic signal controller will limit the number of vehicles that can request priority to 1-2 buses per cycle. No on-street testing is expected before completion of this study.

The buses used on King Drive operate from the 77th Street Garage, which is equipped to support the BSMS on-board schedule adherence monitoring functions. A key component of equipping buses with on-board schedule adherence monitoring capabilities is developing an interface between CTA’s current paper-based bus scheduling system and the electronic schedules and GIS database used by the BSMS. The Archer Avenue Garage houses the CTA buses that operate in the Western Avenue corridor and is not currently equipped to support these functions. If necessary, CTA can transfer buses to the Archer Avenue Garage to support TSP testing along Western Avenue.

2.3. Pace Intelligent Bus System

Pace has received bids for its Intelligent Bus System (IBS), which will provide many of the same functions as CTA’s BSMS. Siemens was selected as the vendor for this system in the fourth quarter of 2001 and trial runs are scheduled to be conducted by the second quarter of 2002. In contrast to the Cermak Road test of TSP, IBS-equipped buses will be able to request priority only when they are behind schedule. IBS will support multiple short-range communications technologies for vehicle-to-traffic signal controller communications, including inductive loops, infrared, and video detection.

2.4. Bureau of Electricity Opticom Test

The Bureau of Electricity (BOE) tested an interface between a 3M Opticom infrared receiver and the Peek LMD40 controller at 59th Street and Western Avenue intersection in Spring 2000. This intersection was selected because there was room in cabinet for electronics and because the sight distance was very clear.

For this test, 3M developed custom software for its signal controller interface (phase selector) that allowed the LMD40’s ‘manual control enable’ mode to be used with a phase advance interval of 200 milliseconds. Normally this interval is 2 seconds. The manual control enable approach allowed for faster recovery from priority sequences than would be possible using the LMD40’s built-in preemption inputs.

The demonstration was successful. The hardware remains on site.
3. Study Area Existing Conditions

3.1. Traffic Characteristics and Geometric Conditions

Western Avenue is a key north-south arterial street in the City of Chicago. It has been designated as a Strategic Regional Arterial route (SRA) and is maintained by IDOT. The route carries an Average Daily Traffic (ADT) ranging from 19,000 to 47,000 vehicles per day. The corridor has continuous bus service, and connects to six CTA rapid transit stations and two Metra commuter rail stations.

The existing geometry typically includes two through lanes in each direction separated by a 12-foot median along Western Avenue with exclusive left turn lanes at the intersections. The right through lane is typically 18 feet wide allowing loading zones, parking and bus stops to be effectively served. No exclusive right turn lanes are included in the existing geometry, except at 87th Street. Total pavement width is typically 70 to 72 feet throughout the corridor.

Between 59th Street and 87th Street, Western Avenue carries an average annual daily traffic volume (AADT) of between 26,600 and 34,300 vehicles per day. CDOT has collected traffic volumes in the Western Avenue corridor using an automated Roadway Traffic Monitoring System (RTMS). In addition, several small-scale traffic studies have been conducted at certain intersections in the corridor to support recent signal installations. These data suggests that the peak periods are between 7:00 a.m. and 9:00 a.m. and between 4:00 p.m. and 6:00 p.m.

Insufficient existing traffic data was available to support a microsimulation traffic model and traffic volumes and turning movement counts and other data were collected during the study by CDOT under separate contract. Turning movement volume counts as shown in Figure 3.1 on the following page were conducted at 13 intersections in February and March 2001. These traffic volume counts consisted of turning movement counts at each study intersection during the morning and afternoon peak periods of traffic activity. The 87th and 79th intersections experience heavy cross-street traffic volumes nearly as great as those on Western Avenue.

The travel time study was conducted on Wednesday, 14 February 2001. Five runs starting and ending at the study area boundary were made during both the morning and afternoon peak hours for northbound and southbound directions. For the morning peak period, the average travel time was 633 seconds for northbound and 560 seconds for southbound. For the afternoon peak period, the average travel time was 599 seconds for northbound and 715 seconds for southbound.
Figure 3.1: Balanced Traffic Volumes and Turning Movement Counts

AM Peak Hour

PM Peak Hour
3.2. Existing Transit Services

Transit service within the study limits is operated by both the CTA and Pace. Along Western Avenue, routes include the CTA X49, CTA 49 and Pace 349 / CTA 49A. There is an overlap of CTA X49 and Pace 349 / CTA 49A operations between 79th to 87th Streets. The Route X49 is an express limited-stop service that stops on the 1/2-mile street grid. The X49 bus route operates within the same corridor as the existing local CTA 49 bus route, which stops every 1/8 mile. The X49 express route typically stops at nearside intersections (except at the 79th Street bus terminal) and only at 59th, 63rd, 69th, 79th and 87th within the study corridor. This operation allows the X49 to achieve travel speeds 25% faster than the local bus. The 18-mile X49 service crosses the City of Chicago, traveling through a diverse set of neighborhoods and land uses. It connects with five CTA rail branches and two commuter rail stations (Metra). In the study area, CTA X49 operates weekdays only from 5:40 a.m. southbound and 6:00 a.m. northbound to 8:00 p.m. in southbound and 8:15 p.m. northbound. It operates with 15-minute headways during peak periods and with 20-minute headways during off-peak periods. The local CTA 49 bus route operates 24 hours everyday with different headways. Between 12:00 a.m. and 4:00 a.m. it operates on 30-minute headways. Then the service runs every 6 to 10-minutes during peak periods and every 15-minutes during off peak periods. The peak period is from 6:00 a.m. to 8:00 p.m. on weekdays, 6:00 a.m. to 6:00 p.m. on Saturdays and 12:00 p.m. to 8:00 p.m. on Sundays and holidays.

The Pace 349/CTA 49A bus route is a shared route on which CTA operates runs as far as the southern city limits at Blue Island and Pace operates runs to Harvey. The bus route operates from 5:00 a.m. to 10:40 p.m. on weekdays and to midnight on Saturdays and from 6:00 a.m. to 11:00 p.m. on Sundays. On weekdays, the bus operates on 15-minute headways from 7:00 a.m. to 7:00 p.m. and on 30-minute headways during other times. On Saturdays, the bus operates on 20-minute headways from 8:00 a.m. to 6:00 p.m. and on 30-minute headways during other times. On Sundays, the bus operates on 30-minute headways.

Table 3.1 summarizes existing bus services in the corridor. Figure 3.2 on the following page shows CTA and Pace routes and bus stop locations in the corridor. Table 3.2 on the second following page shows CTA and Pace bus stop locations and their relationship with each intersection, such as whether each is near side (NS), far side (FS), mid-block, or off-street.

<table>
<thead>
<tr>
<th>Bus Route</th>
<th>Service Board</th>
<th>Express or Local</th>
<th>Peak Headway</th>
<th>Route Termin</th>
<th>Route Termin</th>
</tr>
</thead>
<tbody>
<tr>
<td>X49</td>
<td>CTA</td>
<td>Express</td>
<td>15 min.</td>
<td>Berwyn / Western - Evergreen Plaza</td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>CTA</td>
<td>Local</td>
<td>6 min.</td>
<td>Berwyn / Western - 79th / Western</td>
<td></td>
</tr>
<tr>
<td>63</td>
<td>CTA</td>
<td>Local</td>
<td>7 min.</td>
<td>63rd St. Beach House - Midway Airport</td>
<td></td>
</tr>
<tr>
<td>67</td>
<td>CTA</td>
<td>Local</td>
<td>15 min.</td>
<td>67th / South Shore - 71st / Pulaski</td>
<td></td>
</tr>
<tr>
<td>79</td>
<td>CTA</td>
<td>Local</td>
<td>3 min.</td>
<td>79th / South Shore - Ford City Mall</td>
<td></td>
</tr>
<tr>
<td>87</td>
<td>CTA</td>
<td>Local</td>
<td>7 min.</td>
<td>91st / Commercial - 87th / Cicero</td>
<td></td>
</tr>
<tr>
<td>349/49A</td>
<td>Pace/CTA</td>
<td>Local</td>
<td>15 min.</td>
<td>79th / Western - 154th / Park</td>
<td></td>
</tr>
</tbody>
</table>
### Table 3.2: Intersection Conditions

<table>
<thead>
<tr>
<th>Cross-Street Name</th>
<th>Traffic Control Type</th>
<th>Southbound Bus Stop Location</th>
<th>Northbound Bus Stop Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>59th Street</td>
<td>Traffic Signal</td>
<td>NS (49+X49)</td>
<td>NS (49+X49)</td>
</tr>
<tr>
<td>60th Street</td>
<td>NS (49)</td>
<td>NS (49)</td>
<td>NS (49)</td>
</tr>
<tr>
<td>61st Street</td>
<td>Traffic Signal</td>
<td>NS (49)</td>
<td>NS (49)</td>
</tr>
<tr>
<td>62nd Street</td>
<td>Traffic Signal</td>
<td>NS (49)</td>
<td>NS (49)</td>
</tr>
<tr>
<td>63rd Street</td>
<td>Traffic Signal</td>
<td>NS (49+X49)</td>
<td>NS (49+X49)</td>
</tr>
<tr>
<td>64th Street</td>
<td>NS (49)</td>
<td>NS (49)</td>
<td>NS (49)</td>
</tr>
<tr>
<td>65th Street</td>
<td>Traffic Signal</td>
<td>NS (49)</td>
<td>NS (49)</td>
</tr>
<tr>
<td>66th Street</td>
<td>NS (49)</td>
<td>NS (49)</td>
<td>NS (49)</td>
</tr>
<tr>
<td>67th Street</td>
<td>Traffic Signal</td>
<td>NS (49)</td>
<td>NS (49+67)</td>
</tr>
<tr>
<td>68th Street</td>
<td>NS (49)</td>
<td>NS (49+67)</td>
<td>NS (49+67)</td>
</tr>
<tr>
<td>69th Street</td>
<td>Traffic Signal</td>
<td>NS (49+X49), FS (67)</td>
<td>NS (49+X49+67)</td>
</tr>
<tr>
<td>70th Street</td>
<td>NS (49+67)</td>
<td>NS (49+67)</td>
<td>NS (49+67)</td>
</tr>
<tr>
<td>71st Street</td>
<td>Traffic Signal</td>
<td>NS (49+67)</td>
<td>NS (49), FS (67)</td>
</tr>
<tr>
<td>72nd Street</td>
<td>NS (49)</td>
<td>NS (49)</td>
<td>NS (49)</td>
</tr>
<tr>
<td>73rd Street</td>
<td>NS (49)</td>
<td>NS (49)</td>
<td>NS (49)</td>
</tr>
<tr>
<td>74th Street</td>
<td>Traffic Signal</td>
<td>FS (49)</td>
<td>NS (49)</td>
</tr>
<tr>
<td>Rail Road (Alley)</td>
<td>NS (49)</td>
<td>NS (49)</td>
<td>NS (49)</td>
</tr>
<tr>
<td>76th Street</td>
<td>NS (49)</td>
<td>NS (49)</td>
<td>NS (49)</td>
</tr>
<tr>
<td>77th Street</td>
<td>Traffic Signal</td>
<td>NS (49)</td>
<td>NS (49)</td>
</tr>
<tr>
<td>78th Street</td>
<td>NS (49)</td>
<td>NS (49)</td>
<td>NS (49)</td>
</tr>
<tr>
<td>Bus Terminal</td>
<td>Off-St. (49A/349+ X49)</td>
<td>Off-St. (49A/349+ X49)</td>
<td></td>
</tr>
<tr>
<td>79th Street</td>
<td>Traffic Signal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>80th Street</td>
<td>NS (49A/349)</td>
<td>NS (49A/349)</td>
<td>NS (49A/349)</td>
</tr>
<tr>
<td>81st Street</td>
<td>NS (49A/349)</td>
<td>NS (49A/349)</td>
<td>NS (49A/349)</td>
</tr>
<tr>
<td>82nd Street</td>
<td>NS (49A/349)</td>
<td>NS (49A/349)</td>
<td>NS (49A/349)</td>
</tr>
<tr>
<td>83rd Street</td>
<td>Traffic Signal</td>
<td>NS (49A/349)</td>
<td>NS (49A/349)</td>
</tr>
<tr>
<td>Forest Preserve</td>
<td>Mid-block (49A/349)</td>
<td>Mid-block (49A/349)</td>
<td></td>
</tr>
<tr>
<td>Forest Preserve</td>
<td>Mid-block (49A/349)</td>
<td>Mid-block (49A/349)</td>
<td></td>
</tr>
<tr>
<td>87th Street</td>
<td>Traffic Signal</td>
<td>NS (49A/349+ X49)</td>
<td>NS (49A/349+ X49)</td>
</tr>
</tbody>
</table>
CTA route 67, which is primarily an east-west route, runs on a small segment of Western Avenue between 67th Street and 71st Street. Other bus routes that cross Western Avenue are CTA 59 at 59th Street, CTA 63 at 63rd Street, CTA 79 at 79th Street and CTA 87 at 87th Street. The CTA 59 bus route operates from 6:00 a.m. to 9:00 p.m. on weekdays and from 8:00 a.m. to 9:00 p.m. on Saturdays and no service on Sundays. On weekdays, the bus operates on 15-minute headways from 6:00 a.m. to 9:00 a.m. and from 1:00 p.m. to 6:00 p.m. and on 20-minute headways during other times. On Saturdays, the bus operates on 20-minute headways.

The local CTA 63, CTA 79 and CTA 87 bus routes operate 24 hours everyday with different headways.

CTA route 63 operates on 30-minute headways from 1:00 a.m. to 4:00 a.m., on 20-minute headways from 4:00 a.m. to 5:00 a.m. on 15-minute headways from 8:00 p.m. to 11:00 p.m., and on 20-minute headways from 11:00 p.m. to 1:00 a.m. Between 6:00 a.m. and 8:00 p.m. the bus runs every 7 to 10 minutes. On weekends, it runs every 8 to 10 minutes from 7:00 a.m. to 10:00 p.m., every 15 minutes from 10:00 p.m. to 12:00 a.m., every 20 minutes from 12:00 a.m. to 5:00 a.m., and every 15 minutes from 5:00 a.m. to 7:00 a.m.

CTA route 79 operates on 30-minute headways from 2:00 a.m. to 4:00 a.m., on 20-minute headways from 4:00 a.m. to 5:00 a.m., on 12-minute headways from 11:00 p.m. to 12:00 a.m., and on 20-minute headways from 12:00 a.m. to 2:00 a.m. Between 5:00 a.m. and 11:00 p.m., the bus runs every 3 to 10 minutes. On Saturdays, it runs every 4 to 10 minutes from 6:00 a.m. to 11:00 p.m., every 15 minutes from 11:00 p.m. to 12:00 a.m., every 30 minutes from 2:00 a.m. to 4:00 a.m., every 20 minutes from 4:00 a.m. to 5:00 a.m., and every 15 minutes from 5:00 a.m. to 6:00 a.m. On Sundays, it runs every 6 to 10 minutes from 9:00 a.m. to 12:00 a.m., every 30 minutes from 12:00 a.m. to 6:00 a.m., and every 20 minutes from 6:00 a.m. to 9:00 a.m.

CTA route 87 operates on 7- to 12-minute headways from 5:00 a.m. to 10:00 a.m., on 30-minute headways from 10:00 a.m. to 3:00 p.m., on 7- to 12-minute headways from 3:00 p.m. to 8:00 p.m., on 15-minute headways from 8:00 p.m. to 1:00 a.m., and on 30-minute headways from 1:00 a.m. to 5:00 a.m. On Saturdays, it runs every 8 to 10 minutes from 9:00 a.m. to 8:00 p.m., every 15 minutes from 8:00 p.m. to 11:00 p.m. every 20 minutes from 11:00 p.m. to 1:00 a.m., every 30 minutes from 1:00 a.m. to 5:00 a.m., and every 15 minutes from 5:00 a.m. to 9:00 a.m. On Sundays, it runs every 15 minutes from 9:00 a.m. to 10:00 p.m., every 20 minutes from 10:00 p.m. to 1:00 a.m., every 30 minutes from 1:00 a.m. to 6:00 a.m., and every 20 minutes from 6:00 a.m. to 9:00 a.m.

The bus terminal at 79th Street is a turnaround and layover point for southbound CTA route 49 buses operating from Berwyn Street and northbound Pace 349 / CTA 49A buses operating from Harvey / Blue Island.

The CTA and Pace were not able to provide sufficiently detailed transit service information to support development and calibration of the microsimulation traffic model and related measures of effectiveness. Transit service data, including travel times, dwell times, and bus occupancy were collected during the study by CDOT.

An in-vehicle travel time study was conducted for the X49 express bus service for both peak periods in both directions. The northbound in-vehicle travel time for X49 was 960 and 864 seconds for the morning and afternoon peak periods, respectively. The southbound travel time
was 850 and 1,055 seconds for the morning and afternoon peak periods, respectively. The X49 dwell time was between 10 and 80 seconds, with an average of 30 seconds in the morning and 35 seconds in the afternoon. For northbound X49 buses, the average bus occupancy was 30 riders in the morning and 15 in the afternoon. For southbound X49 buses, occupancy was 20 in the morning and 35 in the afternoon.

3.3. Traffic Control Inventory

Western Avenue includes thirteen signalized intersections between 87th Street and 59th Street as shown in Table 3.1 in the previous section and in Figure 3.3 on the following page. In general, intersections that are not signalized have 2-way stop sign traffic control on the minor street.

3.3.1. Controllers

The Peek LMD40 Series controller is operated by CDOT at all signalized intersections in the study area. This controller can be programmed for a variety of sequences, either pre-timed or actuated, with 2- to 8-phase operation. Ten actuation inputs are available to allow phases to be programmed as both callable and extendible, without switching signal plans. The unused actuation time can be added to a selected interval to maintain the cycle length during coordination. The added time feature can be inhibited by time clock so that, during off-peak hours, the LMD40 can operate in a variable cycle length mode based on actual demand. In this mode, the controller can be set up to rest at the end of the main street green phase, where it will respond immediately to side street demand. Signal sequence information is customized to the specific intersection application. The LMD40 can store 8 unique signal plans and 5 preemption sequences. Data is programmed via a front panel keyboard, including signal plan and timing plan configuration. Two security codes are available, one for signal plan programming, and one for timing plan programming.

The controllers are capable of actuated control. However, no detection is provided at 59th, 63rd, 65th, 67th, 69th, 77th, 79th, and 83rd Streets so they operate in a pre-timed mode. These intersections have three timing plans selectable by time-of-day criteria, AM peak period, PM peak period and off-peak period. Presence detector loops are buried at 61st, 62nd and 74th so that these intersections operate with semi-actuated controllers, which means that controllers vary the length of different phases to meet demand on these streets.

3.3.2. Displays

Three vertical signal faces are typically provided for each through traffic direction at each intersection. Two are typically mounted over the sidewalk and the other is suspended over the roadway on a mast arm pole.

Left turn phases are shown as a separate phase as requested by traffic demand presence detector loops buried in the pavement at 61st, 71st, and 87th Streets. The length of these left turn phases varies based on demand.
Figure 3.3: Traffic Control in the Study Area

- 59th Street
- 63rd Street
- 67th Street
- 71st Street
- 75th Street
- 79th Street
- 83rd Street
- 87th Street

- Bus Terminal

Symbol meanings:
- Red circle: Pretimed Traffic Control
- Purple circle: Semiacutated Traffic Control
4. **Interfacing Systems**

On Western Avenue, the TSP system will function within a framework of existing and planned systems operated by the transit service providers and CDOT. Both CTA and Pace operate bus service in the study area. (The Pace service, route 349, is provided south of 79th Street.) Both agencies are in the process of developing automatic vehicle location systems as part of larger bus service management initiatives. CDOT, through its Bureau of Electricity, operates the traffic signal control system in the corridor.

4.1. **Automatic Vehicle Location Systems**

The planned automatic vehicle location (AVL) deployment programs for CTA and Pace will facilitate management and operation of transit priority activities through identification of vehicle location and schedule adherence information. In order to evaluate the ability to interface with CTA’s proposed Bus Service Management System (BSMS) and Pace’s proposed Intelligent Bus System (IBS), this report will address several key areas:

- On-board capabilities to provide location, schedule adherence, and passenger count data,
- Ability to communicate data to a traffic signal controller or signal system in order to initiate transit signal priority for one or more signalized intersections, and
- Current status of deployment for each of the systems.

Both of the systems utilize Global Positioning System (GPS) technology for accurate tracking and reporting of the locations of all GPS receiver-equipped vehicles. Both CTA’s BSMS and Pace’s IBS will provide the ability to store schedule information on the vehicles using an on-board computer and driver interface. In turn, this data can support features such as remote monitoring of schedule and headway adherence, display of real-time next stop information on board the bus, estimated time of arrival information to waiting commuters at bus stops, as well as selective output of transit priority signal actuations.

Both systems include deployment of automatic passenger counters (APCs) on a fraction (less than 20%) of the fleet. APC-equipped buses are typically assigned to routes on a rotating basis for data collection purposes.

4.1.1. **CTA Bus Service Management System (BSMS)**

CTA’s BSMS is based on Orbital Sciences Corporation’s (Orbital’s) ORBCAD system, which is being implemented along with a system-wide radio communications upgrade. The proposed BSMS wayside equipment includes spread-spectrum radios and antennae, processors that communicate with the on-board computers, NEMA-4 enclosures for the processors, and interconnect cable between the wayside processors and the signal controllers.
Orbital AVL systems in the past have supported two types of signal priority:

- Direct radio frequency or other (e.g., connection to strobe emitter) communication to local traffic signal controller requesting priority,

- Direct communication of location coordinates at a particular location in advance of a traffic signal, occurring between the bus and the central control center location (fixed end), with the AVL information translated into a format that can then be transmitted to a centralized signal system.

The BSMS has been designed by Orbital to provide communication directly to the signal controller using wireless digital packet communications. Given that the current City of Chicago traffic signal operations utilize arterial master operations, rather than a large central system (except in the downtown area), it is expected that the traffic signal controller will be the main focus of TSP functions.

The main implementation issue has been that the BSMS deployment has undergone considerable delay, and is not expected to be completed before the end of 2001. Use of the BSMS for providing bus location or schedule adherence information on Western Avenue would require the development of electronic schedule-location databases for any routes receiving TSP treatment. In addition, the BSMS’s use of RF communications between transit vehicles and roadside traffic signal controllers has not been tested.

4.1.2. Pace’s Intelligent Bus System (IBS)

Presently, Pace is responsible for fixed-route, paratransit / demand response, and vanpool transportation services in suburban Chicago. Although Pace directly operates most of the fixed route services, some services are contractor-operated. The Pace-operated fixed-route services are currently using voice radio communications for dispatching the buses. On the other hand, the contractor-operated services are dispatched by the contractor’s own personnel, using their own radio system, though the vehicles are owned by Pace.

Pace has contracted with Siemens to furnish and install its Intelligent Bus System. According to the Pace Intelligent Bus System (IBS) Specification dated June 2000, the IBS will include a Global Positioning System (GPS)-based AVL function that includes central monitoring of vehicle location, schedule adherence, and route adherence. While the existing Pace radio communication system is voice-based, the proposed IBS radio communication system will support voice as well as data packets over the analog system, as well as new fixed-end and mobile communications units. In addition, Pace plans to replace the existing analog radio system in approximately year 2003 with a digital radio system.

The IBS includes an on-board computing system with features similar to CTA’s. The IBS will support up to three vehicle-to-roadside communications systems for use in TSP applications, including transponder-to-pavement loop detector, optical, and video technologies. The transponder-to-pavement loop detector communications is the detection technology used on the initial Cermak Road demonstration project. Regardless of the communications technology used, on-board schedule adherence and other data will be used to make conditional priority requests, such as only when the bus is behind schedule. This conditional priority is in contrast to the
original Cermak Road demonstration, which requested priority each time a bus passed over a pavement loop.

The IBS includes deployment of door sensors on all buses, which may be used to trigger priority requests as the vehicle is leaving a near-side bus stop. The IBS also includes installation of automatic passenger counters on a sample of Pace buses (less than 20% of the fleet) that may be used in the development of priority requests based on certain loading conditions, such as requesting priority only when the bus exceeds a predefined occupancy threshold. However, this feature would not be available on all buses because of its limited deployment.

4.2. Traffic Signal Control Systems

The standard (upgraded) traffic signal controller used throughout the City of Chicago (except in the downtown area and in areas with adaptive traffic control) is the Peek LMD40 Series controller. CDOT uses this equipment at all signalized intersections in the study area. In general, CDOT and Bureau of Electricity personnel are satisfied with the performance of this controller in the City’s pre-timed and semi-actuated traffic signal network. CDOT has no current plans to change to a different standard traffic signal controller.

The LMD40 controller can be programmed for a variety of sequences, either pre-timed or actuated, with 2- to 8-phase operation. Ten actuation inputs are available to allow phases to be programmed as both callable and extendible, without switching signal plans. The unused actuation time can be added to a selected interval to maintain the cycle length during coordination. The added time feature can be inhibited by time clock so that, during off-peak hours, the LMD40 can operate in a variable cycle length mode based on actual demand. In this mode, the controller can be set up to rest at the end of the main street green phase, where it will respond immediately to side street demand. Signal sequence information is customized to the specific intersection application. The LMD40 can store 8 unique signal plans and 5 pre-emption sequences. Data is programmed via a front panel keyboard, including signal plan and timing plan configuration. Two security codes are available, one for signal plan programming, and one for timing plan programming.
5. General Requirements

In contrast to many earlier demonstrations of TSP treatment, such as along Cermak Avenue, the Western Avenue TSP system is required to have the capability to grant conditional priority to transit vehicles based on schedule adherence or other service parameters. In this manner, priority will only be granted to transit vehicles when they are running behind schedule or meet other service criteria. Like many transit signal priority systems, priority will also be granted only when the timing of the bus in relation to the intersection and the signal phase is such that the bus can make use of green extensions, red truncations, or other accommodations within certain predefined thresholds. Conditional priority requires an interface with a bus AVL system.

The Western Avenue TSP pilot project is also required to interoperate with existing traffic signal control systems in the study corridor. This technology review considers issues associated with implementing TSP treatments in other parts of the region where traffic control systems may differ. For this reason, the system requirements of the Western Avenue pilot project may differ somewhat from the system requirements described in this section based on the capabilities of the traffic control systems in the study corridor.

5.1. General Traffic Operations Needs

The following basic operational functions shall be included in the Transit Signal Priority System:

1. **Conditional Priority.** The proposed Transit Signal Priority System technology shall be capable of granting conditional priority to a transit vehicle, pending conditions related to the bus schedule, position of the traffic signal time cycle, or other conditions on the main roadway or cross street.

2. **Quick Recovery.** The proposed Transit Signal Priority System shall accommodate “force offs” and “holds” on the traffic signal timing cycle with minimal upset to the overall traffic flows for the main route and cross streets of the corridor.

Typical TSP elements include the ability to change signal timings, a communication system to allow data upload/download, and some type of operator workstation for determining the signal timings and provision of priority if a centralized control system is realized in the future. The existing system along Western Avenue provides the ability to modify signal timings and implement changes to the timing plans.

Figure 5.1 illustrates the required operational capabilities of the TSP system and related system goals for the Western Avenue corridor.
**Figure 5.1:**
Transit Priority Operational Capabilities Required to Satisfy System Goals

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Priority and activation of selected transit movements</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
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<tr>
<td>Adjust nature of transit priority movements</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Extended Main Street Green</td>
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<td>○</td>
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<tr>
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<td>Phase skipping</td>
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<td>Queue jumping</td>
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<td>○</td>
<td>○</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Ability to locate transit vehicles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communication between vehicles, central dispatch, and signal system</td>
<td>●</td>
<td>●</td>
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<td>●</td>
</tr>
</tbody>
</table>

**KEY:**
- ● Primary Satisfaction of Goal
- ○ Support Goal

These system-related goals include:

1. **Transit Signal Priority and Actuation of Selected Traffic Movements** – Identifying the presence of transit vehicles on the corridor will be a necessary component in providing transit priority. This requires the ability to detect transit vehicles in some fashion, with this detection in turn transmitted to the signal controller either locally or via the central system. Priority can be provided on a localized or centralized basis at minor intersections along the corridor. A communication system will be necessary for a centralized priority system as additional corridors are added.

2. **Ability to Adjust Nature of Transit Priority Movements** – Transit priority operations may involve different types of localized and corridor control schemes in order to provide preference to transit vehicles, as indicated below.
   - **Extended Main Street Green Phase.** Extended green phases will permit buses to clear the intersection in a timely fashion without stopping. This is considered to be the most common and most effective transit priority scheme, and provides the least delay to cross-street traffic.
   - **Early Main Street Green Phase.** Early greens may be provided once any conflicting minimum cross street movements, turning movements, and/or...
pedestrian clearances are safely completed. This often involves phase skipping or early phase termination once minimum green or clearance intervals have been provided.

- **Phase Skipping.** Upon notification that a bus is approaching the intersection, side street or conflicting left turn movements, along with cross-street pedestrian phases, may be skipped in order to assure that they do not get pre-empted prior to completion of a minimum green period or minimum clearance interval. This activity is most appropriate for situations where buses are behind schedule and are fully-loaded. Per a study presented in the “Journal of Public Transportation” (Vo.2, No. 2, 1999) by Michael Garrow and Randy Machemehl, the experience in Toronto, Canada, indicated that “truncation of red” (early green) tended to be less effective than green extensions, when considering cross-street traffic impacts. Thus, *side street phase skipping is most appropriate at those intersections with minimal cross street traffic volumes, typically a 3:1 ratio of major street per-lane volumes to minor street per-lane volumes.*

- **Queue Jumping.** Early green intervals may be provided exclusively to transit vehicles at intersections where buses have a near-side stop. This will assure that there is no conflict between the bus and right turning traffic. To ensure that this is done safely, right turns on red should be prohibited or specific signal indications should be provided to prohibit the right turn movement when the bus is in the near-side stop area as well as after its departure, until the bus has cleared the intersection. *Queue jumping is appropriate for those intersections with minimum cross-street traffic volumes.*

3. **Ability to Detect Presence and Monitor Location of Transit Vehicles** – As discussed above, CTA and Pace are deploying Automatic Vehicle Location (AVL) systems on their fleets, allowing for the tracking of transit vehicles. The AVL will include dispatching and schedule adherence monitoring systems. Other components of a transit priority system include standard passive detection (loops, microwave, or video image processing) or localized transponder / strobe light activation to provide a confirmation of transit vehicle presence as it arrives at the signalized intersection.

4. **Communications between Vehicles, Central Dispatch, and the Traffic Signal System** – In order to provide TSP to the extent necessary in a safe and efficient fashion without significant negative impacts to other vehicle operations, there must be the ability to communicate schedule adherence information from vehicles to both the transit operators’ central control centers and to the traffic signal system as the priority system grows.

To minimize disruption of coordination, signal timings along the priority route should be reconfigured in order to build in “early green” and “extended green” for the priority approaches as actuated phases. When the transit signal priority does not occur, the extra time would revert to an extended side street green or protected left turn movements (if actuated). The system would be required to allocate the appropriate amount of early green or extension, along with side street (or protected left turn) movements.

These components are additions to the typical provision of signal timings via controllers using pre-timed / time-of-day type operation. The implementation of real-time detection and controller
modifications introduces functional requirements and constraints that will be addressed later in this study.

5.2. **Compatibility with City of Chicago Traffic Control Equipment**

Two basic requirements for the planned field traffic control equipment with respect to compatibility with the existing system are presented as follows:

1. The equipment shall be capable of operating with the standard (upgraded) signal controllers in use by the City of Chicago, namely Peek LMD40 controllers. The equipment for interfacing with the traffic signal controller shall be housed external to the traffic signal control cabinet maintained by the Bureau of Electricity.

2. Data from the operation of the system shall be stored for remote downloading by either the transit agency, the Bureau of Electricity, or CDOT. The data shall be accessible locally, or through the communication systems associated with an interconnected traffic signal system or bus service management system.

Based on the Study Team’s discussions with Peek Traffic Systems, Inc., manufacturer of the LMD40 traffic controller, it will be possible to implement transit priority through one or more inputs to the controller. This is further addressed in the alternatives presented in Section 6.

5.3. **Functional Requirements (High-Level)**

This study will develop functional requirements, system architecture, and a concept design for the specific transit systems, traffic signal systems, physical conditions, and operational conditions in the Western Avenue study corridor. However, the development of the system design will secondarily consider issues of scalability and adaptability to other locations and traffic control environments in the region. The following high-level functional requirements were developed for an ultimate implementation in a corridor where TSP proves feasible and where traffic control systems may have capabilities not present in the Western Avenue corridor. Because of the desire to interoperate with existing traffic control systems, the functional requirements of the Western Avenue TSP pilot project may differ.

The functional requirements for the proposed Transit Signal Priority System are based on:

- Review of Required Capabilities,
- Understanding of Transit Priority Process,
- The Functions and Market Packages of the National ITS Architecture,
- Understanding of current Traffic Control System (TCS) functionality, and
- Understanding of proposed AVL operations.
The top-level operational functions of a transit priority system (described in Figure 5.2) include collection of traffic data (e.g., identification of bus presence), analysis of priority conditions (e.g., identification of whether bus is on or behind schedule and adjustment of the priority scheme based on this), and implementation of desired priority scheme (e.g., adjustment of signal timings and offsets to permit transit priority). Other operational requirements include database and maintenance support functions.

**Figure 5.2: Transit Signal Priority High-Level Process**

- **1. Identify Bus Presence**
- **2. Establish Schedule Adherence**
- **3. Analyze Priority Requirements**
- **4. Implement Desired Priority Scheme**

The identification of bus presence and the establishment of schedule adherence may involve some combination of traffic control system (TCS) and AVL capabilities. Accordingly, this has been grouped into a single set of requirements entitled “Data Collection.”

### 5.3.1. Data Collection

Data Collection shall include the following requirements:

1. **Monitor Vehicle Location and Characteristics.** The Transit Signal Priority System shall utilize an AVL system that recognizes transit vehicle location utilizing vehicle tracking location (e.g., GPS coordinates). The AVL system shall determine schedule adherence (ahead of, on, behind schedule), and shall recognize passenger loading information generated by on-bus systems, where available. This information shall be displayed to the driver on-board the bus and shall be transmitted to the transit management location (dispatch) according to the design of the transit operator’s AVL system.

2. **Collect Data from System and Local Detectors.** Where actuated or traffic-adaptive signal control systems are used, the Transit Signal Priority System shall utilize standard TCS capabilities to collect count and presence data from detectors at or near stoplines (local detectors) as well as from detectors located upstream from the intersection (system detectors), where traffic is typically operating at or near cruise speed.

3. **Advance input from transit vehicle.** The Transit Signal Priority System shall utilize advance inputs of transit vehicle presence, which shall be provided using one or more of the following alternative methods:
   - **Priority Request from Transit Vehicle** (e.g., Strobe Light Emitters, radio transmission, etc.) selected through automated means from the AVL system’s on-
board components. This function should be transparent to the transit vehicle operator.

- **Passive Detection**, occurring through some means of transit vehicle classification or through some on-board device that communicates with the detection function. Examples include loop detectors with unique classification amplifiers, radar detectors, or video image processors, each with algorithms that classify the transit vehicle in a unique fashion or that “read” a particular component on a bus such as a windshield-mounted or underbody radio-frequency identification tag.

### 5.3.2. Priority Analysis Requirements

The TCS and AVL system shall have the capability to work in a coordinated fashion as described below:

1. **Correlate AVL data and location to Priority Signal Location.** The AVL system (either centrally or on-board the bus) shall correlate information on bus location with the location of intersections where TSP is supported.

2. The TCS, to support TSP operations, shall have the ability to:
   
   - **Respond to input from local detectors (normal traffic).** Controller shall be able to adjust signal timings and call upcoming phases based on input from traffic detectors at the intersection.
   
   - **Respond to transit priority detection based on advance input from transit vehicle.** System or controller shall respond to local priority, detector or AVL location data in determining the need for priority at a local intersection.
   
   - **Process data and provide resulting commands.** The system or controller shall select appropriate timing plans and system actions based on the collection of specific traffic detection and priority actuation data.
   
   - **Permit monitoring, analysis, and review of system performance.** The system shall provide the ability to calculate delay, stops, fuel consumption, and environmental impacts based on real-time detector and signal timing information.
   
   - **Archive operations data.** The system shall maintain an activity log available for remote downloading and archiving by CDOT.
5.3.3. Implementation of Priority Scheme

The following requirements provide a set of TCS requirements that are broadly applicable throughout the region. The implementation on Western Avenue may have only a subset of these requirements, given the desire to integrate with existing traffic control systems.

1. **Timing Options.** The system or controller shall be capable of selecting a timing plan based on specific traffic flow pattern criteria, which could include some function of traffic volume and weighted occupancy (percentage of time in which vehicles are passing through detection zones). (Requires system detection.)

2. **Download/Upload Timing Plans.** The system shall be capable of downloading signal timing plans to one or more controllers in the field. Conversely, the controller shall be capable of receiving timing data from central or master locations, and shall be capable of providing information on existing settings, timings, and operations to the system operator.

3. **Fully-actuated (all approaches and phases based on vehicle presence).** The system and controller shall permit all traffic movements to be actuated based on vehicle presence, and movements shall be programmed for phase-skipping should there not be vehicle presence.

4. **Semi-actuated operations.** The system and controller shall permit actuation of selected signal phases for approaches not utilized every cycle, permitting reduction in unnecessary delay to major traffic flows.

5. **Signal preemption (emergency and transit).** The system and controller shall permit signal preemption without violation of minimum green and clearance timings on conflicting phases. Preemption directly from the vehicle or from central control input shall be possible.

6. **Allocation of timings.** For a given coordinated cycle length and offset, controller shall be capable of allocating the appropriate amount of early green or green extension for transit priority, as well as the corresponding amount for side street (or protected left turn) movements.

7. **Priority recovery.** The system shall integrate transit signal priority operations into the intersection phase sequences where it is required, such that minimal time is needed to restore operations.

8. **Future Real-time Adaptive Control.** Where it proves to be feasible based on modeling and traffic analysis, the controller may have the capability of receiving real-time platoon length and arrival data for the purposes of adjusting a phase green start and finish time, plus calculation of phase and cycle lengths on a cycle by cycle basis. Data may be received either from central system based on central calculation or provided to a single controller from upstream controllers.
5.3.4. Maintenance of Transit Priority Data

The Transit Signal Priority System shall require the TCS to perform the following:

1. **Maintain priority timing algorithms and routines.** The system and controller shall permit specific timing plans, algorithms and routines at the controllers to be implemented based on the detection and transit vehicle priority information discussed above, including location, route type, schedule adherence, and potentially passenger loading information.

2. **Provide time synchronization.** The system shall provide a single network-wide time base for all controllers, calibrated to a recognized time standard such as that provided through radio coordination to the WWV national time clock.

5.3.5. Support of System Maintenance Activities

The Transit Signal Priority System shall require the TCS to have the following system capabilities:

1. **Monitor failure status of field equipment.** The system shall monitor any display, communications, or operational failures in the controller, cabinet, or for any of the displays.

2. **Monitor phase status.** The controller shall display current phase and next phase status as well as detector actuation and priority request data for next/upcoming phases.

5.4. Operational Requirements

The Transit Signal Priority System will have a number of operational requirements. These have been developed based on the National ITS Architecture as well as pertinent NEMA and emerging National Transportation Communications and ITS Protocol (NTCIP) standards. Currently, AASHTO and ITE are undertaking activities that will result in operational standards for Transit Signal Priority that will be incorporated into NTCIP. In the development of a preliminary design in Section 9, WSA will incorporate these draft standards as they are developed in more detail and are deemed relevant and practical for deployment in this project. They are discussed in further detail below.

5.4.1. Communications and Hardware Interconnect

The Transit Signal Priority System will include several different communications links. These links will have specific requirements associated with enacting transit priority, but will also be fully integrated with other TCS activities. Specific communications requirements include:

1. **Signal Display to Controller.** Local interconnect of signal displays to the controller shall be handled through local power supply, with load switches and conflict monitors provided; conflict monitors shall meet all pertinent NEMA standards to assure that conflicting signal indications are not displayed.
2. **Controller to Controller.** Depending on the system options considered, communication between controllers may be utilized in order to monitor upstream and downstream traffic flows and transit vehicle presence. This option may be considered for signalized intersections that are relatively closely spaced and have no bus stop locations between them, and may reduce the costs of deploying communications receivers or priority request sensors at individual intersections. If central TCS operations are implemented, such functionality may be used as a “back up” for centrally supervised operations.

3. **Controller to Central / Master.** Depending on the system options considered, communications between controllers and either area masters or the central system shall be provided in order to:
   - permit selection of signal timings
   - provide uploads of current timing parameters to a central location
   - provide downloads of signal timing parameters and plans to the controller
   - monitor detector traffic flow and vehicle presence information
   - provide direct control of signal operations (if a central control configuration is utilized for the TCS in the future)

4. **Transit Vehicle to Signal Controller.** Transit Priority requests shall utilize either direct communication of transit vehicle presence to the intersection controller, either in lieu of, or in addition to, detectors provided in advance of signalized intersections.

### 5.4.2. Future Option - Operator Control

The following section describes the high-level functional requirements for a potential future centralized control system, should that be utilized for both standard TCS activities as well as the Transit Signal Priority System:

1. **Operator Control and Monitoring** shall be provided at a central location where access to both traffic engineering and transit operations capabilities is easily provided, either with on-site presence or through close coordination of operations between transit agency staff and the City of Chicago Traffic Engineering staff.

2. **Operator Interface.** The system shall provide a user interface that accesses one or more traffic signal locations or roadway segments within the system for the purpose of controlling and/or monitoring current operations mode, signal timing parameters, timing plans, traffic-responsive or adaptive timing parameters, and time-of-day schedules. The interface shall access current priority status and its display shall be able to monitor the location of buses along the corridor(s).

3. **System and Area-Wide Monitoring.** To provide a complete assessment of transit and traffic operations in the area, it is necessary to be able to access current signal, traffic flow, and transit vehicle location on a continuous basis. Thus, displays and interfaces...
need to provide immediate access to any controller or device within the priority system concurrently.

4. **Controller Commands.** Provide specific controller commands that support real-time information on traffic flow and transit vehicle location. These shall include the following:

- Phase/green extension
- Phase early start or red truncation
- Red interrupt or special phase
- Phase suppression/skipping
- Queue jumping (advance phase for buses leaving a near-side stop)
- Compensation
- Window stretching (adjustment of start and finish of green to permit priority progression)

5. **Built-In Transit Signal Phasing.** Signal phasing and operations will be best served through developing phasing schemes that “build in” transit priority phases as follows:

- Early green on bus approach, truncate maximum side street green extension interval
- Extended green on bus approach, begin side street green later, shorten maximum side street green extension interval

5.4.3. **System Standards**

The following section addresses candidate standards to be addressed by the Transit Signal Priority System; either implemented through this project or incorporated in the TCS and AVL systems that will be utilized for transit priority. Overall standards shall be based upon NTCIP, which contains several related standards and communications profiles. These shall include, but are not limited to, the following:

- NTCIP 1401 – Transit Communications Interface Protocol (TCIP) Framework Standard
- NTCIP 1101 – NTCIP Simple Transportation Management Framework

Information on individual standards can be obtained at the following Internet URL:
Field Communications Standards

For future controller replacements, NTCIP Actuated Signal Control (ASC) standards shall be followed in order to assure that the agencies are not “locked” into specific products or vendors and that expansion of system size and functionality may be accomplished without replacement of existing field and system components. System shall support both NEMA-type controllers and emerging technologies including Advanced Traffic Controllers (ATC). NTCIP standards relevant to this shall include the following:

- NTCIP 1201 – NTCIP Global Object Definitions
- NTCIP 1202 – NTCIP Object Definitions for Actuated Traffic Signals
- NTCIP 1209 – NTCIP Object Definitions for Transportation Sensors
- NTCIP 2201/2202 – Transport Profile
- NTCIP 2101/2102 – Subnet Profile

Mapping and Location Standards

In order to assure a common basis for transit vehicle location information and traffic signal locations, map engines and location coordinates for both the CTA and Pace planned AVL system should be related to the TCS Intersection coding convention such that the interface between systems does not require extensive “translation” on more than one side. One set of standards that may be considered is NTCIP 1405, “TCIP Spatial Representation (SP) Business Area Standard.” It is noted that the Gary-Chicago-Milwaukee Corridor is utilizing Navigation Technologies’ map standards and is in the process of updating a regional license for using the map engine and coordinates for the purposes of traveler information and operator displays.

Vehicle-to-Roadside Interface Standards

The information related to on-board operations and status should follow NTCIP 1406, “TCIP On-Board Objects”. These interfaces need to address the transmission of priority request data, and the data needed to interface between on-board AVL systems and any separate technology utilized to communicate with traffic signals (e.g., control of a strobe emitter communications system in lieu of local packet radio communications to a controller).
6. Technology Alternatives

This section begins with a discussion of various constraints associated with operation of traffic signals and transit services along Western Avenue, particularly associated with the different forms of TSP technology either under development or implemented by both CTA and Pace. Based on this discussion, two potential technology options are identified to permit deployment of a Transit Signal Priority System along Western Avenue.

Currently, there are two TSP approaches that have been defined to date: pavement loop detector approach, which was implemented under an Operational Test sponsored by Pace and the Illinois Department of Transportation along Cermak Road; and the radio frequency approach, which is being implemented as part of the CTA BSMS development efforts along Martin Luther King, Jr. Drive.

6.1. Comparison between Current TSP Approaches

The CTA BSMS and the Pace IBS both utilize GPS-based location strategies and communications to accurately locate buses on the network and support schedule adherence monitoring and dispatch activities. However, there are a number of differences between the two systems as they have been specified. Additionally, both systems are in various stages of deployment and are not yet in full operation.

Current transit priority approaches either in place or under development in the region include the following:

1. **Radio Frequency:** CTA has included in the BSMS a requirement for digital packet communications between buses and local controllers. This communication would occur in advance of departing a bus stop, and would issue a priority request for the next signal to enact its priority routine in order to reduce delay in clearing the intersection and reaching the next stop. The priority request would be issued based on the actual location coordinates programmed in the database (e.g., departure from bus stop) as well as whether the bus was on or behind schedule. At the controller location, a wayside radio receiver housed in a NEMA-4 enclosure would be connected to one of the signal controller’s special functions, where it can serve as an input to the local TSP routine.

   Alternatively, a similar concept has been used elsewhere by Orbital for communication to a strobe emitter, such as that provided by 3M (Opticom). An interface from the onboard computer to the strobe emitter permits a similar function to occur. This requires installation of a strobe receiver on the signal mast arm, which is then connected to one of the signal controller’s special functions as an input to the local TSP routine.

2. **Pavement Loop:** IDOT, in coordination with Pace, tested the use of specially-developed induction loop detectors in association with special on-vehicle transmitters located undercarriage. The LoopCom “hockey puck,” so-named because of its size and shape, when it passes over the loop detector, transmits a “signature” which alters the impedance input to the detector, and thus indicates bus presence. The loop is wired to a special function in the Econolite 2100 closed loop, inter-connected NEMA signal controllers
used in the corridor, and transit signal priority is implemented based on the bus detection by adding seconds to the trailing green phase. The TSP input is implemented using a small piece of additional equipment (approximately the size of a loop amplifier) in the signal controller cabinet that runs the proprietary TSP software.

When the LoopCom approach is used with a continuously activated transponder, it permits a passive transit priority request to be implemented. However, the Pace IBS specification requires that future implementations of the transponder permit activation only when certain conditions are sensed by the on-board computer, such as a bus running behind schedule. The Pace IBS specifications also require that the system support conditional priority using alternative detection technologies in the future.

6.2. Potential Alternatives to Interfacing with City Traffic Signals

There is overlap of CTA and Pace operations between 79th to 87th Streets, which would require that transit signal priority activities accommodate both systems. Given that the Pace system uses (at least initially) a different detection system than the CTA, there are two potential short-term alternatives that may be considered:

6.2.1. Interface Alternative 1: Support Two Priority Detection Systems

This alternative involves support of both the radio communications from BSMS-equipped CTA vehicles and the LoopCom or equivalent loop detection system and transmitters for Pace vehicles. Both devices would be connected into the local signal controller and would provide the same type of priority request. This concept is illustrated in Figure 6.1. The concept would require either:

(a) Accommodation of two separate types of priority input into the signal controller through RS-232 inputs, or

(b) A “black box” type integration of the two different types of priority requests such that only one controller input is required.

Of the two concepts above, (a) provides a more elegant and cost-effective solution, reducing the specialized equipment that would need to be developed. A primary disadvantage would be the need to provide additional field hardware, including the installation of in-pavement loops, which require additional maintenance as well as temporary maintenance-of-traffic measures during installation.

Additionally, the above solution is dependent on the deployment and successful testing of the CTA BSMS system, which includes the radio communication capability to the local controller location in advance of the intersection. Further delays in that deployment would cause further delays in successfully deploying the Western Avenue Transit Signal Priority System. The Pace IBS deployment is not as significant an issue due to the prior experience and current operation of transit priority strategies using the LoopCom system.
6.2.2. Interface Alternative 2: Implement Single Technology for Priority Request

Depending on the completion schedule for AVL systems, it may be appropriate to consider a more flexible transit priority detection scheme that can operate both with and without various types of AVL systems, and can be shared by both CTA and Pace buses. This would be particularly useful for implementation in other corridors and for flexible alteration of CTA and Pace bus operations.

This interface alternative (Figure 6.2) looks at implementation of a common priority request detection system for both CTA and Pace. Some potential sub-alternatives are listed as follows:

1. Migration of Pace IBS system to similar RF communications as are being implemented by CTA. This would provide region-wide standardization and compatibility for all buses and eventually all signals. This would likely be the most expensive and elaborate option, but would ultimately support regional compatibility as defined by the GCM Corridor Strategic Plan and the Northeastern Illinois ITS Strategic Early Deployment Planning Study.

2. Strobing or infrared signal to a mast arm-based receiver (similar to 3M’s Opticom system) would provide a common priority basis for both systems. While it would require modifications to the proposed CTA BSMS scheme for priority (the onboard computer would interface to the strobe emitter rather than through RF to a wayside receiver), the technology is
proven. In addition, optical traffic signal preemption systems have been installed in more than 90 suburbs for emergency vehicle purposes and some of the installed base of hardware could be reused for TSP.

3. **Implementation of Loop/Transponder Priority System (e.g., LoopCom).** This would involve implementation of specially-equipped loop detectors along with conditionally activated under-bus transmitters. Given both the cost of adding street and bus hardware throughout the City, this sub-alternative is not recommended.

**Figure 6.2: Interface Alternative 2:** Integrate CTA and Pace Priority Technologies

*Diagram showing the integration of CTA and Pace Priority Technologies with LMD40 Controller and CTA Bus Control Head.*
6.3. Technology Review

For the alternatives described above, review of technologies and applications used elsewhere will be very useful in helping determine the best approach for Western Avenue as well as future TSP applications in the City of Chicago. Various detection methods and approaches influence the data quality, resolution and density. These various detection methods differ in cost and level of implementation, but all may have similar ability to influence signal timings and local operations.

6.3.1. Types of Systems

There are three types of detection systems defined by Paul Olson [“Discussion 1: Traffic Signal Priority, Transit Operations.” Correspondence, September 13, 1999] namely zone, point and continuous.

1. **Zone:** The zone detection system simply says that the vehicle is within this zone but not exactly where. **Technologies:** Optical signal (infrared or strobing) or radio frequency signal, e.g., packet radio (CTA’s proposed method for the BSMS demonstration).

2. **Point:** Determines that the vehicle is at a certain fixed point at a certain time. Location is only detected at the fixed point; it is not known elsewhere. **Technologies:** Automatic Vehicle Identification (AVI) systems using Dedicated Short-range Communications (DSRC), Loop-Detector Based Systems (e.g., Pace’s “hockey puck”), Vehicle Odometer Based Systems, Sign-Post Systems.

3. **Continuous:** Continuous detection is a special form of point detection, but with continuous or frequent sampling of location. **Technologies:** GPS, multiple AVI. Through development of predictive travel time or arrival information based on this continuous tracking, schedule adherence information may be obtained for locations downstream of a particular transit vehicle, thus supporting real-time passenger information services.

Of the above, some combination of point and zone detection is appropriate in order to establish a specific request for priority. Point detection could result in a request for priority, while zone detection indicates that the vehicle is approaching. A vehicle entering the beginning of a physical zone could provide a point-based priority request, with the presence in a particular zone permitting the maintenance of the priority request, and the departure from the zone (another point detection) resulting in the completion of the priority routine.

6.3.2. Technology Experiences

Numerous demonstration projects providing priority to transit vehicles at signalized intersections have been initiated in the past, but not all have remained as permanent systems. Many systems experience significant difficulties and delays associated with routing a priority request through a central control facility, most starting at isolated intersections. Many earlier installations also did not involve the use of traffic signal controllers that could provide adequate flexibility to support transit priority. More recent implementations have yielded improved results. The following provides discussion of specific technology and application experiences.
Transit Detection Applications

The signal from the bus to controller may be transmitted through various technologies including:
(1) under-bus emitters to in-pavement loop detectors (e.g., Pace’s current technology); (2) light
emitters and receivers (the predominant technology used for emergency signal pre-emption and
for many transit priority schemes to date); or (3) radio frequency emitters and receivers (packet
radio, Automatic Vehicle Identification tags, or similar). Bus detection equipment costs vary by
application; approximate costs of three makes of equipment are provided for comparison:

- **Opticom by 3M** - emitters $1,000 per bus, $400 per direction per intersection, plus signal
  interface and software
- **TOTE by TOTE, Inc.** - RF tags $35 per bus, RF readers at roadside $1,000 per
  intersection, plus signal interface and software
- **LoopCom by Detector Services** - transmitter $150 per bus, $7,500 per intersection, plus
  signal interface and software

Examples of transit detection applications include:

**LoopCom System: Cermak Road, Berwyn, Illinois** - A recent installation, the Illinois DOT and
Pace participated in the development of a passive signal priority application. Transponders
mounted under buses (“hockey pucks”) would transmit a signal though existing and auxiliary in-
pavement detector loops to a NEMA controller. Customized logic in the controller senses the
arrival of a bus in the control zone and provides an early green (red truncation) or extends a green
interval within a coordinated signal system operation. IDOT has evaluated system performance,
and, along with Pace, appears to be satisfied with the performance of this system, which has
resulted in improved schedule adherence and greater operating speed for Pace vehicles.

**Opticom System: Charlotte, North Carolina** – Most applications of Opticom throughout the U.S.
have been in support of emergency vehicle pre-emption, with some applications in Los Angeles
and New Orleans for transit, generally with mixed success. The City of Charlotte instituted the
application of an Opticom signal preemption system for buses in the mid-1980’s. Selected
express buses are equipped to emit the signal preemption signal that can be received at 11
intersections along more than 4 miles of Central Avenue. The system has been reported to reduce
bus delay for the express buses by 67 percent in the area of priority treatment.

Vehicle Tracking and Management Applications

In addition to CTA, many larger transit properties, such as New York and Toronto, have installed
or are installing automated vehicle location and computer aided dispatch (AVL/CAD) systems.
Two key reasons for deployment of these systems include:

- Allows transit users to access real-time information on the location of buses prior to
taking trips or while en-route (improvement of customer service and support of regional
traveler information needs), and
• Allows transit operators to track the progress of its buses while on their routes. This provides operators with the opportunity to adjust, based on real-time information, the bus schedules to allow for timely transfers and to maintain bus headways according to policy or schedule.

Vehicle tracking and the real-time location information that it provides also supports the use of traffic signals to help keep buses on schedule, through TSP. Real-time location information can be used to automatically extend or truncate signal phases to allow buses to remain on schedule and maintain optimum headways along the routes. TSP systems can often be implemented concurrently with AVL systems, as is the intent of CTA’s BSMS deployment. This not only saves hardware costs, but also permits conditional priority. For example, priority may be denied to a bus that is running ahead of schedule, so that it does not get further ahead of schedule. Also, it does not leave the decision of priority to the driver, who might want to finish his or her route as quickly as possible.

Some concerns with transit priority include the potential negative effect on traffic on the side streets intersecting the main road. A careful analysis of traffic signal timings, traffic volumes, and lane configurations will determine the applicability of priority schemes. Some examples of the use of vehicle tracking with traffic signal priority/preemption are presented as follows:

Montgomery County, Maryland – Currently, Montgomery County, Maryland has installed AVL technology on its Ride On transit vehicles. The county also has a full-featured Traffic Management Center (TMC) that includes traffic signal control. The TMC receives location and on-time status information from vehicles, processes it, and sends directions to the signal controller that: 1) priority is not necessary because the signal is already in or about to change to a green phase; 2) grant priority by extending the green phase; or 3) deny priority based on a combination of signal phasing, vehicle schedule adherence, impact on traffic in the vicinity, or known special events. The TMC has the capability to deny all priority requests based on traffic incidents such as special events, weather conditions, etc. Additionally, when implemented, Montgomery County is considering integrating automatic passenger counting data into the signal priority algorithm so that an extended green cycle would only be granted if the transit vehicle were carrying a specified minimum load.

Seattle, Washington Area – The Washington State Department of Transportation (WSDOT) uses AVI data to implement traffic signal priority treatment. In addition to using bus location information to help determine when to grant priority, the agency uses buses as probes to determine the effect of priority on traffic flow. One of the greatest concerns with this program was TSP’s effect on traffic flow. Since the region allowed priority only if a vehicle was behind schedule, it was clearly important that significant impacts on crossing traffic be avoided. WSDOT has also looked into the use of Automatic Passenger Counters data to determine if a bus was at a threshold of capacity.

The selected system configurations are as follows:

• The system would be required to identify the bus within 25 ft. of a specified location, i.e., an antenna / reader location;

• Upon verification by the antenna / reader, a signal would then be relayed to a black box – the smarts of the system – which would determine the eligibility for priority;
If priority is warranted, then a signal would be sent to the low priority input of the traffic signal controller;

Upon receipt of the low priority input, the signal controller would process the routines necessary for implementation of each signal agency’s predetermined control strategy.

Control strategies considered included green extension/red truncation, lift strategy (upstream detection identifies the priority vehicle and the controller responds by placing a hold by ‘lifting the detection calls’ on all phases after servicing clearance but the transit phase), queue jump, and Optimized Policy for Adaptive Control (OPAC) for person-responsive priority.

The system design included the following four major components:

1. Buses carry devices for storing its data (transponder) to relay to roadside device.

2. Antennae are used to transmit the signal that triggers the on-board equipment to transmit data.

3. Roadside reader / RF modules emit a signal that triggers the transponder. Data is then relayed to fourth component.

4. Black box (interface module). This component makes the decision to issue priority after scanning the data for necessary criteria.

Orlando, Florida – Lynx Transit’s LYMMO service, a free downtown shuttle, uses signal preemption and an AVI-based location system. More than 90,000 passengers per month utilize the service, which operates 7 buses in a circuit through downtown Orlando. The signal priority operations are tied to the exclusive use of bus lanes and AVI detection. The system has been somewhat less successful in terms of the operation and maintenance of information kiosks and location displays as well as in the tracking of vehicle location.

6.4. Recommendations

For the near future, it is expected that TSP activities will build upon existing traffic control technologies. However, the ultimate system design, through definition of key interfaces, should permit implementation of upgraded traffic control systems without replacement of on-bus or bus-to-roadside communication technologies. For this reason, the regional and national ITS architecture schemes, which support a tight integration of information capabilities, should be applied in the design of the system. Integration of multiple traffic control systems of different origins and interfaces, while it will introduce a level of complexity, is feasible provided that key interfaces between different systems, as well as operational strategies, are well-defined.

6.4.1. Technology Alternatives

The two alternatives discussed in Section 6.2 are compared below in terms of the basic functionality required. The comparison addresses specific trade-offs with respect to system functionality.
• Alternative #1: Peek LMD40 controller with transit priority inputs from CTA bus (packet radio) and from Pace bus (special loop detectors).

• Alternative #2: Peek LMD40 controller with transit priority inputs from identical priority detection technologies for CTA and Pace buses, e.g., Opticom or RF transmission.

The key trade-off area involves the standardization of the interfaces to the Peek signal controller, and ultimately, to other types of future controllers to be implemented in the City as well as in suburban areas (for future deployments). Alternative #2 provides the opportunity to standardize the inputs to the Peek controller (and future controllers) and to standardize transit priority throughout the region, which could reduce the cost of street hardware modifications as a result of the economies of scale associated with a regional transit priority deployment. On the other hand, the Peek controller does have the ability to handle two different types of priority requests under Alternative #1. To do this would require street hardware including installation of loop detectors in some locations along Western Avenue, wayside RF receivers in all locations, and both in those locations with overlapping CTA and Pace service.

Given that Pace has not selected the same AVL vendor as CTA, it is difficult to determine if it will be possible for Pace to replicate CTA’s BSMS approach to transit priority request, without the BSMS vendor (Orbital) providing a published protocol and compatible radio systems.

In addressing the trade-offs, it appears that both alternatives are technically feasible, assuming that the proposed RF transmission function for the CTA BSMS is tested and implemented. However, in terms of developing regional operational compatibility, it is recommended that a single technology for transit priority in the region be adopted, as described by Alternative #2. As discussed above, the ability to exactly replicate the CTA BSMS transit priority approach for the Pace IBS depends on there being technical compatibility between both systems and the ability to support the same priority request data and RF communications scheme.

6.4.2. Detection Options

The use of IR or strobe-light sensors is a proven technology and can be integrated with current and future AVL implementations. RF communications, while it involves somewhat less communications hardware and field equipment, may be somewhat less reliable depending on frequency conditions and potential for interference, especially for deployment elsewhere in the City where radio transmission may be constrained by surrounding buildings, Midway airport, or other obstacles.

It is recommended that infrared or optical detection be considered as the bus-to-TSP controller technology for the Western Avenue TSP pilot project. This technology has been implemented in more than 90 suburbs to facilitate emergency vehicle signal preemption and thus provides an installed base of hardware for future region-wide implementation.
7. Concept Design

Transit signal priority (TSP) is a strategy agreed to by traffic management and transit management agencies to prioritize transit vehicle flow through signalized intersections based on certain criteria and conditions. The objective of the strategy is to minimize traffic disruption while optimizing passenger volume through an intersection.

This section presents a concept design for the TSP pilot project on Western Avenue. The section begins with a discussion of technical features of the system in the context of the National ITS Architecture. A generic discussion of TSP treatments and their relationship to other ITS initiatives serves as an introduction to the preliminary system architecture and concept design for the pilot project. The section concludes with a discussion of the physical modifications in the corridor required to support TSP.

7.1. National ITS Architecture

The discussion of TSP and its relationship to the market packages, subsystems, equipment packages, and other components of the National ITS Architecture are derived from architecture documentation published by the U.S. Department of Transportation.

7.1.1. Market Packages

In the context of the National ITS Architecture, TSP is part of the Multi-Modal Coordination Market Package, which is depicted in Figure 7.1 on the following page. This market package establishes two-way communications between multiple transit and traffic agencies to improve service coordination. Intermodal coordination between transit agencies can increase traveler convenience at transfer points and also improve operating efficiency. Coordination between traffic and transit management is intended to improve on-time performance of the transit system to the extent that this can be accommodated without degrading overall performance of the traffic network. More limited local coordination between the transit vehicle and the individual intersection for signal priority is also supported by this package.

Where TSP technology is also used to provide signal preemption for emergency vehicles, the Emergency Management Market Package is also relevant. However, this pilot project on Western Avenue is not expected to specifically include this functionality.
7.1.2. Subsystems

The Multi-Modal Coordination market package includes four subsystems:

1. Transit Vehicle Subsystem
2. Roadway Subsystem
3. Traffic Management
4. Transit Management

The Transit Vehicle Subsystem (VS) resides in a transit vehicle and provides the sensory, processing, storage, and communications functions necessary to support safe and efficient movement of passengers. The Transit Vehicle Subsystem collects accurate ridership levels and supports electronic fare collection. An optional traffic signal prioritization function communicates with the roadside subsystem to improve on-schedule performance. Automated vehicle location functions enhance the information available to the Transit Management Subsystem enabling more efficient operations. On-board sensors support transit vehicle
maintenance. The Transit Vehicle Subsystem also furnishes travelers with real-time travel information, continuously updated schedules, transfer options, routes, and fares.

The Transit Management Subsystem (TrMS) manages transit vehicle fleets and coordinates with other modes and transportation services. It provides operations, maintenance, customer information, planning and management functions for the transit property. It spans distinct central dispatch and garage management systems and supports the spectrum of fixed route, flexible route, and paratransit services. The subsystem's interfaces allow for communication between transit departments and with other operating entities such as emergency response services and traffic management systems. This subsystem receives special event and real-time incident data from the traffic management subsystem. It provides current transit operations data to other center subsystems. The Transit Management Subsystem collects and stores accurate ridership levels and implements corresponding fare structures. It collects operational and maintenance data from transit vehicles, manages vehicle service histories, and assigns drivers and maintenance personnel to vehicles and routes. The Transit Management Subsystem also provides the capability for automated planning and scheduling of public transit operations. It furnishes travelers with real-time travel information, continuously updated schedules, schedule adherence information, transfer options, and transit routes and fares. In addition, the monitoring of key transit locations with both video and audio systems is provided with automatic alerting of operators and police of potential incidents including support for traveler activated alarms.

The Roadway Subsystem (RS) includes the equipment distributed on and along the roadway which monitors and controls traffic. Equipment includes highway advisory radios, dynamic message signs, cellular call boxes, CCTV cameras and video image processing systems for incident detection and verification, vehicle detectors, traffic signals, grade crossing warning systems, and freeway ramp metering systems. This subsystem also provides the capability for emissions and environmental condition monitoring including weather sensors, pavement icing sensors, fog etc. HOV lane management and reversible lane management functions are also available. In advanced implementations, this subsystem supports automated vehicle safety systems by safely controlling access to and egress from an Automated Highway System through monitoring of, and communications with, AHS vehicles. Intersection collision avoidance functions are provided by determining the probability of a collision in the intersection and sending appropriate warnings and/or control actions to the approaching vehicles.

The Traffic Management Subsystem (TMS) operates within a traffic management center or other fixed location. This subsystem communicates with the Roadway Subsystem to monitor and manage traffic flow. Incidents are detected and verified and incident information is provided to the Emergency Management Subsystem, travelers (through Roadway Subsystem Highway Advisory Radio and Dynamic Message Signs), and to third party providers. The subsystem supports HOV lane management and coordination, road pricing, and other demand management policies that can alleviate congestion and influence mode selection. The subsystem monitors and manages maintenance work and disseminates maintenance work schedules and road closures. The subsystem also manages reversible lane facilities, and processes probe vehicle information. The subsystem communicates with other Traffic Management Subsystems to coordinate traffic information and control strategies in neighboring jurisdictions. It also coordinates with rail operations to support safer and more efficient highway traffic management at highway-rail intersections. Finally, the Traffic Management Subsystem provides the capabilities to exercise control over those devices utilized for AHS traffic and vehicle control.
7.1.3. Equipment Packages

Each of the four Subsystems is associated with an Equipment Package related to providing TSP treatment:

1. Transit Vehicle Subsystem: On-board Transit Signal Priority
2. Roadway Subsystem: Roadside Signal Priority
3. Traffic Management: TMC Multi-Modal Coordination
4. Transit Management: Transit Center Multi-Modal Coordination

The On-Board Transit Signal Priority Equipment Package provides the capability for transit vehicles to request signal priority through short-range communication directly with traffic control equipment at the roadside. This Equipment Package is associated with two Architecture Flows: the local signal priority request from the Transit Vehicle Subsystem to the Roadway Subsystem, and the transit vehicle schedule performance from the Transit Vehicle Subsystem to the Transit Management Subsystem. This Equipment Package is also associated with Process Specification (PSpec) 4.1.2.5.

The Roadside Signal Priority Equipment Package provides the capability to receive vehicle signal priority requests and control roadside signals accordingly. This Equipment Package is associated with four Architecture Flows: the local signal preemption request from the Emergency Vehicle Subsystem to the Roadway Subsystem, the local signal priority request from the Transit Vehicle Subsystem to the Roadway Subsystem, signal control data from the Traffic Management Subsystem to the Roadway Subsystem, and the request for right-of-way from the Roadway Subsystem to the Traffic Management Subsystem. This Equipment Package is also associated with PSpecs 1.2.7.1 and 1.2.7.3, but only 1.2.7.3 has substantial applicability to the pilot project.

7.2. Preliminary System Architecture

The Western Avenue TSP solution is envisioned as a subset of the functions supported by the National ITS Architecture. Because of the requirement to interface with existing systems, including the City’s local traffic signal control system, and CTA’s Bus Service Management System (BSMS), certain peripheral functions are provided by existing systems and are considered external to the project or are not supported. For example, communications between buses and the Transit Management Subsystem (CTA’s Control Center) are provided by the existing BSMS. Similarly, communications between the roadside traffic signal controller and the Traffic Management Subsystem (under development by the City) is provided by existing logging and dial-up communication functions of the Peek LMD40 traffic signal controller.

Because the proposed TSP system decentralizes TSP requests to vehicle-to-roadside communications at each intersection, certain functions supported by the National ITS Architecture are not included. For example, no systematic communications between the City’s Traffic Management apparatus and the CTA Control Center are considered part of the project. These communications are typically used with centralized bus management systems and centralized traffic signal control systems, such as in Columbus, Ohio.
Figure 7.2 illustrates the preliminary system architecture for the Western Avenue TSP pilot project. This basic system architecture is applicable to multiple bus service providers and multiple traffic signal control system throughout the region. The concept design employs an optical vehicle-to-roadside communications system, which has been used extensively for emergency vehicle preemption and transit vehicle priority applications throughout North America. The basic technology is available from multiple vendors and has been in use for more than 20 years.

**Figure 7.2: Preliminary System Architecture**

Components furnished and maintained by CDOT
- CTA BSMS Control Center Subsystem
- CTA BSMS Bus Garage Subsystem
- Optical Emitter
- Traffic Signals
- Peek LMD40 Traffic Signal Controller
- Phase Selector
- Optical Detector

Components furnished and maintained by CTA
- CTA BSMS Mobile Data Terminal
- Traffic Management Subsystem
- 59th Street Master Controller

Components furnished by project
- CDOT Traffic Management Subsystem
- TrMS Transit Mgmt.
- VS Vehicle
- TMS Traffic Mgmt.
- RS Roadway
7.2.1. Architecture Flows

The proposed TSP system includes three main components that are not part of existing systems: the Optical Emitter on the bus that is activated by the BSMS, the Optical Detector at the intersection, and the Phase Selector that provides the interface with the existing traffic signal controller. In terms of the National ITS Architecture, the communications between these components is defined as a whole as the “local signal priority request” Architecture Flow.

Figure 7.3 describes the data flows between components in more detail.

Figure 7.3: Conceptual Data Flow Diagram
The process by which a typical TSP sequence takes place begins with the CTA BSMS Mobile Data Terminal. This unit is currently deployed on the majority of the CTA bus fleet. It processes GPS location signals and manages digital data traffic between the vehicle and the CTA Control Center. This unit is able to track a vehicle’s schedule adherence by comparing the current position with an electronic schedule stored in memory. The schedule is loaded either by floppy disk or wireless data connection at the bus garage. However, no electronic schedules have been developed for the X49 route. The CTA will need to provide these schedules before the pilot project can be implemented. Currently, only the 77th Street Garage is equipped to support wireless data transfer and electronic scheduling functions.

The Mobile Data Terminal will be programmed to activate the Optical Emitter when certain conditions are met. For this pilot project the following conditions are recommended: the bus is in the signal priority corridor (between 59th and 77th Streets on Western Avenue), and the bus is behind schedule. A tolerance level of lateness before priority is requested shall be software selectable in the Mobile Data Terminal by authorized users at the bus garage. Also, the activation of local signal priority requests shall be able to be disabled both before rollout at the bus garage and at any time remotely from the CTA Control Center.

When these conditions are met, the Optical Emitter is activated by a simple contact-closure-type signal via the J1708 port on the Mobile Data Terminal. The Optical Emitter then begins to strobe an infrared signal from the front of the bus to downstream intersections. A modulated, high frequency strobe is used to carry vehicle identification information. The range for these signals can be as much as 2,500 feet in ideal conditions, but in practice, a distance of up to one city block may be used (660 feet). At 30 miles per hour, this distance corresponds to 15 seconds of travel time.

The Optical Detector receives these optical strobe signals, converts them to electrical signals, and transmits them to the Phase Selector. The Optical Detector shall be mounted on the signal mast arm or other appropriate location at the intersection. Some signal preemption systems employ a confirmation light on the mast arm to give the driver assurance that a green signal will be granted, but this is primarily used for emergency vehicle applications. No such device is specified for this project.

The Phase Selector is located in an auxiliary cabinet mounted to the side of the traffic signal cabinet. This arrangement provides physical separation between signal priority components and traffic control components and conserves limited space inside existing traffic signal cabinets. Where space permits, it may be possible to install the Phase Selector inside existing cabinets pending CDOT approval. The Phase Selector filters out random signals, signals that are outside a specified distance range, and any signals produced by unauthorized vehicles.

When a valid signal is received, the Phase Selector can implement transit signal priority treatment on the LMD40 using one of two different methods of triggering the controller: a built-in preemption input or manual control enable mode. With the preemption input, the Phase Selector sends a 6.25Hz square wave signal to one of the low-priority preemption inputs on the Peek LMD40 Traffic Signal Controller. With manual control enable, the Phase Selector advances the LMD40 through one phase every 200ms as required until the priority phase is reached. In its operational test of 3M Opticom TSP equipment at 59th Street, CDOT found that the manual control enable mode provided quicker response than other methods of advancing through phases to provide signal priority.
The Phase Selector is also able to distinguish between transit vehicles and emergency vehicles and thus would support future emergency vehicle preemption without the need for additional hardware, except for a confirmation light on the mast arm.

The Peek LMD40 uses its own internal logic to provide a red truncation (force off) or an extended green (hold) when a priority input signal is received. The LMD40 stores generic preemption plans in read-only memory (ROM), which can be modified for each intersection. For each program, intersection-specific values for a number of variables can be defined. Variables include:

- **Delay Before Preemption**: This corresponds to the travel time from where the bus first requests priority to the intersection under normal operating conditions.

- **Last X Seconds**: This prevents the start of a new interval just before a preemption sequence begins by extending intervals already in process during this period.

- **Minimum Re-Service**: This limits negative effects on cross-street traffic by specifying the number of minutes after a preemption sequence completes before a new preemption sequence is allowed to begin. A related variable “Preemptions During Minimum Re-Service” allows for the limitation to be defined as “no more than three in ten minutes,” for example.

- **Override Time**: This limits the amount of time that the controller will wait for a bus to enter the intersection after a priority request is received. This is useful for preventing cross-street delay for unused preemption sequences when the bus is delayed at near-side stops or in long traffic queues.

- **Phase Parameters**: For each phase, minimum and maximum time values may be defined. Each phase can also be programmed to hold until a priority input stops, is canceled, or times out. Phases can also be programmed to skip to other phases under certain conditions.

Preemption sequences are programmed by defining a series of phases beginning at each interval. The LMD40 controller provides great flexibility in the definition of priority sequences. These sequences will be tailored to the characteristics of each intersection. Figure 7.4 provides an example of how TSP treatment could be implemented at a typical intersection. The figure shows how the traffic signal controller would service priority requests with early green or extended green phases when received at different points in the signal cycle.
The LMD40 logs the time and date at which each priority sequence begins and ends. This information is available for download to a remote location by dial-up connection. The 59th Street traffic signal controller currently contains the modem used for dial-up connections. All of the other controllers in the project corridor are connected to this master controller for data retrieval purposes. The LMD40 can be programmed either to provide reports on a user-initiated (request) basis or to automatically direct dial the traffic management center according to a predefined frequency schedule. The LMD40 does not support real-time remote monitoring of signal priority activities.

7.2.2. Pspecs

1.2.7.3 - Manage Indicator Preemptions: This PSpec is associated with the Roadway Subsystem and the Roadside Signal Priority Equipment Package. This process shall receive indicator (e.g. signal) preemption and priority requests from other functions within ITS. These requests shall enable the process to give selected vehicles (e.g. those that belong to Transit Authorities or Emergency Services) signal preemption or priority at intersections, pedestrian crossings and multimodal crossings in the surface street and freeway network served by the instance of the Manage Traffic function. Sending of the priority request output shall also generate an output to the monitoring process to suspend its activities while the priority request is being served. This process shall only generate its data flow outputs when input data is received.

Functional Requirements: This process shall: (a) continuously monitor for receipt of the unsolicited input flows listed above; (b) maintain both output flows for as long as any of the input flows are present; (c) remove the output flows when the input flows cease to exist. The proposed optical signal priority system provides the functionality that meets these requirements.
This process is associated with the following Data Flows:

- **emergency_vehicle_preemptions (in):** This data flow is not supported in the pilot project, but the installed hardware shall support this functions at a later date if implemented by the City.

- **indicator_monitoring_suspend (out):** Monitoring functions are provided by the LMD40 controller.

- **indicator_preemption_override_for_highways (out):** This data flow is not applicable on the Western Avenue arterial street corridor.

- **indicator_preemption_override_for_roads (out):** Override functions are provided by internal logic in the LMD40 controller.

- **transit_vehicle_roadway_preemptions (in):** The Phase Selector provides this data flow to the LMD40 traffic signal controller when an authorized transit vehicle is detected.

4.1.2.5 - Request Transit Vehicle Preemptions: This PSpec is associated with the Transit Vehicle Subsystem and the On-board Transit Signal Priority Equipment Package. This process shall provide the interface through which requests for preemption can be output from a transit vehicle. The output shall be received by the process as a result of data sent from another process in the Manage Transit function. In this case, local transit priority requests are triggered by schedule adherence conditions monitored by the Mobile Data Terminal. The process shall provide the output in a form that can be used by the controllers at intersections, pedestrian crossings and multimodal crossings on the roads (surface streets) and freeway network served by the Manage Traffic function to provide priority of the transit vehicle. In this case, the output is in the form of a contact closure that activates the infrared strobe Optical Emitter on the front of the bus. If no data is received from the other process, or it shows that no preemption is needed, the process shall produce no output.

Functional Requirements: This process shall meet the following functional requirements: (a) continuously monitor for receipt of the unsolicited input flow listed above; (b) when the flow listed above is received, produce the solicited output flow listed above in a form that can be used by roadside intersection controllers to give priority to the transit vehicle; (c) if no input flow is received, or it indicates that preemption is not required, produce no output data flow.

This PSpec is associated with the following Data Flows:

- **transit_vehicle_preemption_request (in):** The Mobile Data Terminal provides a contact closure signal to the Optical Emitter when certain location and schedule adherence conditions are met.

- **transit_vehicle_roadway_preemptions (out):** The Optical Emitter provides a high frequency, modulated infrared strobe signal to roadside Optical Detectors when activated by the Mobile Data Terminal.
7.3. Physical Modifications

Transit signal priority can be implemented at bus stops in any relationship to an intersection, near-side, far-side, or mid-block. However, far-side bus stop locations provide the traffic signal control system with greatest flexibility to serve priority requests. For far-side stops, either early green or extended green phases can be provided to allow a bus through the intersection depending on the timing of its arrival. Near-side stops, in contrast, work best with early green only, because in order to avoid wasted priority phases, the bus must request priority only when it is ready to depart the stop. In addition, this works best with door sensors that detect when the bus is about to depart. To support this feature on Western Avenue, door sensors would need to be added to CTA buses and an interface with the TSP and/or proprietary AVL system would need to be developed.

It is recommended that bus stops for the X49 service be relocated to the far side of the intersection. This approach is consistent with the CTA TSP demonstration on Martin Luther King Jr. Drive and has been tested and proven on a number of transit signal priority and bus rapid transit systems, including the Los Angeles MetroRapid system. In Los Angeles, the MetroRapid replaced a limited-stop bus service that operated in combination with a local bus service, much like the X49 does today. Local bus stops remained at the near side of each intersection and MetroRapid stops were added on the far sides. In an interview with the Los Angeles County Metropolitan Transportation Authority, which operates the service, no safety problems have been experienced with the splitting of bus stops between services.

This involves the relocation of six X49 bus stops at three intersections: 59th Street, 63rd Street, and 69th Street. Because of issues associated with ADA accessibility, parking restrictions, signage improvements, it is recommended that the CTA begin this process as soon as possible to avoid delays to other components of the TSP project implementation.

In order to minimize passenger inconvenience associated with split local and express stops, it is recommended that the design of relocated X49 bus stops include upgraded passenger shelters and countdown displays to give passengers advance warning of approaching buses. The design of these improvements is considered outside the scope of this study.
8. Simulation Results

8.1. Introduction

VISSIM, a German acronym for “traffic in towns-simulation,” is a stochastic simulation model. It was developed by PTV AG in Germany and is distributed in the North America by Innovative Transportation Concepts (ITC). VISSIM was selected for this project based on its ability to model transit priority signal timing and the fact that the RTA is currently using this platform to model transit signal priority treatments in a number of other corridors in the region.

The VISSIM model is made up of two components. The first component, the traffic simulator, simulates the movement of vehicles and generates outputs. The second component, known as a signal state generator (SSG), simulates the operations of a traffic signal controller through the use of a vehicle actuated program (VAP), which is written in Visual BASIC.

VISSIM is extraordinary among traffic simulation models for its ability to track specific types of vehicles individually through the network. This allows certain types of vehicles, in this case transit buses, to be given certain special treatments, in this case priority phase actuations at intersections. The literature does not document the integration of this capability into other signal timing software such as PASSER, TRANSYT-7f, SYNCHRO or CORSIM.

8.2. Data Collection

The traffic volumes including truck percentages, turning movement counts, and signal timing plans, in addition to layout geometric plans were obtained from the City of Chicago Traffic Engineering Division. The actual published schedules and routing by the CTA and Pace on Western Avenue were used to define transit operations. Field visits were conducted in order to verify transit dwell time, bus occupancy, boarding and aligning counts at each bus stop in addition to bus travel time studies. These data were needed in the development of the simulation model. No attempt was made to optimize signals using HCS, Synchro, PASSER or any other optimization tool.

8.3. Methodology for Model Development

Of the thirteen intersections under normal operation, seven operate as 2-phase, three operate as 3-phase, one operates as 4-phase, and two operate as 8-phase. For this model, each intersection is assigned a default ‘VAP’ file (for example, 59th.vap) in to which the user has entered intersection-specific controller timing and coordination parameters. This default VAP file was provided by ITC and represents a standard NEMA-type traffic signal controller. This represents a subset of the capabilities of the Peek LMD40 controller currently in use on Western Avenue.

Because there is no preemption capability within the VAP module provided, several NEMA phases were dedicated to the bus priority timing intervals and were therefore not available to be assigned to their normal vehicle movements. This limitation was present for all intersections, for which there were Western Avenue NB or SB left turns; and, for the left turn and through
movement green phases for the minor streets. These dedications of these phases were necessary to utilize both their detector inputs (for detecting an arriving bus) and due to their order in the normal NEMA phasing sequence. These phases served as the bus ‘preemption input’ for generating either the ‘early’ or ‘late’ green added to the normal green of the Western Avenue main-lanes. Traffic signals are modeled as ‘fixed time’. Fixed time and coordination program parameters are entered directly into the model for each intersection.

There is only one ‘default’ (or template) VAP file available at this time. The capability does exist for the end-user to write a user-defined VAP file to add extensible features to the simulation. While it was felt that the current VAP capability was adequate for our current simulations, an enhanced VAP file may be required if a much more detailed analysis of the effects of the proposed ‘priority’ methodology is required.

Bus priority phase sequencing for early and late greens on Western Avenue was accomplished by adding unused Phase 5 and Phase 7 for the early and late green timing intervals, respectively. Detectors for the targeted vehicles (in this case, express buses) were added for Phases 5 and 7 in both NB and SB main lanes. Depending on when the bus arrives within the detectable proximity of the intersection, Phase 5 would service early green or Phase 7 would service late green. These early and late green phases were set at a fixed length of 10 seconds. However, in practice, the use of preemption inputs on the LMD40 controller will allow these phases to have variable lengths, subject to a maximum duration, based on the arrival time of the bus. In this manner, the model represents a worst-case scenario for cross-street traffic because more green time may be given to the bus than it actually needs.

The model assumes that every X49 bus requests transit signal priority treatment every time it approaches an intersection. In practice, the integration of the proposed TSP system with the CTA Bus Service Management System (BSMS) will allow priority requests to be made only when the bus is running behind schedule. In this manner, the model also represents a worst-case scenario for cross-street traffic because in practice priority will likely not be requested or granted as often as modeled.

8.4. Calibration Procedure

Preliminary VISSIM simulations of each peak hour AM and PM were performed and the results were compared with field observations to ensure that the model were simulating the actual conditions in the real world. Several iterations of the model were conducted by adjusting model parameters at various locations until the models satisfactory represented the existing traffic conditions at all locations within the study area. These adjustments included relocating turning movement decision points, redefining yield priorities at various intersections and adjusting speeds for all modes in the model to better reflect real-word conditions. The model output for average travel time between 59th Street and 87th Street was 640 seconds, whereas field-observed travel time was 633 seconds.

8.5. Results Evaluation

A comparison of VISSIM outputs for the study area was conducted for two scenarios: the existing condition with no priority treatment and priority treatment. The priority treatment
scenario includes the relocation of X49 bus stops to the far side of intersections with TSP treatment. Additional scenarios were considered outside the study scope of work. The measures of effectiveness (MOEs) used for comparisons were bus travel times, bus delay and stopping time, passenger delays and delays on the side streets.

Table 8.1 summarizes the average travel time results in seconds for CTA Route X49 for the AM and PM peak hours. The transit signal priority contributes up to 14.8% in AM and up to 9% in PM of the time saving. These results are similar to real-world project experience on the Pace/IDOT Cermak Road TSP Demonstration and recent implementations by the city of Los Angeles Department of Transportation for the Metro Rapid BRT project. These studies demonstrated time savings of approximately 10% of total travel time.

<table>
<thead>
<tr>
<th>Period</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direction</td>
<td>SB</td>
<td>NB</td>
</tr>
<tr>
<td>Non Priority</td>
<td>919.7</td>
<td>979.8</td>
</tr>
<tr>
<td>Priority</td>
<td>876.9</td>
<td>835.2</td>
</tr>
<tr>
<td>Time Saving</td>
<td>42.8</td>
<td>144.6</td>
</tr>
<tr>
<td>% Saving</td>
<td>4.7</td>
<td>14.8</td>
</tr>
</tbody>
</table>

Another MOE is the time the bus spends stopped in traffic due to red lights at intersections or a build up of queues. This time excludes the dwell time at bus stops during which passengers board and alight. This measure is a very intuitive indicator of the benefits of TSP and a good indicator of rider comfort. The less a bus accelerates and decelerates, the more comfortable the passengers’ ride. Table 8.2 shows the total traffic delay experienced by X49 buses during an hour (approximately four bus headways) in the AM and PM peak periods in the northbound and southbound directions.

<table>
<thead>
<tr>
<th>Period</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direction</td>
<td>SB</td>
<td>NB</td>
</tr>
<tr>
<td>Non Priority</td>
<td>473</td>
<td>733</td>
</tr>
<tr>
<td>Priority</td>
<td>310</td>
<td>117</td>
</tr>
<tr>
<td>Time Saving</td>
<td>163</td>
<td>616</td>
</tr>
<tr>
<td>% Saving</td>
<td>34.5</td>
<td>84.0</td>
</tr>
</tbody>
</table>

The results show that the four X49 buses could save up to 10 minutes in the AM period and up to 4.5 minutes in the PM period for the overall segment. This also means less acceleration and deceleration for buses and hence less wear and tear on brakes and a reduction of bus emissions. These values could be plugged into any of various fuel consumption equations to estimate the gallons per hour saved.

Since the TSP strategy improves main street bus operations by reducing green time for the cross streets, it was important to evaluate the cross-street delay. Tables 8.3 to 8.6 are intended to assess
the impact of TSP on cross-street and major-street delay at each intersection level. The delay values are in seconds per person. The cross-streets experience an extra delay that is less than 5 seconds per person except for Columbus Street in the AM and eastbound 65th Street in the PM, which traffic volume, is only 19 vehicles per hour. The 62nd Street appears to benefit from TSP but it has volume less than 140 vehicles per hour. As expected, the major street generally benefits from the TSP strategy except at very few intersections, and where there is a disbenefit, it was less than 2 seconds per person.

Table 8.3: TSP Effect on Cross-Street Delay for AM Peak Period

<table>
<thead>
<tr>
<th>Intersection</th>
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<tr>
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Table 8.4: TSP Effect on Cross-Street Delay for PM Peak Period

<table>
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### Table 8.5: TSP Effect on Major-Street Delay for AM Peak Period

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### Table 8.6: TSP Effect on Major-Street Delay for PM Peak Period

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<tr>
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<td>0</td>
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<tr>
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<td>-0.1</td>
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<td>0.9</td>
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</table>

Tables 8.7 and 8.8 summarize the overall delay in seconds per person at each intersection for the two scenarios and the average savings. Intersections generally benefit from the TSP strategy. Where there is a disbenefit, it was less than 0.5 seconds per person.
The results show that providing transit signal priority is feasible and desirable for improving the on-time performance of the X49 by adjusting the signal timing at intersections for buses as their approach is detected. This would greatly improve the quality and effectiveness of the bus services provided to passengers. Also the potential adverse impacts on cross street traffic were found to be minimal, even in the exaggerated conditions for priority phase duration and frequency of priority requests that were modeled.
9. Functional Requirements

Based on the results of the microsimulation traffic operations analysis, TSP treatment is recommended at 59th, 61st, 63rd, 65th, 67th, 69th, 71st, 74th, 77th, and 83rd Streets. High cross-street traffic volumes preclude TSP treatment at 79th and 87th Streets. TSP treatment is not justified at 62nd Street because priority requests were found to be rare at this location due to low cross-street traffic volumes and the fact that Western Avenue already receives at least 70% of the green time. Bus stop relocations are thus required for the X49 service at 59th Street, 63rd Street, and 69th Street. No relocation is required at 79th Street or 87th Street due to the off-street bus terminal and the lack of TSP treatment, respectively.

It is recommended that the pilot project not include the Pace 349 bus route because it would pass through only a single TSP-equipped intersection (83rd Street) and the barely measurable time savings this would not justify equipping a number of Pace buses at this time. If the TSP corridor were extended south at a later date, such an investment should be considered. The concept design thus focuses on the CTA X49 arterial express bus route. This is consistent with the X49’s bus rapid transit characteristics, which provide higher-speed limited stop services on which schedule reliability is an important marketing factor.

9.1. System Description

A. Optical Vehicle-to-Roadside Communications: The priority control system shall employ modulated strobe communications in the infrared frequency range to identify the presence of designated priority vehicles. A record of system users by vehicle classification and identification number shall be created to filter out unauthorized priority requests. When a valid signal is received, the system shall request the traffic signal controller to advance to and/or hold a desired traffic signal display selected from phases normally available.

B. Automatic Operation: The system shall require no action from the vehicle operator. The system shall operate on a first-come, first-served basis. Although not required for this project, the system shall have the capability to distinguish between higher priority requests (such as for emergency vehicles) and lower priority requests (for transit vehicles). Higher priority requests shall override lower priority requests. The system shall interface with the existing Peek LMD40 traffic signal controllers in the corridor and shall not compromise normal operation or existing safety provisions.

C. System Components: The required priority control, data-encoded, infrared communications system shall consist of a matched system of four basic components: Optical Emitter, Optical Detector, Phase Selector and System Software. To ensure system integrity, operation and compatibility, all components shall be from the same manufacturer. The system shall offer compatibility with most signal controllers, including NEMA (National Electrical Manufacturers Association) controllers and the Peek LMD40.

1. Optical Emitter: The Optical Emitter shall communicate local signal priority requests from the transit vehicle to the roadside equipment. It shall send an
encoded infrared signal to the Optical Detector. The signal shall be detectable and recognizable by infrared detectors over a line-of-sight path of up to 2,500 feet (762m) under clear atmospheric conditions. Optical Emitters shall be mounted on 25 CTA buses designated for use on the X49 service during the demonstration period of the pilot project.

2. Optical Detector: The detector will change the infrared signal to an electrical signal. It shall be located at or near the intersection, typically on the signal mast arm. One detector shall be provided in each direction along Western Avenue. The Optical Detectors shall send the electrical signal, via detector cables, to the Phase Selector.

3. Phase Selector. The Phase Selector shall process the electrical signal from the detector to ensure that the communication (1) is a valid base frequency, (2) is correctly data encoded, and (3) is within a user-selectable range. If these conditions are met, the phase selector will generate a priority control request for the approaching priority vehicles, or record the presence of approaching probe vehicles by classification and identification number. Unless specifically authorized for installation inside the existing cabinet at each intersection by CDOT, the Phase Selector shall be located in an auxiliary traffic control cabinet mounted to the side of the existing CDOT traffic signal control cabinet at each intersection. It shall draw power from the existing traffic signal controller power supply.

4. System Software. The system software shall include two components: Vehicle Software and Roadside Software. Vehicle Software shall include modifications as necessary to program the CTA BSMS Mobile Data Terminal to activate the Optical Emitter when certain transit operating conditions are met. Roadside Software shall include software required to set system parameters on the Phase Selector and intersection-specific preemption plans for the existing traffic signal controllers.

9.2. BSMS Interface

A. The Vendor shall coordinate with the CTA BSMS Vendor (Orbital Sciences Corporation) and effect the necessary changes in Mobile Data Terminal software and software settings to enable the Mobile Data Terminal to output the required contact closure signal when all of the following conditions are met:

1. The bus is located on Western Avenue within range of the signal priority-equipped intersections between 59th Street and 83rd Street,

   AND

2. The bus is behind schedule (late) by more than the user-selectable lateness threshold. The default value for this lateness threshold shall be zero seconds,

   AND
3. The TSP system has not been disabled either by the switch on board the bus or remotely by the CTA Control Center.

B. The Mobile Data Terminal shall output the activation signal to the Optical Emitter when these conditions are met without any intervention from the bus operator.

C. The Schedule Adherence Threshold and the System Disable settings shall be changeable only by CTA-authorized personnel.

D. The CTA will be responsible for the development of the electronic schedule-location database required to support on-board computation of schedule adherence by the Mobile Data Terminal. This database is derived from route timetables and is stored in memory on the Mobile Data Terminal.

E. The revised Mobile Data Terminal software, updated settings, and associated schedule-location databases and shall be installed on up to 25 buses designated by CTA for use on the X49 service during the TSP demonstration period. This demonstration period is expected to last at least 3 months.

9.3. Optical Emitter

A. The Vendor shall be responsible for the installation, testing, and acceptance by the CTA of Optical Emitters and related components on up to 25 buses designated by CTA for use on the X49 service during the TSP demonstration period.

B. The Optical Emitter shall generate the infrared signal, which serves as the trigger to the rest of the priority control system. The infrared signal generated by the data encoded emitter shall be a series of intense flashes from a single light source with integral power supply. The data-encoded emitter shall have a consistent flash intensity with an energy output per flash of 0.84 Joules. The flash signal shall consist of a fixed frequency base signal and a coded overlay signal that can be used to transmit information. The flash sequence generated by the data-encoded emitter will carry three types of information:

1. The first type shall be one of three distinctly different base frequencies of either 9.63855Hz ±0.0014Hz for an emergency vehicle emitter, or 14.03509Hz ±0.003Hz for a transit vehicle emitter, or 11.25873Hz ±0.00190Hz for a probe vehicle.

2. The second type shall be a vehicle classification and identification code that is interleaved into the base frequency flashes. Setting the vehicle classification and identification code will be accomplished through emitter programming software. Each Optical Emitter shall be capable of setting 10 different classifications with 1,000 different identification numbers per class for a total of 10,000 codes per base frequency.

3. The third type shall be reserved for setting the intersection detection range. The system shall enable the traffic engineer to activate the range code from his/her vehicle using a specially equipped emitter control module with a range setting
command switch. The system shall accommodate setting a separate range from 200 feet (61m) to 2,500 feet (762m) for both emergency vehicle and transit vehicle priority signals.

C. The Optical Emitter shall be powered by the DC voltage supplied from the vehicle's battery, 10 to 16 volts DC. The unit will be equipped with a weatherproof in-line fuse holder and a weatherproof quick-disconnect plug. The emitter shall be supplied complete with a 25 foot (8.0m) installation cable. The emitter shall operate over a temperature range of –30°F (-34°C) to +165°F (+74°C). The emitter shall operate over a relative humidity range of 5% to 95%. The emitter and any other piece of equipment supplied as part of the TSP system intended for use in or on priority vehicles shall operate properly across the entire spectrum of combinations of environmental conditions (temperature range, relative humidity, vehicle battery voltage).

D. The Optical Emitter, including all electronics, shall be miniaturized to a size no greater than 5.900 inches (14.986 cm) wide by 3.800 inches (9.652 cm) high by 3.500 inches (8.890 cm) deep to accommodate standalone and internal lightbar installation. The emitter shall be available with an optional visible light-blocking filter. The data-encoded emitter shall be configured with a grating to provide precise directionality control.

E. The Optical Emitter shall include a multi-purpose RS-485 serial port compliant with the SAE J1708 communication standard. This port enables unit configuration to be set into the emitter and read from the emitter using Microsoft® Windows-compliant software, which shall be provided by the Vendor.

F. While operating, the data-encoded emitter shall conduct self-diagnostics designed to monitor data transmission integrity by checking for missing pulses. Any failures of the self-diagnostic tests shall be displayed by flashing of the ON/OFF switch indicator light.

G. An ON/OFF switch (available for each data-encoded emitter) shall be equipped with an indicator light providing internal diagnostics to assist in troubleshooting. The indicator light will operate as follows:

1. Steady on when the emitter is operating
2. Flash at a 0.5Hz rate when the emitter is intentionally disabled
3. Flash at a 4Hz rate when the emitter is inoperative

9.4. Optical Detector

A. The Vendor shall provide one Optical Detector and related hardware for each direction of Western Avenue at each of the following ten signalized intersections along Western Avenue: 59th, 61st, 63rd, 65th, 67th, 69th, 71st, 74th, 77th, and 83rd Streets. Each detector shall accept infrared signals from one direction and provide a single electrical output channel.
B. The Optical Detector shall be a lightweight, weatherproof device capable of sensing and transforming pulsed infrared energy into electrical signals for use by the Phase Selector.

C. The Optical Detector shall be designed for mounting at or near an intersection on mast arms, pedestals, pipes or span wires. Depending on intersection geometry and existing conditions, the mast arm shall typically be used as a mounting location. Each detector shall be supplied with mounting hardware to accommodate installation on mast arms. The Vendor shall provide all mounting hardware required for installation at CDOT-approved locations.

D. The Optical Detector design shall include adjustable tubes to enable their reorientation for span wire mounting without disassembly of the unit.

E. The Optical Detector shall receive power from the phase selector and will have internal voltage regulation to operate from 18 to 37 volts DC. The detector shall have a built-in terminal block to simplify wiring connections.

F. The Optical Detector shall respond to a clear lens data-encoded emitter with 0.84 (±10%) Joules of energy output per flash at a distance of 2,500 feet (762m) under clear atmospheric conditions. If the emitter is configured with a visible light filter, the detector will respond at a distance of 1,800 feet (549m) under clear atmospheric conditions. The noted distances shall be comparable day and night.

G. Detector Cable: The infrared detector will deliver the necessary electrical signal to the phase selector via a detector cable up to 1,000 feet (305m) in length. The detector cable shall deliver sufficient power from the phase selector to the infrared detector and will deliver the necessary quality signal from the detector to the phase selector over a non-spliced distance of 1,000 feet (305m). The cable shall be of durable construction to satisfy direct burial, conduit and mast arm pull, and exposed overhead (supported by messenger wire) installation methods. The outside diameter of the detector cable shall not exceed 0.3 inches (7.62mm). The insulation rating of the detector cable will be 600 volts minimum. The temperature rating of the detector cable will be +158°F (+70°C) minimum. The conductors will be shielded with aluminized polyester and have an AWG #20 (7 x 28) stranded and individually tinned drain wire to provide signal integrity and transient protection. The characteristic impedance of the detector cable shall be 0.6ohms/1000’ and 14.3µF/1000’. The shield wrapping will have a 20% overlap to ensure shield integrity following conduit and mast arm pulls. The detector cable will have four conductors of AWG #20 (7 x 28) stranded, individually tinned copper, color-coded insulation.

9.5. Phase Selector

A. The Phase Selector shall accommodate modulated signals and is intended for use directly with numerous controllers. These include the Peek LMD40 controller used by the City of Chicago, California/New York Type 170 and Type 2070 controllers with compatible software, NEMA controllers, or other controllers when supplied with a suitable system card rack, interface equipment, and controller software.
B. The Phase Selector shall be a plug-in, two channel, multiple-priority device intended to be installed directly within an auxiliary traffic controller cabinet or into a card rack located in a standard traffic controller cabinet.

C. The Phase Selector shall be powered from 115 volt (95 volts AC to 135 volts AC), 60Hz mains and will contain an internal, regulated power supply that supports at least four infrared detectors.

D. The Phase Selector and any other equipment supplied as part of the TSP system intended for use in the controller cabinet or auxiliary cabinet shall meet the following electrical and environmental specifications spelled out in the NEMA Standards Publication TS2 1992, Part 2:

2. Power source frequency per NEMA TS2 1992, Paragraph 2.1.3.
4. Temperature range per NEMA TS2 1992, Paragraph 2.1.5.1.

E. Programming the Phase Selector and retrieving the data stored in it shall be accomplished using an IBM PC-compatible computer and Microsoft® Windows-compliant system interface software. The connection can be made either directly, via the computer's communication (COM) port, or remotely via a modem. The communication port on the phase selector will be an RS232 interface located on the front and back of the unit.

F. The Phase Selector shall have the capability of storing up to 1,000 of the most recent priority control calls, probe frequency passages, or unauthorized vehicle occurrences. When the log is full, the phase selector will drop the oldest entry to accommodate the new entry. The Phase Selector will store the record in non-volatile memory and will retain the record if power is interrupted. Each record entry will include ten points of information about the priority call, as follows:

1. Classification: Indicates the type of vehicle.
2. Identification number: Indicates the unique ID number of the vehicle.
3. Priority level: Indicates whether high (emergency vehicle), low priority (transit vehicle), or no priority (probe vehicle) is requested by the vehicle.
4. Direction: Indicates the vehicle's direction of travel by channel on which the detector input was received.
5. Call duration: Indicates the total time in seconds the priority status is active.
6. Final greens at end of call: Indicates which phases are green.
7. Duration of final greens: Indicates the total time of priority greens.
8. Time and date call ended: Indicates the time a priority status ended, including second, minute, hour, day, month, year.
9. Maximum signal intensity: Indicates the strongest signal intensity measured by the phase selector during call.
10. Priority output active: Indicates if the phase selector requested priority from the controller for the call.

G. The Phase Selector shall include several control timers that will limit or modify the duration of a priority control condition, by channel, and can be programmed from an IBM PC-compatible computer. The control timers shall be as follows:

1. Max Call Time: Sets the maximum time a channel is allowed to be active. It will be settable from 120 to 65,535 seconds in one-second increments.
2. Call Hold Time: Sets the time a call is held on a channel after the priority signal is no longer being received. It will be settable from one to 255 seconds in one-second increments.
3. Call Delay Time: Sets the time a call must be recognized before the Phase Selector activates the corresponding output. It will be settable from zero to 255 seconds in one-second increments. Its factory default must be zero seconds.
4. Re-Service Time: Sets the minimum time between low-priority service calls.
5. The Phase Selector's default values shall be re-settable by the operator using an IBM PC-compatible computer, or manually using switches located on its front.

H. The Phase Selector shall be capable of three levels of discrimination of modulated infrared signals, as follows:

1. Verification of the presence of the base infrared signal of either 14.03509Hz ± 0.01773Hz for high priority (emergency vehicles), 9.63855Hz ± 0.00836Hz for low priority (transit vehicles) or 11.25873Hz ±0.01141Hz for no priority (probe vehicles).
2. Validation of the infrared signal data-encoded pulses.
3. Determination of when the vehicle is within the prescribed distance range.

The Phase Selector shall properly identify a high-priority call with the presence of 10 low-priority signals being received simultaneously on the same channel.
I. The Phase Selector's card edge connector shall include primary Optical Detector inputs and power outputs. Two additional detector inputs per channel will be provided on a front panel connector.

J. The Phase Selector shall include one opto-isolated NPN output per channel that provides the following electrical signal to the appropriate pin on the card edge connector:

1. 6.25Hz ± 0.1Hz 50% on/duty square wave in response to a low priority call.
2. A steady ON in response to a high priority call.

K. The Phase Selector shall accommodate three methods for setting intensity thresholds (emitter range) for high and low priority signals:

1. Using a data-encoded emitter with range-setting capability.
2. Using any encoded emitter by manipulating the front panel switches.
3. Inputting the range requirements via the communication port.

L. The Phase Selector shall have a solid state POWER ON LED indicator that flashes to indicate unit diagnostic mode and illuminates steadily to indicate proper operation.

M. The Phase Selector shall have internal diagnostics to test for proper operation. If a fault is detected, the Phase Selector shall use the front panel LED indicators to display fault information. The Phase Selector shall have the capability of functionally testing connected detector circuits and indicating via front panel LEDs non-functional detector circuits. The Phase Selector shall also have a test switch for each channel to test proper operation of high-priority or low-priority.

N. The Phase Selector shall have a high-priority and a low-priority solid state LED indicator for each channel to display active calls. The Phase Selector shall have write-on pads to allow identification of the phase and channel.

O. The Phase Selector shall provide one isolated confirmation light control output per channel. However, for this pilot project, no confirmation lights shall be installed. These outputs shall be user configurable through software for a variety of confirmation light sequences.

P. To support future deployment at a variety of locations throughout the Chicago region, the Phase Selector shall be available in a model that has outputs for the control of NEMA controllers that lack internal preemption capability. This function shall be accomplished through the use of Manual Control Enable, Interval Advance, and Phase Omit options. This model of the Phase Selector shall have the ability to set Interval Advance rates as low as once every 200 mSec for Low Priority calls. It shall also be able to operate in the Manual Control Enable Mode for Low Priority calls and activate a standard preemption output for High Priority calls.
Q. The Phase Selector shall have the capability of recording the presence of a vehicle transmitting at the specified probe frequency. The Phase Selector shall at no time attempt to modify the intersection operation in response to the probe frequency.

R. The Phase Selector shall have the capability to discriminate between individual ID codes, and allow or deny a call output to the controller based on this information. The Phase Selector shall have the capability to assign a relative priority to a call request within Command or Advantage priority. This assignment is based on the received vehicle class. The Phase Selector shall also have the capability to log call requests by unauthorized vehicles.

S. Interface Software: The priority control interface software will be provided on 3.5", 1.44MB diskettes or CD-ROM to interface with the Phase Selector. It must run on IBM-compatible computers equipped with at least 512KB RAM, Microsoft® Windows 95 or a newer version thereof, and color VGA display capability. The priority control interface software must accommodate operation via a mouse or via the keyboard, or in combination. The priority control interface software must accommodate:

1. Setting up and presenting user-determined system parameters.
2. Viewing and changing settings.
4. Displaying and/or downloading records of previous activity showing class, code, priority, direction, call duration, final greens at end of call, duration of final greens, time call ended in real time plus maximum signal intensity (vehicle location information). This information may be used to reconstruct the route taken by a priority (or probe) vehicle to track the vehicle.
5. Setting of valid vehicle ID and class codes.
6. Establishing signal intensity thresholds (detection ranges), modem initialization, intersection name and timing parameters.
7. Setting of desired green signal indications during priority control operation and upload and download capability to view.
8. Resetting and/or retrieving logged data and priority vehicle activity.
9. Addressing for each card in a multi-drop connected system.
10. Confirmation light configuration.
9.6. **Auxiliary Traffic Cabinet**

A. The Vendor shall provide an auxiliary traffic cabinet mounted to the side of the existing traffic signal controller cabinet at each intersection, unless specifically permitted to install the Phase Selector hardware in the existing traffic controller cabinet by CDOT.

B. The cabinet shall be constructed of cast or fabricated aluminum with a minimum wall thickness of 3.18mm. Grinding, sanding, or other appropriate means shall be used to effect a smooth surface. All non-aluminum parts shall be made of stainless steel.

C. The cabinet shall be sized to accommodate not less than two Phase Selector units as furnished by the Vendor.

D. The cabinet shall include a door that covers substantially the full area of the front of the cabinet. The door shall be hinged on the right side with a 25mm x 25mm stainless steel plane hinge for the entire height of the door. The door shall be equipped with a self-locking heavy duty brass cylinder lock compatible with the lock used by CDOT for the main traffic signal controller cabinet. An adjustable stainless steel striker shall be attached to the inside of the housing to ensure positive locking. Keying shall be per CDOT policy.

E. The cabinet shall be furnished with a vent. The vent shall be designed to prevent the entry of rain, sleet, snow, and insects.

F. The cabinet shall be furnished with mounting hardware, card racks, ground bus, terminal blocks, and/or other components as required to accommodate not less than two Phase Selector cards as furnished by the Vendor.

G. Electrical equipment supplied and its method of installation shall conform to all appropriate National Electrical Code and Underwriters Laboratory standards and meet City of Chicago and Commonwealth Edison requirements. The gauge of all insulated wires between various parts and components shall be adequately sized. All wires shall be cut to the proper length before assembly. No wires may be doubled back to take up slack. All wires shall be neatly labeled, laced into cables with cable ties, and secured with nylon cable clamps.

H. The cabinet shall be attached to the right side of the existing controller cabinet or as instructed by CDOT. The cabinet shall be attached with four stainless steel bolts. The length of the bolts shall not interfere with the removal of the backboard or other components inside the existing controller cabinet. The attachment shall be made watertight.

9.7. **Traffic Signal Controller Interface**

A. AT CDOT’s option, the Phase Selector shall provide a 6.25Hz ± 0.1Hz 50% on/duty square wave electrical signal to the appropriate low-priority input or an appropriate trigger for manual control enable mode in response to a low priority call on the Peek LMD40 Traffic Signal Controller.
B. The Vendor shall be responsible for the development of intersection-specific Preemption Plans for the LMD40 controller at each of the ten TSP-equipped intersections included in the pilot project.

C. The Vendor shall activate logging functions on each LMD40 controller as required to document each local signal priority request served. At CDOT’s option, the Vendor shall enable either periodic automatic reporting to the CDOT Traffic Management Center or on-request reporting. All communication to the CDOT Traffic Management Center shall be conducted over the existing dial-up connection to the 59th Street controller.
10. Implementation Requirements

This section describes an initial operational test plan, cost estimates, and a general outline for an intergovernmental agreement needed to support implementation of the TSP pilot project.

10.1. Operational Test Plan

A quantitative approach is needed to measure the performance of the proposed TSP system along Western Avenue. A key issue will include the evaluation of traffic impact on major side streets following the introduction of the system on Western Avenue.

The operational test plan should take the form of a before and after study of actual field conditions. Three criteria shall be field measured to test operational effectiveness: travel time/speed along the corridor, bus occupancies and vehicular stop delay at the intersections. These parameters have been determined as part of the data collection effort for the microsimulation traffic operations analysis or can be determined before installation, and then reevaluated after implementation of TSP.

- Travel Speeds: The average vehicular travel times and speeds along the corridor during peak hours was determined in the field by the test car method in March 2001. Average travel times and speeds for the Route 49X buses were also measured. A duplicate test car study and bus study will be performed after signal prioritization is in place. The average travel times and speeds will be compared to see if there is any change.

- Bus Occupancy: Improved operational efficiency of the route after signal prioritization should yield an increase in riders. Bus occupancies of the 49X route were recorded in the field during peak hours. A duplicate study will be performed after signal prioritization is in place. The occupancies will be compared to see if there is any change.

- Intersection Delay: Dwell time and stopped time were measured for bus routes on the Western Avenue cross streets. These times will be measured after signal prioritization is in place. The times will be compared to see if there is any change. Stop delay at intersection approaches has not yet been measured. However, if this measure of effectiveness is to be included in the operational test plan, the delays can be field measured at each approach of all signalized intersections, or at a sample of the signalized intersections in the corridor. After TSP is in place the same test will be conducted to see if there are any changes in delays.

10.2. Cost Estimate

A preliminary cost estimate has been prepared for the installation of required equipment by a turnkey vendor on 25 buses and at 10 intersections to support the TSP pilot project. The cost estimate was prepared using unit costs provided by a leading vendor of optical TSP systems. No cost estimates are included for efforts by CDOT and/or CTA associated with project administration, field inspections, and other management and acceptance testing tasks. Likewise, no allowance has been included for CTA’s efforts associated with bus stop relocations, the
development of the schedule-location database needed to support on-board schedule adherence computations by the BSMS Mobile Data Terminal, or any changes in software settings on the Mobile Data Terminal required to enable the signal to the Optical Emitter.

Table 10.1 summarizes the preliminary construction cost estimate for the TSP system.

### Table 10.1: Preliminary Construction Cost Estimate

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Unit Cost</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Roadside Equipment:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase Selector</td>
<td>1</td>
<td>$1,800</td>
<td>$1,800</td>
</tr>
<tr>
<td>IR Detector, 2 dir.</td>
<td>2</td>
<td>$400</td>
<td>$800</td>
</tr>
<tr>
<td>Auxiliary Cabinet</td>
<td>1</td>
<td>$150</td>
<td>$150</td>
</tr>
<tr>
<td>Cable, 500 ft.</td>
<td>1</td>
<td>$200</td>
<td>$200</td>
</tr>
<tr>
<td>Installation / Software</td>
<td>16</td>
<td>$60</td>
<td>$960</td>
</tr>
<tr>
<td>Total per Intersection</td>
<td></td>
<td></td>
<td>$3,910</td>
</tr>
<tr>
<td>Number of Intersections</td>
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<td></td>
<td>10</td>
</tr>
<tr>
<td><strong>Total Roadside Equipment</strong></td>
<td></td>
<td></td>
<td>$39,100</td>
</tr>
<tr>
<td><strong>Vehicle Equipment:</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>IR Emitter</td>
<td>1</td>
<td>$1,000</td>
<td>$1,000</td>
</tr>
<tr>
<td>Installation / Software</td>
<td>4</td>
<td>$60</td>
<td>$240</td>
</tr>
<tr>
<td>Total per Vehicle</td>
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<td></td>
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<tr>
<td>Number of Vehicles</td>
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<td></td>
<td>25</td>
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<tr>
<td><strong>Total Vehicle Equipment</strong></td>
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<tr>
<td><strong>Subtotal Construction Cost</strong></td>
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<tr>
<td>Contingency</td>
<td>20%</td>
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<td>$14,020</td>
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<tr>
<td><strong>Total Construction Cost</strong></td>
<td></td>
<td></td>
<td>$84,120</td>
</tr>
</tbody>
</table>

Note: Cost estimate does not include X49 bus stop relocations to far-side by CTA, BSMS schedule development for X49 service by CTA, or project coordination and evaluation by CTA and CDOT.

A separate cost estimate has been included for the evaluation of the TSP system by another turnkey vendor. This cost estimate was developed based on experience with data collection at the beginning of this study to support the development of the microsimulation traffic operations analysis. All cost estimates assume that data collected in February and March 2001 can be reused for the study to represent the “before” condition. Thus, to ensure maximum comparability, it is recommended that the “after” study take place at approximately the same time of year in 2002. Three alternatives are provided:

- **Alternative 1:** The cost to implement a before and after study of average travel speeds, bus occupancies, and cross street bus dwell and stop times, which includes all field measurements and a summary report is $8,300. This alternative assumes no additional data collection to represent the “before” condition. Corresponding data will be collected to represent the “after” condition.

- **Alternative 2:** The cost to implement a before and after study as above (Alternate 1) with the addition of a before and after measurement of intersection stop delay at 3 signalized intersections during the AM and PM peak hours, which includes all field measurements and a summary report is $14,400. This alternative assumes reuse of previously collected...
data, supplemented by limited intersection stop delay data collection to represent the “before” condition. Corresponding data will be collected to represent the “after” condition.

- Alternative 3: The cost to implement a before and after study as above (Alternate 1) with the addition of a before and after measurement of intersection stop delay at all 13 signalized intersections in the project corridor during the AM and PM peak hours, which includes all field measurements and a summary report is $30,600. This alternative assumes the same types of data collection as Alternative 2, but at more intersections.

10.3. Draft Intergovernmental Agreement

Before an operational test can be conducted, an intergovernmental agreement between the Chicago Transit Authority and the City of Chicago will need to be prepared. There are three main steps in the development of this agreement.

1. **Prepare Draft Intergovernmental Agreement:** The purpose of the Draft Agreement is to bind the City of Chicago and the CTA to share the costs for construction, operations (energy), and maintenance for the Transit Signal Priority System along Western Avenue between 59th Street and 87th Street.

   The following items will be identified:
   
   - Who will bear the cost of construction?
   - Who will maintain the system after construction?
   - Who will bear the energy cost?
   - Who will service the system in event of damage caused by equipment malfunction, incidents, and natural disasters.

2. **Review and Gain Concurrence:** The Draft Agreement will be reviewed and commented on by both parties until concurrence is achieved.

3. **Execute Agreement:** Upon the concurrence of the proposed agreement, each governing Board/Council will pass a resolution (copy to be attached) authorizing its agent/representative to sign and execute the agreement. Two (2) copies of the agreement, one for each party will be prepared and executed.