CONCEPT OF OPERATIONS

FOR THE

REGIONAL TRANSIT SIGNAL PRIORITY IMPLEMENTATION PROGRAM (RTSPIP)

DEVELOPED FOR:

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**DOCUMENT STATEMENT OF LIMITATIONS**

This Concept of Operations (ConOps) presents a conceptual overview of the proposed Transit Signal Priority (TSP) system to be implemented under the Regional Transit Signal Priority Implementation Program (RTSPIP). This report is conceptual in nature and is not to be used as the sole basis for final design, construction or remedial action, or as a basis for major capital decisions. Further documentation will be prepared to lead TSP implementers through final design and construction phases of the RTSPIP.
1. INTRODUCTION

This Concept of Operations (ConOps) has been developed to illustrate at a conceptual level how a regionally interoperable Transit Signal Priority (TSP) system will be implemented through the Regional Transit Signal Priority Implementation Program (RTSPIP).

1.1. PURPOSE OF DOCUMENT

The purpose of this ConOps document is to describe how a regionally interoperable TSP system will function for Pace Suburban Bus (Pace) and the Chicago Transit Authority (CTA) throughout the region. The document will include a high-level operational description of the proposed TSP system from each user’s perspective and a summary of the operational needs and impacts on each stakeholder.

1.2. REGIONAL TSP OPERATIONS BACKGROUND

The Regional Transportation Authority (RTA) began planning for regional TSP deployments in 2001 with a two-phase TSP Location Study that identified suitable sites for deployment of an integrated TSP system throughout the RTA region. Phase 1 of the study identified segments of potential TSP corridors for more detailed evaluation, while Phase 2 evaluated these segments using microscopic transit simulation models.

Also in 2001, the RTA assisted with a feasibility study of TSP operations along Western Avenue in coordination with City of Chicago Department of Transportation (CDOT), CTA, and Pace Suburban Bus Service. An optical-based TSP system was later deployed in 2009 along two segments of Western Avenue that feature CTA transit services. Traffic signal timings were also optimized along much of the corridor.

The RTA also assisted with the planning and deployment of a TSP system implemented by Pace Suburban Bus around the Pace Harvey Transportation Center. Planning for the corridor began in 2006 with the system installation and operations beginning in 2010. The Pace TSP system utilized Wi-Fi-based communications between buses and intersections to enable TSP at intersections.

Pace and CTA have also conducted TSP demonstrations independent of the RTA over the years. IDOT coordinated with Pace and the CTA in 1997 on the Cermak Road TSP demonstration, and Pace has also more recently demonstrated the use of an optical-based TSP System along Washington Street in collaboration with the Lake County DOT in 2013.

These field demonstrations have proven the value of TSP systems to both CTA and Pace through increased schedule adherence and improved transit travel times along TSP corridors. Future expansion of TSP systems throughout the region is anticipated.
in the coming years through federal Congestion Mitigation and Air Quality (CMAQ) funding provided to RTA by the Chicago Metropolitan Agency for Planning (CMAP). This funding will support a five-year program of TSP implementation along priority corridors for the benefit of strategic CTA and Pace bus routes in the region. The RTSPIP supports the goals of CMAP’s GO TO 2040 comprehensive regional plan and improves air quality.

1.3. **SCOPE OF RTSPIP PROJECT**

The Regional Transportation Authority is leading the RTSPIP, which will provide a framework for the implementation of a regionally coordinated and integrated TSP system. The program will involve up to 400 miles of roadway and 1,000 signalized intersections across multiple jurisdictions. The programming of specific TSP corridors and the limits of the improvements are subject to change based on program planning and engineering considerations. A preliminary table of corridors for the five-year program is maintained by the RTA at: [http://www.rtams.org/rtams/transitSignalPriority.jsp](http://www.rtams.org/rtams/transitSignalPriority.jsp)

The Program Objectives include the development of regional standards and guidelines for the design, implementation, operation and maintenance of a multi-jurisdictional TSP system. The RTSPIP has been developed and is being implemented in coordination with regional stakeholders including the Chicago Transit Authority, Pace, the Illinois Department of Transportation (IDOT), the Chicago Department of Transportation, local DOTs, the Chicago Metropolitan Agency for Planning, and other municipalities.

The URS Team has been selected by RTA to lead the four work tasks identified for the RTSPIP:

1. **Task 1: Program Management** – Includes on-going Program Management support to the RTA and the other program participants for the RTSPIP.
2. **Task 2: Systems Engineering** – Includes establishing regional TSP standards and guidelines for design, installation, and operations and maintenance of a regionally interoperable TSP system. Systems Engineering will include a Concept of Operations and Technical System Requirements for TSP system implementers.
3. **Task 3: Implementation Oversight** – Includes oversight of vendors and installers so that individual TSP projects within the RTSPIP are planned, designed, and implemented in accordance with the Regional TSP Standards and Implementation Guidelines document.
4. **Task 4: Program Validation** – Includes developing performance measures for the RTSPIP and measuring the program’s overall effectiveness and benefits to the region.
This ConOps document follows the outline proposed by the Federal Highway Administration (FHWA) in their Systems Engineering Guidebook for ITS Version 3.0. The outline can be accessed at:
http://www.fhwa.dot.gov/cadiv/segb/views/document/Sections/Section8/8_4_5.htm

1.4. DOCUMENT ORGANIZATION

This document is divided into the following sections:

- Section 1 – Introduction – Presents the purpose of this document and an overview of the RTSPIP Program and the overall scope
- Section 2 – Program Goals and Objectives – Describes the goals and objectives of the TSP system and performance measures that will be used to evaluate system effectiveness over time
- Section 3 – TSP System Overview – Provides a description of the interrelationships of TSP system components and outlines stakeholder roles and responsibilities in operating the TSP system
- Section 4 – Operational and Support Environments – Describes the facilities, equipment, technologies, operational procedures, coordination, communications between agencies, and agreements between various agencies necessary to operate, support, and maintain the TSP system
- Section 5 – Operational Scenarios – Describes a sequence of user activities and operational process procedures for various scenarios of TSP operations throughout the region
- Section 6 – System Implementation Overview – Identifies next steps that regional stakeholders will need to follow in the Systems Engineering process of deploying and operating the TSP system
- Appendix A – Includes various stakeholder meeting minutes and related material disseminated at TSP Workgroup stakeholder meetings
- Appendix B -- Presents a compliance matrix demonstrating this document’s compliance with FHWA Rule 940

1.5. REFERENCED DOCUMENTS

5. Regional Transportation Authority Mapping and Statistics (RTAMS) – Transit Signal Priority. Available at: http://www.rtams.org/rtams/home.jsp


8. Chicago Metropolitan Agency for Planning (CMAP) GO TO 2040 Comprehensive Regional Plan. Available at: http://www.cmap.illinois.gov/2040/download-the-full-plan


2. **PROGRAM GOALS AND OBJECTIVES**

This section of the ConOps presents a Needs Assessment for the RTSPIP and outlines program goals, objectives, and performance measures to be used in assessing the overall effectiveness of TSP systems deployed under the RTSPIP.

2.1. **NEEDS ASSESSMENT**

The RTSPIP arises out of the following three general needs:

1. Improved schedule adherence and reduced travel times for transit and improved signal coordination for general vehicles
2. Regional TSP interoperability between Pace, CTA, CDOT, IDOT, and other local DOTs. Open standards for TSP can provide the benefits of not being tied to a single TSP vendor, simplify operations and maintenance (O&M) for traffic agencies, allow for Pace and CTA to request TSP from a single device within the signal cabinet, and provide centralized monitoring of TSP activity
3. Compliance with Northeastern Illinois Regional ITS Architecture, given the federal funding involved in the RTSPIP

As the Chicago region continues to prosper, the demand for fast and reliable transit travel times along major transit corridors in the region continues as well. In addition, the Chicago region is pursuing TSP to help address other operational issues associated with operating bus routes along congested arterials. These issues include maintaining route schedule adherence along signalized arterial routes that present challenges to arriving at key destinations as listed on posted schedules. Operational challenges to maintaining schedule adherence generally include recurring traffic congestion along the corridors and traffic signals that may not be optimally timed to allow for buses and general traffic to proceed along the corridor.

Reducing transit travel times along the length of a corridor can also help to improve the perception of public transit as a desirable mode of travel. To address this need, Pace is moving forward with an Arterial Rapid Transit (ART) program, while the CTA is proceeding with a Bus Rapid Transit (BRT) program. TSP operations, in conjunction with other premium transit features along the ART and BRT corridors, will provide transit customers with faster and more reliable transit travel times between destinations on these corridors.

Both CTA and Pace have successfully conducted field demonstrations of TSP systems, along with traffic signal timing optimization, and have experienced the benefits of improved schedule adherence and reduced transit travel times as a result of these efforts. These benefits have led to a desire for additional TSP systems along key arterial corridors, including future ART and BRT corridors. The existing capabilities of these TSP Systems vary based on the vendors chosen for TSP Implementation, but generally include vehicle and intersection-based TSP equipment communicating when TSP is needed along the corridor. Vehicle-based TSP
equipment has integrated with existing AVL Systems for requesting TSP when behind schedule, though there are different communications methods between buses and intersections.

Secondly, there is an overall need for regional TSP system interoperability between transit and traffic agency stakeholders in future TSP system deployments. Future TSP corridors may include overlapping CTA and Pace transit services across multiple jurisdictions of traffic signal controllers operated by CDOT, IDOT, and other local / county DOT’s. In the event that Pace buses would request TSP at an intersection with different TSP equipment deployed by CTA, TSP could not be granted given the proprietary communications capabilities of the previously deployed TSP Systems.

Other benefits of regional interoperability include locational flexibility in fleet deployment, providing the ability to assign vehicles to different locations without losing TSP functionality, and the simplicity of maintaining similar on-board TSP equipment. For example, service changes such as replacing CTA routes with Pace service along a TSP corridor could be implemented without losing TSP functionality.

Clearly, based on the existing infrastructure environment, there will be some variability in the types of TSP on-board technologies implemented within an individual agency. The need for a variety of TSP technologies presents installation, integration, and maintenance challenges for vehicle technicians responsible for coordinating and maintaining multiple on-board transit technologies deployed by Pace and CTA. Any success in limiting the number of deployed technologies will be beneficial in this regard. Several vehicle-based communications systems exist that could be leveraged to meet the needs of TSP expansion throughout the region, including Automated Vehicle Location (AVL) systems that calculate and communicate vehicle location to CTA and Pace centralized operations personnel, which could eliminate the need for on-board equipment to communicate directly with roadside equipment.

Regional interoperability with CDOT, IDOT, and other county DOT’s is also desired to ensure that traffic signal controllers can effectively serve both CTA and Pace buses with TSP at the same intersections, while minimizing negative impacts to general and side street traffic operations. Traffic signal technicians must maintain the safe and efficient operation of the traffic signal controller granting TSP requests, and multiple types of TSP equipment within one signal cabinet may impact the technician’s ability to maintain TSP operations for both Pace and CTA on a long-term basis. A single system of intersection-based TSP equipment that can respond to both CTA and Pace buses would ease CDOT / IDOT / Local DOT maintenance of TSP systems.

A single system of intersection-based equipment could successfully provide TSP benefits to both Pace and CTA through the use of standards-based protocols for messages sent from buses to intersections. The use of NTCIP standards for communications protocols can provide a base for different TSP system manufacturers to develop their TSP system to meet the needs of both transit and traffic agencies in
the region. This would allow Pace and CTA buses with different types of AVL and TSP equipment to successfully make TSP requests at traffic signals that have had different TSP equipment deployed by either Pace or CTA through the RTSPIP.

Finally, there is also a need for RTSPIP compliance with the Northeastern Illinois Regional ITS Architecture, given the federal funding involved in the RTSPIP. The current 2007 Regional ITS Architecture is being updated by CMAP to reflect the current state of existing and planned ITS deployments in the region. The RTA will communicate with CMAP during the Architecture update to ensure that the planned TSP system implementations under the RTSPIP reflect the communication flows and NTCIP standards that are defined by the updated Regional ITS Architecture.

The RTA, CTA, and Pace have recognized these general needs as necessary to ensure that TSP can effectively operate across multiple jurisdictions in order to improve schedule reliability and transit travel times. The TSP system described within this ConOps document will address the following four key technological characteristics that meet the needs described within this section:

1. Utilize, to the extent possible, existing on-board AVL systems and vehicle technology to generate TSP requests
2. Create standards-based communication protocols between buses and intersections (i.e., no proprietary communication protocols)
3. Utilize readily available off-the-shelf communication technology (e.g., Dedicated Short Range Communications (DSRC), Wi-Fi, cellular) for vehicle to intersection communications
4. Leverage TSP communications infrastructure for other transit ITS applications along a TSP corridor

A summary of benefits and opportunities for program stakeholders with respect to Transit Signal Priority operations is presented in Figure 2-1. The benefits to the traveling public, as indirect stakeholders in the program, are also displayed at the bottom of the figure.

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<thead>
<tr>
<th>Agency</th>
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<th>Description</th>
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<tr>
<td>Pace / CTA</td>
<td>1</td>
<td>Better schedule adherence of transit services along TSP Corridors</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Improved transit travel times along TSP Corridors without skipping signal phases or interrupting of signal system coordination</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Improved transit service along planned Bus Rapid Transit (BRT) and Arterial Rapid Transit (ART) corridors</td>
</tr>
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<td></td>
<td>4</td>
<td>TSP strategies on TSP corridors with overlapping Pace and CTA bus service as determined by Service Boards and DOTs</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Improved ease of vehicle equipment maintenance</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Ability to leverage existing on-board equipment for TSP operations</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Reduced operations costs through increased operations efficiency</td>
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Figure 2-1. RTSPIP Stakeholder Benefits and Opportunities

<table>
<thead>
<tr>
<th>Agency</th>
<th>ID</th>
<th>Description</th>
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<td>CDOT / IDOT / Local DOT’s</td>
<td>8</td>
<td>Leverage TSP implementation for optimizing traffic signal timings</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Minimize amount and variety of intersection-based TSP equipment that needs maintenance</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Leverage TSP implementation for interconnecting signalized intersections and upgrading signal controllers, where needed</td>
</tr>
<tr>
<td>Traveling Public</td>
<td>11</td>
<td>Better schedule adherence of transit services along TSP Corridors</td>
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<td></td>
<td>12</td>
<td>Improved transit travel times along TSP Corridors without skipping signal phases or interrupting of signal system coordination</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>Improved roadway operational performance for drivers</td>
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2.2. GOALS AND OBJECTIVES

The overall goal of the program is to develop a regionally interoperable TSP system for Pace and CTA buses traveling through multiple jurisdictions that will improve transit performance in the region.

More specific TSP system goals and objectives that address the basic needs of Pace and CTA bus operations discussed earlier in this document are also outlined in Figure 2-2.

Figure 2-2. RTSPIP Goals and Objectives of Interoperable TSP System

<table>
<thead>
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<tr>
<td>Develop and Implement a Regionally Interoperable TSP system for Pace and CTA Buses across multiple jurisdictions</td>
<td>Establish Regional TSP Standards and Implementation Guidelines for TSP System</td>
</tr>
<tr>
<td></td>
<td>Utilize, to the extent possible, existing on-board AVL Systems and vehicle technology to generate TSP requests</td>
</tr>
<tr>
<td></td>
<td>Create standards-based communication protocols between buses and intersections</td>
</tr>
<tr>
<td></td>
<td>Utilize readily available off-the-shelf communication technology (e.g., DSRC, WiFi, cellular) for vehicle to intersection communications</td>
</tr>
<tr>
<td></td>
<td>Leverage TSP communications infrastructure for other transit ITS applications along a TSP corridor</td>
</tr>
<tr>
<td>Improve schedule / headway reliability, travel times and fuel efficiency</td>
<td>Reduce variability in transit travel times and running times, and reduce transit signal delay.</td>
</tr>
<tr>
<td></td>
<td>Reduce transit and general vehicle travel times along the corridor and minimize negative impacts of TSP to private vehicles on arterials and cross streets</td>
</tr>
<tr>
<td></td>
<td>Reduce transit and general vehicle fuel consumption along TSP corridors.</td>
</tr>
</tbody>
</table>
An interoperability demonstration will be conducted along a TSP corridor when both Pace and CTA have both deployed TSP equipment through the RTSPIP. Many corridors feature both CTA and Pace transit service as listed within the CMAQ grant application, such as 95th Street and Dempster Street. Specific corridor limits will be chosen for the interoperability demonstration at a later date.

The Systems Engineering process will be followed to achieve Program Goals and Objectives for the RTSPIP and all TSP deployments that occur through the program. The Systems Engineering process will follow the guidelines in the “System Engineering Guidebook for ITS”, version 3.0 dated November 2009, published by the Federal Highway Administration/California Division, which is available at: http://www.fhwa.dot.gov/cadiv/segb/

2.3. PERFORMANCE MEASURES

Given the program goals and objectives, Pace and CTA transit performance will be measured by improved schedule adherence / “on-time” performance, reduced transit travel times along TSP corridors, and other measures as deemed appropriate. These are displayed in Figure 2-3.

It should be noted that data on performance measures may need to be collected along TSP corridors at three different stages in order to properly measure the effectiveness of TSP operations. Traffic signal timing optimization is generally performed by traffic agencies prior to TSP system implementation so that new signal timings reflect current traffic patterns. Performance measures will be collected before and after signal timing optimization, as well as after TSP system implementation, to isolate the improvements that can be attributed to each activity.

Figure 2-3. RTSPIP Summary of Proposed RTSPIP Performance Measures
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<td>Improve transit schedule (or headway) adherence / reliability</td>
<td>Increased schedule adherence / “on-time” performance</td>
<td>Pace / CTA AVL Systems</td>
<td>Improvement of bus schedule adherence or “on-time” performance measured by on-board AVL system for TSP-equipped buses operating along the corridor. “On-time” is generally defined as less than 5 minutes behind schedule and no more than 1 minute ahead of schedule.</td>
</tr>
<tr>
<td>Improve transit travel times along TSP Corridors without skipping signal phases or interrupting of signal system coordination</td>
<td>Reduction in transit travel times</td>
<td>Pace / CTA AVL Systems</td>
<td>Improvement in transit travel times along corridors where traffic signals have been equipped with the TSP system. TSP system will be de-activated for a short period of time to allow for travel time data collection for TSP-equipped buses operating along the entire corridor, and then re-activated to allow for a before-and-after comparison.</td>
</tr>
<tr>
<td>Improve traffic signal operations and minimize negative impacts of TSP to private vehicles on arterials and cross streets</td>
<td>Reduction in general vehicle travel times</td>
<td>Travel Time Runs (As necessary)</td>
<td>Reduction in general vehicle travel times along corridors where traffic signals have been equipped with the TSP system.</td>
</tr>
</tbody>
</table>

### 2.4. RTSPIP Program Validation

Regional and project level performance measure guidelines will be developed for use by the RTSPIP participants. The regional performance measure guidelines will be consistent with the goals and guidelines provided from CMAP for the CMAQ Program. The project level performance measure guidelines will be consistent with RTA’s goals and will primarily focus on:

- Headway or schedule reliability
- Travel time improvements
- Fuel efficiency
- Additional performance measures for individual TSP corridor projects (as needed)

As part of this task, an RTSPIP Data Collection Plan will be developed that focuses on what data is needed to measure on-going improvements and benefits from deploying the RTSPIP. This Plan will identify the types of data needed and who is responsible for the collection of the data.
Types of data will likely include timestamps from the AVL systems on Pace and CTA buses before and after signal timing optimization and TSP system implementation to measure travel time improvements. Timestamps of TSP events will be useful to measure when TSP was requested and its effects on travel times and schedule reliability along a TSP corridor.

As noted above, performance measures may need to be collected before and after signal timing optimization, as well as after TSP system implementation, to isolate the improvements that can be attributed to each activity.

The Systems Engineering Management Plan (SEMP) developed for this project contains more information on the Program Validation that will be performed upon completion of TSP system implementations.
3. **TSP System Overview**

This section of the document provides a high-level description of the interrelationships of key components of the TSP system, along with stakeholder roles and responsibilities for operating and maintaining the system over time.

3.1. **Comparable TSP Systems**

This section provides an overview of three TSP Systems in large metro areas that have similar characteristics of the proposed TSP System under the RTSPIP. Though there are some key differences in types of equipment deployed on buses and at intersections, the TSP systems described herein generally reflect the goals and objectives of regional TSP interoperability across jurisdictions.

3.1.1. **King County Metro (Seattle) TSP System**

King County Metro (KCM) operates a TSP System in the Seattle, WA metro area that is built around Transit Communications Interface Profiles (TCIP) standards defining TSP operations. TCIP-based TSP message sets are generated from the AVL unit on buses and transmitted through an on-board mobile communications router via the 4.9 GHz band to roadside wireless access points along the TSP Corridor, which send the message sets to the roadside Transit Priority Request Generator (TPRG).

The TPRG receives TSP message sets from buses along the corridor and determines the need to request TSP from the signal controller. There are certain conditions placed on TSP operations, such as the current phase state of the signal controller. TSP log data is sent from TPRG units in the signal cabinet through a combination of fiber networks back to a central office for monitoring and evaluation purposes.

Figure 3-1. Overview of TSP Operations for King County Metro in Seattle, WA
3.1.2. Los Angeles County TSP System

The Los Angeles County Metropolitan Transit Authority (LACMTA) operates a similar TSP System to the KCM TSP System. It is also built around TCIP open architecture standards and sends TSP message sets from the on-board AVL system through existing on-board communications equipment to roadside wireless access points along the TSP Corridor. One difference is the use of the 2.4 GHz band for vehicle to intersection communications.

Another key difference from the KCM system is the centralized nature of TSP operations for LACMTA. TSP message sets from buses along the corridor are sent to the traffic signal controller, which then relays the TSP request to a central traffic management system. This central system determines whether or not TSP should be granted to buses and adjusts the signal controller phases as appropriate.

Figure 3-2. Overview of TSP Operations for Los Angeles County MTA

3.1.3. New York City MTA TSP System

The New York City Metropolitan Transit Authority (MTA) operates a centralized TSP System that was recently built around NTCIP open architecture standards. MTA buses would send TSP message sets from the on-board AVL system through on-board cellular communications equipment to TSP software installed at the MTA Transit Management Center. The software package would receive the messages and determine the need for TSP at upcoming intersections.

The MTA Transit Management Center would then communicate requests for TSP to centralized traffic management software at the New York City DOT Traffic Management Center (TMC). The DOT TMC would then grant or deny TSP requests at signalized intersections based on traffic operational considerations such as time available within the affected signal cycles.
It should be noted that this centralized approach of TSP System operations utilizes fiber optic cable connections between centers, as well as between the DOT TMC and signal controllers in the field to minimize potential latency in communications between TSP System components.

3.2. CHARACTERISTICS OF PROPOSED RTSPIP SYSTEM

The proposed TSP system to be deployed through the RTSPIP is illustrated in Figure 3-4 on the following page and described in further detail in the sub-sections that follow. The system is divided into three general areas of communication between system components:

1. **Vehicle-to-Intersection (V-2-I):** Represents equipment on-board Pace and CTA buses that communicates TSP requests and message sets to intersection-based equipment.
2. **Intersection-to-Intersection (I-2-I):** Represents equipment at intersections that can relay TSP requests to signal controllers and to other intersections as needed for the purpose of TSP operations
3. **Intersection-to-Center (I-2-C):** Represents the communications equipment that can relay operations data and logs from TSP equipment to Pace / CTA and CDOT / IDOT central offices for system administration purposes.

The proposed TSP System will not access or interfere with the security of traffic signal operations and associated communications systems without expressed authorization of the transportation agency having jurisdiction.
Figure 3-4. Overview of Proposed RTSP/P TSP System Operations

V-2-I Vehicle-to-Intersection Communications

CTA Buses
- Clever Devices AVL
- Wireless Comm. Equipment
- TSP Message Sets via Radio Comm.

Pace Buses
- Trapeze AVL 800 Mhz
- Wireless Comm. Equipment
- TSP Message Sets via Radio Comm.

I-2-I Intersection-to-Intersection Communications

CDOT TSP Corridor Roadside
- Signal Cabinet
  - TSP / PRS Device
  - TSP Request + Status
  - Traffic Signal
- Signal Interconnect Fiber / Copper Option
- Master Controller
- CBOX Equipment
- Wireless Option

I-2-C Intersection-to-Center Communications

CDOT TMC
- Signal Monitoring and Control

Legend
- Existing Components / Data Flows
- New Components / Data Flows

Interim Public Cellular Network
- Internet

CDOT TMC System Administrator
- CTA / Pace Transit Management Centers
- Remote TSP Monitoring

IL Transit Gateway
- IL Transit Hub
- IDOT / Local DOT TMCs
- IDOT / Local DOT System Administrators

Communications Cables
(Fiber / Copper Where Available)
3.2.1. Vehicle-to-Intersection (V-2-I) Communications

The V-2-I equipment on board Pace and CTA buses will generate requests for TSP based on input from the on-board AVL systems. While Pace and CTA operate AVL systems from two different manufacturers, each AVL system has the ability to create a request for TSP.

The V-2-I equipment at the intersection will receive TSP requests in the form of a standardized message set and will be integrated with the traffic signal controller to initiate controller routines for priority treatments (e.g., green light extension and red light truncation). The various signal controller models found throughout the region have varying levels of TSP logic to extend green lights and shorten red lights while minimizing disruption to mainline and side street vehicle traffic. While previous TSP field demonstrations have had some successes with TSP operations on the various existing controller types in the region, the capabilities of signal controllers to process TSP requests continues to evolve and will require further discussions with traffic signal jurisdictions and traffic signal manufacturers prior to TSP system deployment.

The communication of standardized TSP message sets and requests to the intersections are expected to occur through a mobile router, radio, and antenna. It should be noted that a router may not be needed if the AVL system has sufficient ports on it. The message set would be received by corresponding communications equipment at the intersection and sent to the signal cabinet for further processing and logging of the message set and request. Further investigation into the communications frequency (e.g., 4.9 GHz, 5.9 GHz, etc.), over the air protocols, and authorization will be performed as the RTSPIP proceeds into the Technical System Requirements development.

The two main options for providing V-2-I communications that will be explored further include using private infrastructure or public infrastructure. An example of private infrastructure is a wireless network deployed, owned, and maintained by one of the stakeholder agencies (or a sister agency) that is used for TSP and other potentially other transit ITS applications as shown in the following schematic.

The V-2-I equipment at signalized intersections will receive requests for TSP from Pace and CTA buses traveling along the corridor. TSP message sets transmitted to the intersection may be processed by an intermediate TSP / PRS device in the signal cabinet or may be processed directly by the signal controller.
Figure 3-5. Private Infrastructure: V-2-I communications over private wireless network

Examples of public infrastructure would be commercial cellular or WiMAX networks that are available to the public as shown in the following schematic.

Figure 3-6. Public Infrastructure: V-2-I communications over cellular network

### 3.2.2. Intersection-to-Intersection (I-2-I) Communications

The I-2-I communications equipment is needed to send intersection-based TSP data from multiple intersections on a corridor to a single intersection for the purpose of sending the aggregated data intersection-based TSP data to a central location for central monitoring. There are various approaches that can be utilized for sending TSP between intersection, depending on the signal systems and jurisdiction at which TSP systems may be deployed.

In the City of Chicago, OEMC operates and maintains roadside communications equipment for a City-wide camera network that could potentially be utilized for
TSP operations. The Chicago DOT and CTA are currently in the process of utilizing the OEMC communications network for TSP communications on the Jeffery Jump service. This roadside communications equipment is referred to as the Chicago-BOX (CBOX) in Figure 3-4. The equipment will provide a means of communicating between multiple intersections along a corridor. Additionally, V-2-I communications can be facilitated by installing a radio in the CBOX for the TSP system. This option will continue to be studied during development of the Technical System Requirements and monitored as the Jeffery Jump TSP system is further developed.

IDOT and local county DOT’s operate and maintain many closed loop signal systems along arterial corridors that are interconnected with either fiber-optic or copper cable. In the case of fiber-optic interconnects, Ethernet connections could potentially be used to provide I-2-I communications for TSP. Additional roadside equipment will be required where there are gaps in the interconnects and to provide V-2-I communications.

Access to IDOT and local DOT signal cabinets will likely need to be done using separate raceways since existing raceways may be at or near capacity and the National Electric Code (NEC) prohibits power and communication circuits sharing the same raceway.

The following schematics provide various examples of potential I-2-I communications options.

![Figure 3-7. I-2-I communications over cellular network](image-url)
3.2.3. Intersection-to-Center (I-2-C) Communications

The I-2-C communications equipment is needed to facilitate the backhaul of TSP data from multiple intersections on a corridor to a centralized location for TSP operational review and monitoring. Figure 3-4 illustrates two options for I-2-C communications.
The first option involves the use of a wired broadband connection between TSP corridors and the central office. This option would utilize the available wired communications networks between traffic signals and Traffic Management Centers (TMCs) in the region for retrieving TSP data from intersections as shown in the following schematic.

Figure 3-10. I-2-C communications over wired network

The second option involves the use of a public cellular network for retrieving TSP data from intersections. This option could be chosen for TSP corridors along closed loop signal systems that have no fiber / copper network connection with a TMC.

Figure 3-11. I-2-C communications over cellular network
In each case the TSP message sets and logs would be transmitted in a standardized format and accessible through a user interface to be developed at a later stage of the RTSPIP.

3.2.4. Centralized TSP System Communications

In the long-term, the proposed TSP system to be deployed through the RTSPIP could migrate towards a Centralized TSP System in which TSP requests are originated from Pace / CTA Transit Management Centers. This would require an additional layer of communications between transit and traffic management centers, as shown in Figure 3-12 on the following page. The system could be divided into four general areas of communication between system components:

1. **Vehicle-to-Center (V-2-C):** Represents equipment on-board Pace and CTA buses that communicates on a frequent basis (e.g., second-by-second) with Pace / CTA transit management centers.

2. **Center-to-Center (C-2-C):** Represents the communications network equipment (e.g., fiber, cellular, T1) that can relay TSP requests from Pace / CTA transit management centers to CDOT / IDOT traffic management centers.

3. **Center-to-Intersection (C-2-I):** Represents the fiber network / wireless communications equipment that can receive TSP requests from CDOT / IDOT traffic management centers and relay operations data and logs from TSP equipment to Pace / CTA central offices for system administration purposes.

4. **Intersection-to-Intersection (I-2-I):** Represents equipment at intersections that can relay TSP operations data and logs from TSP equipment to other intersections along the corridor.

This ConOps document does not address this Centralized TSP configuration further, but the long-term approach of migrating from the TSP configuration presented in Figure 3-4 to what is shown in Figure 3-12 should be re-visited in the future by the TSP Working Group.
Figure 3-12. Overview of Potential Centralized TSP System Operations under RTSPIP

- **V-2-C** Vehicle-to-Center Communications
  - CTA Buses
    - Clever Devices AVL
    - Wireless Comm. Equipment
  - Pace Buses
    - Trapeze AVL 800 Mhz
    - Wireless Comm. Equipment

- **C-2-C** Center-to-Center Communications
  - CDOT TMC
    - CDOT TMC System Administrator
    - IL GATEWAY
  - CTA / Pace Transit Management Centers
    - TSP Request Monitoring
    - CTA / Pace TSP System Administrators
    - IL TRANSIT HUB
    - IL GATEWAY

- **C-2-I** Center-to-Intersection Communications
  - CDOT TSP Corridor Roadside
    - Signal Cabinet
      - TSP /PRS Device
      - TSP Granted / Denied
      - Master Controller
      - Signal Interconnect Fiber / Copper Option
    - CDOT TSP Corridor Roadside
      - Signal Cabinet
        - TSP /PRS Device
        - TSP Granted / Denied
        - Signal Controller
        - Signal Interconnect Fiber / Copper Option

- **I-2-I** Intersection-to-Intersection Communications
  - IDOT / Local DOT TSP Corridor Roadside
    - Signal Cabinet
      - TSP /PRS Device
      - TSP Request + Status
      - Signal Controller
      - Master Controller
      - Signal Interconnect Fiber / Copper Option

Legend:
- Existing Components / Data Flows
- New Components / Data Flows

Communications Cables (Fiber / Copper Where Available)
3.3. Stakeholder Roles and Responsibilities

Stakeholder roles and responsibilities are discussed in further detail in the following sub-sections based on their relation to the V-2-I, I-2-I, and I-2-C communications areas displayed in Figure 3-4. General roles are summarized in a Responsible, Accountable, Consulted, Informed (RACI) matrix in Figure 3-13. As it relates to the proposed system, these terms are defined as the following:

- **Responsible** – Personnel that are responsible for the operation of TSP systems throughout the region
- **Accountable** – Personnel that are accountable for how the TSP system meets performance measures (e.g., configuring AVL schedule adherence thresholds, enabling TSP system operations)
- **Consulted** – Personnel that can provide valuable input to those who are responsible and accountable for operation of the TSP system
- **Informed** – Personnel, including the general public, that are kept informed about the status of system operations

![RACI Matrix](image)

### 3.3.1. Vehicle-to-Intersection (V-2-I) Roles and Responsibilities

The V-2-I area of Figure 3-4 illustrates Pace and CTA buses sending requests for TSP and message sets to traffic signals operated by CDOT and IDOT / Local DOTs. The roles and responsibilities generally include the following:

- **RTA**: Determine content of TSP message set to be transmitted via TCIP protocols; oversee Technical System Requirements that outline TCIP standards that will be applied to RTSPIP operations; identify the standard radio technology for RTSPIP (4.9 GHz, 5.9 GHz, etc…)
- **CTA / Pace**: Work with AVL vendors to understand what content can be used in TCIP message sets for TSP operations; develop interface with on-
board communications equipment; operate and maintain on-board communications equipment; troubleshoot issues that may arise with TSP requests made from AVL system and other on-board equipment

- CTA / Pace: Procure and maintain separate TSP equipment (if necessary) installed at signal cabinet locations; monitor TSP equipment and evaluate TSP activity at intersections

### 3.3.2. Intersection-to-Intersection (I-2-I) Roles and Responsibilities

The I-2-I area of Figure 3-4 illustrates requests for TSP and message sets being processed at traffic signals operated by CDOT and IDOT / Local DOTs, as well as communications between intersections. The roles and responsibilities generally include the following:

- **RTA / CDOT / IDOT / Local County DOTs:** Communicate with CTA and Pace on status of traffic signal and TSP operations along TSP corridors; communicate with signal controller vendors / manufacturers on how TSP operations are serviced by different signal controller types; determine potential use of fiber / copper / wireless network for transmitting TSP message sets to CTA and Pace Transit Management Centers
- **CDOT:** Communicate with CTA and Pace on use of CBOX equipment for V-2-I and I-2-I communications
- **CTA / Pace:** Procure and maintain separate TSP equipment (if necessary) installed at signal cabinet locations; monitor TSP equipment and evaluate TSP activity at intersections

### 3.3.3. Intersection-to-Center (I-2-C) Roles and Responsibilities

The I-2-C area of Figure 3-4 illustrates two options for how TSP data from the field can be communicated back to CTA and Pace Transit Management Centers for remote monitoring of TSP activity. The roles and responsibilities generally include the following:

- **CTA / Pace:** Perform remote monitoring of TSP activity along TSP corridors; inform CDOT / IDOT / Local DOTs on issues needing resolution at traffic signals (e.g., lack of connectivity with corridor, abnormal TSP operations at an intersection)
- **CDOT / IDOT / Local DOTs:** Perform troubleshooting in resolving issues with TSP operations at intersections; communicate with CTA and Pace on fiber network plans and potential impacts to remote TSP monitoring

Other general stakeholder roles and responsibilities are described within Figure 3-14.
Figure 3-14. Anticipated Stakeholder Roles and Responsibilities

<table>
<thead>
<tr>
<th>Agency</th>
<th>Roles and Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regional Transportation Authority</td>
<td>Provides oversight to transit agencies (Pace and CTA) during the RTSPIP to verify compliance with Technical System Requirements and overall project objectives</td>
</tr>
<tr>
<td>Chicago Transit Authority</td>
<td>Operates and maintains TSP System equipment installed on transit vehicles and at signalized intersections; communicates with traffic signal agencies regarding potential issues with traffic signal operations; monitors TSP System operations remotely through the use of TSP Central Control Software</td>
</tr>
<tr>
<td>Pace Suburban Bus Service</td>
<td>Operates and maintains TSP System equipment installed on transit vehicles and at signalized intersections; communicates with traffic signal agencies regarding potential issues with traffic signal operations; monitors TSP System operations remotely through the use of TSP Central Control Software</td>
</tr>
<tr>
<td>City of Chicago DOT</td>
<td>Operates and maintains traffic signals along TSP corridors in the City of Chicago; assists transit agencies in troubleshooting issues with TSP operations; communicates with OEMC regarding use CBOX communications equipment for TSP</td>
</tr>
<tr>
<td>Office of Emergency Management and Communications (OEMC)</td>
<td>Operates and maintains Chicago BOX (CBOX) wireless communications equipment located near traffic signals within the City of Chicago; communicates with CDOT regarding use of CBOX equipment for TSP operations</td>
</tr>
<tr>
<td>Illinois DOT</td>
<td>Operates and maintains traffic signals along TSP corridors throughout the region; assists transit agencies in troubleshooting issues with TSP operations</td>
</tr>
<tr>
<td>County DOTs and City Traffic Departments</td>
<td>Operate and maintain traffic signals along TSP corridors in their jurisdictions as TSP is deployed in the region; assists transit agencies in troubleshooting issues with TSP operations</td>
</tr>
</tbody>
</table>

3.4. SYSTEM INTERFACES

The TSP system will include existing AVL systems installed on buses, new equipment to be installed at signalized intersections that interface with existing signal controllers, and existing and/or new communications equipment to facilitate the communications between buses and intersections.

Centralized software will allow system administrators to monitor TSP system performance and configure TSP system operations.

3.5. COMMUNICATIONS NEEDS ASSESSMENT

This section outlines communications-related items for the region to consider in supporting future TSP Implementations. A more detailed Communications Needs
Assessment will be performed as part of the Technical System Requirements phase of the RTSPIP so that Technical System Requirements can be met by existing and future communications equipment. The needs assessment will include information gathered during face-to-face meetings with the appropriate stakeholders (i.e., Pace, CTA, CDOT, IDOT, and local DOTs) to discuss existing and planned bus technology and communications infrastructure. URS will follow these meetings with a more formal request for information from the agencies to get specific detailed information on the various systems discussed during these meetings that can be incorporated into this needs assessment. The Communications Needs Assessment will consider the following communications-related items by provider:

- Vehicle to traffic signal infrastructure
- Intersection to Intersection infrastructure
- Central to traffic signal infrastructure
- Bandwidth (for TSP and other ITS applications)
- Coverage/interference
- Compatibility with existing CTA and Pace efforts

### 3.5.1. VEHICLE TO INTERSECTION (V-2-I) INFRASTRUCTURE

Out of the three types of communications, V-2-I communications requires the most interoperability. Each agency that needs to generate and receive TSP requests in a corridor will need a way to communicate with the equipment at the intersection that grants the TSP requests. Communications must be done using equipment that is compatible with each other, or multiple pieces of equipment must be installed at the bus and/or intersection to communicate with each agency. The former method is preferred but a hybrid approach may be applied as the systems are developed concurrently with the development of the requirements.

#### 3.5.1.1. CTA INFRASTRUCTURE

The CTA currently operates an optical-based TSP system along Western Avenue which includes infra-red emitters installed on 50 buses which communicate with optical receivers installed at 10 signalized intersections along the corridor.

Other existing equipment on board CTA buses that could be leveraged for expanding TSP operations includes a GPS-based Automated Vehicle Locator (AVL) system manufactured by Clever Devices. This AVL system currently interfaces with an Automated Voice Annunciation System (AVAS) as well as an Automated Passenger Counter (APC) system.

The CTA has also installed a cellular modem on its buses to provide real-time vehicle location to the general public through the CTA Bus Tracker system. This cellular modem interfaces with the AVL system and reports the current locations of CTA buses and trains throughout the region. CTA buses also
have a bulk data transfer radio as part of the Clever Devices Intelligent Vehicle Network (IVN).

The CTA has also installed an on-board Cisco 3230 Mobile Access Router (currently in-active) with 4.9 GHz radios and one 2.4 GHz radio for the purpose of transmitting vehicle information to garage locations.

The CTA has also installed Utility “Rocket” routers on newer buses for the Jeffery Jump BRT project and newer articulated buses for the purpose of sending TSP requests and data to intersections along the Jeffrey corridor. These on-board routers utilize a 5.0 GHz communications frequency to send data to corresponding Utility “Rocket” routers installed on the roadside along the Jeffrey Jump corridor.

### 3.5.1.2. PACE INFRASTRUCTURE

Pace currently operates a Wi-Fi-based TSP system manufactured by Novax around the Harvey Transportation Center which includes a TSP Priority Request Generator (PRG) installed on 55 buses which communicates with Wi-Fi equipment along the TSP corridor and through to 20 signalized intersections with TSP equipment. Pace also operates an optical-based TSP system on Washington Street in Lake County which includes 40 infrared emitters on buses and optical receivers at 10 intersections similar to the CTA TSP system.

Other existing equipment on board Pace buses that could be leveraged for expanding TSP operations includes a GPS-based Automated Vehicle Locator (AVL) system manufactured by Trapeze that operates based on two 800 MHz data frequencies supported by five towers located throughout the region. Pace also operates four 800 MHz voice frequencies to support voice communications between buses and central dispatch. In 2013, Pace will expand to four 800 MHz data frequencies supported by eleven towers located throughout the region that will support AVL and dispatch operations.

### 3.5.2. CENTRAL TO INTERSECTION INFRASTRUCTURE

Pace currently operates a Wi-Fi-based TSP system around the Harvey Transportation Center which includes a TSP Central Management Package that requests TSP Data from TSP intersections in the field. Pace also operates a software package that monitors the Wi-Fi based network around the Harvey Transportation Center.

The Chicago Department of Transportation (CDOT) currently operates a MIST centralized traffic management system that monitors and controls over 230 signals in the City of Chicago. It is anticipated that future TSP projects will be operated under the centralized signal control system with hybrid fiber / wireless communications to the extent possible.
The Illinois Department of Transportation (IDOT) currently operates many closed loop signal systems within the region. These systems are de-centralized in that there is no central control of traffic signal activity. Other County DOTs also operate closed loop signal systems within their jurisdictions in a similar manner as IDOT.

The Lake County DOT (LCDOT) currently operates a Traffic Management Center (TMC) that communicates with traffic signals and other ITS devices in the county via fiber-optic cable network.

### 3.5.3. Bandwidth (for TSP and other ITS Applications)

Bandwidth needs for TSP are minimal and most modern communications equipment will provide more than sufficient bandwidth for the TSP system alone. However, future needs will be considered for other more bandwidth intensive applications such as the transfer of video or real time On-Board Diagnostic (OBD) maintenance data from the buses. While the technical system requirements will determine what bandwidth is required for the TSP system it is recommended that additional bandwidth be provided for system expansion.

Latency, or the time between sending a communication and receiving the communication, is a critical component to the V-2-I communications needs. The latency of the system will determine whether a request will be received in time to be effective as a bus travels the corridor. The detailed technical requirements will include guidelines on latency for the future systems deployed. It is likely that latency requirements will be the driving component of the communications system.

Future ITS applications will be considered and the likelihood of those systems being deployed taken into account. Full motion mobile video is a bandwidth intensive application that could increase the cost of the system. However, the cost of deploying a wireless infrastructure that supports both video and TSP would likely be much less expensive than deploying two separate systems.

### 3.5.4. Coverage/Interference

Coverage and interference requirements shall be defined to the level that allows the designer to determine the level of communications that is needed in each corridor. Because wireless coverage varies according to terrain, frequency, bandwidth needed, and interference each type of wireless communications will be evaluated and a determination made as to whether the technology would be suitable for a TSP system. Ideally the communications requirements developed would allow multiple manufactures equipment to be used competitively and allow the flexibility to be deployed in various real world scenarios.

### 3.5.5. Compatibility with existing CTA and Pace efforts
The optical and Wi-Fi based TSP systems operated by CTA and Pace are proprietary systems that currently do not interface with one another, given different communications utilized by TSP manufacturers and the proprietary nature of communications protocol between vehicle and intersection equipment. Existing optical and Wi-Fi based TSP systems may also not be compatible with future TSP Systems deployed under the RTSPIP.

3.5.6. **PROPOSED COMMUNICATIONS STRATEGY**

The necessary steps for determining the communications strategy are to evaluate the needs of both agencies, find a common communications architecture that can be used, and set requirements to define the system moving forward. Both Pace and CTA have separate systems that will need to be modified, upgraded, and/or replaced in order to be compatible on the same corridors for a TSP system.

Realizing that there are existing TSP systems of varying types that are already deployed, a solution that considers the existing systems will be sought. Reusing and leveraging existing equipment and systems will also be an important consideration.

Two methods in deploying communications infrastructure are currently being evaluated. The first is purchasing and deploying wireless roadside and bus system equipment to be used by each agency for TSP communications. The second is by using cellular or other public networks to support TSP.

Steps to move forward include but are not limited to:

- Identify infrastructure gaps and requirements for TSP
- Determine if cellular is a viable option for TSP in the region
- Define future needs/uses for the system
- Explore ways to leverage and reuse existing infrastructure that is deployed throughout the region.
- Set common interface requirements
- Evaluate system costs

3.6. **PLANNED CAPABILITIES**

The TSP systems deployed by Pace and CTA under the RTA RTSPIP will provide transit vehicles with signal priority based on certain conditions that must be met by the transit vehicle and along the corridor. Restrictions on TSP system activity at an intersection can be managed by the traffic signal controllers in the field.

Conditions placed on buses are planned to include, at a minimum, the schedule adherence of the vehicles traveling along the corridor. When a bus is detected by the AVL system to be more than “x” minutes or seconds behind its posted schedule, then the AVL system will initiate a request for TSP to the traffic signal controller, either through existing or new communications equipment on the vehicle. The AVL
systems currently installed on Pace and CTA buses may need to be configured to
directly place requests for TSP to traffic signal controllers. A determination of the
“x” number of minutes and seconds will also be made at a later stage in the project
and perhaps modified after an evaluation of TSP impacts on bus operations is
completed.

Other conditions that the AVL system may be able to place on TSP operations could
include time-of-day operations. This would allow the flexibility to prevent TSP
operations during heavy travel periods in which TSP requests may further increase
vehicle delays on side streets or along the corridor itself. Other conditions could
include passenger loads detected on the vehicles, vehicle type, and / or route ID. All
transit system conditions would have to be further investigated with the AVL system
vendor.

Traffic signal controllers will have the capability to place restrictions on TSP system
activity in order to maintain signal coordination along the corridor and minimize
negative impacts to side street traffic operations. TSP firmware installed on the
signal controllers is generally designed so as to not disrupt the overall signal cycle
and mainline traffic progression. All minimum green times specified on the traffic
signal controller are generally served for all directions of travel when TSP requests
are made by TSP-equipped buses and will not violate signal timing standards for
minimum green and pedestrian crossing times. While other restrictions can be placed
on TSP requests, such as time-of-day and signal plan restrictions, these capabilities
will vary among signal controller types, makes, and models.

Traffic signal controllers may have the capabilities to send confirmation messages
back to transit vehicles regarding how TSP requests were handled by the controller.
Further investigation into the capabilities of the signal controller to communicate this
information back to TSP System equipment will be performed during the Technical
System Requirements phase of the program.

3.7. SYSTEM ARCHITECTURE

While it is anticipated that the 2007 Northeastern Illinois Regional ITS Architecture
(http://data.cmap.illinois.gov/ITS/Default.aspx) will be updated for the region in
2013, TSP operations are generally reflected in the current ITS architecture and that
same architecture could still apply to future TSP systems deployed through the
RTSPIP. Specifically, TSP systems are currently represented through the “On-Board
Transit Signal Priority” equipment package for Pace and CTA buses, as well as the
“Roadway Signal Priority” equipment package for traffic signal agencies and
stakeholders throughout the region, including the Illinois DOT, the City of Chicago
DOT, and county DOTs.

The applicable Service Packages that illustrate the operation of Transit Signal Priority
in the 2007 Version of the ITS Architecture are shown in ATMS03 – Surface Street
Control and APTS02 – Fixed Route Operations. The ITS Architecture update to be
performed in 2013 will include APTS09 – Transit Signal Priority service package to further illustrate existing and planned TSP operations.

Future applications of TSP are anticipated to be similar to past installations that involve communications between transit vehicles and signalized intersections along a corridor. This project is anticipated to remain consistent with the 2007 Northeastern Illinois Regional ITS Architecture.
4. OPERATIONAL AND SUPPORT ENVIRONMENTS

This section describes the operational and support environments in which the TSP system will operate once implementation of TSP in the corridor has been completed.

4.1. OPERATIONAL ENVIRONMENT

The Chicago Department of Transportation operates multiple types of traffic signal controllers in the City of Chicago as detailed in the following table. CDOT plans to upgrade older traffic signal controllers with ATC model controllers as part of all future Traffic Signal Modernization projects, Bus Rapid Transit projects, and TSP projects.

CDOT currently operates a MIST centralized traffic management system that monitors and controls 233 signals in the City of Chicago. It is anticipated that future TSP projects will be operated under the centralized signal control system with hybrid fiber / wireless communications to the extent possible.

<table>
<thead>
<tr>
<th>Signal Controller Type</th>
<th>Quantity</th>
<th>Existing Cabinet Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peek LMD40</td>
<td>1,276</td>
<td>M or P</td>
</tr>
<tr>
<td>Peek LMD9200</td>
<td>12</td>
<td>P</td>
</tr>
<tr>
<td>Peek HMC1000</td>
<td>1,245</td>
<td>Pedestal Mount</td>
</tr>
<tr>
<td>Peek ATCs</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>LC40</td>
<td>140</td>
<td>M</td>
</tr>
<tr>
<td>Electro-mechanical</td>
<td>227</td>
<td>Pedestal Mount</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>2,909</strong></td>
<td></td>
</tr>
</tbody>
</table>

The Illinois Department of Transportation currently operates two main types of traffic signal controllers in the IDOT District 1 region (not including the City of Chicago) – Econolite and Eagle controllers. There are approximately 1,850 Econolite and about 1,150 Eagle traffic signal controllers in the district. IDOT maintains approximately 2,400 of these signals while local counties and cities maintain the other 600 controllers.

As noted earlier, the RTSPIP will involve up to 400 miles of roadway and 1,000 signalized intersections across multiple jurisdictions. The programming of specific TSP corridors and the limits of the improvements are subject to change based on program planning and engineering considerations. A preliminary table of corridors for the five-year program is maintained by the RTA at:

http://www.rtams.org/rtams/transitSignalPriority.jsp
4.2. TSP SYSTEM OPERATIONAL ENVIRONMENT

As documented in Section 2.1, the TSP system will address the following four key technological characteristics that meet the collective needs of program stakeholders:

1. Utilize, to the extent possible, existing on-board AVL systems and other in-vehicle technology to generate TSP requests
2. Create standards-based communication protocols between buses and intersections (i.e., no proprietary communication protocols)
3. Utilize readily available off-the-shelf communication technology (e.g., DSRC, Wi-Fi, cellular) for vehicle to intersection communications
4. Leverage TSP communications infrastructure for other transit ITS applications along a TSP corridor

The TSP system will provide signal priority when certain conditions are met, such as transit vehicles behind schedule and the traffic signal controller has available green time within the signal cycle to provide for signal priority.

Emergency Vehicle Pre-emption (EVP) technology is also installed throughout the suburban portions of the region (outside the City of Chicago), which provides emergency vehicles with preferential signal treatment during emergency situations. EVP equipment pre-empts traffic signal operations, whereas TSP equipment merely adjusts the signal split time for phases to allow transit vehicles a limited amount of additional time to pass through the intersection.

In the event of simultaneous requests for EVP and TSP within the same signal cycle, an EVP request will cancel a TSP request given the greater need of emergency vehicles to pass through an intersection.

The specific means of communications between transit vehicles and signalized intersections will be determined by Pace and CTA through procurements that will need to meet Technical System Requirements to be developed at a later stage. This could include the use of existing TSP equipment or additional equipment to facilitate communications between buses and intersections.

A central control software package would allow for monitoring and control of TSP system equipment on buses and at intersections. Fiber-optic cable installed along the corridor could be used for communications between the central software and TSP equipment at intersections. The desire for central monitoring of TSP Operations will be further investigated during TSP system design efforts prior to TSP system procurement.

Communications between the central software and buses could occur via a number of remote communications methods along the corridor. On-board TSP logs could also be obtained directly from each bus either through the use of bulk data transfer radios or by connecting a laptop to the TSP equipment for downloading of logs to the laptop.
This means of retrieving vehicle logs will also be further investigated during TSP system design efforts prior to TSP system procurement.

4.3. SUPPORT ENVIRONMENT

Upon installation and final acceptance testing of the TSP system, TSP System Administrators should have the following documentation to support operations of the system:

4.3.1. TSP System Operational Conditions
This document will summarize the conditions placed on TSP system operations by transit operations and by traffic operations. The document will be a collection of other documents produced during TSP system development and will generally include:
  - Transit schedule adherence values
  - Transit vehicle types of service and TSP conditions placed on those vehicle types
  - Traffic signal timing plans in which TSP is allowed or inhibited
  - Other special exceptions to allowing for TSP operations.

4.3.2. Operator’s Manual
The operator’s manual provides a general description and detailed operating and installation instructions for the TSP system. This manual is produced by the manufacturer of the TSP system and will contain the following information:
  - A general description of the equipment
  - The theory of operation of the system components
  - Routine and sequence of operations

4.3.3. Software Manual
The software manual will include instructions for performing a backup of all software and log files. Procedures for software maintenance and upgrades will also be included. This manual is produced by the manufacturer of the TSP system.

4.3.4. Maintenance Manual
The maintenance manual will provide a general description and detailed maintenance instructions. This manual is produced by the manufacturer of the TSP system. It will contain the following information:
  - Recommended procedures and checklists for preventive maintenance
  - Data necessary for isolation and repair of failures or malfunctions
  - A spare parts list and information on the characteristics of individual spare parts.
4.4. AGREEMENTS / COMMITMENTS REQUIRED

The RTA plans to enter into Technical Services Agreements with Primary TSP implementers (Pace and CTA) to provide funding for TSP system engineering and implementation activities that will be led by the TSP implementers. Further details on these are contained within the Program Management Plan developed for this project.

Operations and maintenance agreements between CTA / Pace and CDOT / IDOT / County DOT’s will need to be completed to address items such as the conditions under which the TSP system will be activated to grant signal priority and intersection maintenance activities to be performed by CTA / Pace / CDOT / IDOT / County DOT’s.

4.5. SYSTEM ASSUMPTIONS / CHALLENGES

Figure 4-2 summarizes the assumptions made within this document regarding TSP system operations and the anticipated challenges that will need to be addressed by Program Stakeholders in the upcoming System Requirements and TSP system design phases of the program.

<table>
<thead>
<tr>
<th>System Assumptions / Challenges</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power for TSP Devices</td>
<td>Power sources are available on-board transit vehicles and at signalized intersections for TSP system equipment.</td>
</tr>
<tr>
<td>AVL Equipment Requests for TSP</td>
<td>It is assumed that existing AVL technology can be utilized for requesting TSP when buses are behind schedule or meet other criteria determined by the AVL system.</td>
</tr>
<tr>
<td>Communications Infrastructure between AVL Equipment and Traffic Signals</td>
<td>A communications mechanism will need to be developed to allow the AVL equipment on buses to send requests for TSP to signalized intersections.</td>
</tr>
<tr>
<td>Field Communications Infrastructure for Vehicle to Intersection Communications</td>
<td>Field communications infrastructure will allow buses to relay TSP requests to corresponding TSP equipment installed in signal cabinets. The location of this infrastructure is anticipated to be on traffic signal mast arms, but could also include other areas along the corridor, such as street light poles or other infrastructure at a high enough altitude to provide a clear path of communications between buses and intersections.</td>
</tr>
<tr>
<td>Communications Infrastructure for TSP Devices in Field</td>
<td>Communications infrastructure will allow TSP devices in the signal controller cabinets to be connected with one another for the purpose of sending TSP log data from one centralized point along the corridor.</td>
</tr>
</tbody>
</table>
### Figure 4-2. TSP System Assumptions and Anticipated Challenges

<table>
<thead>
<tr>
<th>System Assumptions / Challenges</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interoperability With Existing TSP systems in the Region</td>
<td>Existing TSP systems in the region are proprietary and do not allow for TSP requests from other TSP systems. Future TSP deployments following open architecture standards will likely not be able to interact with existing proprietary TSP systems. Pace Wi-Fi based PRG equipment may be able to interface with an interoperable TSP system with some modifications through Wi-Fi-cellular I/O capabilities</td>
</tr>
</tbody>
</table>
5. OPERATIONAL SCENARIOS

This section describes a detailed sequence of user activities and operational process procedures for the following operational scenarios:

- Scenario 1 – TSP Requested and Granted
- Scenario 2 – TSP Requested and Denied
- Scenario 3 – Simultaneous TSP Requests from Buses with the Same Priority Level
- Scenario 4 – Simultaneous TSP Requests from Buses with Different Priority Levels
- Scenario 5 – Simultaneous TSP and EVP Requests
- Scenario 6 – Fleet Changes (e.g., Any Changes In Rolling Stock Or Fleet Expansion, Moving Buses Between Garages)
- Scenario 7 - Service Changes (e.g., Adding or Removing Service to a Corridor, Moving from CTA to Pace Services)
- Scenario 8 – TSP System Central Monitoring
- Scenario 9 – Planned Event Impacting TSP System Operations
- Scenario 10 – Un-planned Event Impacting TSP System Operations
- Scenario 11 – Loss of Central Communications

The purpose of the scenarios is to describe common and unusual transit and traffic conditions that will occur once TSP systems are deployed and operational throughout the region. These scenarios represent only a sampling of all possible scenarios, and numeric values are used for information purposes only. The procedures remain fairly consistent through all scenarios. Once TSP systems are deployed and operational, transit and traffic agencies will want to review the operational procedures and develop an operator’s guide to more fully describe how both types of agencies are involved in system operations. The operator’s guide will need to evolve as TSP systems are modified over time, additional intersections are equipped with TSP devices, and/or staff members are reassigned or job descriptions are changed.

5.1. SCENARIO 1 – TSP REQUESTED AND GRANTED

*Traffic is congested on a Wednesday morning, causing a Route 54B CTA bus traveling northward along Cicero Avenue to fall three minutes behind schedule.*

The AVL system on the CTA bus registers that it is three minutes behind schedule, which is greater than the pre-determined schedule adherence threshold of two minutes for TSP operations. Depending on the AVL system capabilities, the AVL system may be able to vary the schedule adherence threshold for requesting TSP by vehicle location or by time-of-day. The AVL system registers the “late” condition along with bus number, route and direction.
As the bus crosses a “check-in” point and approaches the intersection of Cicero Avenue and 39th Street, the AVL equipment communicates with TSP equipment at the traffic signal cabinet to send a TSP request. The AVL system may also provide capabilities for the bus to “check-in” at a pre-determined, geo-coded point prior to the intersection and “check-out” after passing through the intersection. These points are created to minimize disruption to traffic signal timing when buses make a request for TSP, so that only the amount of time needed for the bus is used during TSP requests. Additional TSP equipment may be needed on the bus to define geo-coded “check-in” and “check-out” points along the TSP corridor. The traffic signal controller receives the TSP request from the TSP equipment in the cabinet.

The signal controller processes the request and grants the green extension to an allowable extent within the signal cycle. The bus driver sees the green light and drives through the intersection. Once the bus crosses a “check-out” point after passing through the intersection, the AVL equipment on the bus stops requesting TSP from the TSP equipment in the signal cabinet, which in turn stops requesting TSP from the signal controller.

Since the bus received an extended green light, it made up time and is now a little over one minute behind schedule, less than the pre-determined schedule adherence threshold of two minutes for TSP operations. The presence of far-side bus stops along the corridor also help to facilitate the movement of buses through intersections when TSP is requested. The driver and passengers on the bus continue along the route to their destinations further north in Chicago without a need for requesting TSP at upcoming intersections.

Data on the TSP request is stored on the AVL equipment on the bus and at the intersection. The traffic signal controller also records a log of the TSP event, specifically when the call was received, when the TSP routine was activated, and when the TSP routine ended.

5.2. Scenario 2 – TSP Requested and Denied

Traffic is congested on a Monday morning, causing a Route 54B CTA bus traveling northward along Cicero Avenue to fall four minutes behind schedule.

The AVL system on the CTA bus registers that it is four minutes behind schedule, which is greater than the pre-determined schedule adherence threshold of two minutes for TSP operations. Depending on the AVL system capabilities, the AVL system may be able to vary the schedule adherence threshold for requesting TSP by vehicle location or by time-of-day. The AVL system registers the “late” condition along with bus number, route and direction. As the bus crosses a “check-in” point and approaches the intersection of Cicero Avenue and 39th Street, the AVL equipment communicates with TSP equipment at the traffic signal cabinet to send a TSP request. The traffic signal controller receives the TSP request from the TSP equipment in the cabinet.
The signal controller receives the TSP request, but denies granting a green extension TSP to the CTA bus. This denial could be because the signal controller has determined that there is not enough time within the signal cycle to adjust the signal timing as requested. Other factors in not allowing TSP requests to be granted may include signal controller conditions that are implemented to minimize disruption of mainline and/or cross street traffic flows. These conditions might inhibit TSP requests that occur in back-to-back signal cycles. Other conditions may prevent TSP requests from being granted within certain times of the day.

Although the CTA bus did not receive an extended green light, it is possible that TSP requests could be granted at signal controllers further downstream along the corridor.

Data on the TSP request is stored on the AVL equipment on the bus and at the intersection. The traffic signal controller also records a log of the TSP event, specifically when the call was received and when the TSP routine was denied. Depending on the signal controller capabilities, the controller may be able to log additional information regarding why TSP requests were denied.

5.3. Scenario 3 – Simultaneous TSP Requests with the Same Priority Level

A Route 54A CTA bus is heading north along Skokie Boulevard and is five minutes late as it approaches the intersection with Dempster Street. At the same time, a Route 250 Pace bus heading east on Dempster Street approaches Skokie Boulevard and is three minutes behind schedule.

The AVL system on the Pace bus registers that it is three minutes behind schedule. As the bus crosses a “check-in” point and approaches the intersection, the AVL system on the bus communicates with the TSP equipment at the traffic signal controller to request priority. Seconds after that, the AVL system on the CTA bus crosses its “check-in” point at the intersection and transmits a similar TSP request to the traffic signal controller.

The signal controller acts upon the first TSP request from the eastbound Pace bus and determines whether or not to grant TSP based on the current phase state of the signal controller and grants TSP to the Pace bus. After being granted TSP by the signal controller, the Pace bus crosses its “check-out” point after passing through the intersection and the AVL equipment on the bus stops requesting TSP from the TSP equipment in the signal cabinet, which in turn stops requesting TSP from the signal controller. The CTA bus requesting TSP in the northbound direction would not be granted TSP and would be waiting for a green light to proceed north.

Depending on the signal controller capabilities, the controller may be able to evaluate both TSP requests from the eastbound Pace bus and the northbound CTA bus.
The TSP request from the northbound CTA bus could be processed by the TSP equipment within the signal cabinet immediately after the eastbound Pace TSP request. It may also be possible for TSP equipment within the signal cabinet to determine whether the CTA TSP request should be granted over the Pace TSP request based on factors other than schedule adherence, such as passenger loads. The traffic signal controller would determine the appropriate course of action depending on the point in time within the signal cycle that the CTA and Pace TSP calls are received.

5.4. Scenario 4 – Simultaneous TSP Requests from Buses with Different Priority Levels

A CTA local bus is heading east along 95th St. TSP Corridor and is three minutes late as it approaches an intersection. At about the same time, a CTA express bus heading west on 95th St. approaches the same intersection, and is five minutes behind schedule.

The AVL system on the CTA local bus registers that it is three minutes behind schedule. As the bus crosses a “check-in” point and approaches the intersection, the AVL system on the bus communicates with the TSP equipment at the traffic signal controller to request priority. Just after this TSP request occurs, the AVL system on the CTA express bus crosses its “check-in” point at the intersection and transmits a similar TSP request to the traffic signal controller.

The TSP equipment in the signal cabinet determines to grant TSP to the CTA express bus heading in the westbound direction, because it has a higher priority level. Once the CTA express bus crosses its “check-out” point after passing through the intersection, the AVL equipment on the express bus stops requesting for TSP to the TSP equipment in the signal cabinet, which in turn stops requesting TSP from the signal controller.

The CTA local bus approaching the same intersection from the eastbound direction may then be served by the TSP equipment within the signal cabinet, provided that the signal controller has determined it will not cause disruption to side street traffic operations or mainline traffic on the corridor.

5.5. Scenario 5 – Simultaneous TSP and EVP Requests

A Route 208 Pace bus is travelling east along Golf Road and is five minutes behind schedule as it approaches the intersection with Harlem Avenue in the late morning. At the same time a fire engine with sirens flashing approaches the intersection heading north on Harlem Avenue to respond to a fire call.

The AVL system on the Pace bus registers that it is five minutes behind schedule. As the bus approaches the intersection of Harlem Avenue and Golf Road, the TSP system on the bus communicates with the traffic signal controller to send a TSP request. The signal controller processes the request and grants the green extension to
an allowable extent within the signal cycle. As it does that, the fire engine on Harlem Avenue gets into range and transmits its EVP request.

The signal controller processes the EVP request, recognizes that it is an EVP request and higher priority than a TSP request, and grants the EVP request. The north/south traffic on Harlem Avenue gets a green light and the fire engine travels through the intersection. The east-west traffic on Golf Road gets a red light and the Pace bus falls another minute behind schedule. When it gets a green light on Golf Road, the driver proceeds through the intersection and the AVL system transmits a TSP request to the next TSP-capable intersection it approaches.

5.6. SCENARIO 6 – FLEET CHANGES (E.G., ANY CHANGES IN ROLLING STOCK OR FLEET EXPANSION, MOVING BUSES BETWEEN GARAGES)

Pace re-assigns 10 buses from the North Garage in Waukegan to the North Shore Garage in Evanston. The 10 re-assigned buses will be assigned to operate on Route 250 that travels along Dempster Street. The corridor includes TSP equipment at a number of intersections.

The AVL systems on the re-assigned Pace buses are already configured to make requests for TSP based on schedule adherence values (i.e., TSP requested when behind schedule by “X” number of minutes) and any other relevant AVL inputs to enabling TSP operations. Depending on the need for additional V-2-I communications hardware on the buses, Pace bus technicians may arrange for the installation of additional communications equipment (if necessary) to enable vehicle to intersection communications.

Upon making AVL system adjustments, Pace bus technicians alert other Pace staff responsible for monitoring TSP activity on buses and along Dempster Street. Pace also notifies the jurisdiction responsible for traffic signal operations of the increase in the number of buses that will be making TSP requests on Dempster Street.

Pace staff then download logs of AVL activity from the re-assigned buses after one week of operation to verify that TSP requests are being made properly. Any issues that are discovered in the logs are communicated with Pace bus technicians for follow-up work on the buses if necessary. The jurisdiction responsible for traffic signal control also notifies Pace of any reported concerns with traffic signal operations.

5.7. SCENARIO 7 – SERVICE CHANGES (E.G., ADDING OR REMOVING SERVICE TO A CORRIDOR, MOVING FROM CTA TO PACE SERVICES)

Pace decides to add transit service and TSP operations to North Avenue (IL 64) between Emroy Avenue and I-355. This area currently does not have any transit services and requires TSP equipment to be installed in signal cabinets at the 19 identified traffic signals along the corridor.
During the Preliminary Engineering phase of this scenario, Pace communicates with IDOT about the need for TSP equipment at the identified signalized intersections along the corridor. Pace coordinates with IDOT and initiates signal timing optimization based on the last optimized date of the signal system along the corridor. Pace selects a third-party signal timing consultant to optimize traffic signal timings along the corridor and ensure that signal timings reflect current traffic patterns. IDOT notifies Pace when signal timing work has been completed and accepted.

During the Design Engineering phase of this scenario, Pace coordinates with IDOT on the procurement and installation of TSP equipment within signal cabinets along the corridor. Pace and IDOT initially determine the appropriate intersections to receive TSP equipment based on factors such as intersection volume-to-capacity ratios, the presence of any railroad crossings, etc… An assessment of the fiber/twisted pair cable infrastructure on the corridor may also impact where TSP is installed and how TSP data can be sent from the corridor back to a central office for data processing and evaluation. Once TSP intersections are selected, Pace leads the procurement and installation of TSP equipment for the corridor.

During the TSP Implementation phase of this scenario, Pace communicates with bus technicians to arrange for the installation of any additional communications equipment (if necessary) to enable vehicle to intersection communications. Pace also monitors the Contractor selected for TSP Implementation to verify that wayside communications is installed at the proper locations. IDOT verifies that installed TSP equipment operates without negatively impacting traffic signal operations.

Once the TSP System is installed, Pace monitors the System Acceptance Testing to verify that Technical System Requirements are met by the TSP System.

5.8. SCENARIO 8 – TSP SYSTEM CENTRAL MONITORING

*Pace desires to make an adjustment to TSP operations by reducing the schedule adherence threshold for TSP requests from five minutes to two minutes for all buses. Pace estimates this will better improve on-time performance and transit travel times along TSP corridors.*

Prior to beginning the schedule adherence adjustments, Pace communicates with RTA and CDOT / IDOT / County DOTs about the desire to reduce the threshold. A before-and-after evaluation of on-time performance and transit travel times is planned to demonstrate the effects of the change in thresholds.

Pace begins to collect AVL data from affected TSP routes from the AVL systems for one to two weeks of time and summarizes the data in report form. This data serves as the “before” snapshot that will be compared to TSP operations after the change.

The AVL systems on the Pace buses receive the change in schedule adherence thresholds to enable TSP operations when greater than 2 minutes behind schedule.
Depending on the AVL system capabilities, the AVL system may be able to vary the schedule adherence threshold for requesting TSP by vehicle location or by time-of-day. Upon making AVL system adjustments, Pace bus technicians alert other Pace staff responsible for monitoring TSP activity on buses. Pace also notifies CDOT / IDOT / County DOT’s of the effective date of the threshold change.

Pace staff then monitors the impact of the AVL system change after one to two weeks of operation through the use of a TSP System Central Software package. Monitoring capabilities provide Pace staff a comparison of the AVL logs against signal controller logs to verify that TSP requests are being received by signal controllers on the corridor. This also provides an understanding of how many more TSP requests are being granted on the corridor after the schedule adherence adjustment. The TSP System Central Software also provides health monitoring capabilities of TSP equipment on buses and on the corridor so that Pace can understand where equipment may need to be serviced by technicians.

Any issues that are discovered in the logs are communicated with Pace bus technicians for follow-up work on the buses if necessary. CDOT / IDOT / County DOTs also notify Pace of any reported concerns with traffic signal operations.

Pace gathers the “after” snapshot of data on TSP requests and summarizes the before-and-after data for the RTA and Program Stakeholders. Any lessons learned during the threshold change are communicated with Program Stakeholders as well.

5.9. SCENARIO 9 – PLANNED EVENT IMPACTING TSP SYSTEM OPERATIONS

A large national conference is planned to be held in Chicago over the course of four days from Thursday through Sunday. Traffic congestion is expected to occur along existing TSP corridors and is also expected impact TSP operations for CTA buses.

In the weeks prior to the planned event, CTA meets with CDOT regarding any planned changes to traffic signal operations that will be implemented by CDOT to ease congestion that is expected to occur on TSP corridors. Planned signal timing changes will provide more green time to mainline traffic along the corridor where higher volumes of traffic are expected to be traveling to and from the event.

CTA assesses where TSP requests may not be needed along the corridor, given that more green time will be provided to bus routes traveling on the corridor. CTA routes crossing the corridor would be delayed given that less green time is being provided to those cross streets. CDOT determines that TSP requests from CTA buses on cross streets would negatively impact the flow of traffic along the mainline during the event.

In the days prior to the planned event, the CTA disables the schedule adherence threshold of the AVL system that acts as the trigger for TSP requests from the buses.
so that TSP requests will not be made during the event. CTA and CDOT verify that no TSP requests are being received by the signal controllers on the corridor.

After the event is completed, CDOT restores the signal timings that were in effect prior to the event. The CTA also restores the schedule adherence threshold on the AVL system to allow for TSP requests along and crossing the corridor.

5.10. **SCENARIO 10 – UN-PLANNED EVENT IMPACTING TSP SYSTEM OPERATIONS**

A CTA rail disruption occurs on a weekday during evening rush hour. CTA desires to run shuttle service along a Pace TSP corridor during the rail disruption. CTA shuttle buses would primarily travel along the Pace routes that have TSP equipment installed at traffic signals.

This scenario assumes that CTA shuttle buses would be able to efficiently shuttle passengers from a CTA rail station to another rail station / bus stop along a TSP corridor that primarily serves Pace buses.

The benefits of regional TSP interoperability between Pace and CTA buses with CDOT and IDOT signalized intersections can allow CTA buses to quickly and efficiently travel along a Pace TSP corridor to shuttle passengers between two points in the event of a CTA rail disruption.

During the scenario, the CTA would notify Pace of their plans to use shuttle service along the Pace TSP corridor and monitor TSP operations remotely as needed. After the rail disruption is resolved and CTA shuttle service is no longer needed, the CTA would stop shuttle service and notify Pace that the rail disruption has ended.

A follow-up review of the success of TSP operations during this type of scenario could illustrate how effective the regionally interoperable TSP System was at aiding the CTA in shuttling passengers during the rail disruption.

5.11. **SCENARIO 11 – LOSS OF CENTRAL COMMUNICATIONS**

Pace staff responsible for monitoring TSP operations find that their central communications to TSP equipment at intersections operated by IDOT has been disrupted and that TSP logs can no longer be downloaded from either TSP equipment or signal controller on the corridor.

In this scenario, center-to-field communications between Pace central offices and TSP intersections along a Pace TSP corridor is disrupted, resulting in a loss of TSP data and logs from signal controllers and TSP equipment. Pace staff may first receive a notification of the failure through the use of TSP System Central Software that includes health monitoring capabilities of TSP equipment on the TSP corridor. It is also possible that IDOT staff may be the first to discover the cause of the central communications failure as a result of a traffic incident.
Other causes in losing center-to-field communications with TSP intersections may be the result of a gap in intersection-to-intersection communications along the TSP corridor. The gap would likely have been caused by a tear in underground communications cables (fiber, twisted-pair, etc…) that is utilized for communicating TSP Data to one location on the corridor that sends the data back to the central office.

Pace contacts the TSP Installer to investigate the communications failure and take corrective actions as necessary. In the event that IDOT would need to restore underground communications cables, IDOT would notify Pace of the timeline for cable repairs. Once the corrective actions have been taken and center-to-field communications are re-established, Pace confirms that TSP logs can again be downloaded from TSP equipment in traffic signal cabinets and continues to monitor TSP activity along the corridor.
6. **SYSTEM IMPLEMENTATION OVERVIEW**

This section details the next steps to be taken by the RTA in the systems engineering process following the completion of this Concept of Operations document. Appendix B presents a compliance matrix demonstrating this document’s compliance with FHWA Rule 940.

6.1. **TECHNICAL SYSTEM REQUIREMENTS**

The TSP Technical System Requirements Document will include functional requirements describing what the components and the system will do, performance requirements that state how well it should perform over time, and under what conditions the system will function. These Requirements will set the technical scope of the TSP systems that are to be procured and implemented by Pace and CTA.

6.2. **REGIONAL TSP STANDARDS AND IMPLEMENTATION GUIDELINES**

The Regional TSP Standards and Implementation Guidelines will address the following items:

- Operational guidelines for requesting and granting TSP and associated TSP actions
- Open Standards for communication protocols between the AVL equipment on the bus and wayside equipment at the intersection
- Compatible technology for communications between the bus and wayside equipment located throughout the region
- The use of centralized TSP System monitoring for operations and maintenance
- Performance Measures to be used to assess the effectiveness of the TSP Systems deployed for Pace and CTA

The Regional TSP Standards and Implementation Guidelines will include a summary of best practices from other national or regional TSP deployments as well as procurement and test plan templates that can be utilized for the region.

The Regional TSP Standards and Implementation Guidelines will also include a Technology Integration Plan that addresses TSP subsystem integration steps necessary for regional interoperability. The integration guidelines will be updated to reflect any changes during the construction and system implementation phases to ensure the actual sequence of steps performed to integrate the TSP systems are documented for on-going regional consistency.

Similar to the Technical System Requirements document, this document will build consensus among stakeholders about the regional standards and implementation guidelines that will be developed. All comments will be recorded and incorporated.
into the final document as appropriate and distributed to stakeholders for a final review.

6.3. TSP System Verification Plans

The TSP System Verification Plan will describe the activities associated with verifying that the system being built meets the specified System Requirements. This plan will include procedures that are the specific and detailed steps to be followed to perform testing of the TSP system.

6.4. Implementation Oversight and Program Validation

Implementation oversight will be performed to verify that individual TSP projects within the RTSPIP are being planned, designed, and implemented in accordance with the Regional TSP Standards and Implementation Guidelines. Oversight activities will include TSP System Design Reviews, TSP Procurement Reviews, and TSP Installation Reviews. Acceptance testing oversight of TSP systems will also be performed as TSP systems become operational.

Program Validation activities will include monitoring performance measures on how well the goals and objectives defined within this ConOps document are being met by the TSP systems that are deployed. Further details on performance measures are provided within this ConOps document in Section 2.3.
A TSP Working Group session was held March 12, 2013 for the Regional Transit Signal Priority Implementation Program (RTSPIP). A PowerPoint presentation and several documents were utilized for the meeting discussion and are available as separate documents. Brief highlights of the meeting are summarized below.

1. Introductions
   • Meeting Participants:
     o Gerry Tumbali, RTA, TumbaliG@rtachicago.org
     o Mark Pitstick, RTA, PitstickM@rtachicago.org
     o Kevin Stanciel, RTA, StancielK@rtachicago.org
     o Rochelle Fulton, RTA, fultonr@rtachicago.org
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     o Dave Tomzik, Pace, david.tomzik@pacebus.com
     o Taqhi Mohammed, Pace, taqhi.mohammed@pacebus.com
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     o Daryle Drew, IDOT, Daryle.Drew@illinois.gov
     o Dave Zavattero, CDOT, dzavattero@cityofchicago.org
     o Jon Nelson, LCDOT, JPNelson@lakecountyil.gov
     o Claire Bozic, CMAP, CBozic@cmap.illinois.gov
     o Daryl Taavola, URS, Daryl.taavola@urs.com
     o Kevin O’Neill, URS (via phone), Kevin.oneill@urs.com
     o Matt Letourneau, URS, matthew.letourneau@urs.com
     o Dan Nelson, URS, dan.nelson@urs.com
     o Kyle French, Ardmore Associates, kfrench@ardmoreassociates.com

   • The desired outcome of the meeting was to understand and reach consensus on:
     o Concept for Regional TSP Program
     o Roles and Responsibilities for Regional TSP Program
     o 2013 Corridor/Project Portfolios
     o Process and criteria for establishing Portfolios for 2014 and beyond
     o Better understanding of NTCIP/TCIP Standards
       ➢ Note: NTCIP/TCIP Standards were briefly discussed and will be covered in more detail on the April 9th meeting.
2. RTA Update

- A meeting between RTA, IDOT, DuPage County, and Kane County occurred on Monday March 4\textsuperscript{th}. The purpose of this meeting was to update the attendees about the RTA RTSPIP project, specifically the Concept of Operations, and to discuss existing IDOT and county traffic signal and communications infrastructure. RTA/URS is to send out meeting minutes to the TSP working group.
- There will be an Iteris TSP demonstration on April 4\textsuperscript{th} at the CDOT signal shop.
- The disposition of SEMP comments and revised SEMP document have been sent out to the working group. URS is currently working on finalizing a disposition of the PMP comments which will be sent out to the working group with the revised PMP document.
- CTA submitted a request for funding to start Preliminary Engineering for the Ashland and Western Avenue BRT corridors and this is being processed. RTA will issue a Letter of No Prejudice that will allow this work to start.

- **Action Items:**
  - RTA/URS to send meeting minutes from March 4\textsuperscript{th} IDOT/County meeting to the TSP Working Group
  - RTA to issue Letter of No Prejudice to CDOT/CTA for Ashland and Western Avenue BRT corridors

3. Concept of Operations

*Please see the meeting minutes for February 12, 2013 for Concept of Operations elements discussed at that meeting.*

- **Chicago Concept Diagram**
  - IDOT Gateway / IL Transit Hub was added to the diagram since the last review.
  - Lake County and IDOT noted that traffic signal cabinets with master controllers have both a master controller and a local controller. The TSP devices will only be able to communicate with the local controllers. It was recommended that this be reflected in the diagram.
  - IDOT noted that the communications connection from the IDOT/Local DOT TMC to the master controllers is dial-up. Connection from master controllers to local controllers is fiber.
  - IDOT noted that stand alone signal controllers exist, not all are connected by fiber/copper (designate interconnect as “where available”).
  - CTA suggested that “Mobile Router Equipment” be changed to “Mobile Router and Radio Equipment”.

- **Roles and Responsibilities**
  - Changes were suggested to the responsibility matrix included as Figure 3-6 in the ConOps document
  - The general roles of each party in the TSP working group were stated.
    - RTA: Program Manager / Project Oversight / Funding
    - URS Team: Support, Complete Contract Work Tasks
CTA / Pace / IDOT / CDOT / Local DOTs: TSP Implementers, TSP Operations & Maintenance
FTA: Funding Agency
- It was noted that the V-2-I, I-2-I and I-2-C roles and responsibilities discussed were the roles specifically for the development phase and not for on-going operations.

- **V-2-I: Vehicle to Intersection roles and responsibilities were discussed**
  - RTA reference was changed to “RTA and TSP Working Group”
  - Responsibilities include: Determining content of TSP message set, outline TCIP standards, identify standard radio technology for RTSP/IP.
  - CTA / Pace
    - Responsibilities include: Working with AVL vendors, developing interface with on-board communications equipment, and purchasing of additional equipment for buses.
    - RTA asked if the AVL vendors had been contacted yet. CTA / Pace are waiting for more requirements to be defined first.
    - Passenger loading information included as part of the requirements was discussed. It was decided that it should be added for future use / expandability.
    - The ability to use Unconditional Priority during certain events was discussed. CTA / Pace to talk to AVL vendors to determine if this is a possibility.
    - Use of wireless communications equipment will also be addressed.
  - CDOT / IDOT / Local County DOTs:
    - Responsibilities include: Coordinating with signal controller vendors/manufacturers on how TSP operations are serviced by different signal controller types.

- **I-2-I: Intersection to Intersection Roles and Responsibilities were summarized**
  - CDOT / IDOT / Local County DOTs:
    - Responsibilities include: cooperate with installation of TSP equipment at the intersection, coordination with signal controller vendors/manufacturers on how TSP operations are serviced by different signal controller types, and facilitating use of fiber/copper network for TSP communications to CTA and Pace Transit Management Centers.
  - CDOT:
    - Responsibilities include: Coordination with CTA and Pace on use of CBOX equipment for V-2-I and I-2-I communications.
  - A section was added for CTA/Pace
    - Responsibilities added were: Perform communications assessments and lead installation of TSP communications equipment.

- **I-2-C: Intersection to Center Roles and Responsibilities were summarized**
  - It was noted that the DOTs also have an interest in being able to remotely monitor TSP activity.
• **Operational and Support Environments**
  o URS summarized the traffic signal and TSP system operational environments
    - CDOT operates a “MIST” centralized traffic management system and the other DOTs operate a mix of closed loop systems with Econolite and Eagle controllers.
    - The RTSPIP system would cover 400 miles of roadway and over 1000 traffic signals.
    - Central monitoring of TSP system activity was stated to be important to identify problems, gaps in service, and interruptions of service.
    - CMAP is in the process of updating the traffic signal inventory database but this is expected to be a longer term effort.

• **Operational Scenarios**
  o The purpose of discussing the operational scenarios was to get an understanding of how a TSP system would operate and to understand the roles and responsibilities of the involved parties.
    - **Scenario 1 – TSP Requested**
      - The values for the conditions of a request were discussed. Values could be variable based on location, time of day, passenger load, etc.
      - It was noted that a TSP request could either extend a green light or grant an early green light.
      - For TSP requests to be most efficient, far side bus stops are preferred. Near side stops would be relocated where permitted.
      - It was suggested that the TSP device should work around a check-in / check-out procedure and that is to be added to the scenario.
      - It was also suggested that our system requirements also include communications from the intersection back to the vehicle to confirm TSP requests received and TSP service status.
    - **Scenario 2 – Simultaneous TSP Requests**
      - The easiest/low level way to handle multiple requests was determined to be first in/first out.
      - It was noted that the way simultaneous requests are handled would depend on the signal controller technology available at each intersection and it is possible that both could even be served depending on the movement of the request.
      - The signal controller would have to be able to determine whether or not to grant a TSP request based on the current phase state.
      - It was noted to revise the term “vehicle” to “bus” in the Scenario 2 ConOps text.
      - It was noted that we need to understand the TSP capabilities of the different controllers including Peek ATC, Econolite and Eagle and this will be investigated through discussions with the signal controller vendors.
    - **Scenario 3 – Simultaneous TSP and EVP Requests**
      - Priority vs. pre-emption technology was discussed. An emergency vehicle request will always override a TSP request.
      - It was stated that the TSP intersection equipment would be responsible for processing decisions, the buses would only be able to send a request.
      - It was suggested that a scenario be developed for different TSP priority levels as it relates to servicing express buses vs. local buses.
- **Scenario 4 – Fleet Changes**
  - It was determined that if all buses are equipped with TSP, fleet changes become a non-issue. Bus assignments will automatically update as part of the AVL system and this already happens. This scenario would only apply for an equipment upgrade.
  - Pace requested that “re-locates” be replaced with “re-assigns”

- **Scenario 5 – Service Changes / New Transit Service**
  - It was noted that the agencies would optimize traffic signal timings at all traffic signals along the corridor but would only install TSP at “appropriate” intersections. This is to be reflected in the scenario.
  - Pace and IDOT would most likely use a 3rd party to optimize signal timing and would like to consider bus movement when optimizing.
  - It was stated that it is beneficial to have the entire corridor interconnected with fiber, twisted pair copper or wireless communication. An assessment would need to take place to determine where interconnects exist. At some isolated intersections, time-based coordination would be used.
  - The way TSP requests would be logged was discussed. There is a desire to have a more user friendly way to compare TSP logs with traffic signal controller logs. The existing method of TSP event logging includes separate logs of TSP requests stored at both the bus and intersection signal controllers. Technical system requirements would need to be developed for a TSP software application to consolidate both sets of logs into one spreadsheet for side-by-side comparison of bus TSP requests and intersection signal controller TSP logs.
  - It was suggested to include the three development stages of Preliminary Engineering, Design Engineering and Implementation in the scenario.

- **Scenario 6 – Incident Management**
  - Pace currently uses a Transit Operational Decision Support System to help manage incidents.
  - It was stated that an interoperable system would allow for buses to be shifted to new corridors and still be granted TSP requests in the case of incidents.
  - After the case of an actual incident management scenario, the operation should be reviewed for future improvements.

- **Scenario 7 – Central Monitoring (changed from central administration)**
  - This scenario is more for central monitoring vs. central administration and will be revised to include TSP logging, diagnostics, etc.
  - The threshold for a TSP request was discussed. It was determined that the threshold could vary based on location and time of day.
  - It was stated that if a change in threshold occurs, data should be collected before and after and then the results reported to the TSP working group.
  - Question was asked if Pace and CTA should be able to see each other’s PRS information.

- **Scenario 8 – Special Events (changed from Incident Impacting TSP Operations)**
  - This scenario was originally a placeholder for “Incident Impacting TSP Operations” and will be replaced with scenarios for “Planned Events” and “Unplanned Events”.
TSP involvement in an emergency evacuation was discussed. It was determined that TSP operations would need to be coordinated with the regional evacuation plan before a scenario could be implemented.

**Scenario 9 – Loss of Central Communications**
- It was stated that this scenario would need to be expanded and clarified.
- IDOT should be recognized because they may be first to identify field incidents and notify Pace.
- This scenario also needs to cover intersection to intersection communication failures.

**System Implementation Next Steps**
- Technical Requirements will be discussed at the April 9th meeting from 9:30am-3pm. The first half of the meeting will be for bus technical requirements and the second half will be for intersection technical requirements.
- CTA noted that Clever Devices (their AVL vendor) is under contract to develop a schedule adherence interface for the Jeffery Jump project and will see what information they can share.

**Action Items:**
- **TSP working group to send ConOps comments to RTA in 1 week (by March 19).**
- **URS to revise ConOps based on meeting discussion and additional comments forthcoming.**
- **CTA to provide specifications information on AVL interface work for Jeffery Jump if possible.**
- **URS to investigate TSP capabilities of Peek ATC, Econolite and Eagle controllers.**
- **Rough draft Technical Requirements will be sent out to the TSP working group the week of April 1st.**

4. **Lunch Break**

5. **Program Management and Systems Engineering Management Plans**
- **Disposition of comments and key revisions to documents**
  - The disposition of SEMP comments and revised SEMP document have been distributed to the working group. A clean finalized copy of the SEMP without track changes will also be issued.
  - URS is currently working on the disposition of the PMP comments and final revisions to the PMP document. They will be sent out to the working group shortly.
  - URS clarified the roles and responsibilities of the involved parties.
  - A new section is to be added to the PMP on agreements.
  - Revisions included language related to synergy between RTSPIP and other initiatives.
RTSPIP will provide “Operational Guidelines” vs. “Operational Conditions” and it is expected that the Service Boards and DOTs will set specific parameters. An example was given of “behind schedule parameters”.

RTA stated that it is preferred to use existing signal controllers where possible and to leverage efforts with other signal improvement modification programs.

RTSPIP funding is desired to be used for spot signal controller improvements only on a priority/TSP needed basis. Broader signal controller replacements for entire corridors should be funded by other sources/grants if possible. It was suggested by CDOT to not set a policy that would limit the ability to replace signal controllers on a corridor if it is needed for TSP.

**Work Breakdown Structure Template/ Cost Estimating Guidance Template**

  - URS stated that the Work Breakdown Structure template is a checklist for engineering and that not all sections will apply to all corridors.
  - It was requested that one time vs. corridor specific items be identified separately within the breakdown.
  - URS stated that the unit cost values are from previous TSP projects and are a rough working amount. It was decided that the 12% amount for preliminary engineering needed to be increased.
  - Pace stated that for item 1.1.3, V-2-C should be included because it may change based on the corridor. URS to add a row for V-2-C.
  - Spot VISSIM analysis for initial corridors was discussed. It was determined that VISSIM analysis would not be needed.
  - TSP performance will be based on pre- and postdeployment reports created through Synchro modeling, from AVL data and other appropriate sources. Implementing parties were determined to be responsible for the reporting.

**Monthly Reporting Template**

- A draft monthly reporting template was reviewed and is expected to be submitted with the monthly invoices if possible.
  - An additional page will be added to the report to allow for submittal of cost details like expenditures for this period, expenditures to date, % work complete, etc.

**Action Items:**

- URS/RTA to send clean version of SEMP document and Disposition (with correct date) to working group.
- URS/RTA to finalize revisions and then send revised PMP document and disposition of comments to working group.
- URS/RTA to include a TSA template as exhibit in revised PMP document.
- TSP working group to send TSA comments to RTA.
6. Corridor/Project Portfolios

- **Review of process and criteria for establishing Portfolios for 2013 and 2014 and beyond**
  - All parties agreed that standards for eligible corridors needed to be completed before the authority to proceed with detailed design and implementation could be established.
  - It was suggested that Pace applications for corridors clarify what corridors are already in preliminary engineering vs. the ones where no activity has started yet.
  - RTA will share CTA’s requests to proceed on Ashland and Western with the working group as an example.
  - 2013 corridors will be acknowledged in a Letter of No Prejudice, giving authorization for CTA and Pace to proceed with TSP Preliminary Engineering. After receipt of the Letter of No Prejudice, CTA and Pace have the ability to proceed. After execution of the TSA, the CTA and Pace may submit invoices for reimbursements to RTA.
  - RTA is responsible for developing TSAs and amending them as needed.
  - URS reviewed the criteria included in the 2003 RTA TSP study and the 2008 Pace TSP plan and came up with a hybrid set of RTSPIP corridor screening criteria:
    - Transit operational issues
    - High ridership, high frequency
    - Transfer locations along corridor segments
    - Overlap of CTA and Pace service.
  - Potential TSP location Criteria that can be utilized by the agencies was discussed. Green time availability and other traffic considerations were added to the list of criteria.
  - URS discussed the screening criteria that RTA/TSP Working Group will utilize to confirm selection of RTSPIP corridors.
    - 1st level criteria will consider if the corridor is part of the CMAQ/FTA funding application, RTA TSP Study, or BRT/ART program. If not, TSP working group would do a more detailed review to see if the corridor warrants TSP.
    - 2nd level criteria will look at the synergy of proposed projects with other initiatives or other partners. Coordination with planned projects and traffic signal modernizations were discussed.
  - The process to develop Corridor Portfolios for 2014 and beyond was also reviewed.

- **Review of 2013 Corridors**
  - CTA:
CTA has already submitted the Ashland and Western corridors (approx. 16 miles each). 79th Street and Chicago Avenue are two other possible corridors.

CTA stated the advanced traffic controller ($14K), CBOX including bus to controller and controller to controller communication ($12K), and MIST integration ($2K) will cost approximately $28,000 total per intersection at their Ashland locations. Interconnects were already in place on this corridor and were not part of the cost.

Pace:

- Preliminary engineering has been started on portions of several corridors: 159th Street, Sibley/147th, Roosevelt Road, Cicero Avenue, and 95th Street. Work started along portions of these corridors includes preliminary engineering assessments and signal optimization, and Pace would like to complete the preliminary engineering.
- Pace stated that their 2013 proposed corridors would be split into two contracts. One of the contracts will include the corridors above, which have already started preliminary engineering, and the other contract would initiate preliminary engineering on: Grand Avenue, North Central Lake County Corridor, Golf Road, River Road, Algonquin Road, and Lincoln Highway.

Action Items:
- RTA to work with CTA and Pace on finalizing 2013 Corridor Portfolios.
- RTA to send Pace a sample Letter of No Prejudice request.
- Pace to send RTA a request for 2013 corridors, identifying corridor limits and explaining what work is already underway and where.
- RTA to issue letters of no prejudice to CTA and Pace.

7. NTCIP / TCIP Standards

- Summary of TSP related national standards
  - Discussion of national standards took place. It was determined that most current deployments use proprietary systems or a modified form of the NTCIP standard. A “Chicago NTCIP (or TCIP)” standard would have to be created for RTSPIP.
  - It was suggested that we focus more on the message set from vehicle to intersection as we develop the RTSPIP standard.
  - CTA/CDOT’s Jeffery Jump project will be utilizing a modified New York City message set and that is an example to be reviewed. URS requested that CTA present details of the Jeffery Jump message set and the project at the April 9 TSP working group meeting. CTA will send a copy of the message set to RTA/URS.

- Action Items:
  - CTA to send copy of Jeffery Jump message set to RTA/URS.
  - CTA to present Jeffery Jump project and message set at April 9 TSP working group meeting.


- **URS** to present more NTCIP/TCIP standards information at the April 9 TSP working group meeting.

### 8. Next Meeting

Next Meeting – April 9\(^{th}\) 9:30am-3pm at CMAP.

**Attachments:**

3/12/13 Meeting Agenda
AGENDA

TSP WORKING GROUP MEETING
9:30 AM – 3:00 PM, TUESDAY, MARCH 12, 2013
LOCATION: BOARD CONFERENCE ROOM, 16TH FLOOR
175 W. JACKSON BLVD. SUITE 1550, CHICAGO, IL 60604

1. Introductions – 5 min.

2. RTA Update – 10 min.

3. Concept of Operations - 120 min.
   • Review/Discuss:
     o Recap of elements discussed at the February 12, 2013 meeting
     o Chicago Concept Diagram
     o Roles and Responsibilities
     o Operational and Support Environments
     o Operational Scenarios
     o System Implementation Next Steps

4. Lunch Break or Working Lunch (as time allows)

   • Disposition of comments and key revisions to documents
   • Work Breakdown Structure Template
     o TSP Preliminary Engineering, TSP Design and TSP Implementation
   • Cost Estimating Guidance Template
   • Monthly Reporting Template

6. Corridor/Project Portfolios – 45 min.
   • Review of 2013 Corridors
   • Review of process and criteria for establishing Portfolios for 2014 and beyond

7. NTCIP / TCIP Standards - 15 min.
   • Summary of TSP related national standards

8. Other Items – 10 min.
   • Radio communications research
   • Next steps for project

APPENDIX B -- FHWA RULE 940 COMPLIANCE MATRIX

Based on 23 CFR, Subchapter K – Intelligent Transportation Systems, Rule 940, states and agencies using U.S. Highway Trust Funds must utilize a systems engineering analysis approach to develop ITS projects. Figure B-1 lists sub-sections from FHWA Rule 940 and where those requirements are addressed in this ConOps document.

Figure B-1. RTA RTSPIP ConOps Compliance Matrix with FHWA Rule 940

<table>
<thead>
<tr>
<th>Applicable Section of Rule 940.11</th>
<th>Section of ConOps</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>940.11 (c) The systems engineering analysis shall include, at a minimum:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-1: Identification of portions of the regional ITS architecture being implemented (or if a regional ITS architecture does not exist, the applicable portions of the National ITS Architecture);</td>
<td>Section 3.7 – System Architecture</td>
<td>TSP system is currently reflected in the Northeastern Illinois Regional ITS Architecture</td>
</tr>
<tr>
<td>C-2: Identification of participating agencies roles and responsibilities;</td>
<td>Section 3.3 – Stakeholder Roles and Responsibilities</td>
<td>Will be addressed in detail in Technical System Requirements</td>
</tr>
<tr>
<td>C-3: Requirements definitions;</td>
<td>Not addressed in this document</td>
<td></td>
</tr>
<tr>
<td>C-4: Analysis of alternative system configurations and technology options to meet requirements;</td>
<td>Not addressed in this document</td>
<td>Will be addressed in detail in Regional TSP Standards and Implementation Guidelines</td>
</tr>
<tr>
<td>C-5: Procurement options;</td>
<td>Not addressed in this document</td>
<td>Will be addressed in detail in High-Level Design Document</td>
</tr>
<tr>
<td>C-6: Identification of:</td>
<td></td>
<td></td>
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<tr>
<td>• applicable ITS standards;</td>
<td>Standards are addressed in NE IL ITS Architecture</td>
<td>Will be addressed in Regional TSP Standards and Implementation Guidelines</td>
</tr>
<tr>
<td>• testing procedures;</td>
<td>Section 2.3 – Performance Measures</td>
<td></td>
</tr>
<tr>
<td>C-7: Procedures and resources necessary for operations and management of the system.</td>
<td>Section 4 - Operational and Support Environments</td>
<td></td>
</tr>
</tbody>
</table>

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